ENHANCING HIGH ORDER SCIENCE VISUAL LITERACY SKILLS IN BIOLOGY LEARNERS

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31 March 2019

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Introduction

Today's consumers also termed as the "Eye Generation" consumes lots of visual data through the net, mobile phones, advertisement, mobile applications and many others. This is because the visuals are considered as a more accessible means of obtaining and communicating messages. Research works have elaborated facts and figures from surveys on students before leaving college. For example, students engaged in over 10,000 hours playing computer games, over 200,000 emails and text messages; over 10,000 hours on cell phones; over 20,000 hours in front of the Television box, exposed to over 500,000 ads (Prensky, 2001). These numbers point towards societies with visual abilities but only as passive consumers without the ability to interpret or to question the veracity of media and visual messages. Bleed, (2005) voiced that:

'A shift to a new form of literacy is required for three reasons.…the changing nature of the younger generation.…the adoption of technology that supports the 21st - century skill sets….and the desire to create.'

Discussion

Visual Literacy

A growing body of research has revealed countless variations on the definition of Visual Literacy. Baca and Braden (1990) have postulated that each author has defined the term from their perspective and professional background. An exact definition remains elusive because of the complexity and multidimensional nature of the skills involved. Debes. J. L, (1969) was the first author to coin the term visual literacy. Many other researchers then referred to seminal work of John. Debes and there were lots of common viewing competencies that were shared between the authors like understanding, reading, using, interpreting, evaluating visual messages as shown in Table 1.

Year	***Author***	***Viewing competencies***
1969	(Debes. J. L, 1969)	*- developing visual competencies* *- seeing and integrating other sensory experiences* *- discriminate visible object* *- interpret visible objects* *- comprehend the masterworks of visual communication* *- enjoy masterworks of visual communication*
1983	(Horton, 1983)	*- understand images* *- read images* *- use images* *- write images* *- think in terms of images* *- learn in terms of images*
1984	(Robinson's, 1984)	*- process visual messages* *- perceive visual messages* *- understand visual messages* *- interpret visual messages* *- analyse visual messages* *- evaluate visual massages*

1986	(Sinatra, 1986)	- *promotes understanding* - *promotes retention* - *promotes recall* - *reconstruction of past visual experience* - *compare between past and incoming visual messages* - *create meaning from past and incoming visual messages*
1993	*International Visual literacy Association (IVLA)* (Pettersson, 1993)	- *Visual competency accompanied by aural & verbal abilities* - *interpret visuals* - *compose\produce messages from visuals* - *encode visual image i.e. convert pictural to verbal mode* - *decode visual image (understand a visual language)* - *evaluate visual information* - *detect visual information from the visual environment* - *produce messages*
1994	(Bristor & Drake, 1994)	- *Understand visual messages* - *interpret visual messages* - *evaluate visual messages*
1996	(Braden, 1996)	- *understand images* - *use images* - *create images* - *think in terms of images* - *learn with images* - *express in terms of images*
1997	(Christopherson, 1997)	- *Interpret visual messages* - *understand visual messages* - *appreciate visual messages* - *communicate visual messages* - *produce visual messages* - *use visual thinking for problem-solving*
1999	(Avgerinou & Ericson, 1997)	- *interpret visual messages* - *create visual messages*
2001	(Brill, Kim, and Branch, 2001)	- *interpret visual messages* - *compose from visual* - *discriminate from visible objects* - *make sense of visible objects* -*create static and dynamic visible objects* - *understand visual messages of others* - *appreciate visuals of others* - *invoke images in the mind's eye* - *categorise visuals*

		- derive meanings from visuals *- generate still and moving visuals*
2002	(Burmark, 2002)	*- interpret visual messages* *- understand visual messages* *- appreciate meanings of visual messages* *- communicate visual messages* *- produce visual messages* *- use visuals for problem-solving* *- applying principles of visual design* *- analyzing visual messages*
2004	(Hughes et al., 2004)	*- create meaning from images* *- analyse visuals* *- evaluate visuals* *- make decisions about visuals*
2006	(Larry Johnson, 2006)	*- see messages hidden in images* *- comprehend messages hidden in images* *- generate visual prompts* *- adapt visual prompts* *- employ visual prompts*
2007	(Robertson, 2007)	*- read visual messages* *- translate from visual to verbal mode*
2008	(Metros, S. E., 2008)	*- decode visual messages* *- encode visual messages* *- infer from visual messages* *- compose meaningful visual* *- communicate meaningful visual to the audience*
2011	(ACRL, 2011)	*- find images and visual media* *- interpret images and visual media* *- evaluate images and visual media* *- use images and visual media* *- create images and visual media* *- consumer of visual media* *- understand visual materials* *- analyse visual materials*

Table 2: Timeline for visual literacies.

The question that arises is: Can teaching and learning visual literacy be envisaged? From the different models from literature like the dual coding theory, information processing theory, learning styles theory, cognitive theory, multimedia theory and multiple intelligence, it can be envisioned to make a person visually literate through a variety of approaches in a variety of settings and subject areas (Ellen, S., 2002). The visual literacy white paper advocates that visual literacy can be employed in various domain of the curriculum and should be taught from the youngest age like children learning their mother tongue.

The most common theories that are related to visual literacy skills are:

1) Cognitive load theory – describes the mental energy needed to process information
2) Information processing theory (IPT) – describing the sensory, working and long-term memory.
3) Dual coding theory – describes the different channels i.e. auditory and visual routes for the three types of memory in IPT.
4) Mayer's multimedia theory – explains how to make connections between the two channels.
5) Learning style theory - The term learning styles refer to individuals' characteristics and preferred ways of acquiring and gathering, organizing, thinking, retaining and retrieving information.
6) Multiple intelligences theory - to understand and teach many aspects of human intelligence, learning style, personality and behaviour in education and industry (Gardner, 2011).

All the theories (Figure 1) share common attributes including the visual and verbal aspects in their various forms in dual coding theory that helped in understanding and enhancing visual literacy in students and at the same time assisting teachers in their teaching process.

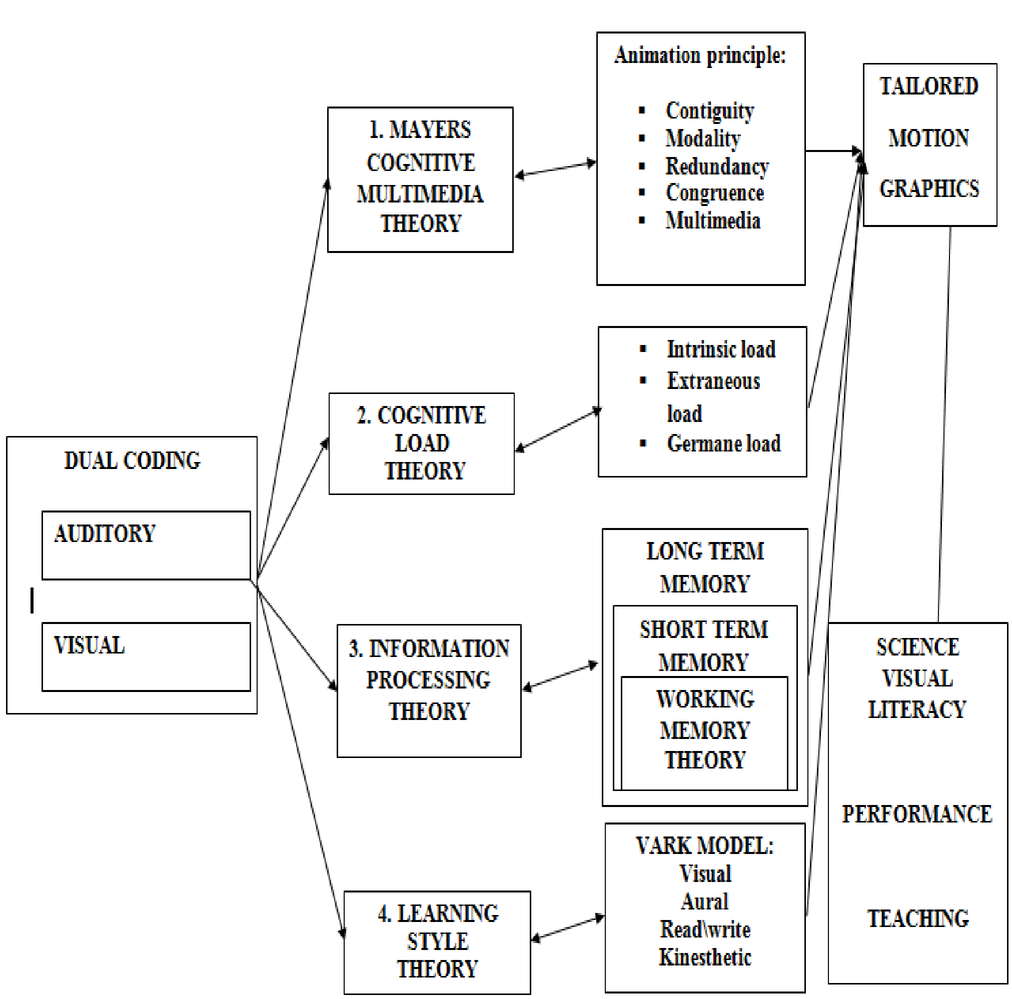

Figure 1: The different theories and visual literacy.

The dual coding theory is a subset of the other theories and includes the two routes that is auditory and visual channel to the sensory, working (short-term memory) and long-term memories. Depending on the type and form of information being processed by the IPT, the cognitive load theory comes into play where the order and form of information contribute to its proper functioning. As for the multimedia theory, it lays out the best principle to be followed when designing visuals and using the two routes for optimum efficiency. As regards to the learning style theory, it is mainly used to identify the learning style of the students before and after the interventions. The last theory on intelligence solves problems using the different intelligences but mostly the spatial and linguistic intelligences. Nevertheless some inconsistencies and conflicting information from the theories pose problem on how the theories could be applied in the educational contexts with mixed ability students.

High order science visual literacy skills

There is a dearth of research on Science visual literacy so far Biology is concerned. Even other domains like Chemistry and Physics lacked information on visual literacy. The literature on visual literacy mostly concentrated on domains like artworks and thus the need to fill in this missing gap by investigating on science visual literacy skills.

Science text-books comprise an array of diagrams with complex meanings that should be unleashed. Science graphics' reading is complex because learners have to attend to both text and the visual and without proper skills they are unaware of the order that the graphics should be examined. This visual information should be identified, selected, processed and interpreted to translate the visual messages into knowledge. Learners get difficulty to filter and distill out the superfluous information from the pertinent one as well as connecting and integrating related knowledge. Smolkin and Donovan's (2004) observed that graphics were used in the classrooms by just pointing to them without venturing through and across them. The reasons are many-fold like the restricted time frame to complete the syllabus, the bulkiness of the syllabus, the lack of training in the creation and use of visuals and the constant pressure to complete the syllabus. Concentration is mostly on reading and writing (Yeh & Lohr, 2010) that promote only low order visual literacy skills. High order science visual literacy skills can be achieved by sparing some time to teach about science still or motion graphics and its purpose and how students should examine graphics effectively (McTigue. E et al., 2011) so that learners can construct meaning from the visuals. The five main steps before understanding a concept are 1. Seeing, 2. Examining and Learning, 3. Interpretation, 4. Communication and 5. Comprehension. A visually literate person uses all the five steps unconsciously. So training is important where students are taught to see ahead that is anticipating for the next idea on the next frame, see behind i.e. referring to what has already been seen to understand the next idea, see above i.e. constantly referring to the context, see through implying going in depth of the concept and finally see besides that is relating and weaving with other concepts already visited. Caldwell & Loader, (2009) mentioned the different facets in the transformation of a school. The concept of transformation can also be applied in the visual literacy skills where learners should be able to describe what they have seen followed by an interpretation.

Little, Felten, and Barry (2010) assert that students are not taught high order visual literacy skills that is how to read, create, analyse and interpret visual messages. More emphasis is laid on texts from books than visual information. Thus, it is important to instill high order visual literacy skills in students (Avgerinou 2009; Tillmann, 2012).Thus students should be subjected to a variety of interesting visual tasks accompanied by questioning and deep class discussion. One task stated by Mangen & Velay (2011) who is known for advocating writing and drawing by hand promote learning since there is direct interaction between the motor action and the visual cortex of the brain receiving information. Deep viewing can be another task together with other sensory experiences like drawing, writing and doing as a way to teach science visual literacy (Bell, J. 2013). Another example is visual thinking which is an approach to organize mental images in a meaningful way (Estrada. F. C. R et al., 2015) by considering the contours, colours and other visual conventions. The skill is essential where students can critically interpret and communicate information through Science experiences. Erin Riesland (2005) favours questions that should come in the mind when thinking visually:

- What is this image I am looking at?
- What message does this image carry and convey to me?
- What is the link between the image and the accompanying texts?
- Is the message from the visual communicating the proper message?

Gangwer. T., (2009) proposes 408 subject-specific visual learning activities for the classroom to strengthen visual literacy skills and hence learning. The activities can be adapted as per the grade level being taught. The author mentioned that the products of the activities are not as important as what is gained in terms of learning when involved in the activities.

Today's Science textbooks

It has been noted that the frequency and variety of science graphics in science textbooks have experienced an increase in recent years. It is known that text that accompanies visual provide very little direction for understanding the ideas or process from the graphics. Studies have shown that 19% of graphics were not accompanied by captions or labels. These are important aspects since they complement and elaborate ideas conveyed in the visuals. Around 39% were accompanied by labels that were useless to the learners (Slough et al., 2010). Moreover, studies have demonstrated that more than half of the questions set in a science evaluation consisted of graphical illustrations. So it is important for students to be visually literate in science to be able to encode and decode the visual representations. The traditional mode of teaching includes text-based instruction compared to a novel way of teaching where technology has paved its way. Today with new technology, learning is becoming more meaningful and more learner-oriented. Access to digital images and graphic packages can be used to manipulate the visual grammars or syntaxes of images to come with desired product with enhanced meaning as per the taste of the user.

Learning Style Instrument

To be able to measure the visual literacy skills in learners it important to identify the learning preference of the students first. There are lots of learning style instruments outside that can be used for the purpose. But it is better to devise new learning style instrument as the context in which the specific audience is evolving. Sinatra. R (1986) said that visual literacy is a primary skill that precedes other literacies like verbal skills during the course of human development. The work corroborates with some facts that we can observe in our daily life like being with babies. At the age of around eight months, they are able to memorise and distinguish their parents from other people. Children at the tender age of one year can read graphics. For example they know that a representation of an orange equates to a real orange. At three, they can produce their own drawings for example showing emotions like happiness. They can even use visual symbols like rectangles and circles to draw a car. Most people are known to be visual learners but that does not mean they possess visual literacy skills.

Another important fact is that the visual cortex of the brain is known to process visual information 60,000 times faster than text (Thorpe, S., Fize, D., & Marlot, C., 1996). Scientists claim that the eyes as the receptor are very close to the brain and the eyes are the primary organ that relays information to the brain directly. This is supported by the fact that 90 percent of the information that comes to the brain is visual which equates to 4,000 images (Williams & Newton, 2007). Besides it has been suggested that the big majority of our nerves fibres which amounts to around forty percent are found in the retina of the eyes and connect directly to the brain through the optical nerve (Caine, G., & Caine, R. N, 1994). Another interesting information on the brain is that approximately half of the brain (30% of the cortex) of human beings is directly or indirectly involved in processing visual input. People can also remember more than 2000 pictures with at least 90 % accuracy (Cheryl L. G., et. Al., 1998). All these founded facts point to our orientation that we have from our birth. It is known that 65% of a population is visual oriented (Manktelow, 1998) and thus it is feasible to instill high order visual literacy skills in a population of students. Fleming. N. (2012) suggested that learners below the age of 13 years are still forming their learning preference\s and thus not advisable to take them as a sample for investigation. VARK model (Fleming. N. & Bonwell.C., 2013) proposes an index of learning style online where people can measure their learning style preference. The online questionnaire helps to assess the individual through 16 general questions each with 4 options pertaining to the Visual, Aural, Reading\writing, Kinesthetic mode. After submitting the form, a result is displayed stressing on the type of learning preference that person is inclined to. But, these questions have been designed for the general audience and the context, culture, background and age groups of participants are different for different countries. Thus, a learning style instrument (LSI) developed as per the factors mentioned above will be more appropriate to get more consistent results. This can be applied to Biology students where a new learning style instrument can be created as per the curriculum and context to identify their learning preference\s in Biology (Bowler et al., 2011). The results can help teachers and students alike to know the learning preference\s that is the way students want to study Biology whether as a single mode or multimodal. Getting information on the learning style of the students can permit teachers to adapt their teaching style\s accordingly to match the learning style\s of the students. Besides, these details on the learning style\s can allow teachers to prepare their assessments which will cater for the different types of learners.

Visual literacy indicators as benchmark

Very limited numbers of research work have been conducted on measuring visual literacy skills in students (Arslan & Nalinci, 2014). Acquaintance with skills related to visual literacy is very important to be able to discern meaning (Brumberger, 2011) because subjects like Sciences make heavy use of images in the learning process. As per Little, Felten, and Barry (2010), visual literacy is an important skill for the twenty-first-century students.

The American Association of College and Research Libraries (ACRL) has issued in 2011, a list of Visual Literacy Competency Standards that steer a person in his quest for visual literacy skills. The Competency Standards can be used across many disciplines. Currently, in all scientific fields, students are employing visuals for academic purposes but without following any benchmark or reference point. These competencies can be acquired through training and visual literacy education. The eight standards that a visually literate student should possess are:

1) Identifies and selects the type of visual materials that will be needed.
2) Finds and accesses the required images and visual media.
3) Examines and understands images and visual media.
4) Evaluates visuals and their sources.
5) Uses images and visual media effectively.
6) Designs and creates meaningful images and visual media.
7) Extract the essence from visual messages.
8) Understands many of the ethical, legal, social, and economic.

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The above-mentioned competencies include learner-generated drawings which in turn includes the different competencies mentioned above. Learner-generated drawings give the prospect to students to transfer, organize and express knowledge and comprehension obtained from reading\writing, listening (verbal instructions) of from pictures with the aim to produce a final product that is a representative diagram. The term “drawings”, points to drawing as artistic expression, demonstration of knowledge in the form of line drawings without colours but can be with light shadings and can also refer to mastering the techniques of other artist\teacher. Learner-generated drawings are known to engage the senses especially in the sciences like generating ideas for good writing, engage in high-level thinking and deep understanding, enhance the memory allowing to draw from memory, improves observation techniques by being attentive to the details and helps in creating mental images and then replicating on paper (Dempsey and Betz, 2001). Other tasks can be drawing the missing step\s in a process, to revisit and then revise a drawing, drawing to show a change and development before and after an event\process i.e. comparison, drawing the enlarge version after close study of a small sections, poster presentation on certain concepts, supplement drawings with writing, observe objects then drawing the observed specimen from under the microscope or from memory afterward, creating or arranging a flip-book in the proper order, testing prior knowledge among many others. The list is non-exhaustive.

Another set of benchmarks is offered by The Mid-Continent Research for Education and Learning Corporation for visual literacy. These are:

1) Interpret visual media which includes animations, graphics, video, television etc.
2) Extract the essence from the visual message.

3) Understands how visuals convey meanings through visual grammar like angles, symbols, color, line, texture, shape, headlines, scale, pattern, sequence of images, lighting, contrast, repetition, pacing etc (Gangwer, T., 2009).

Other authors have coined competencies that can enhance visual abilities. The set of skills are:

1) Critical selection between the useful and unnecessary.
2) Recognition in its context, analysis, evaluation.
3) Understanding.
4) Using and connecting.
5) Producing, interpreting, evaluating the use of visual conventions like signs and symbols and validating through discourse with others.

Yet, another investigation mentioned about two main approaches to enhance visual literacy skills (Tillmann, 2012). These are:

1. Reading\Decoding visuals i.e. carrying out interpretation and decipher the meaning behind, through analysis techniques (not like deep viewing, framing etc).

2. Encode visuals i.e. writing from visuals (April. D. L & Alice. E. s, 2015).

Another term similar to visual literacy with apparently similar indicators that is employed in Science teaching research work are metavisualisation (Newberry, 2010) where a person should have the ability to:

(a) demonstrate understanding for all the modes of representation like diagrams, animations and other visuals.

(b) translate between a metaphor and realism.

(c) construct a representation to explain a phenomenon.

(d) using visualization to make a forecast based on mental images.

(e) use an existing visualization to understand a new phenomenon.

Visual-based learning relies on theories mentioned above including visual literacy and metavisualisation where learners are subjected to a panoply of visuals and hand-on activities where they carry out observation, form mental representative images and analyse charts. These cognitive abilities push the learner to make the mental images more explicit and concrete. Specific skills (Ferk et al., 2003) are required for effective visualization like:

(1) Spatial visualization i.e. the skill distinguish between and understand three-dimensional objects from their two-dimensional counterparts.

(2) Spatial orientation the aptitude to form a mental image of what an image will look like from a different angle.

(3) Spatial relations i.e. the capability to mentally manipulate objects.

Visual literacy indicators

Assessments can be set up with questions pertaining to the visual literacy indicators to test the seven visual indicators listed below, the first six from the American Association of College and Research Libraries (ACRL) issued in 2011 and the last one from The Mid-Continent Research for Education and Learning Corporation for visual literacy. The final marks for each visual literacy indicator were compared with the pretest marks and compiled into a final total mark which was used as an indicator of learning outcomes. These seven visual literacy skills were most appropriate for the age group under study despite the fact that there were several other benchmarks that exist to measure visual literacy. The seven indicators are described below as per (Hattwig et al., (2013).

1. **Identify** the type of visual materials that will be needed. The command word "identify" means recognizing and naming facts, characteristics or concepts that are relevant for understanding a process and an event i.e. knowing what that thing is and naming the thing. The 'identify' standard promotes exploration thus expanding their understandings of the visual materials with a wider range of image types
2. **Find** the required images and visual media. The "find" indicator is a skill that determines, decides and selects the most appropriate visual and naming it. The question below was used to assess the "find" indicator.
3. **Understand** images and visual media. Understand means to know the meaning of something.
4. **Evaluate** images. The evaluate command word means to judge the importance of something where the advantages or disadvantages are laid forward.
5. **Use images** and visual media effectively. The "use" word implies to put something for a purpose.
6. **Create** meaningful images and visual media. The word "create" means making or producing something which new.
7. **Extract the essence** from the visual message. It means to know the gist of the concept i.e. the most important idea. Rieber. L (1991), mentioned about physics students who successfully extracted information when animated sequences were projected.

The seven indicators closely matched (Tillmann. A., 2012) the six levels within the cognitive domain of Bloom's taxonomy (Bloom et al. 1956). The first level is on the knowledge that involved recognizing facts, terminologies, methodologies, classifications and basic ideas without necessarily understanding the meaning. This level was similar to the 'find' and 'essence' indicator. The next level of the cognitive domain was the comprehension stage that involved showcasing understanding the main ideas and facts and should be able to carry out comparison. This level equates to the 'understand' indicator of visual literacy. Next level is the application level which refers to using the acquired knowledge whether it is in the form of facts, procedures and techniques for problem- solving. It also involved identifying links and relationships between components. The third level is similar to the 'use' indicator. The fourth level is known as analysis that involves breaking information into the different components and then finding the relationships between the parts. It also involves drawing a conclusion. This level is analogous to the 'evaluate' indicator. The fifth level is known as synthesis that entails building a whole from parts. This level is comparable to the 'create' indicator. The last level is called evaluation that requires judgment on the validity of ideas. This level is synonymous to the 'evaluate' indicator. The six levels were presented from the lowest level in terms of recalling facts to more complex and abstract levels and finally to the highest order i.e. evaluation.

Conclusion

Being visually illiterate today would be a disadvantage to most of us because we are living in a world where we are constantly bombarded with visuals, whether it is through bill-boards on the high way, media, smart-phones, internet, facebook, advertisements, you tube and so on. The usual and most common form of educational settings comprise, of learners who are mostly exposed to verbal instructions thus not trained to extract meaning from visual aids. This may be attributed to the fact that many educators make use of the verbal form of communication in Science classes with little usage of visuals. As a result, teachers need to learn to teach visually by developing pedagogical-visual-content-knowledge. This will allow them to select effective visuals for a particular class as per the level and context in which students are evolving. And students should develop science visual literacy skills to encode and decode visuals in an efficient manner.

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