AC 2008-177: IDENTIFICATION OF QUALITY INDICATORS OF VISUAL-BASED LEARNING MATERIAL IN TECHNOLOGY EDUCATION PROGRAMS FOR GRADES 7-12

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Identification of Quality Indicators of Visual-Based Learning Material in Technology Education Programs for Grades 7-12.

Abstract – The purpose of this study was to identify the quality indicators of visual-based learning material in technology education for grades 7-12. A three-round modified Delphi method was used to answer the following research questions: RQ1: What indicators should quality visual-based learning material in technology education have to be effective and efficient in transmitting information for grades 7-12? RQ2: What are the indicators of the learner's characteristics that impact the selection of visual-based learning material in technology education for grades 7-12? The quality indicators were determined by consensus reached by a panel of 21 educational experts randomly selected from participants in two NSF funded projects that piloted and field-tested visual learning material in technology education courses. The two funded projects were VisTE and TECH-Know. In the first round, the panel was provided with examples of quality indicators. The example indicators in the first round instrument derived from the literature review. The first round of the modified Delphi method used an open-ended questionnaire format in which the experts were asked to keep, reject, modify or add a new characteristic. The responses generated by the first round contributed to the development of the Round II instrument. In the second round, panelists were asked to value and rank from lowest to highest the items identified on Round I on a 5 point Likert scale. In Round III the experts' panel was asked to accept or reject the quality indicators derived by the second round. Based on an analysis of data collected on Rounds I, II and III conclusions were drawn and 18 quality indicators were found.

Introduction

In learning environments throughout education, the visual elements of courses, lessons, and presentations play an important role in learning. Well-conceived and rendered visuals help any audience understand and retain information [14].
The use of visual technology enhances learning by providing a better understanding of the topic as well as motivating the students . Visualization methods are widely credited for simplifying the presentation of difficult subjects as well as aiding cognition; their use in the power engineering industry and education is enjoying significant growth [7]. Even though the success by which content visualization will facilitate the learner's acquisition of information is related to the individual's level of perceptual and associative learning in the content area, the individual must have sufficient experience and maturity to realize that using visualization is merely an attempt to represent reality vicariously [5]. Much of intended visual communication or self-expression is not perceived, or often misunderstood, especially if it is complex [8]. In addition individual's experience, the visualization itself plays an important role in the learning process.

If all visual-based learning materials were equally effective in facilitating student achievement of all kinds of educational objectives, there would virtually be no problem associated with this type of instruction [5]. However, this is not the case since there are many different types of visuals, differing in the amount of realistic detail they contain. At the present time, educators, when faced with a choice of selecting one type of visualization from an array of available materials, have no way of knowing whether one type of visual is any more effective than another in transmitting certain types of information [5]. From past to current there is a lack of quantifiable measures of quality and benchmarks that will undermine information visualization advances, especially their evaluation and selection [2]. The significance of this dilemma is brought into focus when one becomes aware of the amount of visual-based learning materials that are being used today in the private and public educational sector. As might be expected, the types of visual-based materials used for instructional purposes are the ones that have become most readily available [5]. However, the extensive use of a certain type of visual-based material does not necessarily justify its effectiveness and efficiency. The profusion of visual displays of information without an educated guide to meanings discerned from the information has led to a groundswell of movements seeking to develop metrics and quantifiable quality measures.

Need for Study

The importance of knowing how to select the best type of visual-based learning materials is recognized throughout higher education; however, with the exception of some descriptive literature, few studies have been conducted to identify the essential indicators of visual-based learning materials used in technology education courses for the middle school and high school grades. The reason this study is being emphasized for grades 7-12 is because, technology education is mainly offered for grades 7-12 due to federal funding guidelines such as the Carl D. Perkins Vocational and Technical Education Act that provides federal funds "…to help provide vocational-technical education programs and services to youth and adults in middle school, high school and college level " [14]. Since

the early 1980s there has been very little research to use when selecting specific types of visuals that will be most effective and efficient in facilitating student achievement of designated learning objectives. What is urgently needed is systematic research efforts focused on three basic areas designed to provide data on: (a) what specific individual difference variables in learners actually make a difference in student achievement in the teaching learning process, (b) which of these individual difference variables interact significantly with different kinds of visualization used to complement oral/printed instruction, and (c) what is the extent of the range within specific individual difference variables that are accommodated by the use of specific types of visualization [5].
Once we can describe what makes a particular visual successful to us, we can apply this knowledge to the design of completely new visuals. In instruction, an image may be studied for a long time by the viewer and still be unsuccessful [8].
Therefore, it is essential to identify the indicators of quality visual-based learning materials for technology education curricula. Moreover, it is important to validate these indicators through involvement of educational members in the field of visual learning and technology education. Technology education experts who have knowledge related to visual learning and practical experience, involved in the creation of related materials, are a useful source of information to develop and validate the indicators of visual-based learning materials for technology education.

Research Methodology

The procedures for this research study began with a proposal for conducting the study and a review of literature to acquire information related to the subject and subject matter. Three rounds were conducted to achieve consensus among a group of experts in visual based learning material who were experienced technology teachers involved in pilot and field-testing for visual-based learning material grants such as Visualization in Technology Education (VisTE) and TECH-Know.

In May 2002, the Department of Mathematics, Science and Technology Education in North Carolina State University's College of Education received as a three-year grant (VisTE) from the National Science Foundation to develop instructional units that utilize scientific and technical visualization. VisTE promotes technological literacy by attempting to link engineering, mathematics, science and technology concepts and promote technological literacy through the use of scientific and technical visualization tools and techniques [6].
The TECH know Project was a National Science Foundation funded project that produced 20 instructional units based on technology problems issued by the Technology Student Association (TSA). The problems cover a wide variety of topics in construction, communication, manufacturing, and transportation technology. The competition engages students in hands-on, problem-based learning and is based upon fundamental science, mathematics, and technology concepts" [12].

The study used a modified Delphi method for identifying the quality indicators of supplemental technology education visual-based learning material for the middle and high school grades. The approach used in this study to achieve its purposes was the online modified Delphi methodology. Many existing research studies in the area of information technology utilize

the Internet and the World Wide Web as media to collect consensus data [11].
The number of rounds depended on reaching consensus among panel members. Most Delphi studies find that more than three rounds do not add significant value [3]. All data was gathered via a web site created to host the study and the World Wide Web as a primary mode of communication using Web-based instruments. Upon completion of the modified Delphi method, the indicators of visual-based learning material for middle and high school technology education courses were identified.

A review committee of three individuals who represented the background areas of the expert panel also was randomly selected to review all material and modifications made by the researcher before being sent to the experts for the different rounds. Having the review panel also helped to prevent bias by the researcher during the editing and modifications made to the instruments between rounds. The review panel also participated as a test-piloting group to ensure the instrument being used for a given round was reader-friendly and easily understood [9].
The instrument for Round I of the modified Delphi method was developed from information found in the review of literature. Examples of quality indicators were established and placed in a survey instrument. Once the review panel approved the instrument, the expert panel was given access to the instrument on the web through a username and password. An email was sent to panel members after two weeks as a reminder to complete and return the instrument. Results from Round I were tabulated, with like indicators collapsed together. Participants remained anonymous to each other, avoiding influences of reputation, authority or affiliation. This enabled panel members to change their opinions without losing face [8]. Round II of the modified Delphi method included the rating and ranking of indicators from Round I. The instrument was developed and sent to the review panel for verification. The indicators were placed in random order. This round consisted of rating each indicator from the previous round. Indicators with a mean of 3.01 or higher from a Likert scale of 1-5 were kept for the next round. Also, the Kruskal-Wallis One-Way Analysis of Variance by Ranks test was conducted to determine statistical between rankings through the collected indicators in this round.

In conjunction with the Kruskal and Wallis Test the Spearman's Rank-Order Correlation Coefficient also was employed to identify whether correlation between subjects' scores on two variables had a different value than zero. In addition, the Mann-Whitney U Test was employed with ordinal data in a hypothesis-testing situation involving a design with two independent samples and testing for significant difference between the two medians. Round III consisted of ranking the information gathered from Round II. Indicators kept from this round were those that ranked in the 50 percent above the statistic mean from Likert scale. Those indicators were kept since each was ranked highest by the expert panel, and, therefore, had the highest consensus. In Round III each expert panel member was asked to approve the final outcomes as established from Round II of the modified Delphi method. Once the review panel approved, the third and final round access was given to the experts to complete the instrument. Expert panel members were asked to accept or reject each indicator kept from Round II. The Mann-Whitney U nonparametric test was employed with ordinal (rank-order) data in a hypothesis-testing situation involving a design with two independent samples and testing for significant difference between the two medians.

Demographic Information about Participants

The review panel had three members: A high school technology education teacher, a middle school technology education teacher and a college-level technology teacher educator. The average years of teaching and/or overseeing a visual-based technology education program for the review panel was six years. Every member on the panel had at least a bachelor's degree or higher and had taught at least one visual-based related subject between 2002 -2007. The expert panel consisted of 21 members from two visual-based material related NSF- funded grants. The expert panel members were representatives from across the United States in full-time positions as technology education teachers at the high school or middle school level. Table 1 shows summaries of demographic information on expert panel members in terms of: Positions held, grade levels taught/over seen, highest degree obtained, gender, involvement with visual-based material related grants and experience with visual training during the last five years.

The demographic survey asked panel members: (1) Which title most accurately describes their current position? The three possible answers included: (a) Technology teacher using visual-based learning material, (b) visual-based learning grant related participant and (c) visual-based learning material author. Responses showed that all expert panel members, 100 percent, are technology teachers using visual-based learning material; all expert panel members, 100 percent, are a part of a visual-based learning grant; and few members, 10.5 percent, served as authors for visual-based learning material; (2) what grade level do they currently teach or oversee? Responses showed that almost half of the expert panel members, 42.1 percent, are teaching high school level grades and 57.9 percent at the middle school level grades; (3) what is the highest degree obtained as of January 1, 2007? Responses showed that almost half of the population, 47.4 percent, had a bachelor's degree and more than half, 52.6 percent, were masters degree holders; (4) what is the gender of the expert panel participants? Responses showed that 57.9 percent of the participants were males and 42.1 percent are females; (5) what was the year of graduation of the expert panel participants? This was also asked in order to determine the age of the participants. Results showed that the earliest graduation took place in 1972 and the latest in 1999. Assuming that the most common age for high-school graduation is 18 years old, the age of the participants ranges between 26 and 53 years old; (6) what is their current residence? Responses showed that all expert panel members, 100 percent, are residents of the United States; (7) has anyone had any type of visual training within the last 5 years? This was asked in the demographic survey to determine the expertise of the experts. Responses showed that all-expert panel members, 100 percent, have had some form of training; (8) what courses have they taught within the last years that require visual-based teaching/student capabilities? Responses showed that all expert panel members, 100 percent, have taught various courses, including solid modeling, CAD, Pro Desktop, VisTE materials, Tech Design, TECH-Know units, Dreamweaver and Technology Discovery.

Research Questions

The major emphasis of this study was to determine the indicators that visual-based learning material used in technology education for grades 7-12 to transmit information effectively. To achieve this task two-research questions were proposed dealing with visual-based learning material:

1. What indicators must visual-based learning material in technology education for grades 7-12 have to be effective in transmitting information?
2. What are the indicators of the learner's characteristics that impact the selection of visual-based learning material in technology education for grades 7-12?

Hypotheses

To statistically justify and answer the two research questions, four null hypotheses were proposed concerning the identification of visual-based learning material indicators. Even though hypotheses one, two and four look identical in wording each one utilizes a different a statistical instrument that supports different evidence. The four hypotheses were:

Hypothesis 1: The median of the middle school population for each quality indicator for visual-based learning material in technology education for grades 7-12 equals the median of the high school population for each quality indicator for visual based learning material in technology education for grades 7-12. The Kruskal-Wallis test was conducted to test the hypothesis above. The calculated values for p-value were evaluated in comparison to the critical values for each indicator to determine if the null hypothesis is to be rejected or if there is evidence that fails to reject the claim. If the p-value was less than the critical value (• = .05) the null hypothesis was rejected. The p-value was less than the critical value in none of the indicators.

The Kruskal- Wallis test was used in this study to show representation of consensus for each indicator. All indicators had a p-value higher than .05, which shows good representation of population consensus, and not enough evidence for significant difference in-between the indicators.

Hypothesis 2: The median of the middle school population for each quality indicator for visual-based learning material in technology education for grades 7-12 represents equals the median of the high school population for each quality indicator for visual-based learning material in technology education for grades 7-12. The Mann Whitney U test was conducted to test the hypothesis above. Significance was measured at an • of .05. The calculated values for the p-value statistic were evaluated in comparison to the critical values for each indicator to determine if the null hypothesis is to be rejected or if there is evidence that fails to reject the claim. If the p-value was less than the critical value (• =.05) the null hypothesis was rejected. The p-value statistic was less than the critical value in indicator numbers five: The effectiveness of visual-based learning material in technology education for grades 7-12 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) and thirteen: The effectiveness of visual-based learning material in technology education for grades 7-12 depends upon the level of the technology available to the student.

Indicator number five relates to the technique used to focus student attention on essential learning characteristics in the visualization materials. Due to the large amount of information contained within this indicator, the researcher believes it was difficult for the experts to understand the exact meaning of this indicator and therefore unable to reach consensus which it lead for the null hypothesis to be rejected.

The remaining of the indicators examined in this test had a p-value larger than the critical value

(.05), which indicated that consensus was achieved through the study and indicators were well written and understood by the expert panel members.

Hypothesis 3: In the underlying population the sample represents, the correlation between the ranks of subjects on middle school responses and high school responses equal some value higher than 0. The test compared the ranking scores of the two sample populations (middle school and high school) to each indicator's median. This statistical process revealed the relationship between each indicator's ranked score and the median for that particular indicator to show that no outliers (effects of one or more extreme scores) were influencing the consensus drawing process for the ranking of indicators. Since the ranking of indicators would have a positive mean, the median would be positive for each indicator therefore, a high positive correlation was expected from this data used in the statistical test. A high positive correlation was achieved for all indicators except indicators: a) fourteen (see Table 2), which, it had a low correlation coefficient of - 0.188 and b) indicator sixteen (see Table 2), which, it had a low positive correlation coefficient of 0.164. Both of these indicators support that the efficiency of a visual-based material depends upon the equipment and hardware used to deliver the information. Since some educators are not necessarily experts with instructional technologies and the fact that there is a plethora of them to choose from, it is hard to achieve consensus upon a specific type of equipment that exceeds the rest. Consensus was not represented for those indicators. However, the most significant factor is the overall correlation for the entire ranking of all indicators that had a positive coefficient correlation of 0.741 for the middle school experts and 0.873 for the high school experts.

Hypothesis 4: The median of the middle school population for each quality indicator for visual-based learning material in technology education for grades 7-12 equals the median of the high school population for each quality indicator for visual based learning material in technology education for grades 7-12. The Mann Whitney U test was conducted to test the hypothesis above. The calculated values for the p-value statistic were evaluated in comparison to the critical values for each indicator to determine if the null hypothesis is to be rejected or if there is evidence that fails to reject the claim. If the p-value was less than the critical value (• = .05) the null hypothesis was rejected. The p-value statistic was less than the critical value in indicator number eleven: The effectiveness of visual-based learning material in technology education for grades 7-12 depends upon the relevance of the materials. The reason for this could be due to the nature of the indicator. This specific indicator is very broad, hard to understand and does not specify the kind of relevance within the materials.

Conclusions for Research Questions

The major emphasis of the study involved determining the indicators that visual-based learning material used in Technology Education for grades 7-12 must have to transmit information effectively and also the indicators of the learner's characteristics to be exposed to such material.

Both of the research questions mentioned above were examined through the modified online Delphi method conducted in this study. In the three modified Delphi rounds, a panel of experts in the field of technology education identified quality indicators through a consensus process. The modified Delphi method used in this study validated the quality indicators through the use of

consensus-drawing processes using experts involved with visual-based learning material grants. Stratification measures used for locating expert panel members helped ensure that the indicators represented consensus from across the United States. The statistical tests applied during the study validated that consensus was being achieved and thus consensus-gathering strategies used within the study were appropriate.
Table 2 shows the validated indicators kept from the final modified Delphi round of this study:

Table 1. *Summary of Demographic Information on Expert Panel*

Description	Frequency	Percent
Technology Teacher	19	100.0
Grant Participant	19	100.0
Author	2	10.5
High School Grades	8	42.1
Middle School Grades	11	57.9
Male	11	57.9
Female	8	42.1
Bachelor's Degree Holders	9	47.4
Master's Degree Holders	10	52.6

Note. Total percent for all categories combined is 100 percent.

Table 2. *Validated Indicators kept from Final Round*

Indicator Number	The effectiveness of Visual-based learning material in Technology Education for grades 7-12 depends upon:
1	The amount of detail contained in the Visualization used.
2	The method by which the visualized instruction is presented since method varies with students.
3	Students' interests and engagement.
4	How the objectives are presented to the students
5	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).
6	The type of assessment employed to evaluate student learning, (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).
7	The instructor's ability to effectively and efficiently integrate visual based learning material into the Technology Education classroom environment and curriculum.
8	Time spent teaching background knowledge
9	The quality of the Visualization used
10	The student's ability to effectively and efficiently understand integrated visual-based learning material into the Technology Education classroom environment and curriculum
11	The relevance of the materials
12	The direct correlation between the materials and the learning objective.
13	The level of the technology available to the student.
14	The hardware being used by the student
15	The teacher's confidence in the area of visual teaching

Recommendations for Further Research

The experience of this research suggested many possible recommendations for further study in the areas of quality visual-based learning material in technology education programs for grades 7-12, and the use of the Delphi method as a research tool. The following recommendations are suggested for further study.

1. Additional research is needed on how to establish and assess quality indicators for visual-based learning material in technology education for all grades. This includes elementary, middle school, high school and college level visual-based learning material for technology education programs.
2. Additional studies should be conducted using other research methodologies to better understand the subject matter and aid in validating the information gathered.
3. This study should be replicated in 5 years to see if new quality indicators are identified for visual-based learning material in technology education programs for grades 7-12, and the information should be updated in the final quality indicators list for a more representative up-to-date assessment of visual-based learning materials.
4. Additional research is needed in developing an assessment strategy and model for assessing quality visual-based learning material in technology education programs for grades 7-12 at the national and international level.
5. Validate assessment tools to aid the selection process of quality visual-based learning material in technology education programs for grades 7-12 at both the national and international levels.
6. Additional research should be conducted to define the difference between a visual data and information collected from studies such as this one is beneficial to pre-engineering education and k-12 outreach through the expansion of research and knowledge in general. Visual-based learning courses have a great potential to become a significant part of k through 12 pre-engineering education. Current curricula used in grades k through 12 recognize its value and great efforts are being in place to increase the quality and quantity of visual based materials. However more research is needed to achieve the ultimate goal, which in this case is the effective knowledge transmission through alternative methods of teaching.

References

1. Chaomei, C. (2005). *Top 10 unsolved information visualization problems*. Philadelphia, PA:
   IEEE Computer Society.
2. Clark, C. A., & Mathews, B. (2000). Scientific and technical visualization: A new course offering that integrates mathematics, science and technology. *Journal of Geometry and Graphics*, 4(1), 89-98.
3. Clayton, M. J. (1997). *Delphi: A technique to harness expert opinion for critical decision making*
   tasks in education. Educational Psychology, 17(4), 373-386.
4. Delbecq, L., Van deVen, H, & Gustafson, H. (1975). *Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes*. New York: Scott-Foresman.
5. Dwyer, F. M. (1978). *Strategies for improving visual learning*. State College, PA.: Learning Services.
6. Ernst, V. E., Clark, A. C. (2006). Supporting technological literacy through the integration of engineering, mathematic, scientific, and technological concepts. *Published proceedings of the American Society for Engineering Education Annual Conference and Exposition*, Chicago, IL, Session 370.
7. 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.
8. Lantz, C. (2000). Visual Readability in Instructional Images. *Visual Communications Journal*, 8 (2), 19-27.
9. Martino, J. (1993). *Technological Forecasting for Decision Making*. New York: Elsevier Science Publishing Company.
10. Mayer, M. A., & Booker, J.M. (1990). *Eliciting and analyzing expert judgment: A practical*
    guide. Washington, D.C.: U. S. Nuclear Regulatory Commission.
11. Nesbary, Dale K. (2000). *Survey Research and the World Wide Web*. Boston: Allen and Bacon.
12. TECH-know. (2004). *TECH-know Project.* Retrieved September 16, 2006, fromhttp://www.ncsu.edu/techknow/aboutproject.html

13. U. S. Department of Education. (n.d.). *The Carl D. Perkins Vocational and Technical Education Act, Public Law 105-332*. Retrieved April 17, 2003, from http://www.ed.gov/offices/OVAE/CTE/perkins.html

14. Wileman, E. R. (1993). *Visual communicating*. Englewood Cliffs, NJ: Educational Technology Publications.