Visual Literacy and Visualization in Instructional Design and Technology for Learning Environments

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Abstract

The purpose of this study is to discuss the effects of visuals, visual literacy, visualization and multimedia design strategies using instructional design (ID) models for developing projects in education and science education, as well as engineering education. This study discusses and presents ways to evaluate visuals, visualization, and virtual technologies (as VR/AR and 2D-3D) in science education and engineering education based on research and foundations of visual learning, visual thinking, and visual communication. This study is a literature review work concerning visual effects, visual literacy, learner perceptions and technological variables for designing multimedia instruction and learning projects in visualization. In addition, this paper discusses similarities and constraints in using ID models for designing multimedia projects from the perspective of the use of visuals and ID models for developing visual materials in education. These procedures include the perceptual and theoretical foundations of visual learning, cognitive factors of visual images, visual design and program of systematic evaluation steps, as well as multimedia projects design and development materials with ID models, such as the decide, design, develop, and evaluate (DDD-E) model (Ivers, Barron, 2010) and a human information processing model (Mayer, 2001). With these models, all considerations for visual typology will be indicated in the implementation of visuals, learning design, visualization using virtual reality technologies and evaluation of visuals in multimedia development. Concluding the paper, meaningful connections between visuals and technological variables for developing multimedia project design will be considered. Indicators for learners and designers and teachers will be shown in learning imagery for visualization activity and educational technology. This will be followed by a discussion of the use of visuals and evaluation of visual materials based on the program of systematic evaluation developed by Dwyer (1972, 1978, 1987, 1994).

Keywords: visual literacy, visualization, instructional design and technology, learning.

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1. Introduction

In line with the progress of research in science, education, instructional technology and learning design, the teaching and learning process needs to involve different aspects, such as the conceptual, verbal, virtual or spatial levels. They can be characterized in lessons as problem solving, learning from images and also presented as relationships on macroscopic, microscopic and symbolic levels, especially in the educational and instructional development process using instructional design (ID) models. These levels have been clearly used in science research work and linked to ID models with visualization, which is part of visual literacy and visual thinking (Rundgren, Yao, 2014; Gilberd, 2008; Ipek, 2003, 2010, 2011; Ipek, Ziadinov, 2017; Moore, Dwyer, 1994).

2. Discussion

Visual literacy consists of visual learning, visual thinking, and visual communication (Seels, 1994). The philosophy of visual literacy has a long history of defining visuals, visual designs and information processing as communication in learning forming pictures for how to think in designing visuals and completing parts of figures, such as puzzles. It means how to understand concepts, images and screens while visually thinking in science courses to learn from images. This visualization, is not only part of all scientific fields, such as construction, engineering, architecture, instructional design, and educational technology, but also pertains to geography and chemistry. Visual attributes have been used since the second half of the 19th century due to technological invention associated with the use of photographs and other visuals. In connection with the visualization of culture was a gradually developing visual literacy. The first definition of visual literacy used in 1969 by John Debes, who was one of the pioneers of visual literacy, conducting research in image and visual perceptions. Others who have influenced thinking about the concept of visual literacy include Clarence Williams, Colin Murray Turbanye, Rudolf Arnheim, and Robert McKim (Hortin, 1994). The Eastman Kodak Company also played an important role. Researchers investigating the left and right hemispheres of the brain and perception theory, as well as artists and educators have made important contributions to the visual literacy field. Visual literacy is one of the first areas in literacies, some of which have appeared with the new technologies and developments in learning design with multimedia in science education and engineering education, as well as in the field of instructional design, educational technology, and other areas.

The study of visuals and multimedia design strategies is a broad and complex mixture of many disciplines, perceptions, interests and material design functions, as well as user-learner interface design considerations and learning from pictures. Instructional designers, scholars in visual design and material development activities and experts in distance learning are interested in using visual variables and functions to develop screens using visuals and multimedia development strategies. They also use visual literacy concepts extensively for learning and teaching subjects in education and engineering education. Visual literacy is the main field of understanding all the variables contained in visual design and learning design for teachers and students in order to improve development of instructional elements for visualization in learning (Dwyer, 1978; Moore, Dwyer, 1994). Visual communication; for example, showing graphs and simulations, as well as using concept mapping in the classroom, is one of the important and effective strategies in promoting student learning and assessing student understanding in science, engineering and art education.

The purpose of this study is to discuss the effects of visuals, visual literacy, visualization and multimedia design strategies with ID models to develop projects in education and science, as well as engineering education. The paper also discusses and presents how to evaluate visuals based on research and the foundations of visual learning, visual thinking, and visual communication as components of visual literacy. To improve the design visuals, learners should follow the new technologies and acquire better design strategies, performances, and teaching theories within definition of visual literacy and its concepts for visualization of imagery.

The Definitions of Visual Literacy and Instructional Design and Technology (IDT)

Disciplines, such as art, education, linguistics, philosophy, and psychology have all contributed to human knowledge and understanding of visual literacy, which consists of visual learning, visual thinking, and visual communication. Theoretical foundations and theory of visual literacy also emanate from these disciplines (Barley, 1971: Debes, 1968a, 1968b; 1972). Visual

literacy is based on the four areas of linguistics, art, psychology, and philosophy (Hortin, 1994). From this perspective, visual literacy and perception have a role in the communication and learning process that also involves the instructional design activity and educational technology movement (Seels, 1989: İpek, 2001a, 2001b). In addition, Braden and Hortin (1982) suggested a new definition that "visual literacy is the ability to understand and use images, including the ability to think, learn and express oneself in terms of images" (p. 41).

3. The relationships between visual literacy concepts

As presented above by Moore & Dwyer (1994) and Seels (1994), visual literacy consists of visual thinking, visual learning, and visual communication to provide strategies for learning from pictures and images in the education process. Since the beginning of its development in the 1970s, the concept of visual literacy was defined as instructional and learned ability to interpret visual messages clearly and create messages in learning. In addition to this approach, another definition was presented by Curtiss (1987) in that visual literacy has a further dimension, which adds a communication process to understand visual statement in terms of learning and teaching. Thus, the visual literacy cube shown in Figure 1 was developed to present the relationship between constructs, including visual communication, visual thinking, and visual learning. Figure 2 shows the continuum of those visual literacy components.
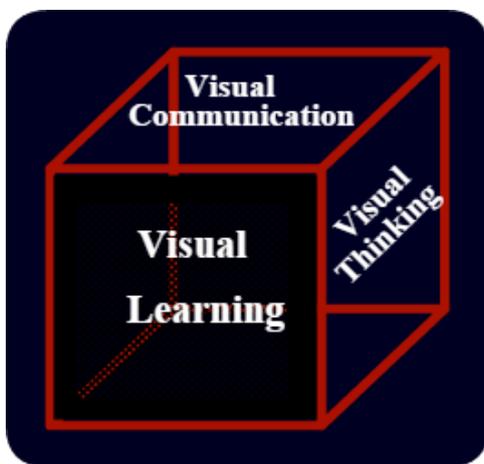

Fig. 1. The Visual Literacy Cube (adapted from Seels, 1994)

Figure 2 shows those visual literacy components from a geometric perspective, a continuous line known as a continuum.

Fig. 2. Visual Literacy Continuum (adapted from Seels, 1994)

The terms used in Figures 1 and 2 are explained below.
Visual Thinking: This is the internal reaction that manipulates mental imagery and a more sensory and emotional combination in the learning process. Thus, it includes the unity of perception and conception, which indicates an ability to see visual shapes as images, including pictures, signs, and symbols (Arnheim, 1969). Visual thinking is connected with the organization of mental images around the visual components which include shapes, lines, color, and textures (Wileman, 1993).

On the other hand, McKim (1980) defines visual thinking as the interaction of seeing, drawing, and imaging as shown in Figure 3. Visual thinking strategies include transform, manipulate, concretize, timescan, and abstract functions. These aspects are very important to keep in mind when developing visuals for multimedia projects design and multimedia learning with user interface design strategies by means of instructional design models. Visual thinking refers to visualization through images, which are also mental pictures of sensory experiences, perceptions or different conceptions in learning environments for science and engineering (Seels, 1994). At this point, the sources of imagery are an important part of the visual thinking process when learning from abstract contents and invisible forms of lessons. Visual thinking contains all human activity, from the abstract and theoretical to the down to earth and everyday aspects for people. Examples of those who adopt the process of thinking in visual images can be seen in the daily lives and careers of surgeons, astronomer, chemists, mathematicians, engineers, business people, architects, and carpenters. This process is carried out by three kinds of visual imagery, drawing, seeing and imaging, as shown in Figure 3.
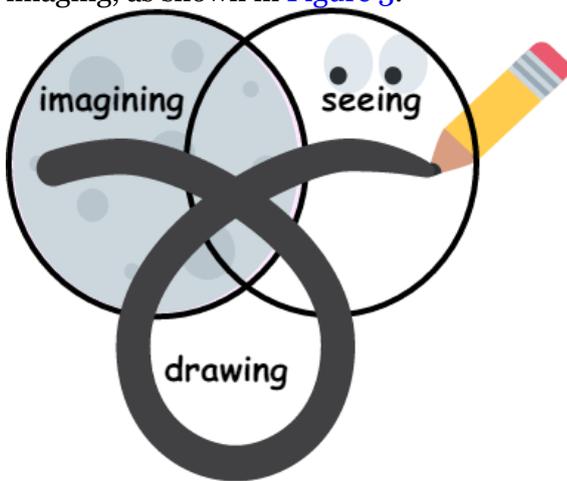

Fig. 3. Components of Visual Thinking (taken from McKim, 1980)

The interactions between the three aspects of visual thinking continue until the contents are visualized and the problem is solved. Thus, visual thinkers utilize seeing, imagining, and drawing in a fluid and dynamic way, and moving from one image to another (McKim, 1980).

Visual Learning: This is located in the most complex theoretical environment because it refers to learning both from the visuals and the research concerning the design of visuals and visual learning materials for instruction (Seels, 1994), as well as science and engineering education in educational technology. Visual learning, referring to learning from pictures and media, was first used as a title of television workshop in New York, State Board of Education in 1976. Visual learning as meaning research was first used by Dwyer (1972, 1978). In addition, Fleming and Levie (1993) presented message design principles for the designing instructional visuals based on behavioral approaches for designers and educators.

Visual Communication: This component should be added to develop the multimedia design process with human information processing and multimedia development model as indicated by Mayer's Model (2001). Wileman (1993) defines visual communication as "the attempt by human beings to use pictorial and graphic symbols to express ideas and to teach people in and out of school setting" (p. 13). According to Seels (1994), visual communication is the use of visual symbols to express ideas and convey meaning. Generally, communication can be defined as an interactive or transactional process in the learning and teaching visually in educational technology.

Thus, it is very important to develop visuals for the design of multimedia projects and multimedia learning with user interface design strategies by means of ID models. Thus, as indicated by Mayer's Model (2001), visual and instructional communication should be incorporated into the multimedia design process using a human information processing and multimedia development model.
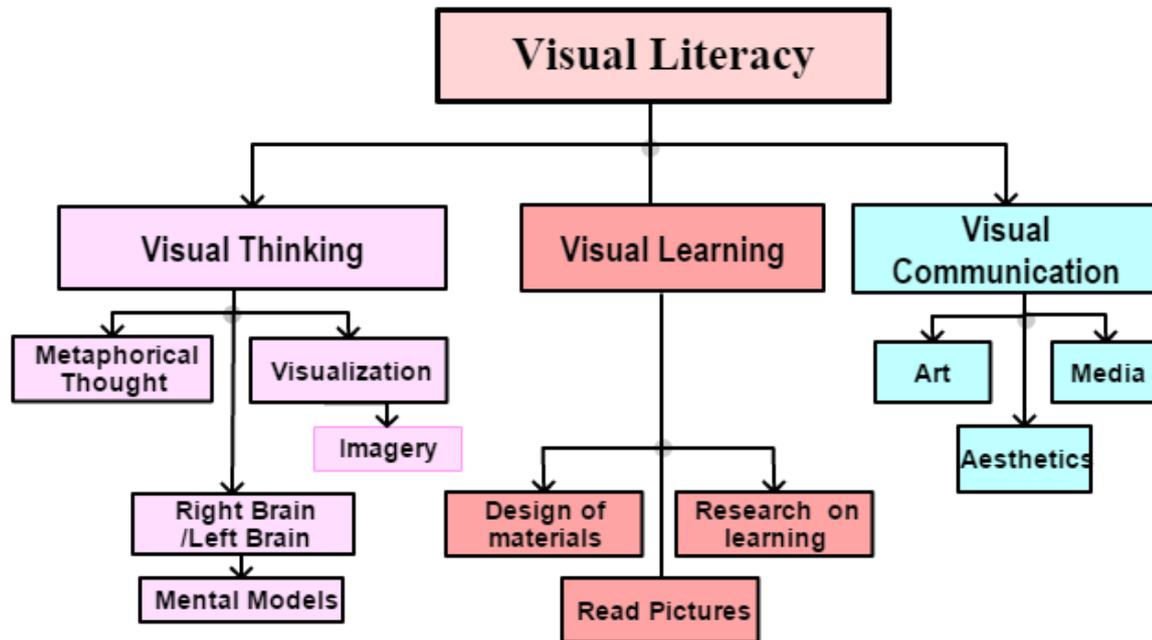
Fig. 4. Relationship of Areas of Study in Visual Literacy (Seels, 1994; taken from Moore, Dwyer, 1994)

Types of Visuals

Visuals as important instructional elements and variables in multimedia learning, visualization in engineering education, and science education can be categorized by size as medium and large. They are also defined based on their purpose, roles and content. Pettersson (1989) refers to symbols and pictures as visual languages and presents three kind of language for creating visuals and information as messages in learning and teaching: verbal, audial, and visual. According to Pettersson (1989), there are new forms in visual literacy, which are audio-verbal, verbo-visual, oral-visual, and texi-visual. They refer to combination of verbal language and visual language for designing learning in the educational process for ID, technology and information design.

On the other hand, there are other definitions of visuals. The characteristics of visuals can be assigned using these three forms (Dwyer, 1994). Static visuals include picture and other printed or projected images. There are also different visuals, such as dynamic, written (static) and spoken (static) verbal elements. Dynamic visuals include animation, video, and film. Personal visuals can be defined as a subset of dynamic visuals, including sign language, body language, and gestures. Written (static) verbal elements refer to words, and all forms of text. As a last type of visuals, spoken (dynamic) verbal elements include the spoken language in audible and visible forms of text (Braden, 1994). In addition to Braden's work, Wileman (1993) created a typology of verbal and visual image relationship. This approach contains seven steps presenting his typology for visual design. Visual designers and software developers should be aware of the types of visuals and their effectiveness on multimedia, learning and e-learning designs to use in the visualization of subjects in science or engineering education.

The definitions of visualization, representation and model in research

Visual communication is essential to promoting ideas in lessons, and visualization has been widely used in science education and learning, instructional and art design to represent scientific and technological concepts over many years to visualize visuals as sensemaking (Cook, 2006; Gilbert, 2008). There are several divisions for visual communication performance, namely art, instructional materials, and audiovisuals Visual communication will be possible using art, instructional materials, and aesthetics for visualization of contents to make invisible contents visible. Visual communication design research includes art history, design fundamentals and

history, philosophy, film critique, photography, human behavior, and any other subjects related to human visual perception and communication. There are also other design areas; e.g., graphics, user experience and user interface that focus on the visual aspects of the design, as well as the user flow behind the design activities for IDT as an educational technology field.

Today, there are different definitions of visualization, but they mainly consist of the external representation (ER), internal representation (IR), and visualizing process (VP) of cognitive and brain activities (Rundgren, Yao, 2014). Visualization also means sensemaking its framework includes several steps in the learning or teaching process, such as providing an information environment, creating cues within community, using the cues and collaboration for creating patterns, building mental models, which create an action plan for the workplace, and building new information, and finally the new information starts as the visualization cycle in learning process. During this process, human cognitive architecture includes a working memory of limited capacity and duration with visual and auditory channels, and effective long-term memory. At this time, cognitive load theory uses this combination of information and cognitive structures to guide instructional design systems and educational technology. For this, as indicated in the visualization framework given above, visualization and instructional design require an information structure and also include human cognitive architecture incorporating short-term memory, working memory, long-term memory, schemas, automation, and some instructional effects, such as split-attention, modality, redundancy, interactivity, and imagination (Sweller, 2018).

Visualization in learning is not the same as visualization in instruction (Winn, 1980, 1982). To understand why this is so, it is important to describe the relationship between learning and instruction to control the learning and teaching process for working in education. As indicated by Shuell (1980), instruction indicates the control of learning processes. This means that instruction uses processes that are external to the learner, while learning uses internal processes which are psychological variables dealing with perceiving information, assimilations, perceptions, storage and interpretations. In addition, a further point should be considered in that learners have mental skills to learn from images for visual thinking in visualization. This imagery can be used in the same situations, shape or form by learners. Imagery is also a basic part of cognitive process and of mental skills. Instruction involves the control of cognitive process and uses learning strategies, such as applying mental skills. In this process, instructional strategies in the instructional design field include orienting tasks and student capabilities. Student capabilities are similar to mental skills as well.
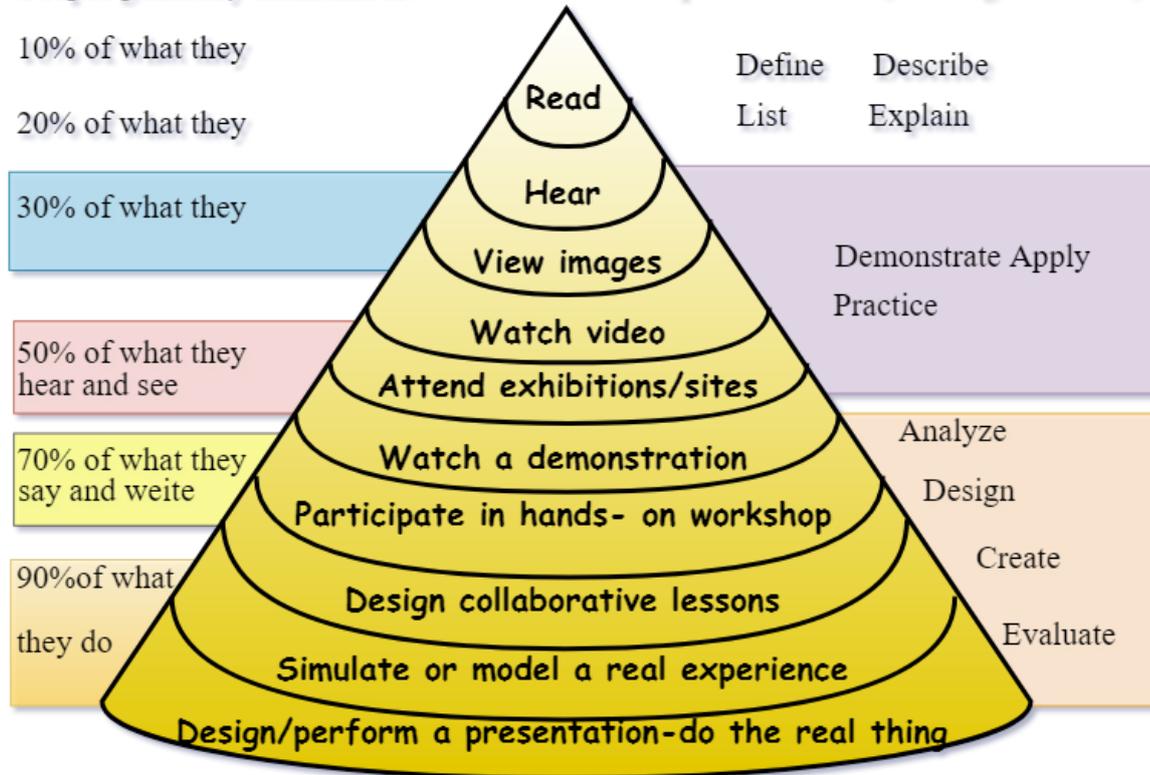
Tufte (1983) views visualization as ER with a systematic demonstration of information in the form of pictures, diagrams, tables, and the like. By the same token, in the later years, colleagues in different research groups have defined visualization as any type of physical representation designed to make an abstract concept visible or understandable for learning objects (Rapp, Kurby, 2008; Uttal, O' Doherty, 2008). Visual representations (VRs) are essential for communicating ideas and concepts in science education, engineering and architecture, but it is not always beneficial for designers and learners in the educational process. Basically, VR deals with science concepts, such as graphics, invisible phenomena, and ID principles concerning the learner's cognitive structures for learners and educators. These graphics are often used to present multiple relationships and learning strategies in the design of instructional materials; e.g., visual and verbal information. In this process, VR in science and engineering considers the way of creating design strategies, making a decision point, and future interpretations for learners (Cook, 2006). As a result, prior knowledge, cognitive load theory, and ID considerations, such as multiple representations, animations, dual-mode effect, instructional guidance, attention, and modality are very important stages in solving problems in visualization and learning design in the science and engineering fields.

Visual Perception and Human Information Processing

A well-known research study was conducted by Dale (1969) in relation to learning with visuals effects. The study included all the processes for experiencing learning through visual literacy and visualization (Figure 5). There is a relationship between this approach and Mayer's information processing model, which starts with the two dimensions of seeing and hearing (Mayer, 2001). Visual perception, visual information processing, and the subsequent creation of adequate concepts for students are essential components of science education. Visualizations are associated

with cognitive performance and mental skills. Visualization allows the application of scientific concepts of science education and engineering within a new design context.


People generally Remember:

10% of what they

20% of what they

30% of what they

50% of what they hear and see

70% of what they say and weite

90%of what they do

People are able to: (learning outcomes)

Read — Hear — View images — Watch video — Attend exhibitions/sites — Watch a demonstration — Participate in hands- on workshop — Design collaborative lessons — Simulate or model a real experience — Design/perform a presentation-do the real thing

Define Describe
List   Explain

Demonstrate Apply
Practice

Analyze
Design
Create
Evaluate

Fig. 5. Dale's Cone of Experience (adapted from Dale, 1969)

Mayer's model, learning with technology and integrated e-learning

Mayer (2001) shows human information processing process in the four parts of multimedia presentation via words and pictures, sensory memory which contains hearing and seeing, working memory, and long-term memory. The multimedia design process is shown in Figure 6.
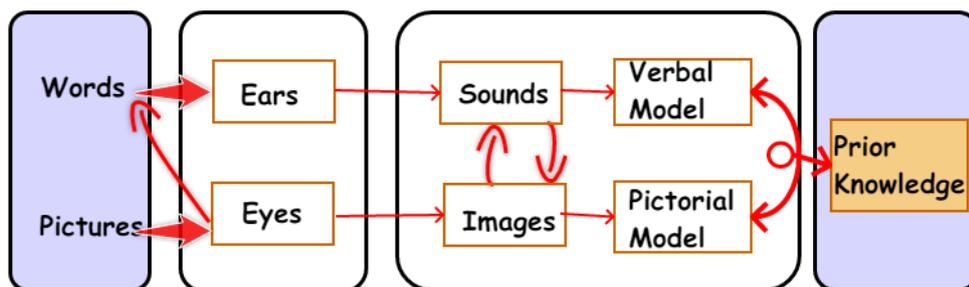

Fig. 6. A Multimedia Model (Mayer, 2001)

On the other hand, multimedia design projects should be developed based on ID models. Thus, many ID models have been developed to meet technological developments and their needs. For instance, distance education as a new area uses e-learning technologies to develop e-learning courses using visuals and multimedia tools. For this purpose, an integrated e-learning model was developed to apply ID rules to e-learning environments (İpek et al., 2008). The approach is given in Figure 7.

With the design considerations in multimedia project design in multimedia instruction, rapid ID models, and rapid e-learning design strategies use effective visuals for the instructional process, such as text, printed projects, images, combination of text and sound, and video.

The characteristics of visuals have been effectively used to develop integrated e-learning process and user-interface design process with e-learning tools and technologies. Thus, developers and designers complete all technological and instructional principles to develop high quality visuals used lessons and software packages. They also create instructional materials to be used by whiteboards and computers in schools, industry and training. At this time, the use of visuals, user-interface design rules, and e-learning design principles can be integrated to develop courseware and e-learning materials through ID models and theories (İpek, Sözcü, 2014; Sözcü, İpek, 2013, 2014). For this reason, all design process should include instructional, pedagogical and technological approaches in e-learning design, which can be defined as integrated e-learning design model (İpek, et al., 2008; Jochems et al., 2005; Sözcü, İpek, 2014).
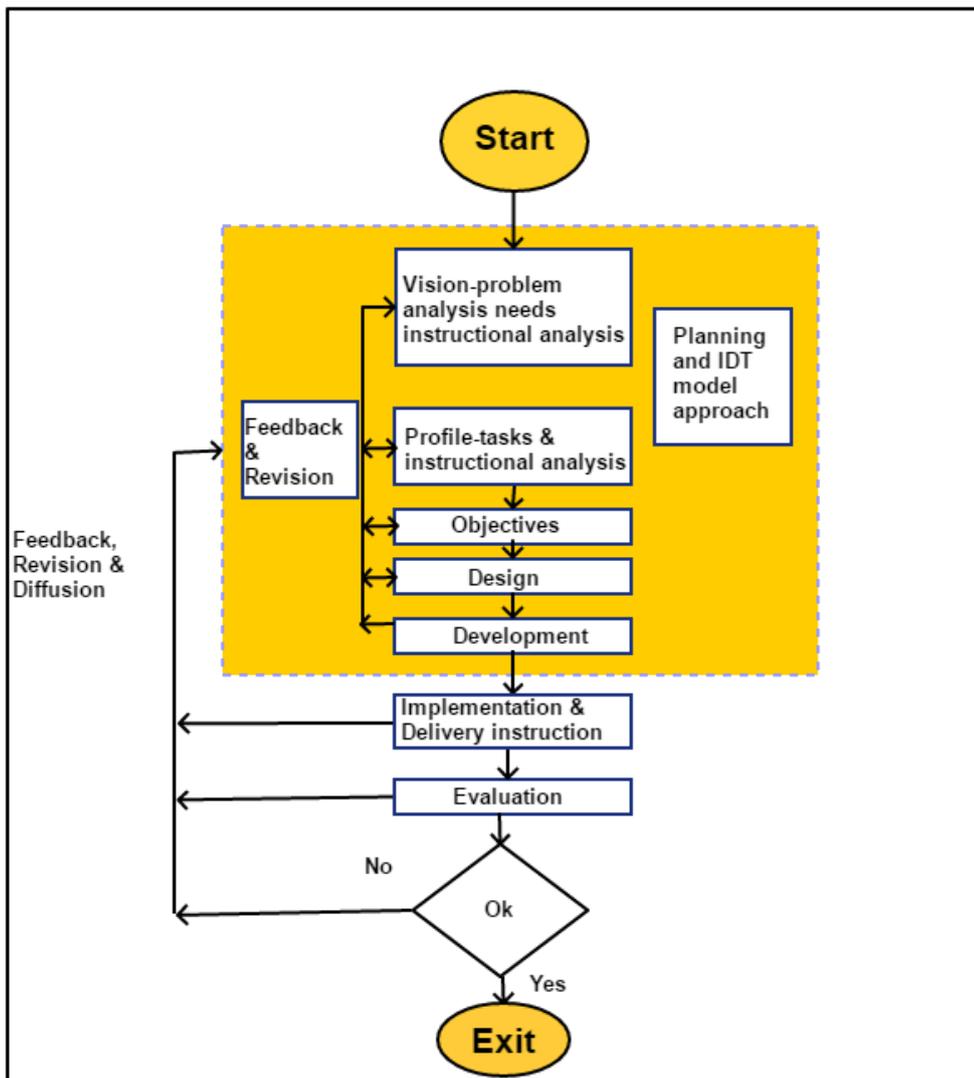
Fig. 7. Instructional Design Model for Integrated E-Learning
(taken from İpek et al., 2008; Jochems et al., 2005)

Types of visualization techniques and learning from images in education

There are several types of visualization techniques, including data, interactive, dynamic, strategy, information, concept, metaphor and compound visualization. Data visualization is a general term that describes any effort to help people understand the significance of data by placing it in a visual context. Patterns, trends and correlations that might go undetected in text-based data can be exposed and more easily recognized with data visualization software. In contrast, virtual technologies trends in education capture people's attention. Virtual or augmented reality have been applied in many sectors such as industry, medicine, education, video games or business. The media presented 2016 as the year in which virtual reality would be available for electronic learning

environments, such as smartphones with different learning styles and teaching processes (Cellean-Jones, 2016; Gutierrez et al., 2015; Gutierrez, Mora et al., 2017; Sag, 2016). Thus, educational organizations can benefit from better accessibility for future performance and learning in educational technology and ID. There is a reality-virtuality (RV) continuum, as well as visual literacy. There are various categories of virtual reality technology which depends on the different degree of immersion in the visualization. For example, cabin simulators utilize a projected reality on a wide screen, augmented reality devices objects in real environments, telepresence can be used to operate in real but different locations, desktop virtual reality offers a regular display or interaction with virtual world, and visually coupled systems are employed for military aviation purposes which include sensors that track the user's eye movements following target object (Gutierrez, et al., 2015; Gutierrez, et al., 2017).

Visualization and Instructional Systems Design-Using ID Models

In the learning and teaching process using images, multimedia technologies have great potential to empower the higher-order thinking skills of learners. There are two important aspects of multimedia. First, incorporating hypermedia to enable knowledge construction by learners and designers, and second, using visualization and virtual communities to create artificial worlds (Dede, 1992). Multimedia products present the delivery of instruction, provide modeling thinking strategies and knowledge structure, building visual materials intellectually, and evaluating instruction and visuals using criteria in science and engineering. In addition, hypermedia provides a representation architecture very important in completing activities in a multimedia database by using linear, non-linear structure for the learners and visual designers as part of hypertext definition with links, nodes and buttons. On the other hand, instructional applications can be gradually developed from tutorials, simulations, games and drill-practice into e-learning environments as virtual worlds and visualization in multimedia learning environments or design. At the same time, visual learning designers and educators are using different ID models to develop efficient visuals. In addition, there are ID models used in education or industry for learning and teaching visual or virtual design, known as Bloom, universal, Seels and Glasgow, Gagne & Briggs, R2D2, Mayer, 4/C ID and integrated e-learning models, and the DDD-E model for multimedia projects design (Güney, 2018; Güney, İpek, 2017; İpek, 1995a, 1995b, 2001a, 2001b; İpek et al., 2008; Ipek, Ziadinov, 2017).

There are several types of visualization, such as sensory transmitters which use ears, eyes and hands to access phenomena. Cognitive transmitters are a second form of visualization that makes intellectual information and knowledge structures visible (Dede, 1992). Hypermedia also supports two type of visualization, computer graphics and video, to develop visuals in the IDT field, and learning design in science education. Research on learning with images shows that meaningful learning depends on the learner's cognitive activity during learning rather than the learner's behavioral activity during the learning process.

The use of visualization for effective learning design and load theory

Visualization makes the invisible visible. Thus, visualization for effective learning should be based on images, infographics, and animation (Gogia, 2018). Visualization is a task or exercise of representing content through visual and verbal ways in order to increase content visibility and retention of information. It is also part of the learning design to have strategies accurately for interpreting all contents, learning points, and main ideas and highlighting the key learning aspects in lessons, as well as creating visuals with good screens.

The use of visuals for visualization in education and engineering education

In our schools, science learning often involves creating abstract representations and models of processes that we are unable to observe with the naked eye. For example, chemistry texts often use images to represent atoms and molecules, and the processes and changes in them. Learners cannot see very well what has happened or will happen there? Since these reactions occur at a very small scale and are invisible or difficult to observe, we must use visualizations and representations to help us understand what is occurring in the process and make it visible with using multimedia technologies such as virtual and augmented reality devices for spatial skills.

An important component of scientific learning is the ability to observe mentally 2-D objects into dynamic 3-D objects for many students, particularly those with learning or cognitive difficulties. Additionally, for students with cognitive or visual impairments, the critical information contained in the representations may be inaccessible if presented in a traditional textbook, such as

text and static graphics. All these visualization techniques should be effectively used in learning environments to achieve learning objectives in science education as well as engineering education. Theories about learning with multimedia can be defined at different levels. At a basic level, psychological theories define memory systems and cognitive learning systems showing how people learn information with different senses, such as spatial ability and spatial visualization with three-dimensional (3D) objects from two-dimensional (2D), presentations. It also includes spatial orientation and special relations ability to visualize the effects of operations or to mentally manipulate images (Korakakis et al., 2012; Paivio, 1986). At this level, ID models, such as universal design or 4/C ID model can be used to learn technical skills in education and science education and programming in education (Güney, İpek, 2017, 2018). However, there are some limitations for learning with virtual technologies in education; e.g., students not being competent in using technologies in an instructional environment. Virtual technologies are no exception to this. The use of new technologies does not involve necessarily innovations and improvements in learning process with instructional theories and design models. For this reason, it is required to design virtual learning environments to provide instructional design approaches to achieve all learning outcomes (Fowler, 2015; Gutierrez et al., 2015; Gutierrez et al., 2017). In addition, Lin & Dwyer (2010) indicated that static and animated visualization can be effectively and efficiently used if the time-on-task is taken into consideration in ID and strategies are practiced during visualization of images.

Program of systematic evaluation (PSE) for visuals in multimedia learning and design

The evaluation of PSE can be envisioned as having progressed through three phases (Moore, Dwyer, 1994). In the first phase, basic conceptual steps for the program were developed. At this stage, types of objectives to be used were defined. Instructional subjects with concepts were constructed. To test these concepts, all necessary criterion tests were constructed and used for students' achievement, as well as drawing realistic photographs with their color. The part includes following selected contents and criteria (Dwyer, 1994). Visual designers should be aware of these considerations in visual literacy and visual design to evaluate visuals for learning in science and education with new technologies. The following phases (Phases 1 to 3) were conducted by Dwyer (in 1972, 1978, 1987) Phase 1 was defined and summarized as follows (Dwyer, 1994):

1. Visuals do not automatically improve student achievement;
2. All types of visuals are not equally effective in providing student achievement of different educational objectives;
3. Identical visual illustrations are not equally effective when used for externally-paced and self-paced instruction;
4. A specific educational objective depends on the amount of time that students are permitted to interact with visualized instruction;
5. For students in different grade levels, the same visuals are not equally effective in increasing achievement of identical instructional objectives;
6. For specific students and for specific educational objectives, the use of color in visuals appears to be important;
7. Various visualized treatments on immediate retention tests disappear on delayed retention tests;
8. Student perceptions of the value of different types of visual illustrations are not valid assessments; that is, aesthetically pleasing visuals may deceive students concerning their instructional value;
9. The realism continuum for visuals is not an effective predictor of learning efficiency for objectives;
10. Boys and girls in the same grade level (high school) learn equally well from identical types of visual illustrations when they are used to verbal instruction.

In addition to phase 1, Dwyer (1978) indicated that strategies for visual learning include many variables, including degree of realism, cueing techniques, level of educational objectives, individual differences, method of presentation, and testing format associated with the effective use of visual materials. The following list (Phase 2) provides generalizations with visual design and learning in multimedia projects;

1.   The realism continuum for visual illustrations is not an effective predictor of learning for all types of educational objectives. An increase in the amount of realistic detail will not produce an increase in the amount of information;

2.   The use of specific types of visual illustrations to reach easily specific types of educational objectives significantly improves student achievement and performance in instruction;

3.   All types of visuals are not equally effective in student achievement when instruction is externally-paced. The type of visuals is most effective for type of information to be transmitted;

4.   The use of visuals specially designed to oral instruction does not automatically improve student performance. However, there is a relationship between educational objectives and a particular instructional method to increase student achievement;

5.   The use of color for specific students and objectives appears to be an important instructional variable in improving student performance;

6.   Oral instruction without visualization is as effective as visualized instruction for specific types of objectives and students;

7.   All types of querying technique are not equally effective in instruction in visual illustrations.

As a final evaluation phase, Phase 3, based on research findings, indicates the variables that deal with visual illustrations and visual design for multimedia instruction. They are very important instructional components of visual design, as well as multimedia learning with visuals (Dwyer, 1978). All these variables can be used for designing visuals and technical design for instructional materials in multimedia projects. Instructional, visual and software developers should be aware of the quality of user-interface design principles, and visual design fundamentals; they should also apply and use instructional design models and their strategies effectively in multimedia learning and visual illustrations (Allen, 2007, 2011). Variables in visual illustrations and program of systematic evaluation (Phase 3) are summarized below (Dwyer, 1987, 1994).

- Cognitive trace compatibility
- Color coding
- Cue summation
- Dogmatism
- Cognitive strategies
- Computer-based instruction
- Cued recall
- Elaborate/reduced step cueing
- Encoding specificity
- Field dependence/independence
- Imagery learning techniques
- Levels of self-pacing
- Mode of instruction
- Networking
- Order of testing
- Realism
- Rote learning strategies
- Visual testing
- Eye movement
- Locus of control
- Interactive/interruptive TV
- Motion
- Free recall
- Organizational chunking
- Post questions
- Programmed instruction
- Rehearsal
- Short-term/long-term retention

Evaluation of multimedia projects

Visuals and instructional elements in the multimedia project design process should be evaluated according to IDT or multimedia design models as indicated before. Visuals and visualization should be completed and evaluated via PSE concepts, research findings, and design strategies. In addition, there is a close relationship between visual design evaluations and learner-user interface design rules to develop high quality multimedia instruction, learning, and design. To evaluate multimedia projects, for instance, the DDD-E model for multimedia projects design, development and applications (Ivers, Barron, 2010), can be used effectively and efficiently to design content, images and user-interface design steps in e-learning environment and visual design.

3. Conclusion

Visuals and visual literacy concepts, including visual learning, visual thinking, and visual communications are important design variables in the instructional design process and human information processing model, which includes the seeing and hearing variables in Mayer's model. So visual and instructional designers and multimedia designers should also be aware of the design considerations for multimedia projects, lessons, software developments, visualization types for learning imagery, and user interface design principles.

To support the development of students' learning through visualization and modeling in science and education, teachers, instructional and visual designers should consider the following rules:

• Look for new technological resources in the media center and virtual reality technologies in education for learning with images and imagery for applying representation techniques in different learning environments, such as schools, industry, and military;

• Ensure that students understand that scientific visualization and modeling are more than graphical, spatial and include visual approaches in the instructional process, such as using design models and new virtual reality and visual design technologies in science and engineering education;

• Encourage students to discuss and critique some of the approaches to models in textbooks, electronic learning environments and virtual technology trends in education. Ask them why conventions in a particular book, virtual reality technology, visual design devices or website are used;

• Consider incorporating the resources listed in literature into their science and engineering curriculum to prepare a program for visual literacy concepts and visualization in learning environments, and discuss how to use instructional design models for linking visual design performances and visualization of subjects (2D or 3D) and visual perception skills for visual materials design in educational technology.

In addition, PSE should be used to evaluate visuals, multimedia designs and future visualization activities in science and engineering education.

In conclusion, educators, designers and teachers should be aware of visual design principles, visualization types, and principles of learning from pictures to develop visuals and learning environments in science and engineering education. For this, PSE contributes to ID models in the development of visuals in multimedia learning and different visual learning environments to visualize images with mental skills, cognitive ability, and virtual reality technologies in the field of IDT.

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