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ABSTRACT

This instructional development project evaluates the effect of a matrix-based strategy to assist multimedia authors in acquiring and applying principles for effective multimedia design. The Multimedia Matrix, based on the Park and Hannafin "Twenty Principles and Implications for Interactive Multimedia" design, displays a condensed version of those principles. Space is provided for students to generate their own responses to the presence or absence of elements as they evaluate multimedia modules before and after they begin their own designs. Formative evaluation of the project is based on qualitative and quantitative data reflecting perceptions toward the matrix-based approach of graduate students (n=17) enrolled in a course containing a multimedia authoring component. Their perceptions toward the Matrix-based authoring instructional design and student and evaluator analyses of the students' subsequent multimedia productions are presented and analyzed in relation to the effectiveness of applying two versions of the Multimedia Matrix. Focusing students' attention on specific content structure has shown indications of increasing structural knowledge and retention and keeping students on task. For the task of authoring, the Matrix used to support learning has the potential to decrease demands made on the mental effort the student must expend on remembering authoring "Principles" and to increase effort toward authoring content. Implications for future application and investigation of the Matrix is provided. (Contains 19 references.) (Author/SWC)

Multimedia Matrix: A Cognitive Strategy for Designers

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Abstract

This instructional development project evaluates the effect of a matrix-based strategy to assist multimedia authors in acquiring and applying principles for effective multimedia design. The Multimedia Matrix, based on the Park and Hannafin (1993) Twenty Principles and Implications for Interactive Multimedia design, displays a condensed version of those Principles. Space is provided for students to generate their own responses to the presence or absence of elements as they evaluate multimedia modules before and after they begin their own designs. Instruction followed Jacobson's (1994) Theory-to-Design framework. Formative evaluation of the project is based on qualitative and quantitative data reflecting perceptions of graduate students, enrolled in a course containing a multimedia authoring component, toward this Matrix-based approach. Their perceptions toward the Matrix-based authoring instructional design and their and the evaluators' analyses of the students' subsequent multimedia productions are presented and analyzed in relation to the effectiveness of applying two versions of the Multimedia Matrix. Implications for future application and investigation of the Matrix is provided.

The increase in authoring environments for multimedia[3] design has not necessarily lead to increased quality in the resulting productions (Locatis, Ullmer, Car, Bernard, Le, Lo, & Williamson, 1992; Jones & Smith, 1992; Stanton & Baber, 1994); yet scant guidance is offered to designers to connect them with relevant research and learning theory (Ambrose, 1991). To provide guidance for multimedia designers concerned with developing quality modules, Park and Hannafin (1993), developed Principles and Implications for Interactive Multimedia Design based on twenty psychological, pedagogical, and technological foundations from research findings. For example, to apply their Principle 15 —"Learners become confused and disoriented when procedures are complex, insufficient, or inconsistent."—they suggest that the designer should, "Provide clearly defined procedures for navigating within the system and accessing on-line support." (Park & Hannafin, 199 p. 77-78).

As novice and intermediate level designers attempt to incorporate these Principles into their multimedia productions, while simultaneously integrating technical knowledge of authoring programs and subject matter knowledge, they face challenging, higher order cognitive demands. In such situations, research in cognitive science and instructional technology, suggests that integrated, contextually-based instructional strategies be considered (Tennyson, Elmore, & Snyder, 1992).

Many beginning hypermedia authors tend to be teachers who have subject matter expertise and little or no knowledge about technical aspects of multimedia authoring. No specific guides exist for introducing authoring concepts such as those encompassed by the Principles. An attempt prior to this investigation, to introduce the Principles using a broad-based approach of expository techniques of assigned reading and discussion of the Park and Hannafin article, a demonstration, a brief Principles checklist, and encouragement of incorporation of relevant principles into initial multimedia productions, resulted in modules that were judged by the both the students and the instructor to contain only some aspects of the Principles. The majority of the students, however, expressed concern over the challenges posed by trying to remember the Principles while working in the multimedia environments. (Sherry, 1995). Discussion with one of the authors of the Principles (R. Hannafin, personal communication, February 16, 1995), resulted in agreement about the potential usefulness of developing a visual guide, hereafter referred to as the Matrix. An instructional design was developed that included the use of a Matrix crafted to serve as a visual, cognitive reference with which students could generate specific responses as they worked in a contextually relevant setting.

It is not surprising that research on the effectiveness of matrices to concepts, is mixed (Newell & Olejnik, 1982; Rumelhart, 1980; Siebold, 1989; Spiegel & Barufaldi, 1994), given the great diversity of matrix designs and

[3] Multimedia—"the use of multiple formats for the presentation of information, including text, still or animated graphics, movie segments, video, and audio information. Computer-based interactive multimedia includes hypermedia and hypertext." (Tolhurst, 1995, p. 25).

usage reported in such studies. By employing a systematized approach to usage, combined with feedback from the participants, a critical element in effective evaluation (Reiser & Kegelmann, 1994), a Matrix-based instructional design was developed and refined through the testing of two versions of the Matrix developed to specifically guide users in applying the Principles.

Method

Participants

Seventeen graduate level education majors, involved in multimedia development participated in providing preliminary data on the Matrix-based instructional design project. Technical abilities ranged from beginner to advanced with all having no prior knowledge of the Park and Hannafin (1993) Principles.

Procedures

Instruction was based on the seven steps of Jacobson's Theory-to-Design framework (1994), that employs cognitive flexibility theory (CFT) to support the "development of flexible representation of knowledge that will help promote deep conceptual understanding and ability to adaptively use knowledge in new situations" (p. 146). The seven steps that were followed were:

1) Employing rich cases and examples—An exact statement of the twenty Principles and an abbreviated version of implications for applying the Principles was developed and displayed on versions one and two of a Matrix created for student use. Blank cells were provided for making notations about key elements of effective multimedia authoring that could be identified during a review of multimedia modules. The Park and Hannafin article and five examples of student-produced multimedia modules were provided along with the first version of the Matrix during instructor demonstration and student analyses .

2) Using multiple forms of knowledge representation—The articles, the Matrix v.1, the modules, and a talk-aloud approach were used to present the information in multiple forms. Students, working in self-selected dyads, chose three of the five multimedia modules to evaluate using the first Matrix as a guide.

3) Linking abstract concepts to case examples—A variety of the abstract Principles were contained in the sample modules.

4) Demonstrating conceptual complexities and irregularities—The modules that served as examples varied in the quality and quantity of complex features of multimedia Principles that they incorporated.

5) Stressing the interrelated and weblike nature of knowledge—The Matrix was designed to be interrelated to the Park and Hannafin article. Version one was used when the students evaluated multimedia modules developed by others; version two was used when they evaluated their own modules.

6) Encouraging knowledge assembly from different conceptual case sources—The students were required to analyze modules in writing, as well as to construct their own analysis of the effectiveness of the first Matrix. Their suggestions for change were incorporated in the second version of the Matrix.

7) Promoting active learning—Throughout their authoring experience, students were actively engaged with analyzing and applying both versions of the Matrix, the article, and the modules and with constructing their versions of the Matrix approach.

Data Analysis

Quantitative and Qualitative Data

Both quantitative and qualitative data were gathered to evaluate the overall effectiveness of the Matrix-based instructional design and the students' ability to apply the Principles to their designs. Quantitative data consist of students' mean scores on aspects of the usefulness of the multimedia production and of the Principles, as well as on the overall instructional design of the course. Quantitative data consisted of interval data from a written survey administered at the end of the course; the percentage of completed multimedia productions judged by the student authors as being worthwhile additions to the software preview center of the college; the degree of effectiveness that the students reflected toward the two versions of the Matrix as rated by two evaluators; and the percentage of students meeting criterion-based measures for presentations and reports that reflected attainment of declarative and procedural outcomes as judged by instructor ratings. Qualitative data are reported in an analysis and ranking of comments from

the students about both the Matrix and their modules in relation to application of principles for effective multimedia design and in the instructor's overall evaluation of all components of the evaluation process.

Formative Evaluation—Matrix

Phase I. In Phase I students were asked to provide written evaluations of the first version of the Matrix in terms of its positive and negative effects. Their suggestions for changes to the guide were also sought. Two evaluators analyzed these responses to identify commonalties in the comments. The resulting themes were ranked according to the most frequently occurring items. Based on this analysis, changes were made to the first version of the Matrix. The revised Matrix v. 2, was made available to all the students during their subsequent multimedia authoring.

Phase II. In Phase II, the students' multimedia productions were evaluated by the instructor in relation to their ability to reflect the Principles in their productions. A minimum of ten of the twenty principles was set as the baseline for effective design for their productions. An option was provided for students to analyze their modules in writing in relation to Matrix v.2 and to provide a log of the time spent using the matrices.

Students provided additional written responses in relation to the interactive multimedia component of the course by responding to three items on a Likert-like survey administered at the conclusion of the course.

Results and Discussion

This evaluation emphasized listening to student opinions, as this approach was determined to have the greatest potential for providing relevant data on ways to improve discrete elements of the multimedia module, as well as the overall design of the course (English & Reigeluth, 1996; Lohr, Ross, & Morrison, 1995). The Matrix-based course component was perceived by learners to effectively contribute to their intellectual curiosity (4.5), their satisfaction (4.5), and general perceived usefulness (4.5) as indicated by learner responses to a survey administered at the end of the course, that contained a Likert-like scale for responses that ranged from 1 (almost never or almost nothing) to 5 (almost always, a great deal). Of all the course components, multimedia production was perceived to be the most useful one.

In analyzing the students' perceptions about both versions of the Matrix, comments offered by more than 25% of the students were reviewed. As shown in Table 1, within those parameters, the students provided more negative and change comments than positive ones for the first version of the Matrix.

Based on these evaluations, changes were made to the text of the Matrix to clarify vocabulary and redundant information. A checklist format was adopted for greater consistency and ease of use. The response boxes underwent minor reformatting to systematize the overall design of the instrument. To clearly keep the relationship of the Matrix to its accompanying article, no additional items were added, although some students had made that request. The revised Matrix is depicted in Figure 1.

The analysis of the revised Matrix, indicates a major change with comments in the positive category outnumbering the negative and change categories. According to students the new version does achieve its purpose of simplifying the application of the Principles for the authors. This comment was provided by 82% of the respondents and achieved the top ranking for all items.

While the main negative comments that appeared for the first version did not occur for the second one, the shape of the response boxes was still seen as a problem. Although the newer version appears to support users' needs to a greater extent than the initial one, these results should be interpreted with caution. The results of the student-based evaluations of Matrix v.2 are based on responses from eleven of the seventeen students. In keeping with the constructivist-based design of this part of the course, students could determine whether or not to use and evaluate Matrix v.2. Of the six students who did not elect this option, five had had negative reactions toward the first version. The effect of these students' non participation in the final evaluation needs to be kept in mind to avoid interpreting the students' second round of comments in an overly optimistic manner.

When the students' views of the Matrices are investigated in relation to their skills as authors—novices or more advanced designers—there is a similar pattern within the number of the types of responses each group of students offers in relation to positive, negative and change aspects. For example, novices provided more positive comments than advanced students and less when making negative responses and suggestions for change. It may be that the novices welcomed any type of support, while the advanced students were more discerning about the type of support they required. Novices were more apt to mention version one of the Matrix as contributing to guiding evaluators and supporting consistent feedback. The advanced students also recognized the contribution of guiding evaluators, but were more apt to mention support of consistent feedback and focusing attention. It could be that the

novices perceive consistency as requiring less mental effort when considering the Principles, allowing them to concentrate on mastering the authoring program itself, an issue of less concern for the more advanced learners.

By version two, as the novices had become more experienced in manipulating the authoring program, they cited simplifying the application of the Principles and/or convenience and an effective checklist format as their two most frequently mentioned items. The predominant response of the advanced students was the same for both items, but they also recognized the Matrix as a guide for designers by mentioning that aspect as frequently as they mentioned its checklist feature. As advanced students reported spending less time using the matrices (an average of one hour less with Matrix v.2 than the novices), the former students may have found more time for reflecting on the effect of the Matrix and, thus, come to this conclusion.

Regarding negative comments and suggestions for change, fifty percent of the novices stated that Matrix v.1 was inconsistent if used by many and had vocabulary problems. Only thirty-six percent of the advanced students recognized the issue of inconsistency, and as such, it appeared as the second most frequently appearing item for them in their negative comments. Their most frequently mentioned negative item was redundancy. Forty-five percent cited that issue. After using the second version, the novices showed a marked decline in their negative comments. None mentioned inconsistency as a problem and only twenty-five percent continued to cite the vocabulary problem. Issues of redundancy and requiring prior knowledge appeared at this stage for twenty-five percent of the novices. It may be that as the students became more confident with their developing authoring skills they became more positive. A similar change appeared with the advanced students as negative comments declined to only one. That one comment regarded the design of the response boxes with forty-three percent criticizing the shape. The appearance of that type of comment by a large percentage of the advanced students may be a result of their desire to have more space for their comments as these students were observed to be more apt to write remarks than were the novices.

The change comments followed the pattern for the negative comments. Suggestions for change decreased between the two versions of the Matrix. The novices had requested that the initial matrix be reformatted to a checklist format and that a provision be added for overall scoring. As both these features were incorporated into the revised version, no comments were offered about these topics for Matrix v.2. The advanced students suggested that items other than those covered by the twenty Principles be added to the Matrix after they worked with Matrix v.1. This request indicated their broader knowledge of other aspects of multimedia that were not addressed by Park and Hannafin. As the intent was to create an instructional tool that would support and enhance the Park and Hannafin article, no attempt was made to add items to Matrix v.2. This decision was explained to the students. Both the novices and the advanced students did request that Matrix v.2 be simplified and shortened to be less time consuming. Novices did report spending approximately one hour longer than the advanced students when working with the Matrix, with times reported as 2 1/2 hours for the former and 1 1/2 hours for the latter. Such amounts of time, do indicate a need to refine the instrument for greater efficiency.

The results of the quantitative data in the end of the course survey have greater potential for reliably reporting the students' view toward the overall instructional aspects of the multimedia component as all students provided responses. On a Likert-like scale that ranged from 1 (almost never or almost nothing) to 5 (almost always, a great deal), the learners indicated that the multimedia authoring component effectively contributed to their intellectual curiosity, their satisfaction, and general usefulness as indicated by a mean of 4.5 for each of the threee items.

Ten modules were developed by the students, five by individuals and five by groups. All modules were judged by the instructor to address a minimum of ten of the principles. While this evaluation has the potential for instructor bias, the value of the modules was supported by the multimedia authors. Sixteen of the seventeen students judged their productions as worthwhile contributions to the Technology Learning Center of the college, a site that serves as a preview center for commercially- and student-produced educational software. Peer review and exit interviews have been employed with similar findings by Spector, Muraida and Marlino in their study on CBI authoring (1992).

Conclusions and Implications

Focusing students' attention on specific content structure, in this case, on critical principles for multimedia authoring, has shown indications of increasing structural knowledge and retention (Beasley & Waugh, 1996) and keeping students on task (Shore, Erickson, Garick, Hickman, Stanley, Taylor, & Trunfio, 1992). For the demanding task of authoring, the Matrix that was offered to support learning, has the potential to decrease demands made on the mental effort that the student must expend on remembering authoring Principles and to increase effort toward

authoring content. As one student commented, the learners were required to, "really think about the program [multimedia module] in terms of how fundamentally it teaches. It gets the evaluator past the 'bells and whistles'". A balance does need to be struck between modifying the Multimedia Matrix to a point where it becomes less time consuming for students to use, yet still retains its connection to the original Park and Hannafin article (1993), as well as, continues to encourage students to revise and personalize it.

While the matrix-based approach to instruction appears to have contributed to the development of the multimedia authoring skills for these learners, future studies may reveal that the flexible approach to instruction, particularly instruction that supports the learners' evaluation and adaptation of the Matrix to meet their needs has a more significant impact on learning, more than the actual implementation of the Matrix itself (Jacobson, 1994). Future investigators may wish to compare the effect of other authoring frameworks, such as the Hypermedia Design Model (Garzotto, Mainetti, Paolini, 1995) to the Matrix when studying the implementation of authoring in courses. Similar to Jacobson's Theory-to-Design framework, the matrix-based model appears, in a preliminary analysis, to meet some of the design criteria as a guide on discrete aspects of effective multimedia design.

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Table 1. Most Frequently Occurring Comments Concerning Multimedia Matrices v.1 and v.2

Response Type	Rank	Comment
Positive		
Matrix v.1		
	1	Guides evaluator
	2	Supports consistent feedback
	2	Focuses attention
	4	Simplifies application of principles/easy to use
Matrix v.2		
	1	Simplifies application of principles/easy to use
	2	Provides effective checklist format
Negative/Change		
Matrix v.1		
	1	Redundant
	1	Inconsistent if used by many
	3	Vocabulary too technical: define, simplify
	4	Bad shape for response boxes
	4	Add additional items
	4	Reformat to checklist format
Matrix v.2		
	1	Bad shape for response boxes

Note. Rankings are based on items mentioned by more than 25% of the respondents.

Matrix for Guidelines for Designing Interactive Multimedia*

Title of Multimedia Module

Principle 1. Related prior knowledge is the single most powerful influence in mediating subsequent learning.	***Principle 2. New knowledge becomes increasingly meaningful when integrated with existing knowledge.***
Application 1. Is information presented to accommodate ranges of prior knowledge of learners by: ❑ layering and, abstracting, and/or providing various perspectives on new information? ❑ letting learners assemble their own connections with the concepts?	Application 2. Are structural aids to the new knowledge provided by: ❑ making the structure of the overall lesson explicit? ❑ employing structural organizers, such as headings to differentiate between critical and subordinate information? ❑ summaries of key relationships? ❑ elaboration strategies within the program or generated by the learner?
Comments:	Comments:
Principle 3. Learning is influenced by the supplied organization of concepts to be learned.	***Principle 4. Knowledge to be learned needs to be organized in ways that reflect differences in learner familiarity with lesson content, the nature of the learning task and assumptions about the structure of knowledge.***
Application 3. Is information presented by audio, video, and text: ❑ in consistent interface conventions, such as windows, links, menus for related ideas? ❑ conceptually linked?	Application 4. Do links between/among nodes go beyond mere random access by providing movement: ❑ from one concept to another? ❑ from broad concept to specific data? ❑ with bottom up or top down hierarchies?
Comments:	Comments:
Principle 5. Knowledge utility improves as processing and understanding deepen.	***Principle 6. Knowledge is best integrated when unfamiliar concepts can be related to familiar concepts.***
Application 5. Does the student have the opportunity to: ❑ reflect? ❑ elaborate?	Application 6. Are familiar visual, procedural, and/or verbal metaphors used for: ❑ lesson content? ❑ system interface?
Comments:	Comments

Principle 7. Learning improves as the number of complementary stimuli used to represent learning content increases.	*Principle 8. Learning improves as the amount of invested mental effort increases.*
Application 7. Do sound, motion, text, and/or pictures present information in a way that: ❑ relates directly to the information? ❑ complements the information?	Application 8. Are learners required to expend mental effort through on screen elements that: ❑ focus their attention by key information shown through diverse ways, such as highlighting? ❑ prompt them to predict, hypothesize, and/or generate new schema?
Comments:	Comments:

Principle 9. Learning improves as competition for similar cognitive resources decreases and declines as competition for the same resources increases.	*Principle 10. Transfer improves when knowledge is situated in authentic contexts.*
Application 9. Is new and challenging information presented: ❑ using familiar multimedia conventions? ❑ without superfluous information?	Application 10. Is information presented in: ❑ authentic, significant contexts?
Comments:	Comments:
Principle 11. Knowledge flexibility increases as the number of perspectives on a given topic increases and the conditional nature of the knowledge is understood.	*Principle 12. Knowledge of details improves as instructional activities are more explicit, while understanding improves as the activities are more integrative.*
Application 11. Are learners helped to: ❑ access data in a variety of ways? ❑ work with data in multiple ways?	Application 12. Is an orientation provided to the new information and its organization through the use of: ❑ pre-questions, objectives, advance organizers, and/or probability statements? ❑ questions posed about the information that is presented?
Comments:	Comments:

Principle 13. Feedback increases the likelihood of learning response-relevant lesson content and decreases the likelihood of learning response-irrelevant lesson content.	*Principle 14. Shifts in attention improve the learning of related concepts.*
Application 13. Are the learners provided with opportunities for making: ❑ ample responses about key concepts? ❑ limited responses for incidental(question-specific) information?	Application 14. Is key data presented to gain attention through: ❑ design elements of highlighting, inverse display, change in color, fonts, and/or arrows? ❑ procedural elements of a graphic overview (map of lesson structure) and/or prompts to relevant options? ❑ repetition throughout the module?
Comments:	Comments

Principle 15. Learners become confused and disoriented when procedures are complex, insufficient, or inconsistent.	*Principle 16. Visual representations of lesson content and structure improve the learner's awareness of both the conceptual relationships and the procedural requirements of a learning system.*
Application 15. Within the module are clear procedures given for ❑ navigating? ❑ accessing support?	Application 16. Are lesson content and structure interrelated by: ❑ concept maps? ❑ graphical organizers?
Comments:	Comments:

Principle 17. Individuals vary widely in their need for guidance.	*Principle 18. Learning systems are most efficient when they adapt to relevant individual differences.*
Application 17. Are learners helped In ways to: ❑ use the multimedia module itself, such as, how to access help or a glossary? ❑ use the multimedia module for learning, such as, feedback that is related to current status, or linked relationships ?	Application 18. Does the module personalize the program: ❑ at a nominal level by asking for learner's name, demographics, and/or preferences? ❑ at an advanced level by focusing on different rates of progress and providing relevant examples? ❑ at a conceptual level by adapting tasks to learners?
Comments:	Comments

Principle 19. Metacognitive demands are greater for loosely structured learning environments than for highly structured ones.	*Principle 20. Learning is facilitated when system features are functionally self-evident, logically organized, easily accessible, and readily displayed.*
Application 19. Can the learner monitor progress and/or learning strategies by: ❑ accessing prompts? ❑ using self-checks? ❑ creating linkages? ❑ asking questions? ❑ reviewing?	Application 20. Are on-screen elements designed to: ❑ simplify learner's use of the module? ❑ help learners assess their progress in learning the concepts?
Comments:	Comments:
Total number of checked items: ❑ **Overall comments:**	

*The Matrix is based on: Park, I. & Hannafin, M. J. (1993). Empirically-based guidelines for the design of interactive multimedia. Educational Technology Research and Development, 43, 3, 63-85. The 20 Principles cited in this document are quoted directly from Park and Hannafin. ETR&D is published by the Association for Educational Communications and Technology the copyright holder. The" Principles" are reprinted in the Matrix with permission of the publisher.

Matrix completed
by_____

Matrix designed by Annette Sherry, Dept. of Educational Technology, College of Education, University of Hawaii at Manoa, 1996

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