Spring 2024

Identification of Quality Indicators of Visual Based Learning Material in Technology Education Programs for Grades 6th - 9th in Greek Schools in Cyclades Aegean Islands

Spyridoula Tsouganatou
Old Dominion University, stsou001@odu.edu

IDENTIFICATION OF QUALITY INDICATORS OF VISUAL BASED LEARNING MATERIAL IN TECHNOLOGY EDUCATION PROGRAMS FOR GRADES 6TH - 9TH IN GREEK SCHOOLS IN CYCLADES AEGEAN ISLANDS

by

Spyridoula Tsouganatou
B.A. October 2016, National University of Athens, Greece
M.S. May 2019, Old Dominion University

A Dissertation Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY IN EDUCATION

OCCUPATIONAL AND TECHNICAL STUDIES

OLD DOMINION UNIVERSITY
May 2024

Approved by:

Petros J. Katsioloudis (Chair)

Thomas W. Bean (member)

Philip A. Reed (member)

ABSTRACT

IDENTIFICATION OF QUALITY INDICATORS OF VISUAL BASED LEARNING MATERIAL IN TECHNOLOGY EDUCATION PROGRAMS FOR GRADES 6^{TH} -9^{TH} IN GREEK SCHOOLS IN CYCLADES AEGEAN ISLANDS.

Spyridoula Tsouganatou
Old Dominion University, 2023
Director: Dr. Petros Katsioloudis

The purpose of this dissertation is to identify quality indicators for visual based learning material for technology education classes for grades 6^{th} to 9^{th}. This is a three round Delphi study aimed in answering the following research question. RQ: What are the quality indicators that contribute to the successful selection of visual-based learning material that contribute effectively to transmitting pedagogical information in a technology education classroom for grades 6^{th} -9^{th} ? The quality indicators were determined by the consensus reached by technology education expert panel/educators that have been identified for the contributions and expertise in the field of technology education and have taught in Greek schools in the Cyclades region. In the first round, the panel were given a set of examples with initial quality indicators. These initial quality indicators are examples that have been identified from the literature review. The first round of the modified Delphi method uses an open-ended questionnaire format in which the experts were asked to keep, reject, modify or add a new characteristic to the quality indicators. The instrument of the second round was generated by the responses given from the first round. The second round involved panelists valuing and ranking from lowest to highest the items identified on round I on a 5-point Likert scale. The third and final round involved the expert panel accepting or rejecting the quality indicators derived from the second round. In the final round the panel reached consensus. Final quality indicators were the results of analysis on data collected from Rounds I, II, and III.

Keywords: quality indicators, technology education, middle school.

To my father Athanasios Tsouganatos. Also, to my family, my mother Anna Tsouganatou, my brothers George and Alexander Tsouganatos, my sister Sophia Tsouganatou and my grandmothers Sophia and Spyridoula. Also, I dedicate this to my close friend Phanoulla Ashikis, for her support throughout the prosses.

ACKNOWLEDGEMENTS

I also want to acknowledge the help and support of my committee. Dr. Philip Reed, Dr. Thomas Bean, and my advisor Dr. Petros Katsioloudis for their help and academic support throughout this learning process. In addition, I am also thankful to the late Dr. Bill Owings for all his efforts to improve my research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Visual thinking and visual pedagogy play an essential role in the learning process. The Oxford Dictionary defines a visual as “something such as a picture, photograph, or piece of film used to give a particular effect or to explain something’’ (Oxford Dictionary, 2000, p.1446). Educators and researchers over the years have focused efforts on deciding the most appropriate visual materials that can be incorporated into learning processes and can ultimately improve learning for students (Raiyn, 2016). Furthermore, visuals in education have broadened in the last decades as new technologies are developed and are continuously incorporated into educational methods. Visuals that have been well researched and implemented in learning methods have proven to significantly contribute to the retention of information, thus aiding the learner to acquire new knowledge effectively and for the long term (Raiyn, 2016).

The combination of visuals with words in education for the transmission of information has been apparent in education from ancient times. Simonides states, "Words are the images of things," (as cited in Benson, 1997, p. 141) while Aristotle states, "without image thinking is impossible" (Aristotle, 1994, III, 7, 431a, 14-17). Before Simonides and Aristotle, the Ancient Greeks developed their words and language according to the visual representations they perceived from their surrounding natural environment. In the same way scientists use visuals and images to interpret the world around them (Arnheim, 1969). The mission of education is to continuously improve learning so that learners acquire knowledge according to their own needs. Visualization helps to understand large amounts of text and data better and has proven to be a preferred method of instruction for many learners (Raiyn, 2016). In addition, visualization methods are credited for being able to simplify the instruction of complex concepts, thus aiding cognition (Idowu et al., 2006). The introduction of visualization methods in learning environments means that education has shifted gears from traditional instruction and learning methods related to reading, writing, and memorization (Raiyn, 2016).

Visual literacy, in general, can be described as the "ability to read, interpret, and understand the information presented in pictorial or graphic images" (Wileman, 1993, p. 114). Another definition of visual literacy is by Sinatra (1986, p. 5), who stated that "visual literacy is the active reconstruction of past meaning visual experience with incoming visual messages to obtain meaning." Being visually literate means that the learner can comprehend, analyze, and learn from a visual (Raiyn, 2016). Visuals can be derived from images and graphic forms. A visually literate person can clearly understand the constraints and benefits of each of the visual formats (Raiyn, 2016). Specifically, visual literacy refers to the ability of the individual to express his/her ideas and feelings using some visual presentation (Raiyn, 2016). It is fundamental that the learner is familiar with a variety of visual formats that exist and have the potential to represent information (Raiyn, 2016). A visually literate person can critically analyze and think deeply about the authenticity of the visual and determine its source and purpose. In combination with this ability, visual literacy allows the learner to constructively combine ideas and information from different visual and graphic content (Raiyn, 2016).

Visual learning is an important part of effective technology education and in recent years research and pedagogical methodologies have incorporated visuals inside the learning environment of the technology education classroom (Raiyn, 2016). Technology education involves the deep study of human-designed products, processes, and systems in order to close needs of the current society (ITEEA, 2020). Technology education thus is a complex and broad disciplinary structure that encompasses more specialties (ITEEA, 2020). According to Ernst and Clark (2007), visualization plays a key role in scientific and technological understanding.

Technical visualization includes computer graphics, simulation, image analysis as well as applied arts in order to visually represent information to the learner. Visualization in technology education is not limited to the use of computer-aided design methodologies, but instead implements a broader method of communicating ideas and methods using design concepts interdisciplinary practices and powerful graphic tools (Ernst & Clark, 2007). In addition, The Common Core State Standards (CCSS) emphasize that educational efforts must be placed to develop visual literacy in learners and develop educational instructional methods that fit the needs of visual learners. At the same time the *Standards for Technological and Engineering Literacy* (STEL, 2020; ITEEA, 2020), promote the use of visualization methods to increase and develop technological and engineering literacy in students.

A unique study was conducted by Arneson and Offerdahl (2018), in which they developed the Visualization Blooming Tool (VBT). The researchers first emphasized the importance of visual literacy as a core competency for scientific communication and a key factor in learning skills. In addition, the researchers emphasize the importance to develop further scientific visual literacy in students in an attempt to improve educational outcomes. In their research study, Arneson and Offerdahl (2018), adapted Bloom's taxonomy and adjusted it to visual representations. The purpose was not only to improve the educational outcomes of students but also to aid the instructors in designing their instructional methods and assessments. Thus, the main target of their efforts was to increase visual literacy of undergraduate students. The need for VBT can be characterized by a unique effort to redesign scientific curricula in accordance with appropriate visualizations (Arneson and Offerdahl, 2018).

It becomes thus apparent that visualization is an important part of all scientific disciplines and that quality visual representations aid the process of learning (Duffy, 2021). Visual representations can be used in the form of graphs and computer models according to the needs of each discipline. Visual representations can aid the process of learning in different ways. First of all, they help the student close the gap between unobservable phenomena and scientific theory (Duffy, 2021). In addition, visualizations that help close this gap can help students to better comprehend difficult scientific principles, phenomena and concepts (Arneson and Offerdahl, 2018).

There is a plethora of reasons that educators tend to use visualizations in their scientific instruction. The ability of visualizations to transfer complex messages in a simplistic manner means that educators utilize and develop visualizations in order to model different hypothesis, represent patterns in data or to communicate effectively with students, the community, and other educators (Arneson and Offerdahl, 2018). However, the deep comprehension of a visualization necessitates that both the instructor and the student have developed an appropriate level of visual literacy (Duffy, 2021; Arneson and Offerdahl, 2018). At the same time educators must be capable for generating and interpreting visual representation at a very complex level. It thus becomes apparent that in order for any scientific discipline to utilize visualizations for learning, both the educators and the students must develop their visual literacy (Arneson and Offerdahl, 2018).

Bloom's taxonomy in education has been used mostly to describe and classify the learning process within three domains – the cognitive, affective, and psychomotor (Arneson and Offerdahl, 2018). This phenomenon emphasizes and gives educators the understanding that the first step in the design of learning material is to identify what the students should learn as a result of the instruction that we provide them (Duffy, 2021). Arneson and Offerdahl (2018), mention that there have been some prior studies that focused efforts on the development of visualization criteria according to Bloom's taxonomy. In addition, Arneson and Offerdahl (2018), point out that they developed and designed the VBT in order to assist educators with assessing and evaluating visual learning skills. As such they organized the cognition level for instruction in accordance with Bloom's taxonomy in Knowledge, Comprehension, Application, Analysis, Evaluation, and Synthesis. For each of these levels of cognition there were the specific skills that a student must utilize for each different level of cognition. For example, in the Knowledge level students should have skills such as memorization, recognize, recall, and retrieve (Arneson and Offerdahl, 2018). For the Comprehension level students should be able to understand, interpret, infer, exemplify and classify (Arneson and Offerdahl, 2018). For the Application level, students should be able to execute, implement, and apply their theoretical knowledge into practice (Arneson and Offerdahl, 2018). In the Analysis level, students should be able to differentiate, discriminate, organize, integrate, deconstruct, and attribute what they have already learned (Arneson and Offerdahl, 2018). Lastly, at the Evaluation level students should be able to check, coordinate, critique, judge, and test all their learning processes (Duffy, 2021; Arneson and Offerdahl, 2018).

Subsequently, Bloom's taxonomy can aid instructors on designing and developing visualization learning skills for their students. Arneson and Offerdahl (2018), identified some examples of visualization tasks for their students. Some examples of those visualization tasks are the following: compare between images, sketch a graph with provided data information, and translate information from one visual representation to another (Arneson and Offerdahl, 2018).

Arneson and Offerdahl (2018), also mention that in order for students to achieve success in any scientific discipline they must be constantly reinforced with feedback and receive progress evaluations until they achieve mastery of the discipline. At the same time in regard to visualization learning skills it is important that students practice those skills as well in a repetitive manner until they have developed mastery (Arneson and Offerdahl, 2018).

The importance of visual literacy and visual learning is apparent within the context of technology education as well. At this moment it is important to clarify the difference between Technology Education and Educational Technology. Technology Education is concentrated mostly on the study of the human designed world while educational technology is the use of technological means for instructional and learning purposes (Reed, 2018). According to the International Technology and Engineering Educators Association technology education is the modification of the natural environment to satisfy perceived human wants and needs (STEL, 2020). In other words, this human intervention to the natural environment can also be characterized as human innovation in action (STEL, 2020; Strimel, & Grubbs, 2016; Dugger & Naik, 2001). It is important to clarify that technology education is the study of the processes and knowledge that are related to technology and the requirements to expand human potential (Strimel, & Grubbs, 2016; Dugger & Naik, 2001). Thus, improving technological literacy is the result of students who study technology education in K-12 grades as well as in higher education (Strimel, & Grubbs, 2016; Dugger & Naik, 2001). Design, problem solving, resources, materials, criteria, constrains, technological systems, optimization, and processes are fundamental aspects in the study of technology education (Strimel, & Grubbs, 2016; Dugger & Naik, 2001). Ultimately, students should be able to use, manage, assess, and understand technology in a way that promotes innovation and critical thinking (Strimel, & Grubbs, 2016; Dugger & Naik, 2001). Critical thinking is fundamental for the study of technology as it can have both positive and negative consequences for the society (Strimel, & Grubbs, 2016; Dugger & Naik, 2001).

Visual materials vary in their effectiveness on student achievement of educational objectives, and since the use of visual materials advance student learning in technology education, efforts have been made to identify what visual materials are of high quality. Presently, technology educators have little knowledge on what type of visuals are more effective for the transmission of knowledge (Evagorou et al., 2015; Dwyer, 1978). When selecting visual materials technology educators must have quantifiable measures of quality that can guide them. The lack of those quantifiable measures of quality can seriously undermine learning, and future visualization advances in critical aspects such as evaluation and selection. This study will identify the indicators of quality visual-based learning materials that contribute to the successful implementation of technology education curricula designed by technology educators. The purpose is to develop metrics and quantifiable quality measures that will serve as a guide for technology educators.

Visual tools example in technology education

It is fundamental to understand the importance of visual tools for effective instruction and specifically for technology education instruction. The delivery of technology education concepts through the use of effective visual materials can have a tremendous positive effect on student learning and can aid technology education instructors on selecting the most optimal tools for their instruction (Thornton, Ernst & Clark, 2012). In addition, to graphs, technical models and other visualizations instructors in the technology education field should aim to utilize contemporary and cutting-edge technologies that provide an overall beneficial learning experience to their students that is suited to their learning needs. At the same time, it is crucial that these technologies align also with course content and are able to motivate students further. Augmented reality (AR) can be a very useful example of visual tool for instructors to take advantage of within the field of technology education and which has the potential to engage and excite students (Thornton et al., 2012).

AR can be described as a technological system that allows the user to see the real work with alongside virtual objects that augment the real world and enhance it (Thornton et al., 2012). Thus, augmented reality has the unique purpose to enhance the visual and physical reality of the individual. The visual that enhances the real-world environment is most of the times a three dimensional (3-D) virtual object or image that contributes to the development of the real world. This gives the opportunity to the user to emerge in this predesigned environment and on some occasions modify it as well (Thornton et al., 2012).

It is fundamental for technology education and instructors in the field to have a clear viewpoint about the benefit of virtual reality as a visual tool for their instruction (Thornton et al., 2012). The overlay of data and experiences that AR can provide to real world experiences can aid students in the comprehension of important and sophisticated concepts of technology education. Augmented reality technology usually requires a monitor or camera, and this technological system has the potential to become the most important user interface in the context of education. At the same time students can experience AR through mobile devices and head mounted displays. This fact increases the possibilities of this technology and gives both instructors and educators the ability to design creative visual aids for the transmission of pedagogical information (Thornton et al., 2012). Although, augmented reality technology needs more advanced research and developments for the field of education it can already aid within the instructional classroom. First, it can be incorporated into the classroom as a supplemental learning tool that would allow educators to familiarize themselves with the technology (Thornton et al., 2012). In addition, augmented reality as a virtual tool for technology education can provide students with location-based learning as well as opportunities for experiential learning. Augmented reality can provide technology educators with rich visual materials by providing students opportunities for modeling objects as well as for technological and engineering design For technology education specifically, the process of technological design is crucial as it allows students to better comprehend and transmit complex ideas, concepts, and processes. Especially, 3-D image design is a unique aspect of augmented reality that technology educations students can utilize in their learning process. To be more specific, students can create a 3-D image of a technological system or process through AR technologies and thus actively enhance their knowledge on technology (Thornton et al., 2012).

The aforementioned tools also create the necessity for educators to strive to improve the visual skills of their students. By choosing the appropriate visual materials for their technology education classroom educators have the opportunity to train students in how to use and interpret the various visual tools that are presented to them. This phenomenon creates the necessity for educators to be able to have quality indicators for their lesson planning and instruction that will guide them in selecting and using the most appropriate visual tools for their students (Thornton et al., 2012).

Thornton et al., (2012), also state that understanding design through manipulation can be achieved from the aid of augmented reality interventions and also aid students in the manipulation and viewing of models from the intricacy of multiple perspectives. These interventions have been beneficial for students as they involve the processes of troubleshooting, development, invention, research, experimentation and problem solving. This means that AR for technological systems can provide instant analysis, troubleshoot effectively, and detect errors.

These abilities of AR can have a significant impact on the engagement of students in technology education as their learning experience is always richer (Thornton et al., 2012).

Thornton et al., (2012), emphasize the importance of quality visual tools in technology education and their ability to improve the spatial skills of students. Thus, augmented reality can contribute to the improvement of spatial skills of students which are fundamental skills for the academic success in technology and engineering education. Technology educators should be creative and innovative when selecting visual tools for their instruction. This means that their approach to selecting the best visual tools should benefit the holistic class and take into consideration the learning difficulties that some students have. The constructivist approach to learning that augmented reality provides can benefit students with learning difficulties as well. Especially when trying to comprehend complex visual and spatial relationships, augmented reality provides an appropriate space for discovery-based learning that fits the needs of students and allows for more student intervention and control (Thornton et al. 2012).

Technology educators should research and experiment with the use of augmented reality as a quality visual material for their students as it can provide unique opportunities for students to design interactive objects, experiment with visual models and examine augmented virtual worlds (Thornton et al., 2012; Caruso et al., 2021).

Problem Statement

Currently there is little research related to educational information regarding the selection of quality visual based material for technology education curricula. In addition, few studies have been conducted that focus on identifying quality visual based learning material in middle and high school grades. Currently, educators have difficulty determining and selecting visual based learning material that is the most effective in transmitting certain types of scientific information (Bobek, & Tversky, 2016; Roblyer & Kirby 2014). This is a result of the plethora of available visual materials that exist. The differences between each type of visual material have important consequences for the acquisition of knowledge and the level of achievement of students (Callahan et al., 2019; Kedra & Žakevičiūtė, 2019; Dwyer, 1972; Brumberger, 2019). This phenomenon makes the process of selecting the most appropriate visual materials confusing and impossible.

The research problem is that there is a lack of quality indicators to assess the effectiveness of visual based learning materials for grades 6^{th} - 9^{th}, within the context of middle schools in Greece and secondary technology education curricula. Thus, the purpose of the study is to identify those quality indicators of visual-based learning material that can provide technology educators with educational guidance to select visual material that are effective in knowledge transmission within the educational objectives of technology education for high school grades. At the same time, it is crucial to develop and validate those indicators by involving technology education experts in the process of the study as they have a deeper knowledge in visual learning methodologies within technology education.

Research Question

The main research question of the study is the following:

RQ: What are the quality indicators that contribute to the successful selection of visual-based learning material in a technology education classroom for grades 6^{th} -9^{th} in Greek secondary education?

Background, Significance, and Theoretical Framework

Learning

According to Curry (1981), learning methodology can be described as characteristic cognitive, affective, and psychosocial, behaviors that serve as relatively stable indicators of how learners perceive, interact with and respond to the learning environment. This definition suggests that learners throughout every learning level are affected from previous experiences on how they learn. This phenomenon is crucial for educators as they must be knowledgeable about the learning patterns of their learners to match them with appropriate instructional methods (Arbuthnott & Krätzig, 2015). Various theorists have proposed over the years different theories for how students learn. Some of the most prominent examples include Flemings VARK theory, which suggests four different learning patterns: visual, auditory, tactile, kinesthetic, Kolb's four-way typology, the Felder-Silverman model, and Mill's four-way topology (Scott, 2010).

Kolb's Learning

According to Kolb, "Learning is the process whereby knowledge is created through the transformation of experience" (Illeris, 2018; Kolb, 1984 p. 38). Kolb designed and developed the Experiential Learning Theory in such a way that it allowed for the different learning patterns to be identified. His theory places emphasis in experiences of individual learners that translates into fundamental learning concepts (Illeris, 2018; Kolb, 1981). Kolb's Experiential Learning Model is constructed with a four-stage learning cycle that includes Concrete experience, Observations and reflections, Formation of abstract concepts and generalizations, and Testing implication of concepts in new situations (Illeris, 2018; Kolb, 1981). Figure 1 demonstrates the Experiential Learning model in detail.

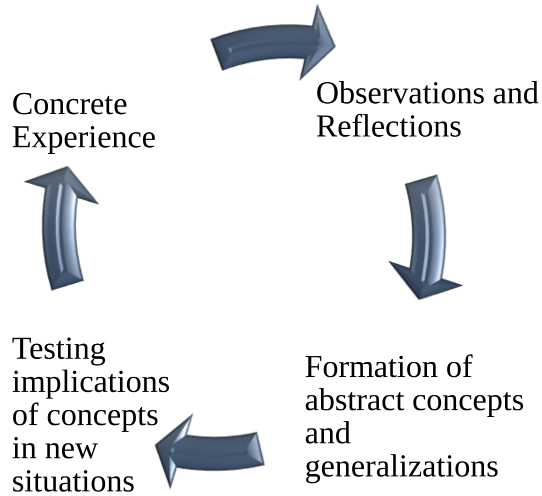

Figure 1

The Lewinian experiential learning model according to Kolb (Kolb, 1984)

Kolb’s theory has been researched and implemented on various educational technology settings. Konak et al. (2014), researched the use and effectiveness of Kolb’s experiential learning cycle (ELC) to improve student learning in virtual computer laboratories.

The learner must actively participate in this direct experiential interaction with a learning event as opposed to the passive participation typically associated with teacher-directed teaching. As was previously established, learning occurs in four stages in Kolb's experiential learning cycle.

The Kolb model has been criticized for a number of reasons, including the fact that learning seldom occurs in sequential, ordered phases but rather overlaps (and that social, historical, and cultural dimensions of learning are not integrated. Nevertheless, none of those objections is severe enough to negate the advantages the model offers when it comes to creating practical information security exercises.

Kolb's ELC is widely applied in literature to examine how learning differs from one student to another. Applications of Kolb's ELC to enhance student learning are typically talked about in relation to training programs or field investigations that take several weeks to finish. A small number of authors recommend enhancing classroom activities with Kolb's ELC. Kolb's ELC is suggested by Svinicki and Dixon (1987) as a framework for creating activities in the classroom. They also offer examples of teaching activities that might complement various ELC phases in a variety of subject areas.

In order to enhance the learning process for students studying chemical engineering, Stice (1987) additionally provides a list of instances of active learning techniques that include all four stages of Kolb's ELC. Abdulwahed and Nagy (2013) include a blend of in-class remote, virtual pre-lab, and hands-on laboratory sessions using Kolb's ELC to address the issue of subpar learning results from engineering laboratories. The exercises center around the prehension dimension of Kolb's Extended Language Curriculum (ELC), which pertains to the ability to acquire knowledge through either real experience, abstract conceptualization, or a mix of the two.

According to Abdulwahed and Nagy (2009), the ineffective activation of the prehension dimension might account for the low information retention during engineering laboratory sessions. Before the next stage of transformation—that is, creating new knowledge by experimentation—can take place, it is crucial that this dimension—that is, that the information be understood or represented—be covered. According to Abdulwahed and Nagy's (2009) research, using a virtual pre-lab session that emphasizes the Kolb model's prehension feature enhances student learning results.

Background Teaching and Learning in Technology Education

Avsec and Szewczyk-Zakrzewska (2015), investigated the predictive validity of learning styles on the technological literacy and academic achievement of students. Their study recruited 150 students from postsecondary education. The researchers of the study utilized a technological literacy test in their empirical research in combination with a learning style inventory (Avsec and Szewczyk-Zakrzewska, 2015). This combination measured learning orientation, processing, information, learning preferences, as well as environmental, emotional, and sociological preferences. The performance of the students was measured on their level of technological literacy as well as their grade point average (GPA) (Avsec and Szewczyk-Zakrzewska, 2015). The results of their research showed that learning styles in the students were predictors of their technological literacy as well as their grade point average (Avsec and Szewczyk-Zakrzewska, 2015). Specifically, the researchers found that visual learning styles can be strong predictors of positive GPA while reflective learning style are a negative predictor of GPA (Avsec and Szewczyk-Zakrzewska, 2015). As far as technological literacy the researchers found that self-directed learning styles are strong predictors of technological literacy (Avsec and Szewczyk-Zakrzewska, 2015). Although contemporary research shows learning styles to be too general of a construct (National Academies, 2018), the learner preferences Avsec and Szewczyk-Zakrzewska (2015) investigated may be of interest to other researchers investigating visual based learning

The historical context of visual pedagogy can be traced back to the educational theorist Paulo Freire and his belief that visual media can have a fundamental impact on students' literacy. The historical antecedents of technology education (TE) in the U.S.A. can be traced back in the 19th century with manual training (Sanders, 2008) and the formation of a new kind of society that was becoming ever more industrious, leaving behind its more agricultural character. The new industrial society that was emerging necessitated the training of new technologists, engineers, and technical specialists. Thus, taking inspiration from the Imperial School of Moscow and its manual training curricula, the United States saw an increase on manual training schools as well. Later, in 1904 as society and technology advanced so did the needs of industry and the people. Manual training curricula started to be replaced by Industrial Arts curricula that were more focused on industry needs and providing students with opportunities inside the industry. The movement of the Industrial Arts curricula started to transition in the 1980s when the American Industrial Arts Association was renamed to International Technology Education Association. This change started to give formation to technology education curricula. Nevertheless, the necessity of the United Stated to provide industrial and then technological education to its citizens was considered crucial for the national security and economic competitiveness of the country (Sanders, 2008).

Significance

Visualization in technology education has been an important part of research in the field. Wiebe and Clark (2003) developed the Visualization in Technology Education project (VisTE) which aimed in improving the technological and scientific literacy of students. The VisTE project developed educational units that promoted graphic visualization skills that aligned with educational standards. The project supports the idea that technological literacy can be improved through the utilization of technical and scientific visualization techniques and tools. Thus, with this approach the researchers give emphasis on the development of spatial literacy and scientific literacy as fundamental factors in the process. Students who participated in the project were able to advance their literacy in technology and science through the use of various graphic technologies. These included 2-D graphing and charting; 2-D image processing; 2-D object-oriented graphics; geographic information systems; as well as 3-D modeling and simulation among others.

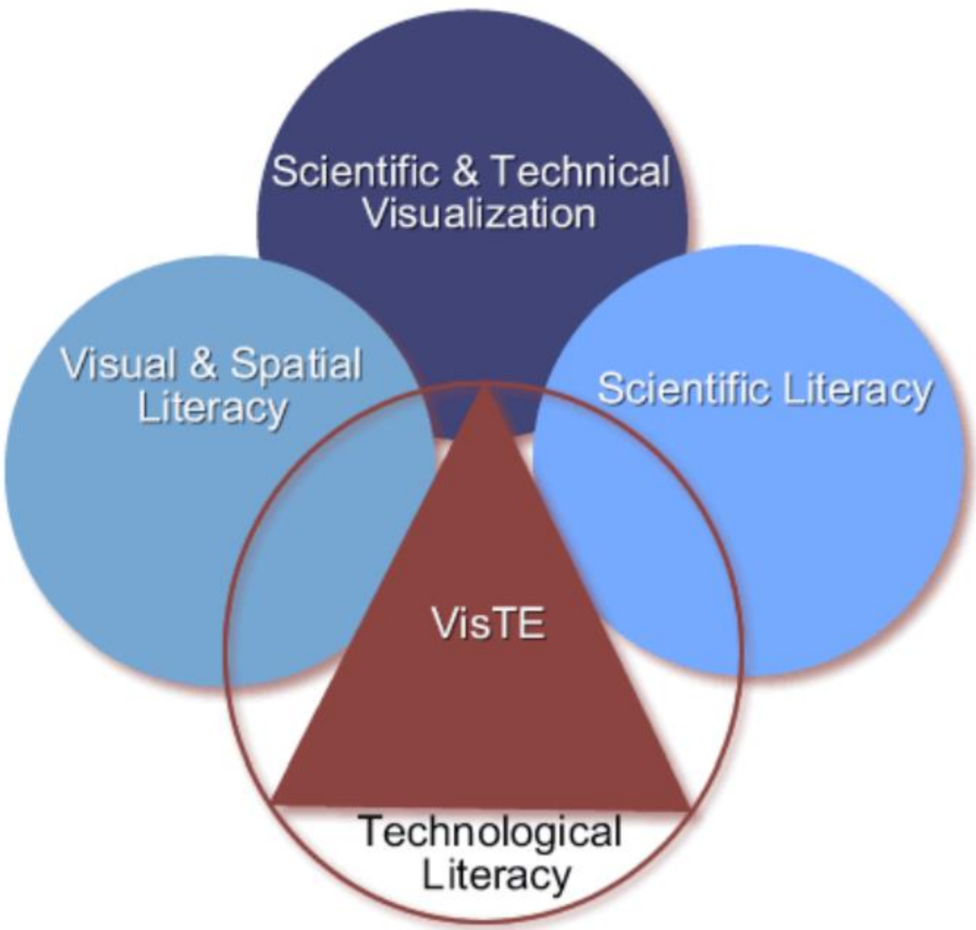

Figure 2

Conceptual Framework of the VisTE Instructional Materials (Wiebe and Clark, 2003)

In addition, Ernst and Clark (2007), focused specifically on scientific and technical visualization in technology education. Specifically, they emphasized the need for America's students to develop a deeper understanding of technological concepts through scientific and technical visualization. The correct use of technical and scientific communication and visualization is able to promote higher-order thinking skills for students and it requires them to advance their competence in sophisticated computer technologies (Ernst & Clark, 2007). At the same time through this process the students gain an enhanced understanding on the most important principles that are involved in the manipulation and creation of graphics. Thus, scientific and technical visualization (SciVis) is able to transform scientific information into a visual form through graphics, image analysis, simulation and applied art. It is important to mention that visualization in technology education does not only rely on the teaching of mechanical computer-aided design. It also requires a bigger approach to better explore and communicate concepts through integrated disciplinary practices and through powerful graphic tools. Visualization as it relates to technology and technological literacy involves the ability to break down complex concepts, problem-solve, and communicate them effectively (Ernst & Clark, 2007).

In other research regarding the use of visualization in technology education the researchers investigated the use of visualization to explain complex technological procedures in the port logistics area to students. Katsioloudis et al. (2011), thus created the VisPort tool to teach and engage students in the processes of port logistics. At the same time this tool combines a high-fidelity simulation of the processes of port logistics with modern, rich multimedia visualizations. This project was designed to provide a multimedia environment for students that would allow them to learn more about careers inside the logistical operations of ports. At the same time, it was focusing on providing a virtual reality and first-hand experience to students regarding the operating equipment and the scheduling decisions within port operations. Katsioloudis and Watson (2011), incorporated visualization methods in the teaching of technological and logistical processes to students by following the Engineering Design Process Model. Lastly, the VisPort tool allowed students to experiment with the simulation of port logistics and alternative equipment (Figure 3).

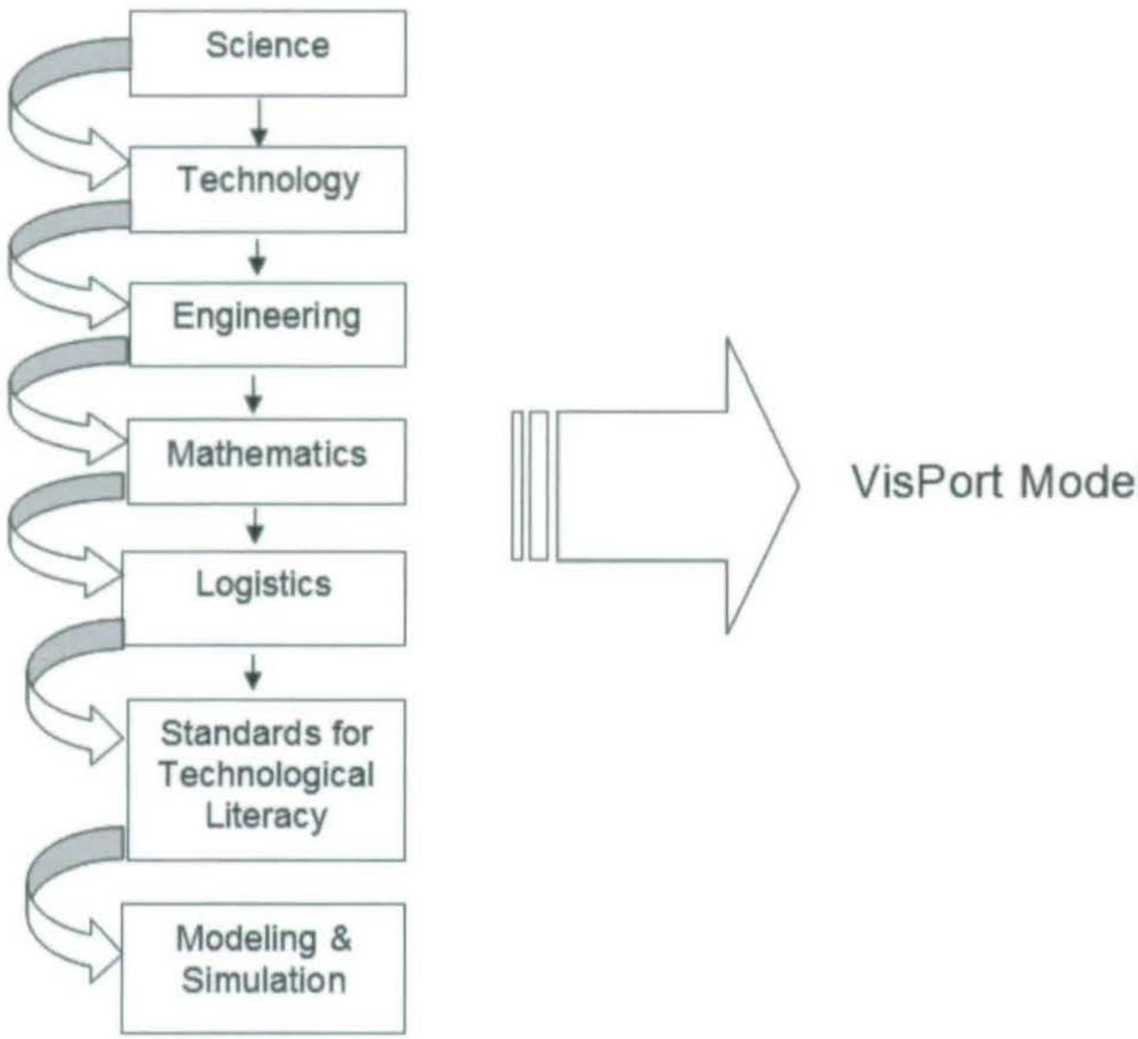

Figure 3

Conceptual Framework for VisPort Project (Katsioloudis & Watson, 2013)

The strong connection between technology and engineering is also apparent in the *Standards for Technological and Engineering Literacy* (ITEEA, 2020). Specifically, the standards align the domains of learning, T & E dimensions, and student outcomes, and they provide a high-quality resource for technology educators. Figure 6 shows the methodical alignment of those three aspects of learning (Figure 4).

Domain		T & E Dimensions		Student Outcomes (as defined by Benchmark verbs)
Cognitive	→	Knowing & Thinking	→	Knowledge
Psychomotor	→	Doing	→	Skills
Affective	→	Knowing, Thinking, and Doing	→	Dispositions

Figure 4

Alignment of the three domains of learning to the Technology and Engineering Dimensions and to Student Outcomes (STEL, 2020)

The levels for each domain of learning are the following:

Cognitive Domain: Remember, Understand, Apply, Analyze, Evaluate, Create (Anderson & Krathwohl, 2001).

Affective Domain: Receiving, Responding, Valuing, Organization, Characterization by Valuing (STEL, 2020).

Psychomotor Domain: Observing, Imitating, Practicing, Adapting (Bixler, 2011).

Levels of Knowledge: Factual, Conceptual, Procedural, Metacognitive (Krathwohl, Bloom & Masia, 1964).

A sample of specific alignment of the different domains of learning with the STEL benchmarks are presented in Figure 5.

STEL Benchmark	Cognitive Domain	Affective Domain	Psychomotor Domain	Knowledge Dimension
1A. Compare the natural world and human-made world.	Analyze		Observing	Conceptual
5G. Evaluate trade-offs based on various perspectives as part of a decision process that recognizes the need for careful compromises among competing factors.	Evaluate	Responding		Conceptual
7Y. Optimize a design by addressing desired qualities within criteria and constraints.	Analyze		Adapting	Procedural

Figure 5

Sample STEL Benchmark Alignment to Domain and Knowledge Dimensions (STEL, 2020)

Limitations and Assumptions

The following assumptions were considered through the study process:

a) The researcher received nonbiased responses when collecting data from teachers, experts, and grant participants.

b) The experts participating in the study would be knowledgeable about the visual learning theories and learning material for technology education.

c) Teachers who participate in the study would need at least three years of experience teaching in grades 6^{th} -9^{th} as technology education teachers.

d) The need to establish this study is based upon the need to provide technology educators with quality indicators in visual-based learning benchmarks to advance the discipline of technology education.

e) Quality indicators would be validated through a modified Delphi process composed of panel experts in technology education.

f) All respondents to the data collecting instruments would fully understand the directions.

Potential limitations of the study are the following:

a) The identification of quality indicators was based on the panel members' ideas, values, and opinions.

b) Web-based modified Delphi method were used to collect data which means that participation can exclude those participants that do not have access to the internet.

c) Respondents were limited to participants identified by the researcher from specific grants.

Procedures

Greek middle school technology teachers with experience in the field were chosen to participate in this Delphi study. A total of 15 participants were selected and emailed a demographic survey as well as the first instrument of Round I. The instruments of Round II and Round III were sent when data were collected from each round. Descriptive statistics were used to statistically analyze the data. In addition, interquartile range analysis was used to determine the degree of consensus among the participants.

Population, Sample and Setting

Participants for this research were selected from schools of the Greek region of Cyclades that focus on technology education programs. The researcher identified 15 participants and contacted them via email. These participants were chosen for their use of visual based methodologies and material in their technology education classrooms. The instruments for data collection were sent to those participants via email again that contained links to the questionnaires. An initial straw model was created with quality indicators that were identified from the literature. Participants were able to add more suggestions in the initial round.

Instruments and Data Collection

The first instrument of data collection was the demographic survey in order to collect the demographic characteristics of the participants. In Round I the initial straw model with quality indicators was given to the participants. Reminder e-mail was also constructed in case it is needed to remind participants in the expert panel to reply. The purpose of this first round of instruments was for the experts to accept, modify or reject a list of quality indicators that the researcher identified from the literature review and to allow the panel of experts to suggest new set of indicators according to their own experience and expertise. The responses to the instruments of the first Rounded were used to formulate the next round of questionnaires.

The purpose of the second Round was to rate and then rank the quality indicators based on a Likert scale of one to five with one being strongly disagree and five being strongly agree. In addition, this round provided the opportunity for the experts to provide any additional quality indicators they came up with.

Finally, the purpose of Round III was to build consensus amongst the expert panel members. More information on the instruments for data collection are presented in Chapter 3.

Definitions of Terms

This section will provide the definitions of the most important terms presented in this study.

1. **Delphi method:** The Delphi method is an iterative process for consensus building from a panel of experts who are anonymous to each other. Delphi is advocated as the most appropriate means to achieve optimally reliable expert consensus (Garson, 2012, p. 13).
2. **Engineering:** The profession of or work performed by an engineer. Engineering involves the knowledge of the mathematical and natural sciences (biological and physical), gained by study, experience, and practice that are applied with judgment and creativity to develop ways to utilize the materials and forces of nature for the benefits of mankind (STEL, 2020).
3. **Engineering Education**: Engineering education is the activity of teaching knowledge and principles to the professional practice of engineering (ASEE, 2014).
4. **Learning:** Learning methodology can be described as characteristic cognitive, affective, and psychosocial, behaviors that serve as relatively stable indicators of how learners perceive, interact with and respond to the learning environment (Curry, 1981).

5. **Middle School:** A school intermediate between an elementary school and a high school, typically for children in the sixth, seventh, and eighth grades.
6. **Technology Education:** Technology Education is the study of technology where students learn all the knowledge and processes related to technology. This field of study covers the human's potential to change and shape the physical world in order to meet needs, through the manipulation of materials, tools, and different technological techniques. This field closes the disconnect that exists between the popular usage and the lack of knowledge in regard to the technical components of each technology (ITEEA, 2020). Technology education aims in developing the technological and engineering literacy of students.
7. **Technology:** 1. Human innovation in action that involves the generation of knowledge and processes to develop systems that solve problems and extend human capabilities. 2. The Innovation, change, or modification of the natural environment to satisfy perceived human needs and wants (STEL, 2020).
8. **Technological Literacy:** The ability to use, manage, understand and assess technology (STEL, 2020).
9. **Quality Indicators:** Quality indicators are defined as "Measurable, objective, indicators of the efficiency of the key segments of a system." Fundamental attributes of quality indicators are their measurability, objectivity, validity, and reliability (Vuk, 2012, p.25).
10. **Spatial Visualization:** A complex process that requires apprehending, encoding, and mentally transforming objects in the spatial world. Performing complex and multi-step mental transformations characterizes spatial visualization (Miyake et al., 2001: Voyer et al., 1995).

11. Visualization: Visualization is the process of abstract mental representation of human experiences as they relate to some form of technology" (Lis, 2014, p. 111).

Summary and Overview of Chapter

Chapter one is an introduction to the most important terms that are investigated in this study. The primary purpose of this study was to investigate the quality indicators for visual based learning in technology education grades 6th – 9th. This chapter also presented specific limitations and assumptions that the researchers encountered during the investigation. The background and significance of the study were also analyzed and the connection between visualization, learning and technology education was described in detail. The second chapter of this study presents an overview of the literature as it relates to visual pedagogy and technology education.

CHAPTER II

LITERATURE REVIEW

Scientific visualization in technology education is fundamental to the success of student learning. Technology educators are able to utilize scientific visualization methods in order to provide students with a breakdown of complex scientific and technological concepts. In the past, little research has been conducted on the effectiveness of the visual material in technology education and even fewer studies focus on identifying quality visual based material for technology education (Clark & Wiebe, 2007).

The review of literature aims at providing the reader with a deep understanding of the context, both historical and educational, in which visual pedagogy and technology education were developed and the important links between them. At the same time this chapter provides an overview of the importance of spatial ability and spatial visualization for technology education as well as engineering education. Finally, this chapter lays the foundation on which the importance of having quantifiable measures for the effectiveness of visual based material in technology education is fundamental to the field.

Historical Context of Visual Pedagogy

During the second half of the 20th century the expansion and development of communications media and visual culture radically changed the way information and knowledge were transmitted and acquired (Farné, 2017; Goldfarb, 2002). The educational world was facing a dilemma as some considered visual media to be a threat to traditional ways of developing literacy and other saw it as a potentially powerful tool that would transform education (Farné, 2017; Goldfarb, 2002). A major educational theorist, Paulo Freire, saw education as a direct result of a specific cultures politics (Dale et al., 2010; Farné, 2017; Goldfarb, 2002). Radical societal transformation in terms of industry and technology, which took place in the 20th century deeply impacted the traditional educational methods of the countries (Farné, 2017; Goldfarb, 2002). Thus, Paolo Freire proposes to take a critical consideration of education that is directly linked to the specific culture and society in which it is being implemented. To limit education and literacy simply in language and speech literacy would undermine crucial visual and graphic tools that contributed to societal transformation (Farné, 2017; Goldfarb, 2002).

The opposition to visual pedagogy supported the idea that visuals constitute a more primitive approach to learning that was untrustworthy for the successful transfer and production of knowledge (Farné, 2017; Goldfarb, 2002). However, Freire strongly believed that to be literate is not simply developing language techniques, but it is the ability to think critically in order to act politically through reading, writing, and speech (Farné, 2017; Goldfarb, 2002). Eventually, the emergence of new media and visual technologies would be accepted from all parts of society and thus from the education sector as well (Farné, 2017; Goldfarb, 2002). This new emergence of technologies would gradually revolutionize educational and learning methodologies and would lead to the democratization of information as well (Dale et al., 2010; Farné, 2017; Goldfarb, 2002).

Unsolved Visualization Problems

Chaomei (2005), proposes that ten major unsolved problems exist with visualizstion. Those are usability, understanding elementary perceptual cognitive tasks, prior knowledge, education and training, intrinsic quality measures, scalability, aesthetics, paradigm shift from structures to dynamics causality/virtual interference/predictions, and knowledge domain visualization.

Usability is a critical component of visualization. Chaomei (2005), proposes that new usability studies need to be conducted that are successfully aligned to current methodologies in scientific and information visualization. In addition, these usability studies need to include recognizable patterns of information from the user.

The problem with understanding elementary perceptual cognitive tasks is closely related with scientific and engineering visualization systems and tasks. Chaomei (2005), mentions that Higher – level user tasks need to be closely aligned with the evaluation of the usefulness of visualization components. Tasks like searching and browsing as well as the ability to judge the relevance of presented information require higher level cognitive skills.

The issue of prior knowledge refers to the user having basic information to understand fully the intended message from a visualization. This information relates first to the knowledge of how to operate a specific device or how to interpret the visualization system and second it relates to the cognitive domain knowledge that interprets the visualized content. The problem in education and training is focused on the fact that there is lack of consistent research conducted on visualization. We need to dramatically increase the number of researchers and practitioners who share and learn the principles of scientific visualization and communication as well as their semiotics (Chaomei, 2005; Laramee & Kosara, 2007).

The next problem of intrinsic quality measures refers to the need of the field to establish intrinsic quality metrics. Chaomei (2005, p.14), specifically states: “The lack of quantifiable measures of quality and benchmarks, however, will undermine information visualization advances, especially their evaluation and selection.” Scalability problem should be studied regarding high-performance computing levels and hardware that can be successfully utilized by scientific visualization as well as advance the field of visualization even further. The next problem of aesthetics in visualization takes into consideration the actual representation of information or knowledge. With this problem we must consider how to solve complex issues such as the interaction of aesthetics with the acquisition of knowledge. The goal is to create and sustain appealing visualizations. The issue of paradigm shift from structures into dynamics takes into consideration the traditional approach of visualizing information which was based on structures such as cone trees, tree maps and hyperbolic views. The shift must happen to more dynamic visualizations that are based on representing dynamic properties of important phenomena (Chaomei, 2005; Laramee & Kosara, 2007).

Causality/visual inference/and predictions problems refer to the role that visual thinking, reasoning analytics have on powerful visualization methodologies for finding causality and forming hypothesis. The last unsolved visualization problem according to Chaomei (2005), is the knowledge domain visualization where we still need to differentiate as well as explore the links between information and knowledge. It becomes apparent that scientific visualization is a crucial part of representing scientific information in a way that is more comprehensive for the scientist and the learner. However, issues still exist in visualization methodologies as there is a lack of quantifiable measures that indicate quality visualization materials. More research and funding must be allocated to investigating and exploring the issues in the future (Laramee & Kosara, 2007).

Evolution of Technology Education

The historical antecedents of technology education (TE) in the U.S.A. can be traced back in the 19th century with manual training (Sanders, 2008). The transition of society from an agrarian to an industrial culture created the demand for more skilled workers and resulted in the growth and formations of cities. These changes had tremendous impact on public education as well. Public education had to adjust to these rapid changes in industrial and social structures. At that time education was primarily only for the wealthy citizens, but the societal changed shaped education into becoming important for educating new workers and for integration new immigrants into American society (Sanders, 2008).

This was the context in which engineering education and technology education briefly found common ground in the late 18th century (Sanders, 2008). It was at the Imperial Technical School of Moscow where a new pedagogical system had already begun in which an education system was developed that aimed in preparing civil and mechanical engineers. Before this effort, students at the Imperial Technical School of Moscow learned simply by observing and imitating a skilled engineer or tradesman. Thus, technical training was also being established in the U.S. with this methodology as well. It was also a pedagogy adapted from the apprentice system (Sanders, 2008). In the 1860s Professor Ershov examined a more efficient instructional method by overseeing the development of new instruction shops. With this new system students had to construct technical exercises with an increasing difficulty which were graded, and which were constructed from a set of tools provided to the students. Woodturning, blacksmithing, and locksmithing were courses taken by students (Sanders, 2008).

In 1867, the new Director of the Imperial School, Victor Della-Vos, continued to develop this “Russian System” of education (Sanders, 2008). This new system was first presented in the U.S. at the 1876 Centennial Exhibition in Philadelphia. At this exhibit the Russian System had a profound impact on Dr. John Runkle who was then President of the Massachusetts Institute of Technology (MIT). This led him to convince the governing board of MIT to adopt the instruction shops in the engineering instruction of students there. The initial steps of MIT shaped the way for K-12 engineering education. Thus, the establishment of the School of Mechanic Arts was established from MIT which led engineering education for the secondary students in Boston. Subsequently, this led the way for the introduction of engineering education in all the public schools in Boston (Sanders, 2008).

Professor Calvin Woodward, a Harvard graduate, also was inspired by the Russian System and Runkle's work. Thus, he established the first Manual Training School in St. Louis in 1879. Manual training in the U.S. is considered the forerunner of technology education. With this endeavor Woodward was promoting the "general education" aspect of manual training in the U.S. (Sanders, 2008)

By 1875, new pedagogies and practices were being implemented in Massachusetts. These pedagogies emphasized relevance, self-direction, discovery, and observation and they replaced the traditional form of instruction for manual training (Sanders, 2008). Thus, a movement for progressive education was being more widely accepted and it was thought to promote imagination, thinking and the student's good health. John Dewey was greatly influenced by the practices of progressive education and at that time he founded an experimental school at the University of Chicago. Dewey's fundamental belief was that learning occurs through experimentation, experience and from "doing". Dewey's ideology was a radical shift from the philosophy of Aristotle to the one of Dewey. Aristotle's contradiction was that he believed that superior knowledge comes only though idle thought (Sanders, 2008).

The new progressive reality of education necessitated the implementation and adoption of new activities that would replace the structured and traditional exercises of manual training as they were designed in the 19th Century. The new industrial culture led to the development of activities that were drawn directly from the industry activities. These new activities were in alignment with progressive education and philosophy, and it provided opportunities for students in the industries (Sanders, 2008).

In 1904, we can see the first intention to rename manual training to industrial arts. This suggestion was made by Charles Richards head of the Manual Training Department of Teachers College Columbia. The new industrial society had to find an education system to fit the new societal industrial needs and Industrial Arts were able to fill this need. Frederick Bonser and Lois Coffey Mossman (1923, p. 5) defined industrial arts as “a study of the changes made by man in the forms of materials to increase their values, and of the problems of life related to these changes.” The purpose of industrial education was to educate the student holistically by focusing on health, economic, aesthetic, social, and recreational purposes (Sanders, 2008).

From a philosophical point of view, IA was a general educational program for all students in which the use of tools, equipment, and materials to achieve the goals of the curriculum allowed the educational IA administrators and educators to regard IA labs as "professional/vocational workshops" (Sanders, 2008). These vocational workshops were developed and designed according to the state and local needs of the industry. A result of this phenomenon was the establishment of state offices of IA in departments of vocational education (e.g., Virginia and south along the east coast) while others established these offices adjacent to general education subjects (e.g., Maryland and North along the East Coast). In the mid-1960s, an IA contingent successfully lobbied for formal inclusion of IA, for the first time in federal vocational education legislation (Sanders, 2008).

Another important figure that contributed to the development of the industrial arts in the U.S. was Professor William Warner of The Ohio State University. In 1929, he founded the Epsilon Pi Tau honorary society which aimed to promote the recognition, dignity, and prestige of

the Industrial Arts program. At the same time, he founded the Laboratory of Industry as the main facility for researching and achieving the goals of the IA curriculum (Sanders, 2008).
The further promotion and idea of IA as a general education core curriculum for students was further promoted by Warner in a series of presentations, he made at the National Education Association conference in 1936 (Sanders, 2008). The enthusiastic results of this presentation led Warner to initiate the foundation of the American Industrial Arts Association (AIAA) in 1939.

The new industrial arts curricula that were being developed mainly from Warner and his students were concentrated around six main categories (Sanders, 2008). Those categories were management, communications, construction, power, transportation, and manufacturing. Of these categories five of them were implemented and reflected within *Standards for Technological Literacy* (ITEEA, 2007). These advancements paved the way for the transition to technology education (Sanders, 2008).

We can observe more major developments in this sector during the 1960s with the launch of Sputnik. Prominent curriculum projects in this era included the Industrial Arts Curriculum Project (IACP) and the Maryland Plan (Sanders, 2008). In addition, we can see that at the same period two important publications were formalized that further contributed to the future of technology education from the efforts of IACP. Those publications were the *World of Manufacturing* and the *World of Construction* (Sanders, 2008).

In regard to the Maryland Plan, Donald Maley of the University of Maryland developed a different approach to the Industrial Arts. Maley headed the Industrial Arts Curriculum at the University of Maryland from the 1950s to the 1980s. The main concern of Maley was that there was too much emphasis on the materialistic aspect of education and specifically within the industrial arts curricula (Sanders, 2008). A focus on processes, materials, and projects provided little attention and concern for the individual learner. Furthermore, the teaching processes were determined completely by the educator and thus the students only learned what the teacher knew. By changing this fundamental aspect of education Maley emphasized the importance that must be given on how students learn and the methodologies rather than focusing on content. Drawing mainly from progressive educators of the time as well as Dewey, Maley was able to transition focus and energy from the content of education to the psychological needs of the individual as well as their capabilities (Sanders, 2008).

In one example of the changes that the Maryland Plan brought to the classroom was the following. The adoption of an anthropological approach to the study of the American industry in the 6th grade allowed for students to not only study the theory of the history but also to work on building projects such as the development of a historic industrial model that they would later need to report and present to the class (Sanders, 2008).

In another example of the Maryland Plan, Maley developed the Research and Experimentation (R & E) course for 9th grade students (Sanders, 2008). In this course students were self-directed in the exploration and the investigation of research projects involving materials science (Sanders, 2008). One of the main responsibilities of the students was to contact experts in the field by applying the scientific investigation methodology and by utilizing tools in their R & E labs like the telephone. The students then reported their findings to the class in weekly seminar style presentations as well as during the end of the total course (Sanders, 2008).

In general, we can see a failure of the industrial arts curricula to establish themselves as general education as well as the philosophy for its goals and purposes started to be undermined. At the same time educators and the general public did not see IA as an education that could develop the human potential further but rather only develop specific technical skills. Specifically, although IA curricula was a unique place for students to express their creativity, we can see a shift in the curricula from the post-World War II era (Sanders, 2008).

In 1985, we can observe the renaming of AIAA to International Technology Education Association (ITEA). This meant the initial shift from the IA curriculum to the technology education (TE) curriculum. The organization thus focused efforts on designing and publishing a comprehensive framework for the TE curriculum. As a result, *A Conceptual Framework for Technology Education* was published and it focused mainly in the "technological method" instead of the "project method" (Savage & Sterry, 1990; Savage, 2002; Sanders, 2008).

It is important to mention that the project method was synonymous with the IA curriculum especially in the 20th century and it required students to build models and projects in cooperation with one another (Sanders, 2008). However, in the mid-1980s we can see the birth of "design briefs" as replacement to the project plans of the previous period (Sanders, 2008). The design brief as an instructional activity became widespread in the United Kingdom and was based on the creation of an analytical description in one or two pages of a specific design challenge (Sanders, 2008).

With this design challenge students were responsible for creating and using tools from their TE laboratories in order to design, build and test a technological solution to the challenge described inside their brief (Sanders, 2008). This gave the students the opportunity to research, gather information, and advance their intellectual thinking in ways that the project method did not (Sanders, 2008). In addition, it provided students with opportunities of higher order thinking and aesthetic creativity. This method was able to motivate students and increase their interest in success, motivation and innovation (Sanders, 2008). In addition, we can see that the Conceptual Framework for Technology Education (Savage, 2002) started to implement and incorporate design challenges for students as ideas for activities which later became the signature pedagogy of technology education (Savage & Sterry, 1990; Savage, 2002; Sanders, 2008).

A significant contribution to the field at this period was also the Technology for All Americans Project (TfAAP) which provided a strong platform for those outside the profession of technology education to get more involved in the field (ITEEA, 2007; Sanders, 2008). The main aim of this project was to increase and promote technological literacy for all students (Sanders, 2008). As a consequence, the *Rationale and Structure for the Study of Technology* was published which facilitated and started the discussion for technological literacy among educators and professionals in the field of education (ITEEA, 1996). This was an important step to standardize technology education in the U.S. Education system and it was fundamental to the development of the *Standards of Technological Literacy: Content for the Study of Technology* (STL) (ITEEA, 2007).

The evolution of the 2007 *Standards of Technological Literacy* led to the creation and the need for the *Standards for Technological and Engineering Literacy* (STEL) (ITEEA, 2020). The literacy component of these standards is fundamental for educators in the field to understand. A report by the National Academies of Sciences, Engineering, and Medicine (2016), mentioned the term foundational literacies to include deep knowledge of any specific domain. For technological and engineering literacy we can observe however that there are some links between their literacy in the emphasis they give to process and action, as well as designing and making. Thus, the main purpose and need of the STEL standards was to articulate all the components of technological and engineering literacy. Enhanced literacy across these disciplines is possible to yield a functional literacy that can solve society's crucial issues (ITEEA, 2020). At the same time STEL standards focus on teaching and learning methodologies that span all the domains of learning:

affective, cognitive, and psychomotor. The urgency for more people to study these disciplines comes from the reality of modern-day life, environment, and society. Technology and Engineering affect most aspects of our lives that we must be able to comprehend their function (ITEEA, 2020).

The need for STEL can be identified by national efforts to increase the technological, engineering, and mathematical literacy of U.S. students (ITEEA, 2020). Thus, the purpose of the STEL standards is to articulate the components of technological and engineering literacy. The rationale is that all citizens of the United States need to know more about technology and engineering. Currently, most of the people have a surfaced view about both technology and engineering. The goal of the standards however is not to make everyone follow technological and engineering careers but broaden the technological and engineering literacy of people so that they can make informed decisions and choices related to technology and engineering and contribute more successfully to the design, development, and use of ideas and technology (ITEEA, 2020).

In addition, modern society has seen a vast increase in occupations that require advanced technological and engineering skills. At the same time these occupations require that people are critical thinkers, transdisciplinary thinkers and able to adapt to new and emerging technologies. This fundamental need of modern society can be addressed by expanding the technology and engineering education of students (ITEEA, 2020). At the same time technology and engineering have become integral parts of everyday life in modern society. This has increased the socio-technological and socio-cultural effects for the structure and functioning of society. Technological and engineering products can often be utilized for unintended purposes. Thus, the broader public needs to be informed about how to use technology in harmful ways. Learning more about technology and engineering can equip people with knowledge about the implications on society and the environment through the misuse of technology. The STEL document is a valuable map for administrators, teachers, and other professionals to create relevant and rigorous PreK-12 technology and engineering programs (ITEEA, 2020).

Technology and Engineering (T & E) in STEM (Science, Technology, Engineering, Mathematics) education can also be understood as two synonymous concepts. However, it is important to define exactly the intent to include engineering in the STEL context. Technological and engineering literacy place emphasis on technological products, design, technology/society interactions and provide a broader inclusive focus on both T & E, rather than focusing exclusively on engineering context and its subfields of civil, electrical, mechanical etc. Another way in which the T & E relationship can be characterized is by referring to engineering as a noun (Engineering) and the use of engineering design and applied engineering habits of mind as a verb (engineering) (ITEEA, 2020). This characterization of the relationship between T & E is used in the STEL Standards.

Lastly, STEL emphasizes the integrated and interdisciplinary approach to technological and engineering studies. Thus, the Standards seek to integrate multiple disciplines that contribute to the development of safe and innovative products. Thus, technology and engineering education provide opportunities for hands-on, designed-based strategies for engaging students in learning and teaching (ITEEA, 2020).

Visualization in Technology Education

The study of visualization as well as graphic/visual communications has a long history within technology education (Lis, 2014). Visualization within the aspect of technology education has been used both as a valuable tool and as a goal of technological design activities (Lis, 2014).

Visualization can be defined as “the process of abstract mental representation of human experiences as they relate to some form of technology” (Lis, 2014, p. 111). Visualization can include representations of two-dimensional (2D) and three-dimensional (3D) virtual or physical models (Lis, 2014). The development, designing, and creation of these models encompasses critical areas of technological design such as analysis, animation, rendering, prototyping, and virtual modeling (Lis, 2014).

The main goal of visualization in technology education is to be able to represent effectively and accurately a plethora of information by creating visual and graphic representations for learners (Lis, 2014). A more widely used term that applies to the goal is the term “scientific and technical visualization” (Lis, 2014). Visualization in technology education is not just limited to the teaching of mechanical and architectural computer aided design software and programs (i.e., CAD), but it is more fundamentally an approach to design and communicate complex scientific ideas and concepts by using a variety of powerful graphical tools in an interdisciplinary approach (Lis, 2014). The ability to breakdown, analyze and visually present these complex concepts though visualization methods is the cornerstone for visual literacy (Lis, 2014). Overall, students should be able to know when, where, and how, to design, create, implement, and evaluate different types of visualizations in order to communicate scientific information effectively and precisely. Figure 5 shows the different types of visualization models students in technology education can utilize (Lis, 2014).

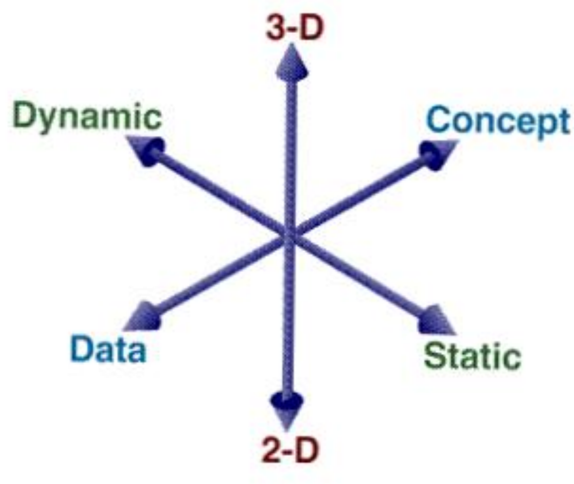

Figure 6

Types of visualizations (Ernst & Clark, 2007)

Visualization within the technology education context should be considered as a holistic process and not as a simple representation of graphics (Lis, 2014). For this reason, students must have a deep understanding and knowledge of the two fundamental types of visualization in order to implement them in the most appropriate way (Lis, 2014). The first one is conceptual modeling. Conceptual graphic models (such as the visualization of scientific phenomena, the flow of fluids, artifacts and other structure) are used to simplify otherwise difficult scientific concepts that would be harder to comprehend though mathematical, text or spatial models (Lis, 2014). Conceptual models are thus created and used when an idea is not easily understood through text or mathematics, but it is better understood through a picture that allows for a better communication of the idea (Lis, 2014). The conceptual models can either be 2D or 3D, and they can also be separated further into static (picture) or dynamic (animation). An ideal example where conceptual modeling is beneficial is the topic of a virus. Viruses cannot be seen from the human eye; thus, it is harder to understand the complex processes involved in the formation and development of viruses (Lis, 2014). The creation of a conceptual model is ideal for this specific scientific topic.

A second fundamental type of visualization modeling is data driven modeling. Data driven modelling uses large amount of data and numerical information to present it in a more coherent way (Lis, 2014). This type of information is usually presented in many types of graphs and charts. Whether the visualization is conceptual, or data driven students' need to have a clear understanding of each type of modeling and they must be able to distinguish between types of information that are given to them as problems in order to then develop models and present this information to a variety of audiences using the most appropriate techniques and methodologies (Lis, 2014).

Scientific visualization has been used for secondary and post-secondary schools and their technology education programs. Clark and Wiebe (2007), focused on creating and using sophisticated graphic tools to study the sciences at secondary and post-secondary programs. Thus, they created curricula for scientific visualization courses that incorporated the following areas: basic design principles for scientific visualization, graphic/plotting image processing, 2D/3D modeling, animation and simulation, and presentation and publication. The curricula that were designed and developed by Clark and Wiebe (2007), placed an emphasis on the use of computers for developing scientific visualization. Scientific visualization requires that students develop competencies in areas such as coordination of systems, spatial relationships, geometric shapes, time representation, orthographic projections, pictorial projections, and technical presentation skills amongst others (Clark & Wiebe, 2007). The specific curricula build a foundation in students for understanding and creating different types of scientific visualizations. When creating a visualization, the first design is determined by classifying the graphics into two categories. The graphics should be either concept-driven or data-driven. A visualization that is concept-driven is generated from a theory or concept and it is not directly related to any set of empirical data. This does not necessarily mean that that no data supports the theory, but that data are not required for the specific visualization. As an example, if we wanted to represent the development of a volcano over time it would be more beneficial to use diagrammatic techniques to show the different scientific phenomena rather than using graph data values (Clark & Wiebe, 2007). A data-driven visualization uses mostly empirical or mathematical data values in order to formulate the visualization.

The second step to developing a visualization is to determine if the visualization is to be represented in two or three dimensions. Here the evaluation of hardware and software is crucial. At the same time the information to be presented must also be evaluated. The dimensionality of the visualization heavily depends on the capabilities of the computational software and hardware. Both concept-driven and data-driven visualization can take a two- or three-dimensional approach. Thus Clark and Wiebe (2007), have created a matrix that can guide technology educators and students in developing scientific visualizations. The matrix includes four visualization types of 2-D concept-driven, 3-D concept-driven, 2-D data-driven, and 3-D data-driven. Some exercises and techniques to aid students in the development of visualizations can be graphing and plotting, weather data exercises, image processing, MRI scans and animation, modeling, and simulation (Clark & Wiebe, 2007).

Aaron et al. (2000), described how scientific visualization is a fundamental aspect for technology education and its impact on understanding key technological concepts is great. The impact that scientific visualization can have on students learning in relation to technology education can be seen from the competencies they develop in computer technology, data manipulation and management, and in their visualization design skills.

Quality Indicators

Quality indicators are defined as “Measurable, objective, indicators of the efficiency of the key segments of a system” (Vuk, 2012, p. 25). Fundamental attributes of quality indicators are their measurability, objectivity, validity, and reliability (Vuk, 2012).

The quality indicators of visual-based learning material in technology education that were used in the Round I instrument were identified from the literature review and were the following (Aldalalah & Ababneh, 2015; Borkin et al. 2013; Katsioloudis, 2010): 1) the effectiveness of visual-based learning material in technology education for grades 6^{th} -9^{th} depends upon the amount of realistic detail contained in the visualization used, 2) the effectiveness of visual – based learning material in technology education for grades 6^{th} -9^{th} depends upon the method by which the visualized instruction is presented to the students, 3) depends upon students’ engagement and interests, 4) depends upon the type of educational objective to be achieved by students, 5) depends upon the technique used to focus student attention on the essential learning characteristics in the visualization materials such as arrows, motion, visual feedback, 6) depends upon the type of test format employed to assess student information acquisition, and 7) depends upon the properties and quantity of the colors in the Visualization used (Borkin et al. 2013; Katsioloudis, 2010).

Quality Indicators and Course Quality in Technology Education Programs

In their study Mentzer et al. (2022), mention the importance of teaching quality design in technology education. The teaching of technology education is emphasized also in the *Standards* *for Technological and Engineering Literacy* (ITEEA, 2020). The researchers mention that it is often hard for educators to motivate and engage students in technology education classrooms even though they are provided with high quality content. For these reasons, Mentzer et al. (2022), investigated how technology educators might be able to increase student motivation inside the technology education classroom if the design thinking process is improved. To investigate this phenomenon, Mentzer et al. (2022), used the Expectancy Value Theory of motivation to measure the students perceived impact on the course quality, based on ratings of the instructor and content. Mentzer et al. (2022), utilized quantitative methods in order to conduct their research. Their research showed that when making the appropriate changes to the way technology content is delivered to the students then the perceived course quality of the students increases significantly. Expectancy Value Theory can be defined as the relationship between a student's expectancy for success at a task or the achievement of a goal in relation to the value of task completion or goal attainment (Atkinson, 1964).

It is important to mention that quality teaching in technology education is often difficult for educators because the students have to have high programmatic retention skills as well as higher order learning and thinking skills (Mentzer et al., 2022). Mentzer et al. (2022), also mention that when a technology education course is not perceived from the students to be of high quality then it is less likely that they will succeed, attend, or even select a technology education class. Utilizing the Expectancy Value Theory Mentzer et al. (2022), were able to make the appropriate changes to the quality of technology and design courses that were also based in students' expectations of success, the perceived value that students gave to the course, as well as the economic cost that students had in order to engage with course activities. According to Mentzer et al. (2022), the Expectancy Value Theory posits the idea that students are more motivated to perform well on a given task if they acknowledge the value and the quality of the task that is to be done. This means that students should be able to identify the future value of the task that they are performing in the present. In summary, the Expectancy Value Theory recommends a formula for student motivation in accordance with course quality that describes expectancy and value as the main contributors for students' success and motivation but is also undermined by associated costs (Mentzer et al., 2022).

The study of Mentzer et al. (2022), is unique as it measures the impacts of course improvements as they were measured from student evaluations at the end of each course. Their study was conducted in a Midwestern University research institution, inside a first -year Design Thinking and Technology course. In addition, it is fundamental to mention that this study was conducted in post-secondary education. However, it is of high importance for secondary technology educators as well because high quality introductory courses in technology education can impact student retention in the future (Mentzer et al, 2022). The content of the specific course was focused mainly on the teaching of practices such as: systems thinking, making and doing, creativity, critical thinking, collaboration, optimism, attention to ethics, and communication. Such practices are direct focus of *Standards for Technological and Engineering Literacy* (ITEEA, 2020).

The main activities for students in this Design and Technology course were three projects. Two of these projects helped the students learn more in detail about the engineering design process. The last project students had to work on was related to identifying a grand, modern technological challenge and try to identify the major issues, stakeholders, and possible solutions to this challenge. Students were responsible for creating a prototype that was tested further, refined and gained feedback. Mentzer et al. (2022) conducted this study in a flipped classroom format where students had been given prior access to all the course content and class time was used for constructive discussion and feedback.

In order for the researchers to improve the course content and outcomes based on the Expectancy Value Theory the backward design approach was utilized. The three main categories of the backward design process identify expected results, determine the evidence that is acceptable, and plan for appropriate learning experiences in the context of instruction (Mentzer et al., 2022). At the same time the researchers worked collaboratively with different instructors that aided them in better understanding the course materials that students were provided with. As mentioned earlier, the main purpose of the study by Mentzer et al. (2022), was to evaluate the impact of revisions made to the quality content of the course based on the overall course ratings, the improvement in the ratings of the instructors, and most importantly on the improvement on the student's perception regarding the course quality.

The results of the study showed significant differences between the students who participated in the researcher's intervention and course improvement in comparison with students that were included in the traditional course. More specifically the students who participated in the improved Design and Technology Course reported that they were more motivated to keep taking technology courses and they acknowledged the high value and quality of the course. Negative comments for course content were notably less than negative comments made by students in the traditional course. At the same time, it is important to mention that students were able to find meaningful quality in the course that would aid them in their future profession and studies (Mentzer et al., 2022).

Mentzer et al. (2022), thus were able to demonstrate the significance and necessity to provide quality course content specifically to technology education students. This necessity is urgent as many students perceive that technology education has no value for their future studies and profession which leads them to reject any technology education course either in secondary or post-secondary education (Mentzer et al., 2022).

In his 1999 study, Clark identified quality indicators for technology education programs through reaching consensus between experts in Delphi methodology research study. Those identified quality indicators were related to instruction. Some of those Quality Indicators were the following:

> Course material is permitted to develop and experiment with new technologies and regions, course content is influenced by the constant evolution of technology and society's engagement with that technology, all students are given information about technology education course offerings at their school without regard to gender, ethnic background, achievement, handicap, other disadvantage, the technological education program includes people from all walks of life, and sufficient money has been budgeted for equipment and facility enhancements in order to achieve course objectives. (Clark, 1999, p. 23-24)

It becomes thus apparent that the issue of identifying quality indicators for technology education is very important for the specific field. Thus, more research must be conducted in order to improve the quality of this field.

Spatial Ability

Spatial ability is a unique ability separate from other abilities like verbal ability, reasoning ability, and memory skills. Spatial ability is a complex aspect of human intelligence that can be characterized as multidimensional. Spatial intelligence involves forming a model in the spatial world and having the ability to maneuver and work with this model mentally (Gardner, 1983). Spatial ability has an important role in the science, technology engineering, and mathematics (STEM) disciplines (Uttal and Cohen, 2012). According to McGee (1979), two factors that constitute spatial ability are spatial visualization and spatial orientation. McGee (1979, p. 893) explains spatial ability as ‘’the ability to mentally manipulate rotate, twist or invert pictorially presented stimuli’’. In another definition Carroll (1993, p. 304), describes spatial ability “as the ability of individuals to search the visual field, apprehend the forms, shapes, and positions of objects visually perceived and to form mental representations of those forms, shapes, and positions by manipulating these representations.” Lohman (1979) characterizes spatial ability as the ability to generate retain and manipulate abstract visual images. At the most fundamental level, spatial thinking requires the ability to encode, remember, transform, and match spatial stimuli. Spatial relations, spatial orientation, and visualizations characterize spatial ability (Lohman, 1979), and include different features that have a crucial role in developing and understanding spatial ability.

Performance on different tasks such as mental rotation of objects and understanding of how objects appear from different angles are at the core of spatial ability (Sutton and Williams, 2007). Another important feature of spatial ability is 3D Dimensional understanding, which is the ability to receive information about 3D Dimensional objects from 2D Dimensional representations. Sutton and Williams (2007), support that this process demands spatial abilities to manipulate graphical representations mentally. Spatial ability also proves to be essential when working with visualizations. High levels of spatial ability improve learning when visualizations are present (Höffler, 2010). There are different ways to measure the spatial ability level of students.

The Mental Cutting Test (MCT) and the Mental Rotation Test (MRT) are designed to measure spatial abilities (Nagy-Kondor, 2017). In the MCT test, a 3D object is presented with an assumed cutting plane and five alternatives for the cross-section shape. The MRT presents a criterion figure along with four additional figures, two of which present the criterion figure rotated. Other tests that measure spatial ability are the Heinrich Spatial Visualization Test (HSVT), the Purdue Spatial Visualization Test (PSVT) and the Purdue Spatial Visualization Test -Visualization of Rotation (PSVT-R) (Nagy-Kondor, 2017).

One research study focused on ways to improve spatial ability in students. For example, engineering subjects and activities and drafting exercises have been proved to develop spatial ability in students (Olkun, 2003). Students who have a higher level of spatial skills are more likely to be found in the field of engineering, computer science, and mathematics, which demonstrates the importance of the ability for successful completion and retention inside these fields (Olkun, 2003).

Related Studies

Spatial ability skills are highly correlated with retention in STEM programs and success in engineering courses. Many studies have been developed to identify the best practices, curriculums, and techniques that can improve the spatial ability of students. In their study Kinsey et al. (2008), developed and evaluated two tools to improve spatial ability in mechanical engineering students. The first tool was the Physical Model Rotator (PMR), and the other training tool was the Alternative View Screen (AVS) tool, both of which were applied also using Computer-Aided Design (CAD) software (Kinsey et al., 2008). The researchers focused on presenting two-dimensional objects to students and analyzing their ability to visualize it in the three-dimensional space. Their study showed that the students who participated in the targeted spatial ability training had greater improvement in their spatial ability than those who did not (Kinsey, Towle, & Onyancha, 2008). It was concluded that CAD training programs and PMR and AVS training systems can help freshman engineering students improve their spatial ability. In a similar path, the benefits of CAD software for spatial ability were shown in a study by Martin-Dorta et al. (2008). The researchers designed a fast-remedial course to improve the spatial ability of civil engineering students using 3D CAD software. They designed the course so it would be interesting for students, and the CAD software they used was Google SketchUp. The exercises practiced through the software showed that it had a positive impact on the student's spatial ability level as it was measured through the MRT and DAT:SR tests (Martin-Dorta, Contero, & Saorin, 2008).

Lux et al. (2019), in their research study, designed a spatial skills curriculum using Minecraft for middle school students. Their effort focused on determining if Minecraft can be used to support student’s spatial ability and if it can be considered a successful intervention. Minecraft-based puzzles and challenges were designed for middle school students. The researchers concluded that the mental rotation spatial skills of the students increased as a result of this intervention (Lux, LaMeres, Willoughby, & Hughes, 2019).

In a study by Mohler (2008) the spatial ability phenomenon was examined through the student’s perspectives. The qualitative study examined the experiences, background, and education the students themselves deemed important for their level of spatial ability. The researchers interviewed students from a computer graphics technology course. Topics that were found to be highly relevant to spatial development from the participants included childhood toys, specifically playing with Legos, high performance in Mathematics, musical ability, and involvement in sports (Mohler, 2008). Further research is important to be conducted in methods that improve spatial ability in students.

Spatial Visualization

Spatial visualization skills can bring success to the engineering field and is considered an essential skill for professions in the science, technology, engineering, and math fields. Retention in these fields of studies and profession's is higher when levels of spatial visualization ability in students are high. Hegarty and Kozhenikov (1999), described spatial visualization as a complex process that requires apprehending, encoding, and mentally transforming objects in the spatial world. Performing complex and multi-step mental transformations characterizes spatial visualization (Miyake et al., 2001: Voyer et al., 1995).

Spatial visualization ability can be developed in students through different activities. Sketching 3-D objects can aid significantly in the development of this ability (Sorby, 2009). Other activities that help students develop spatial visualization from an early age include playing with construction games, playing video games, participating in mechanics, and drafting classes, and understanding advanced mathematics (Sorby, 2009). Deno (1995), additionally supports that students who were involved in activities like model building, sketching, and assembling of parts in the post-secondary education years scored higher in spatial visualization tests.

Studies have shown that several factors can have an impact on spatial visualization ability, such as age, gender, and life experiences (Strong & Smith, 2002). Additionally, studies have shown that spatial visualization ability can be improved and taught. While some research shows that spatial visualization ability can be developed through various life experiences, other research suggests that spatial visualization can be improved with appropriate instruction (Strong & Smith, 2002).

In the chemical sciences, the spatial ability has also proven to be important. Students with higher levels of spatial skills tend to perform better in organic chemistry and in activities that demand problem-solving skills (Sorby, 2009). Chemistry students' higher level of spatial skills tends to have advanced performance in drawing and manipulation of molecular representations and in drawing efficient structures and diagrams (Sorby, 2009). In the computer science field, spatial visualization is important for success when conducting database manipulations as well as in design software that are supported by computers (Sorby, Casey, Veurink, & Dulaney, 2013). In the virtual reality environment, spatial visualization ability also is a predictor of success. Virtual reality technologies are integrated into computer-aided design software (CAD), which are used in engineering and technology curricula (Strong & Smith, 2002). Higher-level thinking, advanced reasoning skills, and creative processes have been widely associated with a higher level of spatial visualization skills (Sorby et al., 2013).

Related Studies

Scores on spatial tests are considered predictors of success in engineering graphics courses. In a study by Branoff and Dobelis (2012), the researchers examined if any relationship exists between reading engineering drawings and spatial visualization. Engineering drawing includes the ability to understand information from an assembly drawing, visualization of each part, and the ability to create 3D models of the parts in a CAD system (Branoff & Dobelis, 2012). The researchers tested the scores of students from constraint-based modeling courses. The students were tested using the PSVT: R and a Modeling Test. Branoff and Dobelis (2012), concluded that there is a significant correlation between the scores of students in the Modeling Test and the PSVT: R. The study showed the importance of mentally manipulating a two-dimensional part, visualizing it in the three-dimensional space and understanding the geometry so it can be constructed in the 3D modeling system (Branoff & Dobelis, 2012).

Katsioloudis et al., (2014), researched if any difference existed in spatial visualization skills among industrial and technology education students. The spatial visualization skills of the students were measured through technical drawings of different model types which included a sketch from a 2-D drawing, a sketch from a 3-D image, and a sketch from a 3-D object. The results indicated that the students who were presented with 3-D solid models and 3-D computer-generated models scored higher from the students who were presented with a 2-D drawing. The researchers concluded that using 3-D models aids industrial and technology education students to develop their spatial visualization skills (Katsioloudis et al., 2014).

Many higher education institutions have initiated efforts for improving spatial skills in students in engineering programs. Some of them include the Michigan Technological University, Penn State Behrend College, Virginia State University, and Virginia Tech, which have created materials and courses for developing the spatial skills for engineering students taking their graphics courses in their first year (Veurink et al., 2009). Specifically, Michigan Tech developed a supplemental spatial visualization course for students who have low scores on the PSVT: R. The supplemental course aided students in better comprehending the 3-D modeling software and it was found important for the retention of the students in the program (Veurink et al., 2009). Another initiative was developed by the Penn State Behrend named the Visualization Assesment and Training project (VIZ), which aimed in promoting a website platform for training and research on spatial visualization. The initiatives developed by Michigan Tech and Penn State Behrend were incorporated into the engineering curricula of other higher education institutions and in Industrial Design majors (Veurink et al., 2009). Students who participated in those initiatives improved their spatial visualization skills significantly (Veurink et al., 2009).

To conclude it is important to mention that technology and engineering education have a lot of common practices and processes and emphasis has been given to establish a curriculum for student in all educational levels that promotes their knowledge of core concepts in technology literacy and engineering literacy as well. Some of society's crucial problems and needs can be solved and improved through technological and engineering practices. Thus, we must be able as a society to advance and transfer technological and engineering knowledge in all levels of education and make information accessible to all members of society.

Summary

This section has discussed the history of visual pedagogy and has presented the main visualization challenges for the field. In addition, this section described the evolution of technology education programs in the United States and has underlined the importance of the industrial arts curricula in the formation of the modern technology education programs. At the same time the section focused on analyzing visualization in technology education, how it has been implemented so far and what the benefits are for understanding complex scientific concepts relating to technology education. Furthermore, this section described the quality indicators and their importance for quality technology programs. Lastly, the concepts of spatial ability and spatial visualization were introduced and their relation and significance for technology education was explained.

CHAPTER III

METHODOLOGY

This chapter provides an outline of the research methods that were followed in the research study. It provides detailed information on the participants, the criteria for inclusion in the specific study as well as how the participants were sampled. The research design is explained in detail as well as the reasons for this choice by the researcher. In addition, the instruments that were used for the data collection are also described and analyzed. Lastly, this chapter incorporates the statistical analysis that was conducted to better understand the data that were gathered.

Population

The expert panel for this study are expert technology educators that have served as instructors in grades 6th - 9th . Specifically, a total of 15 expert educators participated in the panel. The 15 technology educators are from Greek schools in the Cyclades region and are recognized for their contributions to the field of technology education. Furthermore, these technology educators have incorporated visual-based materials in their technology education classrooms systematically. To identify potential participants for the study the researcher contacted via email those technology educators. The e-mail included a description of the study and asked the experts to nominate other technology educators as study participants as well. For this specific study, the panelists met specific criteria to be included in the research study: Specifically, they should meet four out of five of the following criteria identified from the literature (Katsioloudis, 2010; ITEEA, 2020):

1. Current involvement in education as a technology educator, researcher, and a minimum of five years of experience with visual-based learning material for technology education.

2. Demonstrated leadership in developing, implementing, and evaluating material for educational purposes related to visual-based learning in technology education.

3. They must have a demonstrated record of publications or presentations in visual-based learning in technology education.

4. Teaching and professional practices that are related to the promotion and improvement of skills in visual-based learning methods.

5. Active collaboration with state departments, professional associations, grants, and universities showcases the educator's involvement in developing visual-based learning material.

Linstone and Turoff (1975), state that the ideal number of experts for the Delphi panel is anywhere between 10 to 50 participants, while Delbecq et. al. (1975), suggest that an ideal panel size between 15 to 20 participants. Boulkedid et al. (2011), identified 80 Delphi studies that focused on the selection of quality indicators and found that the median panel size was 17. Skumolski et al. (2007), identified 41 Delphi dissertations within the field of information science and found that most of the studies had a panel size with the range of 12 to 20 experts. Furthermore, it is reported that larger Delphi panel sizes do not contribute to significantly improved validity or reliability of the Delphi method. Although reliability and validity increase as the panel size increases, the increase is not significant once the panel size is more than 30 participants (Garson, 2012). Based on the guidelines for the size of the Delphi panel the researcher of the study used a panel size of 15 participants. Participants of the expert panel were selected with purposive sampling rather than random.

In addition, four technology educators served in the review panel. They ensured the appropriateness of the data collection instruments that were shared with the expert panel. The review panel was responsible for reviewing and verifying each instrument developed by the researcher before it is administered to the expert panel. This means that the review panel reviewed and approved all instruments prior to the initiation of data collection, between each round, and at the end of the data collection process. This ensured avoidance of any duplicate content. The four technology experts that participated as review panel were identified based on the following criteria:

1. They must have publications in the flagship journal of engineering design graphics which is the Journal of Engineering Design Graphics.

The Journal of Engineering and Design Graphics is (JEDG) the flagship journal of engineering graphics. The Engineering Design Graphics Journal is the official publication of the Engineering Design Graphics Division of the American Society for Engineering Education (ASEE). The role of the Journal is the advancement of engineering design graphics, computer graphics, and subjects related to engineering design graphics to:

a. Encourage research, development, and refinement of theory and applications of engineering design graphics for understanding and practice.
b. Encourage teachers of engineering design graphics to experiment with and test appropriate teaching techniques and topics to further improve the quality and modernization of instruction and courses.
c. Stimulate the preparation for papers on topics of interest to the membership (JEDG, n.d.).

2. They must be involved with technology education teacher education programs. Involvement of the review panel in technology education teacher education programs is crucial because it will allow the participants of the review panel to have hands-on experiences themselves with technology education learning materials. In addition, it will demonstrate that their research is dedicated to improving the field of technology educators for future technology educators.

Research Variables

Research variables include quality indicators of visual based learning material which is the dependent variable and the panel of experts which is the independent variable. Figure 8 showcases the relationship between the variables of the study.

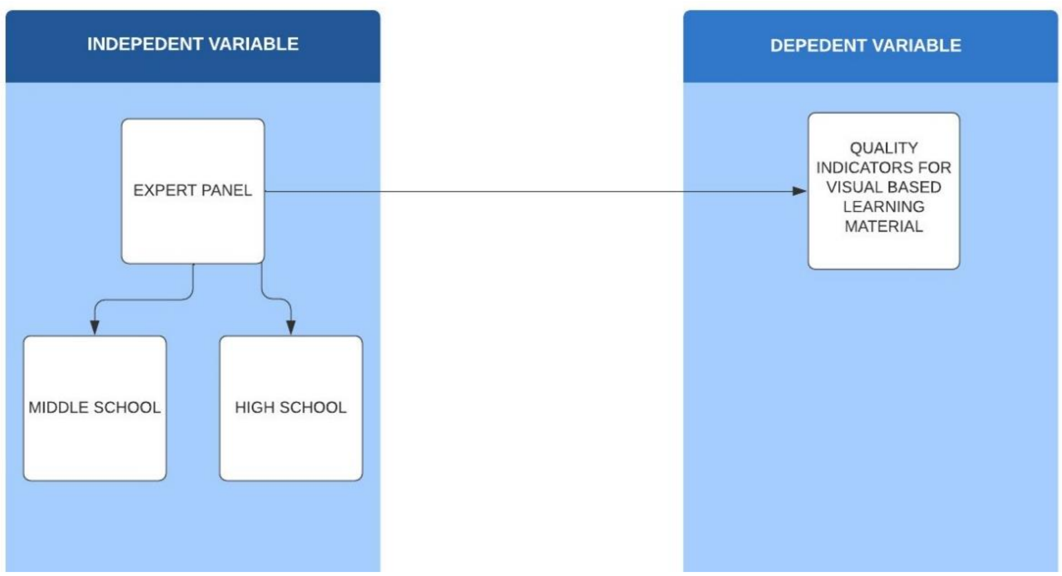

Figure 7

Relationship Between Variables

Delphi Method

Garson (2012, p. 13), states that "the Delphi method is an iterative process for consensus building from a panel of experts who are anonymous to each other. Delphi is advocated as the most appropriate means to achieve optimally reliable expert consensus." The current uses of the Delphi method focus on one of three objectives: a) forecasting future events, b) achieving consensus within organizations, or 3) identifying and receiving feedback from stakeholders for policy outcomes (Garson, 2012). In quantitative research, the Delphi Method is used for reaching consensus in the composition of surveys and data-collecting instruments, as well as in the coding of phenomena and the reaching of consensus in research agendas of a specific study area. The traditional form of the Delphi method distributes detailed questionnaires to a panel of experts, and then responses are utilized and synthesized as feedback to the experts in the next round of questionnaires. A series of rounds are utilized in the Delphi method where experts on the panel do not communicate with each other but only provide responses to the Delphi Administrator (Garson, 2012).

This method of research was initially developed in the 1950s by the RAND Corporations on military operations and organizations, in order to forecast the effect that new military technologies would have on future warfare operations. Garson (2012), states that nowadays the mode of administration of the Delphi study has included new methods of administration through e-mail communication, face-to-face meetings, and online survey methods that are interactive.

It is important to mention that the Delphi is an iterative process which proceeds through successive rounds overseen by an administrator, usually the principal investigator of a research study (Garson, 2012). The experts that are selected to participate in each round need to be experts in the subject matter being explored, in this case visual-based learning material in technology education. Throughout the entire process of the Delphi, experts that are selected are assured of anonymity. This phenomenon of keeping the processing of questionnaires and the feedback anonymous contributes to the avoidance of undesirable group effects such as:

1) Deference to high status individuals or group leaders, 2) Deference to socially assertive individuals, 3) the elimination of the groupthink conformity, 4) and the elimination of pressure towards the respondent that feels that earlier expressed opinions must continue to be defended (Barrett & Heale, 2020; Garson, 2012).

The Delphi method in quantitative research has been applied for a variety of reasons. Some examples of Delphi study methodology have focused on identifying, developing and selecting quality indicators. In their research Boulkedid et al. (2011), surveyed 30 years of Delphi studies (1978-2009), and found 80 important examples of the Delphi methodology that focused on the development, identification, and the selection of indicators of health care quality. The expert panels consisted in these cases from health care practitioners and professionals. In another study Smith et al. (2012), surveyed an international panel of experts in neuropathology in a Delphi study that focused on reaching a consensus on the specific features that were required to define important neuropathological processes.

Linstone and Turroff (1975, p. 3), state that "Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals as a whole to deal with a complex problem." In this structured communication that the researchers describe feedback is provided to individual contributions and views, assessment is provided on the group judgement and the individuals in the group can revise their views under some degree of anonymity that is provided to them. Over the course of the years the Delphi method has been used for a variety of purposes such as putting together the structure of a new model, developing causal relationships in phenomena, and for planning curriculum development (Barrett & Heale, 2020; Garson, 2012).

Some characteristics of the Delphi method are that it can be designed in different forms and can be implemented using a variety of tools. The most widely used method is the paper-and-pencil method which is also called the "Delphi exercise" or conventional Delphi. In this version of the technique a small team monitors and designs a questionnaire that is later given to a larger group of individuals that respond to this questionnaire. The questionnaire is then returned to the monitor team who designs and sends a new questionnaire to the respondents that is based upon the first results. The respondent group can reevaluate and review their original answers at least one time during the whole process (Barrett & Heale, 2020; Linstone &Turroff, 1975).

A second form is the "Delphi Conference", which utilizes a computer instead of a monitor team, which has been programmed to analyze the results of the respondent group. The specific method can create a real-time communication system as it has the advantage of eliminating any delay when analyzing each round of Delphi. This method is referred as real-time Delphi (Barrett & Heale, 2020; Linstone & Turroff, 1975).

Delphi methods and forms are further characterized by two or more basic phases. In the first phase, there is an analytical exploration of the problem that is being examined and each group individual contributes any knowledge they have about the issue. In the second phase the members of the respondent group examine their views one more time to determine where they disagree or agree in terms of desirability, feasibility, and importance. In the third phase, an evaluation of any disagreements is performed that brings out the cause of this disagreement and possible resolutions for the issue. In the last phase, a final evaluation of all information is conducted in order to reach a consensus (Barrett & Heale, 2020; Linstone & Turroff, 1975).

Linstone and Turroff (1975), point out some specific reasons that implementing the Delphi method might fail. Some of the most common reasons that the Delphi study may fail are:

> Imposing monitor views and preconceptions of a problem upon the respondent group by over specifying the structure of the Delphi and not allowing for the contribution of other perspectives related to the problem, assuming that Delphi can be a surrogate for all other human communications in each situation, poor techniques of summarizing and presenting the group response and ensuring common interpretation of the evaluation scales utilized in the exercise, ignoring and not exploring disagreements so that discouraged dissenters drop out and an artificial consensus is generated, underestimating the demanding nature of a Delphi and the fact that the respondents should be recognized as consultants and properly compensated for their time if the Delphi is not an integral part of their job function. (p. 6)

Furthermore, Linstone and Turroff (1975, p. 4), established specific criteria that can be utilized to decide the appropriateness of using the Delphi method. Those criteria are the following:

> When the problem does not need precise analytical techniques but can benefit from subjective judgments on a collective basis, when the individuals who need to contribute to the examination represent diverse background with respect to experience or expertise, when more individuals are needed than can effectively interact in a face-tom-face exchange, when the time and cost make group meetings infeasible, when disagreements are so severe or politically unpleasant that the communication process must be referred and/or anonymity assured, when the heterogeneity of the participants must be preserved to assure validity of the result and to avoid domination by the strength of certain personalities, when a supplemental group communication process can help the efficiency of the face-to-face meetings. (p .4)

Dalkey (1969, p. 17) and Barrett and Heale (2020), highlight some advantages of the Delphi method. Those advantages are the following:

> It is a rapid and efficient way to acquire expert opinions, if well designed the procedure requires less effort form the part of the respondents, from a conference, the systematic procedures contribute to the achievement of objectivity of the outcomes, there is a sense of responsibility due to anonymity, which also decreases social inhibitions, information can be obtained from a large group of experts that are geographically dispersed and who come from diverse backgrounds, the researcher can focus the attention of the participants on the topic of interests, it increases rational input, and it is a relatively inexpensive means for gathering opinion.

Lastly, it is important to mention the reason why a modified Delphi study was chosen. This approach minimizes cognitive biases and effectively utilizes the expert community's pooled knowledge. The first choices in a "Modified Delphi" design are chosen before they are presented to the panel.

Delphi Panel Selection

Delphi panel selection is a crucial part of the design of the modified Delphi study (Barrett & Heale, 2020; Garson, 2012). A successful panel selection means that the researcher has managed to identify the most appropriate experts to examine the researched topic. In addition, a successful panel selection composed of experts in the field provides the study with credibility and maximizes the quality of the responses (Barrett & Heale, 2020; Garson, 2012). The selection of panel experts for this study was done purposefully through e-mail communication. Time and cost are the major advantages of e-mail communication over traditional methods of recruiting. The major source to identify and select expert Delphi panel participants was identified by the researcher as practitioners in the field of visual-based pedagogy within the context of technology education. Thus, the selection of experts was done via e-mail communication (Appendix A).

A total number of fifteen participants (*n* = 15), were selected as panel experts for this Delphi study. Individuals who were selected to serve as panel experts were contacted via e-mail to ask for their contribution to the study. This initial e-mail included the following information: a) invitation letter, b) study overview c) study participation (Appendix A).

The next step in the process is to determine some demographic information of the teachers who were selected to be a part of the expert panel. For this purpose, a demographic survey was conducted that allowed the researcher to gain valuable insight in the expertise of each participant. Questions included in the demographics survey were the following:

1. Which title most accurately describes your current position? (Technology teacher using visual based learning material, visual based learning grant related participant, visual based learning material author).

2. Which grade level(s) do you currently teach or oversee? One of the qualifying indicators of the participants is the teaching background.

3. What is the highest degree obtained as of 30th of August 2022? All participants are required to hold at least a bachelor’s degree and have enough educational background to understand the questions of the study.

4. What is your gender? For demographic purposes and further research that correlates gender and visual expertise.

5. Year of graduation from High School. To identify the participants’ age and do further research.

6. Current residence? To help with the stratifying process and create a more representative population of participants.

7. Have you been involved in any grant related to Technology education and scientific visualization? If so which one?

8. Have you had any type of visual training within the last five years? To justify that all participants are aware of any changes that took place within the last five years and relate to visual-based learning material.

9. What courses have you taught in the last two years that require visual teaching/student capabilities? The purpose of this question is to justify that the participant has been active with visual related material so that the responses were more valid.

The questions included in the demographics survey were created in accordance with Meyers and Booker (1990) recommendations on how to select expert panel participants. This diminished the possibility of the participants being selected based on their favor towards the specific subject matter.

Data gathering instruments will include the Demographics Survey as well as instruments created and distributed by the researcher to a panel of experts in three rounds. The necessity for the three rounds is to reach a consensus on visual-based learning quality indicators between the experts. At this point it is important to mention that a specific website was created for the purposes of this study where all participants would be able to complete all the necessary instruments, instructions, and information. A review panel of four members was consisted as well, that along with the researcher pilot tested each instrument before it was distributed to the panel of experts.

Instrument Design and Implementation

Round I

The instruments that were designed and developed for Round I were developed based on the literature review. The straw model in Table 1 shows a detailed list of the initial quality indicators that were provided to the participants, and that were identified from the literature review. The first instrument the experts had to respond in the first Round was the Demographic Survey. The second instrument of Round I asked the participants to accept, reject, and modify the existing indicators that were identified from the literature review (Table 1) and add additional ones according to their own experiences working with visual learning material. Once the list with quality indicators was formed based on the literature review it was sent to the review panel for review and approval before it was sent to the panel of experts. Once the review panel approved of the first instrument it became available to the expert panel through a Qualtrics link. A reminder e-mail was constructed in case it is needed to remind participants in the expert panel to reply. When the Round I instrument was completed the new suggested indicators were added to the Round II instrument and further modifications were made to the pre-existing indicators.

The second instrument of the first Round specifically is the listing of quality indicators reviewers think that are good characteristics of a visual-based learning material for grades 6^{th} -9^{th} in technology education programs. The title of the instrument is Round One Questionnaire. The first nine indicators are examples of the type of information and writing style the study is identifying. The indicators were used if reviewers choose to KEEP each indicator, if they do not wish to use the category, they REJECT it and write in a new indicator inside the text box provided in the instrument; to use the indicator but make changes in the wording, the reviewers can MODIFY it. If they chose to MODIFY the indicator, they write their changes inside the provided text box underneath the indicator they wish to change. At the end of the instrument a provided text box will exist for the reviewers to ADD NEW indicators. The main objective is to ADD more NEW indicators to the study according to the expertise of the experts. Reviewers will have two weeks to provide their responses. The responses to the Round I questionnaire are used to produce and formulate the next round of questionnaires (Dajani et al., 1979).

Table 1

Initial Quality Indicator Straw Model

Quality Indicator	Sources(s)
The effectiveness of visual-based learning material in Technology Education for grades 6-9 depends upon:	
The manner in which they cause the learner to process the information.	Sentz, J. (2020)
The visual elements that can show spatial relationships or positioning of objects that are being presented within the instruction.	Sentz, J. (2020)
Using proper procedures to differentiate titles and key words.	Aldalalah, O., & Ababneh, Z. (2015).
The manner in which Illustrations and photographs are used.	Aldalalah, O., & Ababneh, Z. (2015).
The appropriateness of standards when using colors.	Aldalalah, O., & Ababneh, Z. (2015).
The amount of realistic detail contained in the Visualization used.	(Katsioloudis, 2012)
The method by which the visualized instruction is presented to the students.	(Katsioloudis, 2012)

Student's interests and engagement.	(Katsioloudis, 2012)
The technique used to focus student attention on the essential learning characteristics in the visualization materials, (e.g., cues such as questions, arrows, motion, verbal/visual feedback).	(Katsioloudis, 2012)
The type of test format employed to assess student information acquisition, (e.g., for certain types of educational objectives visual tests have been found to provide more valid assessments of the amount of information students acquire by means of visualized instruction).	(Katsioloudis, 2012)

Round II

The Round II instrument included the quality indicators proposed by the experts in the previous round as well as the pre-existing quality indicators identified from the researcher in the literature and were kept from the experts. Once the Round II instrument was verified from the review panel it was sent to the experts. The purpose of the second Round was to rate and then rank the quality indicators based on a Likert scale of one to five with one being strongly disagree and five being strongly agree. In addition, this round as well provided the opportunity for the experts to provide any additional quality indicators. After the experts rated all the existing quality indicators the mean, and standard deviations were calculated for each of the quality indicators based on the rating given. Indicators with a mean 3.01 or higher were represented in the next Round III. Quality indicators with a statistical mean less than three are eliminated as not being within the consensus (Mayer & Brooker, 1990). It has been researched that consensus is the same as agreement, and this can be determined by a) the aggregate of individual judgements, b) a move to subjective level of the central tendency, and c) by confirming the stability in the consistency of answers between the successive rounds (Holey et al., 2007).

The Likert scale to be used for rating the indicators was the following:

1= Strongly Disagree that the effectiveness of visual-based learning material in technology education depends upon the specific indicator.

2 = Disagree that the effectiveness of visual-based learning material in technology education depends upon the specific indicator and meets 49% or less of all quality characteristics

3= Neutral position that the effectiveness of visual-based laming material in technology educationdepends upon the specific indicator and is appropriate for 51% or more of all quality characteristics.

4 =Agree that the effectiveness of visual-based learning material in technology education depends upon the specific indicator and is appropriate for 75% or more of all quality characteristics

5=Strongly agree that the effectiveness of visual-based learning material in technology education depends upon the specific indicator and is appropriate for 100% of all quality characteristics.

The second part of Round II included the ranking of the quality indicators. As mentioned previously, the panel of experts in this round had the opportunity to add more quality indicators and that they had to rank and rate those as well. The Ranking of the quality indicators will start with number one being the most important indicator of quality and continue to the final indicator that represents the least value for quality (ex. 1 best, 2, 3, 4, 5, 6, etc.).

Round III

The purpose of Round III was to build consensus amongst the expert panel members. Once the quality indicators of visual-based material were analyzed, ranked, and rated it was time for the experts to reach a consensus. In this Round as well, the instrument was first sent to the review panel for feedback and further revision and then was sent to the panel of experts. In this Round no further modifications to the indicators were allowed. The expert panel was responsible for accepting or rejecting each finalized indicator. After the researcher formulated the final list according to the consensus of the experts the new quality indicators for visual-based material were sent to the experts to see the results of the study. Figure 8 demonstrates the Delphi methodology that was implemented by the researcher and the steps that were followed in each round.

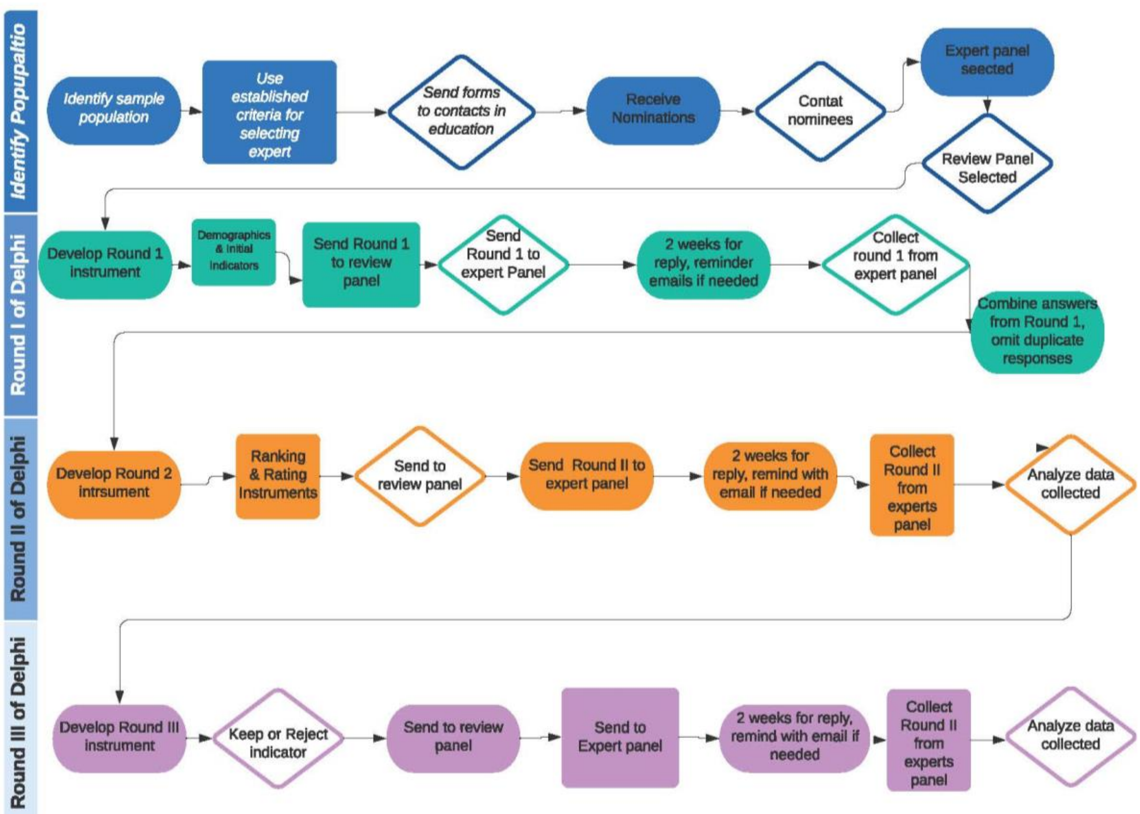

Figure 8

Flow Chart of Delphi Methodology for study

Statistical Analyses to be Conducted.

For Round I it is important to gain the response rate for each indicator. Descriptive statistics were conducted after the collection of data from Round II to identify mean, median and standard deviation of ratings. When Round II was completed the means of the indicators were used to rank them from highest mean to lowest mean. This was conducted in order to allow for the comparison of the statistically ranked means with the rankings conducted by the experts for each indicator. This was necessary in order to see if consensus was being achieved. The experts ranked each indicator in Round II from most important to least important. This allowed for the comparison between the statistical ranking of the indicators (mean ratings) to the ranked indicators' medians as ranked by experts. Interquartile range analysis will also be utilized to achieve consensus. The interquartile range (IQR) was calculated to identify the dispersion of the middle half of the data. It is important to mention that anonymity was provided to the participants in order for their responses to remain confidential. Anonymity was established by assigning one number for every respondent. The Qualtrics website was utilized to design and distribute the survey via web links.

IRB Review

Before data collection the study underwent an IRB review from the ODU IRB process. Upon approval from the ODU IRB reviewers, the researcher began the data collection procedures (see Appendix B for Exempt Letter).

CHAPTER IV

RESULTS

The research problem that this study examined was the lack of adequate quality indicators in order to assess the visual based learning materials for grades 6^{th}-9^{th} in technology education programs in schools in Greece. Through a modified Delphi methodology, the aim of this research study was to pinpoint those quality indicators that support student learning and knowledge transmission. The modified Delphi approach included three rounds that were used to identify the quality indicators. The information offered in this chapter contains the findings from the study's modified Delphi rounds, demographic data about the expert and review panels, and a summary of their combined expertise and backgrounds in relation to the study's topic.

The data gathered during Round 1 utilizing a demographic survey tool and presented in this chapter provide comprehensive information about the expert panel members. This information verifies the panel members' necessary backgrounds, demographics, and response rates to various questionnaires. The facts and understanding gained from each updated Delphi round are then reviewed. The discovery of modified Delphi procedures and processes, statistical analysis, and information-gathering strategies are used in this chapter to demonstrate consensus development for each round.

Demographic Information about Participants

The review panel had four members: A middle school technology education teacher and school vice-principal from Greece, two professors with extended participation in grants and research that are related to technology education and one assistant professor with numerous research publications in technology education. On the other hand, the expert panel consisted of

15 members that have taught technology education in Greek middle schools and have incorporated systematically visual based learning in their teachings (Table 2).

Table 2

Summary of Demographic Information on Expert Panel

Description	Frequency	Percent
Technology teacher	15	100%
Grant participant	4	26.6%
Author	11	73.33%
High school grades	-	-
Middle school grades	15	100%
Male	8	53,4%
Female	7	46,6%
Bachelor’s degree holders	15	100%
Master’s degree holders	15	100%

Round I results of the modified Delphi Method

To determine the quality indicators of visual-based learning material in grades 6^{th} -9^{th} for technology education programs, Round I of the modified Delphi approach started with the creation of a questionnaire (see Appendix A for letters and questionnaire delivered to panel members). The questionnaire provided crucial instructions and definitions for the participant and the study so that each panel member completed the questionnaire in the proper way. Additionally, it took into account the identical meanings of the instrument's essential terms. In order to help the participants with the structure for inputting a new indication or changing an existing one and to kick off the brainstorming process, examples of related indicators from the literature research were shown. The majority of the initial indicators were chosen to be kept for Round II by the panel experts. Table 3 shows the initial suggested indicators and Table 4 shows the new indicators that were added for Round II.

Table 3

Round I Suggested Indicators to Keep, Reject or Modify

Suggested Indicator	Keep	Reject	Modify	Indicator
The effectiveness of visual-based learning material in Technology Education for grades 6^{th} -9^{th} depends upon the amount of realistic detail contained in the Visualization used.	15	0	0	1
The effectiveness of visual-based learning material in Technology Education for grades 6^{th} -9^{th} depends upon the manner in which they cause the learner to process the information.	15	0	0	2
The effectiveness of visual-based learning material in Technology Education for grades 6^{th} -9^{th} depends upon the visual elements that can show spatial relationships or positioning of objects that are being presented within the instruction.	15	0	0	3
The effectiveness of visual-based learning material in Technology Education for grades 6^{th}	15	0	0	4

-9^{th} depends upon the manner in which Illustrations and photographs are used				
The effectiveness of visual-based learning material in Technology Education for grades 6^{th} -9^{th} depends upon the appropriateness of standards when using colors (e.g. every color is used for a specific purpose).	15	0	0	5
The effectiveness of visual-based learning material in Technology Education for grades 6^{th} -9^{th} depends upon the method by which the visualized instruction is presented to the students	15	0	0	6
The effectiveness of visual-based learning material in Technology Education for grades 6th -9th depends on using appropriate procedures and appropriate visual materials to distinguish titles and key words from the rest of the instructional content..	15	0	0	7
The effectiveness of visual-based learning material in Technology Education for grades 6^{th} -9^{th} depends upon the technique used to focus student attention on the essential learning characteristics in the visualization materials	15	0	0	8

(e.g., cues such as questions, arrows, motion, verbal/visual feedback).				
The effectiveness of visual-based learning material in Technology Education for grades 6th -9th depends upon the type of test format employed to assess student information acquisition (e.g., for certain types of educational objectives, visual tests have been found to provide more valid assessments of the amount of information students acquire employing visualized instruction).	15	0	0	9

Table 4

Suggested New Indicator for Round II

New Indicator	Indic. #
The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School classes depends on the competence of the teacher.	10
The effectiveness of the visual educational materials in the	11

Technology Course for the Primary and High School classes depends on the interest and active involvement that the students develop during the teaching.	
The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on the language processing of the texts and the terms used to make them clear, attractive and understandable	12

Round II results of the Modified Delphi Study

Round II of the specific study gave the panel of experts the opportunity to rate and rank all the quality indicators that were determined from Round I (see Appendix B for questionnaires and letters sent to panel members). The rating process utilized a Likert Scale of one through five, and the classifications of the scale were the following: (1) represented disagreement that the effectiveness of visual-based learning material in technology education depends on the specific indicator and meets 49% or less of all quality characteristics; (2) represented disagreement that the effectiveness of visual-based learning material in technology education depends on the specific indicator; (3) represented a neutral stance that the effectiveness of visual-based learning material in technology education depends on the specific indicator and is suitable for at least 51% of all quality indicators; (4) represented an agreement that the effectiveness of visual-based learning material in technology education depends on the specific indicator and is suitable for at least 75% of all quality indicators; and (5) represented a strong agreement that the effectiveness of visual-based learning material in technology education depends on the specific indicator and is suitable for 100% of all quality indicators.

The statistical means and standard deviations for each indicator were computed after all the data had been gathered. For the following round, the indicators with a mean of 3.01 or above were preserved. By keeping just those indications that had ratings at or above the statistical median of 3.01 for the rating range of one to five, the mean of 3.01 indicated that the modified Delphi process was beginning to attain consensus for the rating scale 1 to 5. The expert panel members' ratings of the indicators are included in Table 5, together with the overall averages and standard deviations for each category and indicator from the second iteration of the modified Delphi study.

Table 5

Overall Means and Standard Deviations for Round II Indicators

Indicators	M	SD	N
The effectiveness of visual instructional materials in the Technology Course for Middle School grades			
depends on how they help the student process the information.	4.00	0.06	15

depends on the competence of the teacher.	4.33	.33	15
depends on the language processing of the texts and the terms used to make them clear, attractive and understandable.	4.133	0.73	15
depends upon the type of test format employed to assess student information acquisition.	4	0.33	15
depends on the visual elements that can show the spatial relationships (spatial relationships) and the placement between the objects presented during the teaching.	3.4	0.71	15
depends on using appropriate procedures and appropriate visual materials to distinguish titles and key words from the rest of the instructional content.	3.73	0.44	15
depends on the way in which the photographs and illustrations are presented to the students.	3.46	0.95	15
depends on the appropriateness of the colors to present the corresponding	3	0.73	15

concepts and the application of the standards for the use of colors (e.g. each color is used with a purpose to transmit a specific meaning).			
depends on the amount of realistic detail that the visual materials and media used for teaching have.	3.6	0.87	15
depends on the method by which the visual instruction is presented to the students.	3.93	0.57	15
depends on the interest and active involvement that the students develop during the teaching.	4.33	0.60	15
depends on the technique used to focus students' attention on the essence of learning and on those features of visualization that promote learning.	3.80	0.4	15

No new indicators were added by the expert panel in this round and no indicator was modified further. When Round II was completed, the means for the indicators were used to rank all the indicators from this round, from the indicator with the highest mean to the indicator with the lowest mean. In order to demonstrate that consensus was being reached using the modified Delphi technique, this was done in order to compare the statistically ranked means of indicators with the actual rankings of indicators completed in round two by the experts. Table 6 shows the ranked means of indicators and ranking of indicators from most to least important.

Table 6

Ranked means of indicators and ranking of indicators from most to least important

Indicator The effectiveness of visual instructional materials in the Technology Course for Middle School grades	Mean	Rank
depends on how they help the student process the information.	1.93	#1
depends on the language processing of the texts and the terms used to make them clear, attractive and understandable.	3.26	#2
depends on the competence of the teacher.	3.4	#3
depends upon the type of test format employed to assess student information acquisition.	4.6	#4

depends on the interest and active involvement that the students develop during the teaching.	6.4	#5
depends on the visual elements that can show the spatial relationships (spatial relationships) and the placement between the objects presented during the teaching.	6.5	#6
depends on using appropriate procedures and appropriate visual materials to distinguish titles and key words from the rest of the instructional content.	7.1	#7
depends on the way in which the photographs and illustrations are presented to the students.	8.4	#8
depends on the amount of realistic detail that the visual materials and media used for teaching have.	8.46	#9

depends on the method by which the visual instruction is presented to the students.	8.5	#10
depends on the technique used to focus students' attention on the essence of learning and on those features of visualization that promote learning.	9.2	#11
depends on the appropriateness of the colors to present the corresponding concepts and the application of the standards for the use of colors (e.g. each color is used with a purpose to transmit a specific meaning).	10.06	#12

Round III Results of the Modified Delphi

Round II was the last round of the modified Delphi method and was conducted to determine the degree of consensus for those indicators that were kept from Round II. Once the review panel approved all the changes for the Round III questionnaire then notification was sent to the expert panel to complete this third instrument. In this questionnaire expert panel members could accept or reject each indicator as it was transcribed, but it is important to mention that no further modifications were allowed to be made. The indicators that had a consensus of more or equal to 80% were the ones that were kept as final quality indicators. Many studies suggest that a high agreement rate between participants in a Delphi study, such as 80% or more, enhances the reproducibility of the results if a different panel was selected to rate and rank indicators (Campell et al., 2002; Kroger et al., 2015; Fitch et al., 2015; Von der Gracht, 2012; Giltenane et al., 2021). Table 7 shows the results from Round III.

Table 7

Round III results

INDICATOR The effectiveness of visual instructional materials in the Technology Course for Middle School grades	CONSESUS %
depends on how they help the student process the information.	100%
depends on the competence of the teacher.	100%
depends upon the type of test format employed to assess student information acquisition.	87%
depends on the language processing of the texts and the terms used to make them clear, attractive and understandable.	100%
depends on the visual elements that can show the spatial relationships (spatial relationships)	87%

and the placement between the objects presented during the teaching.	
depends on using appropriate procedures and appropriate visual materials to distinguish titles and key words from the rest of the instructional content.	80%
depends on the way in which the photographs and illustrations are presented to the students.	100%
depends on the appropriateness of the colors to present the corresponding concepts and the application of the standards for the use of colors (e.g. each color is used with a purpose to transmit a specific meaning).	40%
depends on the amount of realistic detail that the visual materials and media used for teaching have.	87%
depends on the method by which the visual instruction is presented to the students.	73.40%
depends on the interest and active involvement that the students develop during the teaching.	100%
depends on the technique used to focus students' attention on the essence of learning	100%

and on those features of visualization that promote learning.

Chapter Summary

This chapter described the findings from the three rounds of the Delphi study that asked participant panel members to Keep or Reject each indicator. Two indicators had a consensus percentage which was less than 80%. Thus, they were eliminated from the final table of quality indicators for technology education visual based materials that reached a consensus and agreement of more than 80%. The two quality indicators that had the lowest consensus percentage were the following: a) The effectiveness of visual educational materials in the Technology Course for the Elementary and Middle School classes depends on the appropriateness of the colors to present the corresponding concepts and the application of the standards for the use of colors (e.g. each color is used with a purpose to transmit a specific meaning) and b) The effectiveness of visual instructional materials in the Technology Course for the Elementary and High School classes depends on the method by which the visual instruction is presented to the students. Each had a 40% and 73.4% percentage of consensus in the third Round respectively.

Analysis from Round II showed that three indicators had the lowest scores in the ranking process. Of these the two were the same indicators that had the lowest scores and consensus in Round III as well. Specifically, the indicator of *The effectiveness of visual instructional materials in the Technology Course for the Elementary and High School classes depends on the method by which the visual instruction is presented to the students* had a rank of 10 with a mean of 8.5. The indicator of *The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on the technique used to focus students' attention* *on the essence of learning and on those features of visualization that promote learning* had a rank of 11 and a mean of 9.2. Lastly the indicator of *The effectiveness of visual educational materials in the Technology Course for the Elementary and Middle School classes depends on the appropriateness of the colors to present the corresponding concepts and the application of the standards for the use of colors* (e.g. each color is used with a purpose to transmit a specific meaning) had the last rank of 12 and a mean of 10.06.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

This chapter is going to present some conclusions and recommendations that are related to the findings of the study. According to some, consensus and agreement in Delphi studies are the same thing, and agreement can be identified by (Dajani et al., 1979):

1) the total judgments (the collection of all judgments),

2) a shift to a level of central tendency that is subjective,

3) Alternatively, by confirming stability, which is defined as "the consistency of answers between successive rounds of the study (p. 84)."

This study tried to identify the quality indicators for visual based material for technology education programs in middle schools of Greece. In total 15 expert participants answered the Delphi rounds. The results showed that ten quality indicators achieved the highest consensus among the expert participants. The ten indicators that reached the highest consensus are presented in Table 8.

Table 8

Top 10 Indicators

Highest consensus within final Indicators
1. The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on how they help the student process the information.

2. The effectiveness of visual educational materials in the Technology Course for the Primary and High School classes depends on the competence of the teacher.
3. The effectiveness of visual educational materials in the Technology Course for the Elementary and Middle School classes depends upon the type of test format employed to assess student information acquisition.
4. The effectiveness of visual educational materials in the course of Technology depends on the language processing of the texts and the terms used to make them clear, attractive and understandable.
5. The effectiveness of visual educational materials in the Technology Course for the Primary and High School classes depends on the visual elements that can show the spatial relationships (spatial relationships) and the placement between the objects presented during the teaching.
6. The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on the technique used to focus students' attention on the essence of learning and on those features of visualization that promote learning.
7. The effectiveness of visual educational materials in the Technology Course for the Primary and Secondary grades depends on the way in which the photographs and illustrations are presented to the students.
8. The effectiveness of the visual educational materials in the Technology Course for the Primary and High School classes depends on the interest and active involvement that the students develop during the teaching.

9. The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School classes depends on the amount of realistic detail that the visual materials and media used for teaching have.
10. The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on using appropriate procedures and appropriate visual materials to distinguish titles and key words from the rest of the instructional content.

Conclusions

For the first indicator which is the effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on how they help the student process the information there is a lot of literature that emphasizes the importance of visual materials and how they aid the student in processing the information that is presented to them. In their research Shabiralyani et al. (2015), state that visual instructional materials are important in education. Those visual instructional materials are utilized to encourage all students learning process as they are able to make the learning process more interesting and engaging. The researchers also point out that the use of visual aids in the classroom is considered the best tool for optimal dissemination of knowledge and the most effective teaching. From the above information we can conclude that visual instructional material are those tools that enable the educator to correlate, establish, clarify, make conceptions that are precise in order to support his/her teaching and develop a learning process that is more motivating, encouraging, active and significant.

Sharafovna and Islomovna (2021), also state that visual instructional materials have a significant impact on increasing the retention of information for students. Specifically, they mention that visual instructional material increases retention by 29-42%. They are also able to aid the students in better engaging them with the material and help them develop higher order thinking skills. At the same time visuals in teaching and learning develop the core skills that are necessary for students to see and comprehend visuals more clearly and they enhance hand-eye-mind connections to be tactile. It is important to mention that those connections are able to improve the ability to retain information and learning and recall facts (Sharafovna & Islamovna, 2021). In addition, to the aforementioned benefits of visual instructional materials Sharafovna and Islamovna (2021), also mention that they satisfy the special requirements of kids who primarily process information visually while also enhancing learning for all pupils, they give certain kids with learning disabilities additional possibilities, while challenging students who are talented or twice exceptional and they can be a crucial component of best-practice intervention strategies for people with autism spectrum disorders.

Raiyn (2017) researched the role of visual learning in improving high-order thinking skills. He found that when presented visually, knowledge is more easily understood in the classroom. Images, flowcharts, infographics, videos, simulations, graphs, cartoons, coloring books, slide shows/PowerPoint decks, posters, movies, games, and flash cards are just a few of the different ways that visual information is conveyed. The instructional technologies discussed above can be used by teachers to present vast amounts of information in ways that are simple to understand and aid in identifying correlations and patterns. According to his study, students retain information better when it is spoken and physically portrayed. These techniques support students of all ages in managing their learning goals and excelling academically. Additionally, visual learning aids in the development of visual thinking, a type of learning in which the learner associates ideas, words, and concepts with images in order to better absorb and retain knowledge. Various interactive visual tools, including 2-D and 3-D visual environments and information and communication technologies (such web services), are used to deliver visual information.

The second indicator that made it to the final list of indicators with the highest consensus was the effectiveness of visual educational materials in the Technology Course for the Primary and High School classes depends on the competence of the teacher**.** In their research Semenog et al. (2019), place an emphasis on the formation of future teachers' skills to create and use visual models of knowledge. In their research they highlight that the competence of teachers is crucial for the successful transmission of information and knowledge through the use of visual instructional materials. Therefore, the educational sector should focus on the visual presentation of learning content in the conditions of rapid IT development. An efficient strategy to stimulate cognitive activity during the teachers' training should be to employ such a presentation as a manner of condensing, but not diminishing, the material content. At the same time Semenog et al. (2019), propose that educators with low levels of competency in using visual materials in the classroom should take part in courses that are designed to develop those skills to every educator. Educators should have the ability to be creative and have ideas of different ways to present visual materials and information to students. They also should know how to use computer visualization tools for the purposes of modeling and compact visual representation of a plethora of objects. Lastly, educators should have the competence to use other various visualization tools to transmit information to students.

The third indicator that made it to the final list because of high consensus was the effectiveness of visual educational materials in the Technology Course for the Elementary and Middle School classes depends upon the type of test format employed to assess student information acquisition. In their research, Murphy et al. (2023), mention the value that using different types of test formats can have and their impact on learning.

The fourth indicator that made it to the final list of indicators because of high consensus among the participants was the effectiveness of visual educational materials in the course of Technology depends on the language processing of the texts and the terms used to make them clear, attractive and understandable. Dickey and Hendricks (1991) investigated the visual qualities of instructional material, and they emphasize the importance of them for making the information more understandable to the learners. In their research they state that teachers frequently ignore the visual perception quality of the materials used in the classroom. For students who struggle with one or more aspects of vision, such as differentiating between letters and words, recalling symbols, or comprehension, the way information is visually presented can make a big impact. When several visual perception skills are required at once, these pupils find it more challenging to use their weak abilities.

Two factors concerning visual perception and the learning process should be kept in mind by teachers: (1) Different students perceive the same stimuli differently; and (2) Different students have different perceptual processes for gathering information and thinking. Some of the qualities that visual instructional materials should demonstrate are visual discrimination, visual memory and visual comprehension. Teachers should assess materials for simplicity and attention-grabbingness in order to support students in making effective use of their visual comprehension abilities. Teachers should make sure that focal points are distinct, well-defined, simple to locate, and free of distractions in order to avoid students' visual fixations from straying. For instance, while using images or color, the instructor should look into its intent to see if it serves as a motivation or merely a distraction. Key words might be highlighted or underlined to help pupils visualize them in their minds. Alvermann (1987) outlines attention-focusing techniques to improve text comprehension in learners. Analogies, oral previews, thematic organizers, and organized summaries are a few of these techniques. Since students require a foundation from which to deepen or broaden their knowledge, there should be an element that is familiar to their visual sense (Dickey & Hendricks, 1991).

The fifth indicator that was on the final list of indicators because of high consensus among the expert panel participants was The effectiveness of visual educational materials in the Technology Course for the Primary and High School classes depends on the visual elements that can show the spatial relationships (spatial relationships) and the placement between the objects presented during the teaching. In their research, Kruger et al. (2022), studied the learning characteristics of learning with augmented reality. They specifically explored the impact of dimensionality and spatial abilities. It should go without saying that a 3D representation of a 3D object provides a more accurate and comprehensive picture of the thing than a 2D representation when it comes to the dimensionality of a visual representation. Wu and Shah (2004), found that learning how to recognize depth cues in 2D representations and how to create 3D mental images based on 2D structures may be challenging for some students. Furthermore, it has been suggested that learning in 3D encourages the creation of mental models that are more accurate than learning in 2D. Using a 3D representation has a positive effect on learning outcomes, according to empirical studies in a variety of fields where spatial aspects are essential (Kruger et al., 2022).

It is important to mention that Chemistry is one of the subject areas where the dimensionality of a representation can be crucial, particularly when learning about molecules is the major objective. Kruger et al. (2022) mention that it is important to facilitate a spatial comprehension of molecular structures using both virtual and physical models. In contrast to only using 2D diagrams training translation between various formats of 2D diagrams in organic chemistry using physical or virtual 3D models led to higher translation accuracy in follow-up tests with the 3D model available, as well as in a delayed test without a model. Geometry and astronomy are two further subject areas in which 3D representations have been contrasted with 2D representations. In astronomy, for instance, employing a desktop-based 3D virtual environment to educate about lunar phases and the relative positions of the sun and the moon produced higher learning outcomes than using merely 2D photographs. In a study on the teaching of geometric figures, students who learned using desktop-based 3D virtual models also performed better on follow-up tests where the visualization was important, but not on tests where it was not. This was in contrast to students in a traditional learning environment (Kruger, 2022). Studies involving the use of virtual or actual 3D models to aid learning are frequently conducted in the field of (bio-)medical education, particularly when it comes to anatomy content because the structures that are taught are essentially spatial. It has been determined that spatial visualization and subsequent 3D learning are crucial in the anatomy domain, which is crucial for medical education since it provides the structural foundation for diagnostic and therapeutic operations. According to a review by Triepels et al. (2020), there are benefits to using virtual 3D visualizations for anatomy learning over more conventional techniques for students in many but not all trials. Another meta-review indicated advantages for students' performance and cognitive burden while using various 3D visualization technologies in the anatomy subject (Hackett & Proctor, 2016).

The sixth indicator that made it to the final list of indicators because of high consensus was The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on the technique used to focus students' attention on the essence of learning and on those features of visualization that promote learning. In their research, Basuki and Christanto (2023) researched methodologies that can increase student understanding and concentration through virtual reality learning media. They conducted the research specifically for electronic records management courses. They emphasized the importance of virtual reality for learning as it contains a plethora of visual aids that can motivate the students, increase their motivation and focus their attention. It was reported that students in traditional classrooms were feeling distracted and uninterested to pay attention and participate. Since users may interact with the virtual world that exists in virtual reality and use all of their senses to experience the environment virtually and visually, Saifullah and Basry (2022) claim that virtual reality learning media can be used to improve concentration. Shabir (2022) asserts that virtual reality can assist students' study more effectively and efficiently than traditional methods like reading books and watching films. The results of their study showed that visual learning material can have beneficial results and effects for students' concentration and increased attention while learning.

The seventh quality indicator that made it to the final list of quality indicators because of high consensus was the effectiveness of visual educational materials in the Technology Course for the Primary and Secondary grades depends on the way in which the photographs and illustrations are presented to the students. Lule (2022), states that visuals facilitate conceptual understanding by igniting the imagination and influencing cognitive processes in learners. The ability of the visual language to expand "human bandwidth"—which includes assimilating, understanding, and analyzing new information—is also well established. According to the researcher illustrations and photographs are crucial for the learning process and they can greatly impact and improve the effectiveness of teaching methods. Specifically, illustrations and images can help store information longer, aid better comprehension, act as stimulators for emotions, make communication better and quicker and they drive motivation as well. The author highlighted the importance of using the most appropriate illustrations and photographs as visuals for learning as unsuitable visual can lead to unsatisfied learners and thus poor learning. The following criteria should be met by the images in any course materials that will truly benefit the students:

- Simplify the complex and text-intensive issues.
- Provide examples with real people, locations, or things.
- Assist the students in making connections between the familiar and foreign materials.

The eighth quality indicator that was on the final list of quality indicators because of high consensus was the effectiveness of the visual educational materials in the Technology Course for the Primary and High School classes depends on the interest and active involvement that the students develop during the teaching. In their study Yousof and Conlan (2015), studied ways to motivate learner engagement through explorable visual narratives. In summary, this project was named VisEN. In their research they state that, Information visualization translates data attributes to visual properties, making it easy to comprehend digital data. In visual analysis and visual exploration tools, where a chosen dataset or a chosen segment of data is automatically rendered, mapping appropriate visuals to datasets or segments of data is common practice. An ordered series of actions made up of visualizations that are linked or connected to enhance the message's memorability is what is referred to as storytelling in information visualization or visual narrative. Visual storytelling are another powerful tool for emphasizing information, arguing a point, and conveying knowledge. Additionally, visual data exploration helps consumers understand data when little is known about it and the aims of the research are unclear. As they display a more in-depth perspective of a particular feature within the visualization that is being examined, visual drill downs enable end users to discover details underlying the presented visualizations. They also state that Learning Analytics (LA), Open Learner Modelling (OLM), and Educational Data Mining (EDM) have received the majority of attention in research on the use of information visualization in the Technology Enhanced Learning (TEL) domain (Yousof & Conlan, 2015). Visualizations have been utilized to support reflection in all three of these areas in order to increase learner motivation and engagement. In LA, visualizations have been employed to provide student activity data to instructors to assist in monitoring students, to students to encourage behavior modification, or to both instructors and students. Using conclusions drawn from learner interactions, visualizations in OLM display student competencies and degree of comprehension to aid in reflection and assessment. EDM uses data mining techniques to analyze logged data in order to provide feedback to students and encourage contemplation. The strategy used by VisEN and covered in their article uses data on student activities to produce explorable visual tales that encourage learning and engagement among students (Yousof & Conlan, 2015).

The ninth indicator that was on the final list of quality indicators because of high consensus score was the effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School classes depends on the amount of realistic detail that the visual materials and media used for teaching have. According to Skulmowski and Rey (2018) realistic details in visualizations are important for the learning process. They also highlight the fact that they require color cues to foster attention. Research on visualizations suggests that realism can be distracting and cognitively demanding, thereby lowering learning performance. These results have been explained using cognitive load theory, assuming that realistic details act as unnecessary mental load. Recent findings from disfluency research, however, imply that under certain circumstances harder-to-perceive learning materials are able to keep learners' attention focused and trigger them to invest more effort. In the context of a task including route learning, Lokka and Cöltekin (2017) compared three distinct visualization approaches. The level of information in each of these three visualization techniques varied. The rote to be learned was represented by untextured, white, flat-shaded models in the abstract visualization, while the roadway and buildings were realistically depicted in the realistic version. It's interesting to note that the study included a middle level of information where the route was shown without textures but just a small number of significant buildings were shown with textures. Routes were displayed as first-person films that were 3D produced. Interestingly, independent of participants' spatial skill, the intermediate version produced the highest recall scores on both the long-term and short-term memory tests. Before and after the learning phase, participants in this experiment were questioned about their preferences for the visual style. Prior to the learning task, the majority of participants said they liked the realistic version; but, after the initial round of tests, they tended to favor the intermediate form. The research of Skulmowski and Rey (2018) concluded that the effect of the realistic detail on a visual learning material has a positive effect for learning, that color coding has a significant relationship with the presence of details in the visualization and that realistic details support retention when it is combined with appropriate colors.

The tenth and final indicator that made it to the final list of quality indicators because of high consensus was the effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on using appropriate procedures and appropriate visual materials to distinguish titles and key words from the rest of the instructional content. The University of Minnesota states that visual instructional materials should be developed and created with appropriate procedures that aid the learning process. Specifically, they mention a visual aid evaluation checklist which is the following (University of Minessota, 2015):

- The presentation's material is clearly interwoven with the use of visual aids.
- Images and graphics are appropriate for the presentation's overall mood.
- The text and images are large and easily readable by the viewer.
- Images are shown with either a caption or a description.
- Labels and headings in informational graphics are distinct and simple to read.
- Informational graphics' text is simple to read (but beware of wordiness, crowded text, or a font that is too small and difficult to read.)
- Options for formatting (color, several fonts, etc.) effective information organization
- There are no mistakes in the visuals' text at all.
- Slides' internal links are functional.
- Hyperlinks' display text is succinct and educational.

Implications for research and conducting future research

This section of the study will present the implications for research in the technology education field. First of all, this study as well as the information that was researched and the results it generated can be an important step to establish an assessment model of all visual based learning material that are used inside the technology education classrooms. Specifically, it will prove beneficial for this course in grades 6th- 9th. Many technology educators will benefit from such an assessment tool which can aid greatly in taking informed decisions for the selection of the most appropriate visual based learning materials.

Second, the final list of quality indicators can be a guide for future authors, teachers and curriculum developers in the fields of visual learning and technology education. Specifically, the list is able to provide with validation for quality indicators especially for authors involved in grants related to visual based learning materials.

In addition, it is imperative to study more in depth the dimension of assessment and quality within the study of technology education. This means that some standards can be developed for visual based learning material in technology education for all grades. This means that when new programs are being developed within the technology education research field, they will have a set of validated standards to follow in order to enhance and promote knowledge and learning.

The above implications of this study thus have a great influence on future research on the issues that are addressed. Quality educational programs, courses and research can only be the result of high quality guidelines and material that aid in the development, design and implementation of educational programs.

Currently, there are few studies that focus on identifying quality indicators for visual based learning materials for technology education courses and for each specific grade. On the other hand, there more research studies that focus on the effectiveness of visuals for learning a various academic disciplines. The implications that were previously mentioned led the researcher of this study to also establish some implications on how to conduct future research related to this issue.

First, the researcher advises creating bigger, more varied panels as a part of the panel selection processes. Having a larger and more diverse panel of participants who are experts in the field could lead to more advanced and more technical information and findings. At the same time, a larger number of participants in the review panel would also be something that could be increased in the future for more detailed feedback to the researcher.

A third implication would be to create something for assessment purposes. The next stage would be to design an assessment instrument to be utilized in the creation of new visual-based learning materials or the evaluation of existing material during the selection process now that the quality indicators have been confirmed by a panel of experts.

A fourth implication for future research that follows a similar Delphi methodology is for the interest of the Delphi panel members. It was observed that the long periods of time that take to fulfil multiple rounds of the Delphi study result in the participants to lose some interest in the overall process. Future studies that follow similar methodologies should try to develop ways to keep and increase the interest of all panel members in the study and the whole process. One way to achieve this objective is by sending reminders and appreciation letters to each participant, especially at the end of each round.

Recommendations for Further Research

The results of this study provided a wealth of potential recommendations for further research in the areas of high-quality visual learning resources in technology education programs for grades 6 through 9, as well as the application of the Delphi method as a research methodology. The recommendations listed below are suggested for additional research.

1. How to design and evaluate quality indicators for visual-based learning materials in technology education for all grade levels requires more investigation. This comprises visual learning materials for technology education programs at the elementary, middle, high school, and college levels.

2. To better comprehend the topic and help validate the data acquired, other investigations employing different research approaches should be carried out, such as qualitative research approaches.

3. To get a more accurate and current assessment of visual-based learning materials, this study should be repeated in five years to see if new Quality Indicators are found for Visual-based Learning Content in Technology Education programs for grades 6^{th} -9^{th} . The information should also be updated in the final quality indicators list.

4. More study is required to create a method and model for evaluating high-quality visual learning content in technology education programs for students in grades 6 through 9 at the national and international levels.

5. At the national and international levels, validate assessment tools to assist in the selection of high-quality visual-based learning content for technology education programs for students in grades 6 through 9.

Recommendations for practitioners

It is recommended that practitioners take advantage of the findings of this research in order to improve their own instruction material that is based on visualization. Specifically, it is recommended that practitioners continue to update their theoretical and technical knowledge and skills in visual based learning through seminars and conferences, and at the same time it is recommended that they try to get more students involved in technology and engineering projects.

Chapter Summary

Chapter five presents a discussion and an analysis of the results of this study. The final list of quality indicators is presented and discussed. Those final quality indicators were the indicators with the highest consensus from the panel of experts. To show the level of consensus from the participants the researcher utilized descriptive statistics that analyzed the data gathered from ranking and rating of indicators. Most quality indicators showed that they are well-written and that they achieved strong agreement and consensus among the experts. In addition, this chapter identified conclusions and recommendations related to the results of the study. Finally, the implications were discussed.

REFERENCES

Aldalalah, O., & Ababneh, Z. (2015). Standards of multimedia graphic design in education. *Journal of Education and Practice, 6*(17), pp. 102-110.

Alvermann, D. E. (1987). Comprehension/thinking skills. In Research within reach: Secondary school reading, edited by D. E. Alvermann, D. W. Moore, and M. W. Conley, 52-63. International Reading Association

Anderson, L.W. (Ed.), Krathwohl, D.R. (Ed.), Airasian, P.W., Cruikshank, K.A, Mayer, R. E., Pintrich, P. R., Raths, J., & Wittrock, M.C. (2001*). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York, NY: Longman.

Arbuthnott, K. D., & Krätzig, G. P. (2015). Effective teaching: sensory learning styles versus general memory processes. *Comprehensive Psychology, 4.* https://doi.org/10.2466/06.IT.4.2

Aristotle. (1994). Aristotle's "De anima". Leiden; New York: E.J. Brill.

Arneson, J., & Offerdahl, E. (2018). Visual Literacy in Bloom: Using Bloom's Taxonomy to Support Visual Learning Skills. *CBE Life Sciences Education, 17*(1).

Arnheim, R. (1969). *Visual thinking*. Berkeley: University of California Press.

Atkinson, J.W. (1964). *An introduction to motivation*. Van Nostrand.

Avsec, S., & Szewczyk-Zakrzewska, A. (2015). Predicting academic success and technological literacy in secondary education: A learning styles perspective. *International Journal of Technology and Design Education, 27*(2), 233-250.

Bagdonavičius, V., Kruopis, J., & Nikulin, M. (2011). Non-parametric Tests for Complete Data.

Barrett, D., & Heale R. (2020). What are Delphi studies? *Evidence-Based Nursing, 23,* 68-69.

Basuki, A., & Novel, P. C. (2023). Increasing student understanding and concentration through virtual reality learning media in electronic records management courses. *International Journal Of Humanities Education and Social Sciences, 2*(6), pp. 2096-2105. https://doi.org/10.55227/ijhess.v2i6.528

Benson, P. J. (1997). Problems in picturing text: A study of visual/verbal problem solving. *Technical Communication Quarterly, 6*(2), 141-160.

Bixler, B. (2011). The ABCDs of writing instructional objectives. https://creativecommons.org/

Bobek, E., & Tversky, B. (2016). Creating visual explanations improves learning. *Cognitive research: principles and implications, 1*(1), 27. https://doi.org/10.1186/s41235-016-0031-6

Borkin, M., Vo, A., Bylinskii, Z., Isola, P., Sunkavalli, S., Oliva, A., & Pfister, H. (2013). What makes a visualization memorable? *IEEE Transactions on Visualization and Computer Graphics, 19*(12), 2306-2315.

Boulkedid, R., Abdoul, H., Loustau, M., Sibony, O., & Alberti, C. (2011). Using and reporting the Delphi method for selecting healthcare quality indicators: a systematic review. *PloS one, 6*(6), e20476. https://doi.org/10.1371/journal.pone.0020476

Bonser, F. G. & Mossman, L. C. (1923). *Industrial arts for elementary scho*ols. Macmillan.

Branoff, T. J., & Dobelis, M. (2012). The relationship between spatial visualization ability and students' ability to model 3d objects from engineering assembly drawings. *Engineering Design Graphics Journal, 76*(3), 37-43.

Brumberger, E. (2019). Past, Present, future: mapping the research in visual literacy. *Journal of Visual Literacy*, *3*(38), 1-16.

Callahan, C., Howell J., & Maddox, L. (2019). Selecting and designing visual curriculum materials for inquiry-based instruction. *Social Studies Research and Practice*, *4*(3), pp. 321-334.

Campbell, S. M., Braspenning, J., Hutchinson, A., & Marshall, M. (2002). Research methods used in developing and applying quality indicators in primary care. *Quality and Safety in Health Care*, *11*(4), 358–364. https://doi.org/10.1136/qhc.11.4.358

Caruso, J., Harmon, L., Born, G., & Dufeau, D. (2021). Efficacy and benefits of augmented and virtual reality based learning during COVID-19. *The FASEB journal, 35*(21)

Chaomei, C. (2005). *Top 10 unsolved information visualization problems.* IEEE Computer Society.

Clark, A. (1999). Identification of quality characteristics for technology education programs: a North Carolina case study. *Journal of Technology Education, 11*(1), 18-26.

Clark, A. C., Wiebe, E. N. & Hasse, E. E. (April 2000). Scientific visualization: A basic in design and technology. Presented at the Design and Technology Association Millennium Conference. London, England

Clark, & E. Wiebe (2007). Scientific visualization for secondary and post-Secondary Schools. *The Journal of Technology Studies, 26*(1)*, pp. 24-32*

Curry, L. (1990). A critique of the research on learning styles. *Educational Leadership, 48*(2), 50-52.

Dajani, J., Sincoff, M., & Talley, W. (1979). Stability and agreement criteria for the termination of Delphi studies. *Technological Forecasting & Social Change*, *13*(1), 83-90.

Dalkey, N. (1969). The Delphi method: an experimental study of group opinion. https://www.rand.org/content/dam/rand/pubs/research_memoranda/2005/RM5888.pdf

Dale, Hyslop-Margison, Hyslop-Margison, Emery J., & ProQuest. (2010). Paulo Freire [e-book] *Teaching for Freedom and Transformation: The Philosophical Influences on the Work of Paolo Freire.*

Delbecq, V., Van de Ven, A., & Gustafson, D. H. (1975). *Group techniques for program planning a guide to nominal group and Delphi processes* (Management applications series). Scott, Foresman.

Deno, J., A. (1995). The relationship of previous spatial visualization ability. *Engineering Design Graphics Journal, 59*(3), 5-17.

Dickey, J. P., & Hendricks, R. C. (1991). Visual perception qualities of instructional materials. *Clearing House, 64*(3), 168. https://doiorg.proxy.lib.odu.edu/10.1080/00098655.1991.9955837

Dugger, W., & Naik, N. (2001). Clarifying Misconceptions between Technology Education and Educational Technology. *The Technology Teacher*, *61*(1), 31.

Duffy, K. (2021). *Using photovoice to navigate social-ecological change in coastal Maine: A case study on visibility, visuality, and visual literacy*. Doctoral Dissertation, University of Maine.

Dwyer, F. (1978). *Strategies for Improving Visual Learning*. Learning Services.

Eilam, B. (2012). *Teaching, learning, and visual literacy the dual role of visual representation.* [e-book]. Cambridge University Press. https://doi.org/10.1017/CBO9781139026611

Ernst, J., & Clark, A. (2007). Scientific and technical visualization in technology education. *The Technology Teacher, 66*(8), 16.

Ernst, J. V., & Clark, A. C. (2007, May-June). Scientific and technical visualization in technology education: the need for America's students to develop a deeper knowledge of the nature, creation, and potentials of technology and its symbiotic role in human society, as well as develop a broader range of technological skills, is progressively more important. *The Technology Teacher, 66*(8), 16. https://link.gale.com/apps/doc/A163864192/AONE?u=anon~5646e56a&sid=googleScholar&xid=38095581

Evagorou, M., Erduran, S., & Mäntylä, T. (2015). The role of visual representations in scientific practices: From conceptual understanding and knowledge generation to 'seeing' how science works. *International Journal of STEM Education, 2*(1).

Fantz, T., & Katsioloudis, P. (2011). Analysis of engineering content within technology education programs. *Journal of Technology Education*, *23*(1), 19-31.

Farné, R.. (2017). Pedagogia Visuale/Visual Pedagogy. *Proceedings*, *1*(9), 872.

Field, B. W. (1999). A course in spatial visualization. *Journal for Geometry and Graphics, 3*(2), 201-209.

Fitch, K., Bernstein, S. J., Aguilar, M. D., Burnand, B., & Lacalle, J. R. (2001). *The RAND/UCLA appropriateness method user's manual, DTIC Document*. Santa Monica, CA: RAND Corp.

Fleming, N. & Bonwell, C. (2019). *How do I learn best?* https://vark-learn.com/wp-content/uploads/2019/07/How-Do-I-Learn-Best-Sample.pdf

Garson, G. D. (2012). The Delphi method in quantitative research. Asheboro, NC: Statistical Associates Publishers.

Giltenane, M., Sheridan, A., Kroll, T., & Frazer, K. (2021). Identification of quality indicators of public health nursing practice: "modified Delphi" approach. *Public Health Nursing, 39*(1), 214-228. https://doi.org/10.1111/phn.13000

Goldfarb, B. (2002). *Visual pedagogy media cultures in and beyond the classroom*. Durham [N.C.]: Duke University Press.

Hackett, M., & Proctor, M. (2016). Three-dimensional display technologies for anatomical education: a literature review. *Journal of Science Education Technology, 25*(4), pp. 641-654, 10.1007/s10956-016-9619-3

Harle, M., & Towns, M. (2011). A review of spatial ability literature, its connection to chemistry, and implications for instruction. *Journal of Chemical Education, 88*(3), 351-360. doi:10.1021/ed900003n

Hegarty, M., & Kozhevnikov, M. (1999). Types of visual-spatial representations and mathematical problem solving. *Journal of Educational Psychology, 91*(4), 684.

Höffler, T. N. (2010). Spatial ability: its influence on learning with visualizations—a meta-analytic review. *Educational Psychology Review, 22*, 245-269. doi:10.1007/s10648-010-9126-7

Holey, E., Feeley, J., Dixon, J., & Whittaker, V. (2007). An exploration of the use of simple statistics to measure consensus and stability in Delphi studies. *BMC Medical Research Methodology*, *7*(1), 52.

Idowu, P., Brinton, G., Hartman, H., Neuhard, S., Abraham, R., & Boyer, E. (2006). Information visualization applied in presenting some fundamental power system topics. Published proceedings of the American Society for Engineering Education Annual Conference and Exposition, Chicago, IL, Session 1335.

Illeris, K. (2018). An overview of the history of learning theory. *European Journal of Education*, *53*(1), 86-101.

International Technology and Engineering Educators Association (ITEEA). (1996). *Technology for All Americans: A Rationale and Structure for the Study of Technology*. Reston, VA: Author. https://www.iteea.org/STEMCenter/Research/resources/42618.aspx?source=generalSearch

International Technology and Engineering Educators Association (ITEEA). (2007). *Standards for technological literacy: Content for the Study of Technology*. Reston, VA: Author. https://www.iteea.org/42511.aspx

International Technology and Engineering Educators Association (ITEEA). (2020). *Standards for technological and engineering literacy: The role of technology and engineering in STEM education.* Reston, VA: Author. www.iteea.org/STEL

Journal of Engineering Design Graphics/JEDG (n.d.). *About the Journal*. Retrieved from http://www.edgj.org/index.php/EDGJ/about

Julià, C., & Antolí, J. (2016). Spatial ability learning through educational robotics. International *Journal of Technology and Design Education, 26*(2), 185-203. doi:10.1007/s10798-015-9307-2

Kaya, M. (2020). The Impact of Visual Literacy Awareness Education on Verbal and Writing Skills of Middle School Students. *International Journal of Education and Literacy Studies, 8*(2), 71.

Katsioloudis, P. (2010). *Identification of Quality Visual-Based Learning Material for Technology Education,* STEMPS Faculty Publications.

Katsioloudis, P., Jovanovic, V., & Jones, M. (2014). A comparative analysis of spatial visualization ability and drafting models for industrial and technology education students. *Journal of Technology Education, 26*(1), 88-101.

Katsioloudis, P., & Watson, G. (2011). *The VisPort Project: Visualization of Port Logistics,* STEMPS Faculty Publications.

Katsioloudis, P., Watson, G.S., Papelis, Y.E., Robison, D.G., and Reed, P. A.(2011). VISPort: A simulation of port-related careers and logistics, Version 2. Norfolk, VA: Opportunity Inc. http://www.vmasc.odu.edu/demos/visport/home.html

Kedra, J. & Žakevičiūtė, R. (2019). Visual literacy practices in higher education: what, why and how? *Journal of visual literacy, 2*(38). https://doi.org/10.1080/1051144X.2019.1580438

Kinsey, B. L., Towle, E., and Onyancha, R. M. (2008). improvement of spatial ability using innovative tools: alternative view screen and physical model rotator. *Engineering Design Graphics Journal, 72*(1), 1-8.

Kolb, D. (1984). *Experiential learning: experience as the source of learning and development.* Prentice-Hall.

Krathwohl, D. R., Bloom, B.S & Masia, B. (1964). *Taxonomy of educational objectives. Book II, affective domain*. David McKay Company Inc.

Kröger, E., Wilchesky, M., Marcotte, M., Voyer, P., Morin, M., Champoux, N., Monette, J., Aubin, M., Durand, P. J., Verreault, R., & Arcand, M. (2015). Medication use among nursing home residents with severe dementia: Identifying categories of appropriateness and elements of a successful intervention. *Journal of the American Medical Directors Association*, *16*(7), 629.e1–629.e17. https://doi.org/10.1016/j.jamda.2015.04.002

Krüger, J. M., Palzer, K., & Bodemer, D. (2022). Learning with augmented reality: Impact of dimensionality and spatial abilities. *Computers and Education Open, 3*, 100065. https://doi.org/10.1016/j.caeo.2021.100065

Laramee, R., & Kosara, R. (n.d.). Challenges and Unsolved Problems. Human-Centered Visualization Environments, 231-254.

Linstone, H., & Turoff, M. (1975). *The Delphi method techniques and applications.* Reading, Mass.: Addison-Wesley Pub., Advanced Book Program.

Lis, R. (2014). Role of visualization in engineering education. *Advances in Science & Technology, Research Journal*, *8*(24), 111-118.

Lohman, D. F., United States., & Stanford University. (1979). *Spatial ability: A review and reanalysis of the correlational literature* (Report No. 8) Stanford, CA: Stanford University School of Education.

Lokka, I. & Çöltekin, A. (2019). Toward optimizing the design of virtual environments for route learning: empirically assessing the effects of changing levels of realism on memory.

International Journal of Digital Earth, 12(2), 137-155, DOI: 10.1080/17538947.2017.1349842

Lubinski, D. (2010). Spatial ability and STEM: A sleeping giant for talent identification and development. *Personality and Individual Differences, 49*(4), 344-351. doi:10.1016/j.paid.2010.03.022

Lule, A. (2022) Illustration is an effective teaching aid in the process of learning. Available at SSRN: https://ssrn.com/abstract=4101758 or http://dx.doi.org/10.2139/ssrn.4101758

Lux, N., & LaMeres, B. J., & Willoughby, S. D., & Hughes, B. E. (2019). *Board 96: designing a middle grades spatial skills curriculum in Minecraft Paper presented at 2019 ASEE Annual Conference & Exposition* , Tampa, Florida. https://peer.asee.org/32469

Martin-Dorta, N., Contero, M., & Saorin, J. L. (2008). Development of fast remedial course to improve the spatial abilities of engineering students. *Journal of Engineering Education*, 505-213.

McGee, M. G. (1979). Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences. *Psychological Bulletin*, *86*(5), 889-918. doi:10.1037/0033-2909.86.5.889

McLeod, S. A. (2017, October 24). Kolb - learning styles. Simply Psychology. www.simplypsychology.org/learning-kolb.html

Mentzer, N., Mohandas, L., Farrington, S., & Laux, D. (2022). Course quality improvement in design education. *Journal of Technology Education*, *33*(1), 21–37.

Meyer, M., & Booker, J. (1990). *Eliciting and analyzing expert judgement a practical guide*. London: Academic.

Miyake, A., Friedman, N. P., Rettinger, D. A., Shah, P., & Hegarty, M. (2001). How are visuospatial working memory, executive functioning, and spatial abilities related? A latent-variable analysis. *Journal of Experimental Psychology: General, 130*(4), 621-640. doi:10.1037/0096-3445.130.4.621.

Mohler, J. L., (2008). Examining the spatial ability phenomenon from the student's perspective. *Engineering Design Graphics Journal. 72*(3), 19-27.

Murphy, D.H., Little, J.L. & Bjork, E.L. (2023). The value of using tests in education as tools for learning—not just for assessment. *Educational Psychology Review 35*(89). https://doi.org/10.1007/s10648-023-09808-3

Nagy-Kondor, R. (2017). Spatial ability: measurement and development. In M. Khine (Ed.), *Visual-spatial ability in STEM education* (pp. 35-58). Cham: Springer. doi:10.1007/978-3-319-44385-0_3

National Academies of Sciences, Engineering, and Medicine. (2016). *Science Literacy: concepts, contexts, and consequences*. Washington, DC: The National Academies Press. doi: 10.17226/23595.

National Academies of Sciences, Engineering, and Medicine. (2016). *Science Literacy: Concepts, Contexts, and Consequences.* Washington, DC: The National Academies Press. https://doi.org/10.17226/23595.

National Academies of Sciences, Engineering, and Medicine. (2018). *How People Learn II: Learners, Contexts, and Cultures*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24783.

Olkun, S. (2003). Making connections: improving spatial abilities with engineering drawing activities. *International Journal of Mathematics Teaching and Learning.* doi:10.1501/0003624

Oxford Dictionary (2000). *Advanced Learners Dictionary*. Oxford University Press

Piaget, J. (1970). *Science of education and the psychology of the child.* New York: McGraw-Hill.

Poon, T. F., & Ng, T. J. (2001). Learning styles: Implications for design and technology education: MRN. *Management Research News, 24*(5), 24-37. http://dx.doi.org/10.1108/01409170110782414

Raiyn, J. (2016). The role of visual learning in improving students high order thinking skills. *Journal of Education and Practice, 7*(24), 115-121..

Reed, P. A. (2018). Reflections on STEM, standards, and disciplinary focus. *Technology and Engineering Teacher, 71*(7), 16-20.

Roblyer, M. & Kirby, E. (2014). The fifth literacy: Research to support a mandate for technology-based visual literacy in preservice teacher education. *Journal of Computing in Teacher Education, 2*(17), 8-15.

Saifullah, H., & Basry, A. (2022). Rancang bangun aplikasigame virtual reality buzz wire berbasis android. *Tekinfo: Jurnal Bidang Teknik Industri Dan Teknik Informatika, 23*(1), Art. 1.

Savage, E., & Sterry, L. (1990). *A conceptual framework for technology education*. Reston, VA: International Technology Education Association.

Savage, E. (2002). A Conceptual Framework for Technology Education: A Historical Perspective. *The Journal of Technology Studies, 28*(1/2), 98-100.

Sanders, M. (2008). The nature of technology education in the U.S. Paper presented at 2008 Annual Conference & Exposition, Pittsburgh, Pennsylvania. 10.18260/1-2—4450

Semenog, O., Yurchenko, A., Udovychenko, O.M., Kharchenko, I., & Kharchenko, S.M. (2019). Formation of future teachers' skills to create and use visual models of knowledge. *TEM Journal, 8*(1), 275-283. DOI: 10.18421/TEM81-38

Sentz, J. (2020). Using visual and graphic elements: while designing instructional activities. In J. K. McDonald & R. E. West, Design for Learning: Principles, Processes, and Praxis. EdTech Books. Retrieved from https://edtechbooks.org/id/using_visual_and_graphic_elements

Shabiralyani, G., Hasan, K., Hamad, N., & Iqbal, N. (2015). Impact of visual aids in enhancing the learning process case research: District Dera Ghazi Khan. *Journal of Education and Practice, 6*, 226-233.

Shabir, A. (2022). Ujicoba Penggunaan Teknologi Virtual Reality sebagai Media Pembelajaran. *Jurnal Pendidikan Tambusai, 6*(1), Art. 1. https://doi.org/10.31004/jptam.v5i3.2773

Sharafovna, G. & Islomovna, M. (2021). The importance of visual aids in learning and teaching. *International Journal of trend in scientific research and development, 5*(2).

Sinatra, R. (1986). *Visual literacy connections to thinking, reading, and writing.* Springfield, Ill. U.S.A.: C.C. Thomas.

Skulmowski, A., & Rey, G. D. (2018). Realistic details in visualizations require color cues to foster retention. *Computers & Education, 122*, 23-31. https://doi.org/10.1016/j.compedu.2018.03.012

Sorby, S. A., Casey, B. M., Veurink, N. L., & Dulaney, A. (2013). The role of spatial training in improving spatial and calculus performance in engineering students. *Learning and Individual Differences, 26*, 20–29. doi:10.1016/j.lindif.2013.03.010.

Sorby, S. A., (2009) Educational research in developing 3-D spatial skills for engineering students. *International Journal of Science Education, 31*(3), 459-480, doi:10.1080/09500690802595839

Stephanie Glen (n.d). "Kruskal Wallis H Test: Definition, Examples, Assumptions, SPSS" From StatisticsHowTo.com: Elementary Statistics for the rest of us! https://www.statisticshowto.com/probability-and-statistics/statistics-definitions/kruskal-wallis/

Strimel, G., & Grubbs, M. (2016). Positioning Technology and Engineering Education as a Key Force in STEM Education. *Journal of technology education, 27*(2), 21-36.

Strong, S., & Smith, R. (2002). Spatial visualization: Fundamentals and trends in engineering graphics. *Journal of Industrial Technology. 18*(1).

Subramaniam, C., Handayani, L., Sahabudin, N., Ali, Z., Hamzah, N., Rahman, N. & Kasim, S. (2019). Learning styles and teaching styles determine students' academic performances. *International Journal of Evaluation and Research in Education, 8*(3), 610-615, DOI: 10.11591/ijere.v8i3. 20345

Sutton, K., & Williams, A. (2007). Spatial cognition and its implications for design. *International Association of Societies of Design Research*. Hong Kong, China. Retrieved from https://www.sd.polyu.edu.hk/iasdr/proceeding/papers/Spatial%20Cognition%20and%20its%20Implications%20for%20Design.pdf

Thornton, T., Ernst, J., & Clark A. (2012). Augmented reality as a visual and spatial learning tool in technology education. *Technology and Engineering Teacher*, *71*(8), 18-21.

Triepels, C. P. R., Smeets, C. F. F., Notten, K. J. B., Kruitwagen, R. F. P. M., Futterer, J. J., Vergeldt, T., & Van Kuijk, S. (2020). Does three-dimensional anatomy improve student understanding? *Clinical Anatomy*, *33*(1), pp. 25-33, 10.1002/ca.23405

University of Minessota (2015). Incorporating effective visuals into a presentation. Retrieved from https://open.lib.umn.edu/writingforsuccess/chapter/14-2-incorporating-effective-visuals-into-a-presentation/

Uttal, D., Miller, D., & Newcombe, N. (2013). Exploring and enhancing spatial thinking: Links to achievement in science, technology, engineering, and mathematics? *Current Directions in Psychological Science*, *22*(5), 367-373. doi:10.1177/0963721413484756

Vuk, T. (2012). *Quality indicators: A tool for quality monitoring and improvement. ISBT Science Series*, *7*(1), 24-28.

Veurink, N. L., Hamlin, A. J., Kampe, Sorby, S. A., Blasko, D. G., Holliday-Darr, K. A., Kremer, J. T., Harris, L.V., Connolly, P. E., Sadowski, M., Harris, K. S., Brus, C., Boyle, L. N., Study, N.E., & Knott, T. (2009). Enhancing visualization skills-improving options and success (EnViSIONS) of engineering and technology students. *Engineering Design Graphics Journal*. *73*(2).

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin*, *117*(2), 250-270. doi:10.1037/0033-2909.117.2.250

Von der-Gracht, H. A. (2012). Consensus measurement in Delphi studies: Review and implications for future quality assurance. *Technological Forecasting and Social Change*, *79*(8), 1525–1536. https://doi.org/10.1016/j.techfore.2012.04.013

Wang L. (2017). Various spatial skills, gender differences, and transferability of spatial skills. In: M. Khine (Ed.), *Visual-spatial ability in STEM education* (pp. 85-105). Cham: Springer. doi:10.1007/978-3-319-44385-0-5

Wileman, *R.E. (1993). Visual communicating.* New Jersey: Educational Technology Publications

Wiebe, E., & Clark, A. (2003, June), *The Vis Te Project: Visualization For Improved Technological And Scientific Literacy*. Paper presented at 2003 Annual Conference, Nashville, Tennessee. 10.18260/1-2—12492

Wu, H. K., & Shah, P. (2004). Exploring visuospatial thinking in chemistry learning. *Science Education*, *88*(3), pp. 465-492, 10.1002/sce.10126

Yousuf, B., Conlan, O. (2015). VisEN: *Motivating Learner Engagement Through Explorable Visual Narratives*. In: Conole, G., Klobučar, T., Rensing, C., Konert, J., Lavoué, E. (eds) Design for Teaching and Learning in a Networked World. EC-TEL 2015. Lecture Notes in Computer Science(), vol 9307. Springer, Cham. https://doi.org/10.1007/978-3-319-24258-3_27

APPENDIX A

EMAIL LETTER TO TECHNOLOGY EXPERTS

July, 2023

Dear professional,

As a leader in visual-based pedagogy material within the context of Technology Education I am sending you this email to ask for cooperation. I am currently doing research on quality characteristics for visual based material in Technology Education as part of my dissertation in Technology Education at Old Dominion University. I will be designing a Delphi study and so I need to create a panel of expert technology education professionals that have experience in visual learning pedagogy within their teaching profession. I would appreciate if you could recommend qualified participants for my study that you believe could best serve on this expert panel. You can submit the names of any grant participant for the study as long as they meet the following qualifications: a)Current involvement in education as a technology educator and researcher and with a minimum of five years of experience with visual-based learning material for technology education, b)Demonstrate leadership in developing, implementing, and evaluating material for educational purposes related to visual-based learning in technology education, c) they must have a demonstrated record of publications or presentations in visual-based learning in technology education. d) teaching and professional practices that are related to the promotion and improvement of skills in visual-based learning methods, and 3) active collaboration with state departments, professional associations, grants, and universities highlights the educator's involvement in developing visual-based learning material.

I thank you in advance for sending me your recommendations for the purposes of this study. Please reply to this email by filling you the information of the names, school, and email address for the individuals you suggest by July 1st. Feel free to contact me for any further questions. Thank you and I look forward to hearing from you.

LETTER TO PROFESSIONALS

July, 2023

Dear technology educator,

Thank you for your cooperation. I am currently conducting research on quality characteristics for visual based learning material in technology education as part of my dissertation at Old Dominion University. Your expertise in the area of visual based learning material was detrimental un my choice to have you in the expert panel of my study. In rider to complete my research that aims in contributing to the field to technology education you will need to complete some tasks over the next few months. The study is composed of three rounds of the Delphi process.

Each round takes only a few minutes to complete, and through the interactive website of the study the study you can submit your responses within a few seconds. You will have two weeks to provide your responses for each round.

In the first round you will be asked to give your responses to a brief demographic survey and then complete the first review of the Delphi process. Instructions for each of the following rounds will be provided to you within the interactive website. If you agree to participate in this study, please reply to this email by typing the words "reviewer agree" to the subject of the email.

Sincerely,

Spyridoula Tsouganatou

STUDY OVERVIEW

Title: Identification of quality indicators of visual based learning material in Technology Education Programs
Researcher: Spyridoula Tsouganatou
School: Old Dominion University
Major: Technology Education
Method: Modified Delphi will be used to generate statements and reach consensus on visual-based learning material quality characteristics.

Currently there is little research related to educational information regarding the selection of quality visual based material for technology education curricula. In addition, few studies have been conducted that focus on identifying quality visual based learning material in middle and high school grades. Currently, educators have difficulty determining and selecting visual based learning material that is the most effective in transmitting certain types of scientific information. This is a result of the plethora of available visual materials that exist. The differences between each type of visual material have important consequences for the acquisition of knowledge and the level of achievement of students (Dwyer, 1972). This phenomenon makes the process of selecting the most appropriate visual materials confusing and impossible.

The research problem is that there is a lack of quality indicators to assess the effectiveness of visual based learning materials for grades 6th -9th , within the context of U.S. high school technology education curricula. Thus, the purpose of the study is to identify those quality indicators of visual-based learning material that can provide technology educators with educational guidance to select visual material that are effective in knowledge transmission within the educational objectives of technology education for high school grades. At the same time, it is crucial to develop and validate those indicators by involving technology education experts in the process of the study as they have a deeper knowledge in visual learning methodologies within technology education.

When selecting visual materials technology educators must have quantifiable measures of quality that can guide them. The lack of those quantifiable measures of quality can seriously undermine learning, and future visualization advances in critical aspects such as evaluation and selection. This study will identify the indicators of quality visual-based learning materials that contribute to the successful implementation of technology education curricula designed by technology educators. The purpose is to develop metrics and quantifiable quality measures that will serve as an educated guide for technology educators.

REVIEW PANEL MEMBER

June, 2023

Dear Review Panel Member,

I would like to thank you for accepting a position on this vital panel for technology education in the United States. You have agreed to participate in our analysis using the Modified Delphi research technique to define quality indicators of visual-based learning material for grades 6^{th} -9^{th} in technology education programs. Your expertise will help technology education teachers across the United States identify and choose the best visual-based instructional material to provide more efficient knowledge transmission for all students using those materials. In order to complete this task, I need every member to respond to each of the three rounds of this research project over the next spring months.

Each round takes very few minutes to complete. Your first task is in the first Delphi round where (a) you will be asked to complete a simple one-page demographic survey about yourself and (b) complete the first review of the Modified Delphi process. Your task as a review panel member is to evaluate the questionnaire and give feedback about needed changes in format and overall structure before the instrument is accesses by the panel experts. Please consider the following two definitions when evaluating the questionnaire: **Quality-a degree of excellence** and relative worth; **quality indicator- a trait or attribute.**

If you see no problems with first Round, you do not need to send anything about the first instrument just the demographics information. Instructions for each round will be included. As the review panel member, all you will need to provide is your time. **Please remember that I need all responses back from each panel member in a timely manner so that each round is complete, and all three rounds can progress so that the study will be a success.** This first round is needed back in 48 hours after receiving it in order to set the process started. Again, thank you for agreeing to cooperate with me on this important study. I know your time is valuable, but the resulting document will help determine the quality indicators of visual-based learning material for grades 6^{th} -9^{th} in technology education programs. If you have any questions or comments, please feel free to contact me at any time.

Sincerely

Spyridoula Tsouganatou

EXPERT PANEL MEMBER

March 25th, 2022

Dear expert panel member,

I would like to thank you for accepting a position on this vital panel for technology education in the United States. You have agreed to participate in our analysis using the Modified Delphi research technique to define quality indicators of visual-based learning material for grades 6th -9th in technology education programs. Your expertise will help technology education teachers across the United States identify and choose the best visual-based instructional material to provide more efficient knowledge transmission for all students using those materials. In order to complete this task, I need every member to respond to each of the three rounds of this research project over the next spring months.

Each round takes very few minutes to complete. Your first task is in the first Delphi round where (a) you will be asked to complete a simple one-page demographic survey about yourself and (b) complete the first review of the Modified Delphi process. Your task as an expert panel member is to identify the quality indicators that you fell are crucial for visual-based learning material to have in technology education programs for grades 6th -9th . Please consider the following two definitions when evaluating the questionnaire: Quality-a degree of excellence and relative worth; quality indicator- a trait or attribute.

Thank you for agreeing to cooperate with me on this important study. I know your time is valuable, but the resulting document will help determine the quality indicators of visual-based learning material for grades 6th -9th in technology education programs. If you have any questions or comments, please feel free to contact me at any time.

Sincerely,

Spyridoula Tsouganatou

APPENDIX B

STUDY PARTICIPATION AGREEMENT

I, ______________________________, have read the study overview provided by the researcher. I pledge that I fully understand the nature of my commitment an intend to do my best to fulfill all the obligation of participation. I also understand that I may withdraw my participation in said study at any time without any negative consequences.

Date: _____________

School: ___________

Title: _____________

Name: ________________

Signature: _____________

E-mail: _______________

Phone Number: ____________

REMINDER EMAIL

March 25th,

Dear expert panel members, just a friendly reminder to submit your responses to the Delphi method study. The successful completion of this research study depends on your contribution and expertise. Many of the panelists have already emailed their responses already. Please submit your responses by August 30th if you haven’t already done so. I look forward to receiving your responses.

Thank you in advance

Spyridoula Tsouganatou

DEMOGRAPHIC SURVEY

1.Which title most accurately describes your current position?

- Visual based learning grant related participant
- Technology teacher using visual based learning material
- Visual based learning material author

2.Which grade level(s) do you currently teach or oversee?

- 6th
- 7th
- 8th
- 9th

3.What is the highest degree obtained as of 30th of August 2022?

- B.S./B.A
- High School
- M.S/M.Ed.
- Ed.D./Ph.D.

4.What is your gender?

- Female
- Male

5.Year of graduation from High School.

6.Current residence? (City/State)

7.Have you been involved in any grant related to Technology education and scientific visualization? If so which one?

8.Have you had any type of visual training within the last 5 years? (online courses, seminar conference, training etc)

9.What courses have you taught in the last 2 years that require visual teaching/student capabilities?

GREEK VERSION - ROUND I

Διαβάστε τα ακόλουθα παραδείγματα δεικτών ποιότητας για το οπτικό υλικό (Powerpoint, CAD, βίντεο, εικόνες, διαγράμματα κ.α.) για τις τάξεις από έκτη Δημοτικού έως Τρίτη Γυμνασίου στα Προγράμματα Τεχνολογικής Εκπαίδευσης. Μπορείτε να ΚΡΑΤΉΣΕΤΕ, να ΑΠΟΡΡΊΨΕΤΕ ή να ΤΡΟΠΟΠΟΙΉΣΕΤΕ τους δείκτες ποιότητας που βρίσκονται παρακάτω. Τοποθετήστε ένα X δίπλα στο ΚΡΑΤΉΣΤΕ εάν θέλετε να διατηρήσετε τον δείκτη ποιότητας, δίπλα στο ΑΠΟΡΡΊΨΕΤΕ εάν δεν πιστεύετε ότι η ένδειξη είναι κατάλληλη ή δίπλα στο ΤΡΟΠΟΠΟΊΗΣΤΕ για να επαναδιατυπώσετε την ένδειξη πληκτρολογώντας στο πλαίσιο κειμένου που παρέχεται στην ενότητα Τροποποίηση. Ο κύριος στόχος σας είναι να ΠΡΟΣΘΕΣΤΕ περισσότερους ΝΕΟΥΣ δείκτες πληκτρολογώντας μέσα στο παρεχόμενο πλαίσιο κειμένου για νέους δείκτες. Μπορείτε να πληκτρολογήσετε όσους ΝΕΟΥΣ δείκτες χρειάζεστε.

1. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τον τρόπο με τον οποίο βοηθάνε τον μαθητή να επεξεργάζεται τις πληροφορίες

ΚΡΑΤΗΣΤΕ
ΑΠΟΡΡΙΨΕΤΕ
ΤΡΟΠΟΠΟΙΗΣΤΕ

2. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τα οπτικά στοιχεία που μπορούν να δείξουν τις χωρικές σχέσεις (spatial relationships) και την τοποθέτηση μεταξύ των αντικειμένων που παρουσιάζονται κατά την διάρκεια της διδασκαλίας.

ΚΡΑΤΗΣΤΕ
ΑΠΟΡΡΙΨΕΤΕ
ΤΡΟΠΟΠΟΙΗΣΤΕ

3. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τα να αξιοποιούνται οι κατάλληλες διαδικασίες και το κατάλληλο οπτικό υλικό για να ξεχωριστούν οι τίτλοι και οι κυρίες λέξεις από το υπόλοιπο εκπαιδευτικό περιεχόμενο.

ΚΡΑΤΗΣΤΕ
ΑΠΟΡΡΙΨΕΤΕ
ΤΡΟΠΟΠΟΙΗΣΤΕ

4. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τον τρόπο με τον οποίο παρουσιάζονται οι φωτογραφίες και οι εικονογραφήσεις στους μαθητές.

ΚΡΑΤΗΣΤΕ
ΑΠΟΡΡΙΨΕΤΕ
ΤΡΟΠΟΠΟΙΗΣΤΕ

5. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από την Καταλληλοτητα των χρωμάτων για να παρουσιαστούν οι αντίστοιχες έννοιες και η εφαρμογή των standards για την χρήση των χρωμάτων (π.χ. κάθε χρώμα χρησιμοποιείται με ένα σκοπό)

ΚΡΑΤΗΣΤΕ
ΑΠΟΡΡΙΨΕΤΕ
ΤΡΟΠΟΠΟΙΗΣΤΕ

6. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται το ποσό της ρεαλιστικής λεπτομέρειας που έχουν τα οπτικά υλικά και μέσα που χρησιμοποιούνται για την διδασκαλία.

ΚΡΑΤΗΣΤΕ
ΑΠΟΡΡΙΨΕΤΕ
ΤΡΟΠΟΠΟΙΗΣΤΕ

7. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται την μέθοδο με την οποία η οπτική διδασκαλία παρουσιάζεται στους μαθητές.

ΚΡΑΤΗΣΤΕ
ΑΠΟΡΡΙΨΕΤΕ
ΤΡΟΠΟΠΟΙΗΣΤΕ

8. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από το ενδιαφέρον και την ενεργή εμπλοκή που αναπτύσσουν οι μαθητές στην διάρκεια της διδασκαλίας.

ΚΡΑΤΗΣΤΕ
ΑΠΟΡΡΙΨΕΤΕ
ΤΡΟΠΟΠΟΙΗΣΤΕ

9. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από την τεχνική που χρησιμοποιείται για να επικεντρωθεί η προσοχή των μαθητών στην ουσία της μάθησης και σε εκείνα τα χαρακτηριστικά της οπτικοποίησης που προωθούν την μάθηση

ΚΡΑΤΗΣΤΕ
ΑΠΟΡΡΙΨΕΤΕ
ΤΡΟΠΟΠΟΙΗΣΤΕ

10. **Παρακαλώ προσθέστε/ γράψτε άλλους δείκτες ποιότητας (quality indicators) που πιστεύετε ότι είναι σημαντικοί για το μάθημα της Τεχνολογίας**.

ENGLISH VERSION - ROUND I

IDENTIFICATION OF QUALITY INDICATORS FOR VISUAL BASED LEARNING MATERIAL FOR GRADES 6^{TH} -9^{TH}

Please review the following examples of quality-indicators for Visual-based material for grades 6^{th} -9^{th} in Technology Education Programs. You may KEEP, REJECT or MODIFY the examples found in this data collection instrument. Please place an X next to KEEP if you wish to keep the indicator, next to REJECT if you do not think the indicator is appropriate or MODIFY to reword the indicator by typing in the text box provided in the Modify section. Your main objective is to ADD more NEW indicators by typing inside the provided text box for new indicators. You may type as many NEW indicators as you need.

1. The effectiveness of visual-based learning material in Technology Education for grades 6^{th} - 9^{th} depends upon the amount of realistic detail contained in the Visualization used.

KEEP

MODIFY

REJECT

2. The effectiveness of visual-based learning material in Technology Education for grades 6^{th} - 9^{th} depends upon the manner in which they cause the learner to process the information.

KEEP

MODIFY

REJECT

3. The effectiveness of visual-based learning material in Technology Education for grades 6^{th} - 9^{th} depends upon the visual elements that can show spatial relationships or positioning of objects that are being presented within the instruction.

KEEP

MODIFY

REJECT

4. The effectiveness of visual-based learning material in Technology Education for grades 6^{th} - 9^{th} depends upon the manner in which Illustrations and photographs are used.

KEEP

MODIFY

REJECT

5. The effectiveness of visual-based learning material in Technology Education for grades 6^{th} - 9^{th} depends upon the appropriateness of standards when using colors (e.g. every color is used for a specific purpose).

KEEP

MODIFY

REJECT

6. The effectiveness of visual-based learning material in Technology Education for grades 6th - 9th depends upon the method by which the visualized instruction is presented to the students.

KEEP

MODIFY

REJECT

7. The effectiveness of visual-based learning material in Technology Education for grades 6th - 9th depends upon students' interests and engagement.

KEEP

MODIFY

REJECT

8. The effectiveness of visual-based learning material in Technology Education for grades 6th - 9th depends upon the technique used to focus student attention on the essential learning characteristics in the visualization materials (e.g., cues such as questions, arrows, motion, verbal/visual feedback).

KEEP

MODIFY

REJECT

9. The effectiveness of visual-based learning material in Technology Education for grades 6th - 9th depends upon the type of test format employed to assess student information acquisition

(e.g., for certain types of educational objectives, visual tests have been found to provide more valid assessments of the amount of information students acquire employing visualized instruction).

KEEP

MODIFY

REJECT

10. **Please add new quality indicators in the text-box below. You can add as many as you need, just keep typing.**

INSTRUCTIONS FOR ROUND II OF THE STUDY

Dear expert panel member,

Thank you for the timely response and quality information you gave in round one of the modified Delphi study on quality indicators of visual-based learning material for elementary and middle school grades (6^{th} - 9^{th}) in technology education programs. I received several new indicators as well as modifications were made to a few indicators. The next phase of the modified Delphi process is to sort through the information and begin to draw consensus. This round will allow you the expert, to rate each indicator given in round one as well as make modifications or add new indicators if needed. The Likert scale to be used for rating the indicators is as follows.

1 = strongly disagree that the effectiveness of visual-based learning material in Technology Education depends upon the specific indicator.

2 = disagree that the effectiveness of visual-based learning material in Technology Education depends upon the specific indicator and meets 49% or less of all quality characteristics.

3 = Neutral position that the effectiveness of visual based learning material in Technology Education depends upon the specific indicator and is appropriate for 51% or more of all quality characteristics.

4 = Agree that the effectiveness of visual-based learning material in Technology Education depends upon the specific indicator and is appropriate for 75% or more of all quality characteristics

5 = Strongly agree that the effectiveness of visual-based learning material in Technology Education depends upon the specific indicator and is appropriate for 100% of all quality characteristics.

Next Rank indicators on a Scale. Starting with (1) being the most important indicator of quality (ex. 1 best, 2, 3, 4, 5, 6...) and continue to the final indicator that indicates the least value for quality. **Rank all available indicators.**

Αγαπητέ μέλος της ομάδας εμπειρογνωμόνων,

Σας ευχαριστούμε για την έγκαιρη ανταπόκριση και τις ποιοτικές πληροφορίες που δώσατε στον πρώτο γύρο της τροποποιημένης μελέτης Delphi σχετικά με τους δείκτες ποιότητας οπτικού εκπαιδευτικού υλικού για τάξεις δημοτικού και γυμνασίου (6η - 9η) σε προγράμματα τεχνολογικής εκπαίδευσης. Έλαβα αρκετούς νέους δείκτες καθώς και έγιναν τροποποιήσεις σε μερικούς δείκτες. Η επόμενη φάση της τροποποιημένης διαδικασίας Delphi είναι να ταξινομήσετε τις πληροφορίες και να αρχίσετε να επιτυγχάνετε συναίνεση. Αυτός ο γύρος θα σας επιτρέψει να βαθμολογήσετε κάθε δείκτη που δίνεται στον πρώτο γύρο καθώς και να κάνετε τροποποιήσεις ή να προσθέσετε νέους δείκτες εάν χρειάζεται. Η κλίμακα Likert που θα χρησιμοποιηθεί για την αξιολόγηση των δεικτών είναι η εξής.

1 = **Διαφωνώ έντον**α ότι η αποτελεσματικότητα του οπτικού εκπαιδευτικού υλικού στην Τεχνολογική Εκπαίδευση εξαρτάται από τον συγκεκριμένο δείκτη.

2 = **Διαφωνώ** ότι η αποτελεσματικότητα του οπτικού εκπαιδευτικού υλικού στην Τεχνολογική Εκπαίδευση εξαρτάται από τον συγκεκριμένο δείκτη και πληροί το 49% ή λιγότερο όλων των ποιοτικών χαρακτηριστικών.

3 = **Ουδέτερη θέση** ότι η αποτελεσματικότητα του οπτικού εκπαιδευτικού υλικού στην Τεχνολογική Εκπαίδευση εξαρτάται από τον συγκεκριμένο δείκτη και είναι κατάλληλη για το 51% ή περισσότερο όλων των ποιοτικών χαρακτηριστικών.

4 = **Συμφωνώ** ότι η αποτελεσματικότητα του οπτικού εκπαιδευτικού υλικού στην Τεχνολογική Εκπαίδευση εξαρτάται από τον συγκεκριμένο δείκτη και είναι κατάλληλη για το 75% ή περισσότερο όλων των ποιοτικών χαρακτηριστικών

5 = **Συμφωνώ απόλυτα** ότι η αποτελεσματικότητα του οπτικού εκπαιδευτικού υλικού στην Τεχνολογική Εκπαίδευση εξαρτάται από τον συγκεκριμένο δείκτη και είναι κατάλληλη για το 100% όλων των ποιοτικών χαρακτηριστικών.

Στο επόμενο βήμα θα πρέπει να **Κατατάξετε τους δείκτες σε μια κλίμακα.** Ξεκινώντας από το (1) που είναι ο πιο σημαντικός δείκτης ποιότητας (π.χ. 1 καλύτερος, 2, 3, 4, 5, 6...) και συνεχίστε μέχρι τον τελικό δείκτη που υποδεικνύει τη μικρότερη αξία για την ποιότητα ενός δείκτη. Θα πρέπει να κάνετε κατάταξη όλων των διαθέσιμων δεικτών.

GREEK VERSION – ROUND II

1. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τον τρόπο με τον οποίο βοηθάνε τον μαθητή να επεξεργάζεται τις πληροφορίες.

Συμφωνώ Έντονα Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ Διαφωνώ Διαφωνώ Έντονα

2. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από την επάρκεια του διδάσκοντος.

Συμφωνώ Έντονα Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ Διαφωνώ Διαφωνώ Έντονα

3. Η αποτελεσματικότητα του οπτικού εκπαιδευτικού υλικού στην Τεχνολογική Εκπαίδευση για τις τάξεις 6ης - 9ης εξαρτάται από τον τύπο της αξιολόγησης που χρησιμοποιείται για την αξιολόγηση της απόκτησης πληροφοριών των μαθητών (π.χ., για ορισμένους τύπους εκπαιδευτικών στόχων, τα οπτικά τεστ έχουν βρεθεί ότι παρέχουν πιο έγκυρες αξιολογήσεις ο όγκος των πληροφοριών που αποκτούν οι μαθητές χρησιμοποιώντας οπτικοποιημένη διδασκαλία).

Συμφωνώ Έντονα Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ Διαφωνώ Διαφωνώ Έντονα

4. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο μάθημα της Τεχνολογίας εξαρτάται από την γλωσσική επεξεργασία των κειμένων και των όρων που αξιοποιούνται ώστε να καθίστανται σαφή, ελκυστικά και κατανοητά.

Συμφωνώ Έντονα Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ Διαφωνώ Διαφωνώ Έντονα

5. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τα οπτικά στοιχεία που μπορούν να δείξουν τις χωρικές σχέσεις (spatial relationships) και την τοποθέτηση μεταξύ των αντικειμένων που παρουσιάζονται κατά την διάρκεια της διδασκαλίας.

Συμφωνώ Έντονα Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ Διαφωνώ Διαφωνώ Έντονα

6. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τα να αξιοποιούνται οι κατάλληλες διαδικασίες και το κατάλληλο οπτικό υλικό για να ξεχωριστούν οι τίτλοι και οι κυρίες λέξεις από το υπόλοιπο εκπαιδευτικό περιεχόμενο.

Συμφωνώ Έντονα Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ Διαφωνώ Διαφωνώ Έντονα

7. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τον τρόπο με τον οποίο παρουσιάζονται οι φωτογραφίες και οι εικονογραφήσεις στους μαθητές.

Συμφωνώ Έντονα   Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ   Διαφωνώ   Διαφωνώ Έντονα

8. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από την Καταλληλοτητα των χρωμάτων για να παρουσιαστούν οι αντίστοιχες έννοιες και η εφαρμογή των standards για την χρήση των χρωμάτων (π.χ. κάθε χρώμα χρησιμοποιείται με ένα σκοπό).

Συμφωνώ Έντονα   Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ   Διαφωνώ   Διαφωνώ Έντονα

9. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται το ποσό της ρεαλιστικής λεπτομέρειας που έχουν τα οπτικά υλικά και μέσα που χρησιμοποιούνται για την διδασκαλία.

Συμφωνώ Έντονα   Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ   Διαφωνώ   Διαφωνώ Έντονα

10. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται την μέθοδο με την οποία η οπτική διδασκαλία παρουσιάζεται στους μαθητές.

Συμφωνώ Έντονα   Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ   Διαφωνώ   Διαφωνώ Έντονα

11. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από το ενδιαφέρον και την ενεργή εμπλοκή που αναπτύσσουν οι μαθητές στην διάρκεια της διδασκαλίας.

Συμφωνώ Έντονα   Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ   Διαφωνώ   Διαφωνώ Έντονα

12. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από την τεχνική που χρησιμοποιείται για να επικεντρωθεί η προσοχή των μαθητών στην ουσία της μάθησης και σε εκείνα τα χαρακτηριστικά της οπτικοποίησης που προωθούν την μάθηση.

Συμφωνώ Έντονα   Συμφωνώ Ούτε συμφωνώ ούτε διαφωνώ   Διαφωνώ   Διαφωνώ Έντονα

ENGLISH VERSION – ROUND II

1. The effectiveness of visual instructional materials in the Technology Course for Elementary and Middle School grades depends on how they help the student process the information.
   Strongly Disagree
   Disagree
   Neutral
   Agree
   Strongly Agree
   Rank:

2. The effectiveness of visual educational materials in the Technology Course for Primary and High School classes depends on the competence of the teacher.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

Rank:

3. The effectiveness of visual-based learning material in Technology Education for grades 6th - 9th depends upon the type of test format employed to assess student information acquisition (e.g., for certain types of educational objectives, visual tests have been found to provide more valid assessments of the amount of information students acquire employing visualized instruction).

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

Rank:

4. The effectiveness of visual educational materials in the course of Technology depends on the language processing of the texts and the terms used to make them clear, attractive and understandable.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

Rank:

5. The effectiveness of visual educational materials in the Technology Course for the Primary and High School classes depends on the visual elements that can show the spatial relationships (spatial relationships) and the placement between the objects presented during the teaching.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

Rank:

6. The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on using appropriate procedures and appropriate visual materials to distinguish titles and key words from the rest of the instructional content.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

Rank:

7. The effectiveness of visual educational materials in the Technology Course for the Primary and Secondary grades depends on the way in which the photographs and illustrations are presented to the students.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

Rank:

8. The effectiveness of visual educational materials in the Technology Course for the Elementary and Middle School classes depends on the Appropriateness of the colors to present the corresponding concepts and the application of the standards for the use of colors (e.g. each color is used with a purpose).

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

Rank:

9. The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School classes depends on the amount of realistic detail that the visual materials and media used for teaching have.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

Rank:

10. The effectiveness of visual instructional materials in the Technology Course for the Elementary and High School classes depends on the method by which the visual instruction is presented to the students.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

Rank:

11. The effectiveness of the visual educational materials in the Technology Course for the Primary and High School classes depends on the interest and active involvement that the students develop during the teaching.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

Rank:

12. The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on the technique used to focus students' attention on the essence of learning and on those features of visualization that promote learning.

Strongly Disagree

Disagree

Neutral

Agree

Strongly Agree

Rank:

ROUND III Instrument

Instructions for ROUND III

Dear expert panel member,

Thank you for the timely response and the quality information that you provided in the second round of this study for the identification of quality indicators for technology programs in grades 6^{th}-9^{th}. The next stage of this study is to indicate whether you want to REJECT or KEEP each indicator that made it to round three. This round will give you the opportunity to KEEP or REJECT every indicators. You can select either yes KEEP or no REJECT to each question.

Below is an example of the process for each question in this round.

Indicator:

The effectiveness of visual based learning material in Technology Education for grades 6-9 depends upon the amount of detail contained in the visualization used.

Rank: 8	Mean: 3.35	Median:4

KEEP ◯ REJECT ◯

The rank, mean of rank and the median are provided from the data collected in the second round.

Οδηγίες για ΓΥΡΟ ΙΙΙ

Αγαπητό μέλος της ομάδας εμπειρογνωμόνων,

Σας ευχαριστούμε για την έγκαιρη ανταπόκριση και τις ποιοτικές πληροφορίες που παρείχατε στον δεύτερο γύρο αυτής της μελέτης για τον προσδιορισμό των δεικτών ποιότητας για τα τεχνολογικά προγράμματα στις τάξεις 6η-9η. Το επόμενο στάδιο αυτής της μελέτης είναι να υποδείξετε εάν θέλετε να ΑΠΟΡΡΙΨΕΤΕ ή να ΚΡΑΤΗΣΕΤΕ κάθε δείκτη που έφτασε στον τρίτο γύρο. Αυτός ο γύρος θα σας δώσει την ευκαιρία να ΚΡΑΤΗΣΕΤΕ ή να ΑΠΟΡΡΙΨΕΤΕ κάθε δείκτη. Μπορείτε να επιλέξετε είτε ναι ΔΙΑΤΗΡΗΣΗ είτε όχι ΑΠΟΡΡΙΨΗ σε κάθε ερώτηση.

Παρακάτω είναι ένα παράδειγμα της διαδικασίας για κάθε ερώτηση σε αυτόν τον γύρο.

Δείκτης:

Η αποτελεσματικότητα του οπτικού εκπαιδευτικού υλικού στην Τεχνολογική Εκπαίδευση για τις τάξεις 6-9 εξαρτάται από την ποσότητα των λεπτομερειών που περιέχονται στην οπτικοποίηση που χρησιμοποιείται.

Rank: 8	Mean: 3.35	Median:4

KEEP ◯ REJECT ◯

Η κατάταξη, ο μέσος όρος της κατάταξης και η διάμεσος παρέχονται από τα δεδομένα που συλλέχθηκαν στον δεύτερο γύρο.

ROUND III QUESTIONNAIRE ENGLISH

1. The effectiveness of visual instructional materials in the Technology Course for Elementary and Middle School grades depends on how they help the student process the information.

[Rank: 1 Mean: 4 Median: 4]

KEEP ◯ REJECT ◯

2. The effectiveness of visual educational materials in the Technology Course for Primary and High School classes depends on the competence of the teacher.

[Rank: 3 Mean: 4.33 Median: 4]

KEEP ◯ REJECT ◯

3. The effectiveness of visual educational materials in the Technology Course for the Elementary and Middle School classes depends upon the type of test format employed to assess student information acquisition.

[Rank: 4 Mean: 4 Median: 4]

◯

KEEP ◯ REJECT

4. The effectiveness of visual educational materials in the course of Technology depends on the language processing of the texts and the terms used to make them clear, attractive and understandable.

[Rank: 2 Mean: 4.13 Median: 4]

KEEP ◯ REJECT ◯

5. The effectiveness of visual educational materials in the Technology Course for the Primary and High School classes depends on the visual elements that can show the spatial relationships (spatial relationships) and the placement between the objects presented during the teaching.

[Rank: 6 Mean: 3,4 Median: 3]

KEEP ◯ REJECT ◯

6. The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on using appropriate procedures and appropriate visual materials to distinguish titles and key words from the rest of the instructional content.

[Rank: 7 Mean: 3.73 Median: 4]

KEEP ◯ REJECT ◯

7. The effectiveness of visual educational materials in the Technology Course for the Primary and Secondary grades depends on the way in which the photographs and illustrations are presented to the students.

[Rank: 8 Mean: 3.46 Median: 4]

KEEP ◯ REJECT ◯

8. The effectiveness of visual educational materials in the Technology Course for the Elementary and Middle School classes depends on the Appropriateness of the colors to present the corresponding concepts and the application of the standards for the use of colors (e.g. each color is used with a purpose).

[Rank: 12 Mean: 3 Median: 3]

KEEP ◯ REJECT ◯

9. The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School classes depends on the amount of realistic detail that the visual materials and media used for teaching have.

[Rank: 9 Mean: 3.6 Median: 4]

KEEP ◯ REJECT ◯

10. The effectiveness of visual instructional materials in the Technology Course for the Elementary and High School classes depends on the method by which the visual instruction is presented to the students.

[Rank: 10 Mean: 3.93 Median: 4]

KEEP ◯ REJECT ◯

11. The effectiveness of the visual educational materials in the Technology Course for the Primary and High School classes depends on the interest and active involvement that the students develop during the teaching.

[Rank: 5 Mean: 4.33 Median: 4]

KEEP ◯ REJECT ◯

12. The effectiveness of visual instructional materials in the Technology Course for the Elementary and Middle School grades depends on the technique used to focus students' attention on the essence of learning and on those features of visualization that promote learning.

[Rank: 11 Mean: 3.8 Median: 4]

KEEP ◯ REJECT ◯

GREEK VERSION – ROUND III QUESTIONNAIRE

1. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τον τρόπο με τον οποίο βοηθάνε τον μαθητή να επεξεργάζεται τις πληροφορίες.

[Rank: 1 Mean: 4 Median: 4]

KEEP ◯ REJECT ◯

2. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από την επάρκεια του διδάσκοντος.

[Rank: 3 Mean: 4.33 Median: 4]

KEEP ◯ REJECT ◯

3. Η αποτελεσματικότητα του οπτικού εκπαιδευτικού υλικού στην Τεχνολογική Εκπαίδευση για τις τάξεις 6ης - 9ης εξαρτάται από τον τύπο της αξιολόγησης που χρησιμοποιείται για την αξιολόγηση της απόκτησης πληροφοριών των μαθητών (π.χ., για ορισμένους τύπους εκπαιδευτικών στόχων, τα οπτικά τεστ έχουν βρεθεί ότι παρέχουν πιο

έγκυρες αξιολογήσεις ο όγκος των πληροφοριών που αποκτούν οι μαθητές χρησιμοποιώντας οπτικοποιημένη διδασκαλία

[Rank: 4 Mean: 4 Median: 4]

KEEP ◯ REJECT ◯

4. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο μάθημα της Τεχνολογίας εξαρτάται από την γλωσσική επεξεργασία των κειμένων και των όρων που αξιοποιούνται ώστε να καθίστανται σαφή, ελκυστικά και κατανοητά.

[Rank: 2 Mean: 4.13 Median: 4]

KEEP ◯ REJECT ◯

5. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τα οπτικά στοιχεία που μπορούν να δείξουν τις χωρικές σχέσεις (spatial relationships) και την τοποθέτηση μεταξύ των αντικειμένων που παρουσιάζονται κατά την διάρκεια της διδασκαλίας.

[Rank: 6 Mean: 3,4 Median: 3]

KEEP ◯ REJECT ◯

6. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τα να αξιοποιούνται οι κατάλληλες διαδικασίες και το κατάλληλο οπτικό υλικό για να ξεχωριστούν οι τίτλοι και οι κυρίες λέξεις από το υπόλοιπο εκπαιδευτικό περιεχόμενο.

[Rank: 7 Mean: 3.73 Median: 4]

KEEP ◯ REJECT ◯

7. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από τον τρόπο με τον οποίο παρουσιάζονται οι φωτογραφίες και οι εικονογραφήσεις στους μαθητές.

[Rank: 8 Mean: 3.46 Median: 4]

KEEP ◯ REJECT ◯

8. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από την καταλληλότητα των χρωμάτων για να παρουσιαστούν οι αντίστοιχες έννοιες και η εφαρμογή των standards για την χρήση των χρωμάτων (π.χ. κάθε χρώμα χρησιμοποιείται με ένα σκοπό).

[Rank: 12 Mean: 3 Median: 3]

KEEP ◯ REJECT ◯

9. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται το ποσό της ρεαλιστικής λεπτομέρειας που έχουν τα οπτικά υλικά και μέσα που χρησιμοποιούνται για την διδασκαλία.

[Rank: 9 Mean: 3.6 Median: 4]

KEEP ◯ REJECT ◯

10. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται την μέθοδο με την οποία η οπτική διδασκαλία παρουσιάζεται στους μαθητές.

[Rank: 10 Mean: 3.93 Median: 4]

KEEP ◯ REJECT ◯

11. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από το ενδιαφέρον και την ενεργή εμπλοκή που αναπτύσσουν οι μαθητές στην διάρκεια της διδασκαλίας.

[Rank: 5 Mean: 4.33 Median: 4]

KEEP ◯ REJECT ◯

12. Η αποτελεσματικότητα των οπτικών εκπαιδευτικών υλικών στο Μάθημα της Τεχνολογίας για τις τάξεις του Δημοτικού και του Γυμνάσιου εξαρτάται από την τεχνική που χρησιμοποιείται για να επικεντρωθεί η προσοχή των μαθητών στην ουσία της μάθησης και σε εκείνα τα χαρακτηριστικά της οπτικοποίησης που προωθούν την μάθηση.

[Rank: 11 Mean: 3.8 Median: 4]

KEEP ◯ REJECT ◯

EXEMPT LETTER

OLD DOMINION UNIVERSITY

OFFICE OF THE VICE PRESIDENT FOR RESEARCH

Physical Address
4111 Monarch Way, Suite 203
Norfolk, Virginia 23508
Mailing Address
Office of Research
1 Old Dominion University
Norfolk, Virginia 23529
Phone(757) 683-3460
Fax(757) 683-5902

DATE:	January 27, 2023
TO:	Petros Katsioloudis
FROM:	Old Dominion University Education Human Subjects Review Committee
PROJECT TITLE:	[1969128-1] Identification of quality indicators for visual based learning material in technology education programs for grades 6th-9th.
REFERENCE #:	
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	
REVIEW CATEGORY:	Exemption category #2

Thank you for your submission of New Project materials for this project. The Old Dominion University Education Human Subjects Review Committee has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

We will retain a copy of this correspondence within our records.

If you have any questions, please contact John Baaki at (757) 683-5491 or jbaaki@odu.edu. Please include your project title and reference number in all correspondence with this committee.

VITA

Spyridoula Tsouganatou is an educator with an interest in STEM education. She holds a Bachelor of Science in Primary Education from the University of Athens in October 2016, a Master of Science in Educational Leadership from Old Dominion University with graduation date of May 2019 and a Ph.D. in Workforce and Organizational Development from Old Dominion University, with a graduation date of April 2024. Interests include how to design schools that are more student center and incorporate in a harmonious way both traditional and modern pedagogical methodologies for teaching and learning. Spiridoula Tsouganatou graduated from Old Dominion University from the Department of Workforce and Organizational Development, at 4101 Education Building II Norfolk, 23529.