Learning from Multiple Representations: Extending Multimedia Learning Beyond the Lab

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Students learned about cell phones by using 18 information cards to complete three homework tasks. Students in the single representation (SR) group received cards that presented all information as printed text. Students in the multiple representation (MR) group received the same information, but each card contained either printed text or an informationally equivalent graphic such as a chart or graph. Students in the MR group performed better than students in the SR group on the accuracy of their homework answers and on the number of cards used during working on the homework tasks. On a subsequent posttest, students in the MR group performed better than students in the SR group both on retention items and transfer items. Homework performance scores were correlated with posttest scores for the MR group but not the SR group. Overall, the results are consistent with the idea that students learn better from multiple representations than from text only, thereby extending multimedia learning principles beyond the lab.

Theoretical Framework

The meaning of information in a multiple-representation (MR) display is driven from the different contributions of both its visual and textual components, each with its various functions due to specific features (Ainsworth, 1999). Cumulative findings suggest that learning with MRs is characterized by: (a) enhanced retention and retrieval of encoded information (Levin, Anglin, & Carney, 1987) according to the theory of dual coding (Clark & Paivio, 1991); (b) increased comprehension of acquired information and improved ability to perform transfer (e.g., Mayer & Gallini, 1990; Mayer & Moreno, 1998; Schnotz & Kulhavy, 1994) due to interactions among the constructed textual and visual mental representations with prior knowledge (Mayer, 2003; Schnotz & Bannert, 2003); (c) difficulties in mapping and integrating MRs. (e.g., Ainsworth, 1999; Yerushalmy, 1991); and (d) performance being affected by spatial contiguity (Mayer, 2003), and split attention (Chandler & Sweller, 1991), which may bring about a high cognitive load (Chandler & Sweller, 1991).

Most prior research has focused on the learning of a simple MR display such as a text accompanied by a single visual representation in controlled lab-like conditions, as compared with learning from text only. We designed our MR and SR (single representation) display to be used in the authentic context of preparing homework assignments and to resemble the richness and complexity of new school textbook designs.

Aim

To investigate students' ability to learn from a rich MR display in the complexity of an authentic context in comparison to learning the same information with single representation (SR) display.

Hypotheses

Learning from a MR display in comparison with learning from text only would:

1) Yield an overall better Task learning performance.
2) Yield an overall better performance concerning retention.
3) Yield an overall better performance concerning ability to transfer the acquired knowledge in the Test performance.
4) Yield a correlation between the number of information sources used and the Test performance.

Method

Participants and Design

The participants were 150 undergraduate students (females n=118; males n=32), ranging in age from 18 to 30 years old. The student were randomly assigned into two groups: multiple representation (MR) group (n=82; Mean age=23.31, SD=2.58, 79% women) and the single representation (SR) group (n=68; Mean age=24.73, SD=5.34, 88% women), with no significant differences in their mean grade point average.

Materials

*SR and MR information card set*s: Eighteen SR information cards, each containing information about cell phones, presented in printed text format, such as exemplified in the appendix.

Eighteen MR information cards contained the same information as a corresponding SR information cards. The pictorial representations contained minimal printed text such as headings, labels, and legends. Each card in each set offered only one representation mode—text or pictorial (See table 1 for the cards information and presentation types).

Table 1: Multiple Representation Card Set (MR) and Textual Representation Card Set (SR) (In number of cards).

SR display	Explanations As printed text 4	Descriptions as printed text 14									**Total 18**
MR display	Explanations As printed text 4	Bar chart 1	Pie chart 1	Flow chart 2	Line graph 1	Drawing 1	Map 1	Photo 2	Computer image 1	Table 4	**Total 18**

The topic of cellular phones was selected because of its relevance and potential interest for individuals. Overall, the cards' information referred to seven major content issues (e.g., the history of this technology, coverage areas)

The information targeted by the various homework task items was presented either on a single card (thus in one mode only) or on several cards (thus in several representation types for the MR group). Card numbering enabled students to report the particular cards they had employed during task performance, thus permitting the analysis to identify the specific information sources utilized by each learner in responding to each item.

Displaying the information on single distinct cards rather than in a fixed arrangement enabled students to benefit from the spatial contiguity effect (Mayer, 2003). Similarly to computer hypertext, our display avoids imposing a linear processing approach.

Homework task sheets. Task 1 contained 4 open-ended questions, which aimed to reveal students' ability to summarize and integrate information across all of the information cards. Task 2 contained 9 statements, which students were asked to verify or refute, indicating their information source. Task 3 contained 18 questions requiring the use of one or more cards to explain a concept, indicate relations, etc.

Posttest. The *Knowledge Retention and Processing Questionnaire (KRPQ),* consisted of 32 multiple-choice items, twelve retention questions and 20 transfer questions.

Procedure

Students were randomly assigned to the SR or MR group. Students were told they would receive a set of information cards that contained all the information they would need for completing homework assignments. The displays constituted a hard copy of either a set of MR cards for the MR group or a set of SR cards for the SR group, which remained at students' disposal while completing three homework tasks. All students received the same three homework tasks, which comprised routine homework assignments for course credit. They submitted each task after a week. The KRPQ was completed individually in the university classroom during class, in the presence of the research assistant, and occurred 2 weeks after completion of task 3 and submission of the information cards.

Data Analysis

The data consisted of the students' written responses to the three tasks and the KRPQ. We performed an initial data reduction on the three homework tasks by coding students' responses for two predetermined criteria: (a) accuracy and (b) number of information cards used (NIC). Regarding accuracy 2 sub-criteria were used (i) incorrect/correct and, for correct responses only, (ii) partial/full comprehensiveness. Average inter-coder agreement of 93% was calculated for a random task sample. KRPQ scores were correct/incorrect. Differences between groups were calculated using *t*-tests. Pearson correlations were calculated for various variables.

Results and Discussion

Do Students Learn Better with Multiple Representations?

Table 2 shows the mean accuracy scores for each of the two groups on the three homework tasks. The mean accuracy score on the three tasks combined was significantly greater for the MR group than the SR group. Similar patterns were obtained on each of tasks individually.

Table 2: Mean Accuracy Score for the MR and SR Groups on the Three Homework Tasks

Group	Accuracy score							
	All 3 tasks combined		Task 1		Task 2		Task 3	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
MR Group	68.6	9.1	9.3	1.8	7.3	1.0	26.3	5.8
SR Group	47.0	12.7	7.6	2.3	6.1	2.1	23.0	5.0
t-test – t(148)	12.10***		5.30***		4.58***		3.62***	
Effect size of d	1.41		0.80		0.71		0.57	

* indicates significant at p < .05; **p < .01; ***p < .001.

Table 3 shows the mean number of information cards used (NIC score) for each of the two groups on the three homework tasks. The mean NIC score on the three tasks combined was significantly greater for the MR group than the SR group. Similar patterns were obtained on each of the tasks individually.

Table 3: Mean NIC Score for the MR and SR Groups on the Three Homework Tasks

Group	NIC score							
	All 3 tasks combined		Task 1		Task 2		Task 3	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
MR Group	34.7	5.3	8.0	8.0	n/a		26.7	4.5
SR Group	31.9	5.8	7.2	3.2	n/a		24.7	4.4
t-test – t(148)	3.04**		1.88*		n/a		2.64**	
Effect size of d	0.49		0.31		n/a		0.43	

* indicates significant at p < .05; **p < .01;

Table 4 shows that the mean posttest score (i.e., KRPQ score) f the MR group were significantly higher than the SR group on overall 32-item KRPQ score. On both the 12 retention items and 20 transfer items, the MR group scored significantly higher than the SR group.

Table 4: Mean Posttest Score (KRPQ) for the MR and SR Groups

Group	All items (n = 32)		Retention items (n = 12)		Transfer items (n = 20)	
	M	*SD*	*M*	*SD*	*M*	*SD*
MR Group	25.7	4.0	6.2	1.7	13.5	2.6
SR Group	17.2	4.0	5.6	1.8	11.7	3.0
t-test – t(148)	13.10***		2.01*		3.86***	
Effect size of d	2.12		0.33		0.61	

* indicates significant at $p < .05$; ***$p < .001$.

Overall there is consistently evidence that students learned better when given information in multiple formats rather than solely in text format.

Is Homework Performance Related to Posttest Performance?

Table 5 summarizes the Pearson correlations between scores on the three homework tasks and scores on the posttest (i.e., KRPQ).

Table 5: Pearson Correlations between Scores on the Homework Tasks and Scores on the Posttest

Homework task score	Posttest score	MR Group	SR Group
Accuracy	Total score on KRPQ	.74*	ns
Accuracy	. Retention score on KRPQ	53*	ns
Accuracy	Transfer score on KRPQ	.68*	ns
NIC	Total score on KRPQ	.39*	ns
NIC	Retention score on KRPQ	ns	ns
NIC	Transfer score on KRPQ	.39*	ns

* indicates significant at $p < .05$.

The presented pattern of results is consistent with the idea that effort during learning was related to subsequent performance on a posttest mainly for the group that received multiple representations but not the group that learned with text-only representations. It seems that the rich, diverse representations in the MR group (presenting different cards regarding the same issue) made the cards' information more distinct than did the fluent text of the SR group thus granting the former an advantage.

Conclusion

Generally, the present study corroborated prior findings from limited displays in controlled lab-like conditions, despite the differences between the present and prior research designs. The MR group outperformed the SR group concerning all three tasks – together and separately, as well as concerning the KRPQ overall and its retention and transfer parts.

The rich variety of representation-types seemed to affect knowledge construction in several ways. The diverse, distinct MRs seemed to afford students the ability to easily notice and identify certain bits of information within the whole display, thus facilitating these students' usage and manipulation of larger amounts and more varied types of information, as compared with the SR group students who noticed less information based on the fluent unitary text only display. It seems that the high diversity of visual representations served as an external organizer of the considerable amount of information presented in the whole display.

Theoretical and Practical Implications

By the use of three conditions (i.e., display richness, authenticity of environment and a long-term task characteristic) we extended the multimedia learning principles beyond the lab. The importance of our findings lies in the current recognition that learning, knowledge, and context are inseparable (Barab & Squire, 2004). Conducting the study in a "noisy" learning context while attending to several variables concurrently and focusing on the authentic situation as a whole is especially important in current educational systems, where inquiry and project learning modes are enacted (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004).

Our findings suggest that students may benefit from current textbooks designs. Some limitations may emerge from the advantages of the "massy research" as it is applied in the authentic context.

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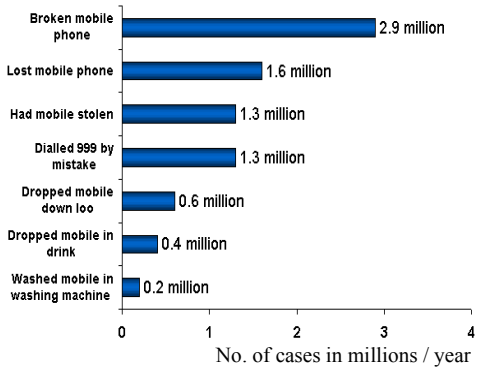
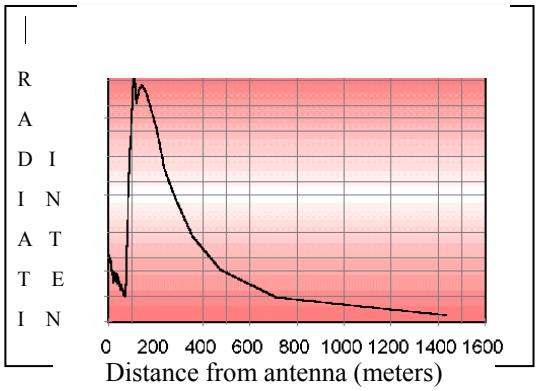
Appendix 1: Examples of Cards: Multiple versus Textual Representation Twin Cards

Multiple Representation Display

Card 3: Visual representation



Card 11: Visual representation



Card 7: Explanations as printed text

7-1 The cellular phone roots back to the 1940s when commercial mobile telephones began. This mobile wireless hasn't progressed further in the last 60 years as did other technologies. For example, we don't have low cost video watch phones. Some of the reasons for this delay were technology and federal regulations.

7-2 The wireless revolution began only after low cost microprocessors and digital switching became available.

7-3 The regulations of the Federal Communications Commission, who controlled frequencies, constituted the most significant factors hindering telephone development, especially the cellular type, delaying that technology in America by years. It took even longer in Europe and Japan. The first commercial cellular telephone systems started in Bahrain, Tokyo, Osaka, and Mexico City.

Textual Representation Display

Card 3: Descriptions as printed text

Broken mobile phones - 2.9 million
Lost mobile phones - 1.6 million
Had mobile stolen - 1.3 million
Dialed 999 by mistake - 1.3 million
Dropped mobile down toilet - 0.6 million
Dropped mobile in drink - 0.4 million
Washed Mobile in washing machine - 0.2 million

No. of cases in millions / year

Card 11: Descriptions as printed text

A line goes through the following points in a 2-axes graph: It starts at a distance of sixty meters from the antenna and a very low radiation intensity; the line rises sharply and reaches a maximum intensity at about one hundred meters' distance from the antenna; the line continues down gradually and reaches average radiation intensity at about four hundred meters from the antenna; The line reaches a low intensity at a distance of eight hundred meters, and is reaching a close to zero radiation at a distance of one thousand and four hundred meters from the antenna.

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