World Transactions on Engineering and Technology Education
Vol.4, No.2, 2005

A new evaluation for integrating multimedia technology with science: student performance in mathematical limit learning

King-Dow Su & Ming-Quey Lee

De Lin Institute of Technology
Taipei, Taiwan

ABSTRACT: The purpose of this study is to investigate the performance of using multimedia technology in the teaching of the mathematic limit field. Two classes of undergraduate students (n=96) participated in the process of this study. The experimental group was taught with abundant multimedia supplementary materials, including conceptual computer *Flash* animations, *Mathematica* static figures, *PowerPoint* bulletins and *e-plus* software computer-based instructions. The control group was taught as usual, using a regular mathematical textbook. After four weeks of learning, and the statistical procedures of the analysis covariance, it was found that the students of experimental group outperformed their counterparts in their mathematical problem-solving ability. The learning attitude of one-way ANCOVA for the experimental group students, indicates their significant differences in their variant of fondness, where *very like* is better than *dislike* in aspects S_1, S_2, S_4, and S_5 in Scheffe's post comparison.

INTRODUCTION

In this era of the knowledge economy, the best and dominant approach of science is through new multimedia technology to emphasise active, direct and developmental information. Multimedia texts, the combination and presentation of characters, graphics, animations and sound effects, attract students' eyesight, stimulate their learning motivation levels, and make for effective and improved learning [1][2].

Many researchers have pointed out the potential benefits of integrating teaching into science, such as the benefits of multimedia and those of science history [3-6]. Other benefits include greater efficiency in facilitating the mastery of scientific concepts and processes, and the learning attitudes of students. A recent methodology to propose computer-based learning helped facilitate students acquiring the basic abilities in technology and information, while also exploring mathematical fields, engaging in independent thinking and fulfilling career programme and life-long learning [7].

Many researchers have addressed questions about why multimedia can promote students' conceptual understanding [8][9]. Mayer and his colleagues have raised a generative theory of multimedia design [10-12]. This theory proposes that materials facilitate the integration of multimedia information in the selection, organisation and design of instructions. Russell et al claim that combining computer-based technology in teaching science expands the means of visualising phenomena, whether fast or slow, and that such visualisations could help students to overcome their alternative conceptions [13]. Burk et al consider that, after instructors take the time to emphasise the particulate nature of matter and conceptual issues through computer-based animations, students will increase their understanding and performance on conceptual examination questions [14]. Thompson and Riding point out that the animated diagram of a mathematical demonstration facilitates the understanding of 11-14 year-old pupils [15].

Although multimedia has been a subject of study for a long time, there is little agreement as to how it facilitates scientific learning. Rieber makes a study of elementary school children on Newton's laws, who concluded that animation did not facilitate learning [16]. Sperling, Seyedmonir, Aleksic and Meadows argue that due to inconsistent findings regarding the benefits of multimedia, authentic instructional science materials are needed to facilitate appropriate design decisions [17]. Lin and Dwyer show that animations are not cost effective, nor an effective strategy, for improving students' achievements in the knowledge acquisition of objectives employed in their Web-based instruction [18]. Lai indicates that animations do not facilitate the recall of learning analogies in computer languages [19].

Recent advancements in computer technology have allowed educators to incorporate textual, visual and aural resources into a profound computer-mediated program [20]. Computer-based technology provides powerful means for fostering scientific understanding, because it can represent multilevel science thoughts. Malcolm argues that successful science education provides a background in science and that scientific learning gives students' greater confidence to participate in advanced studies [21]. He suggests that, if this background is lacking, then the confidence to participate further in science education will be essentially determined by family and social influences, which could be negative or inequitable. Konradt advocates that multimedia computer-based learning is important, not only in scholarly, but also in vocational contexts [22]. It has several advantages over traditional forms of training, such as user-driven learning, just-in-time learning, just-in-place learning and self-place-learning, and has a high level of cost efficiency.

Researchers have shown that mathematical teaching using computer environment can improve students' understanding of mathematics [23]. A multimedia learning environment can promote constructive learning that, in turn, enables students' problem-solving abilities to be easily handled [24].

The purpose of this study is designed to investigate the effectiveness of integrating multimedia technology into mathematical teaching and to focus on students' conceptual understanding and scientific application in the experimental group. The traditional ability of algebra will not be emphasised in this computer-based study.

METHODOLOGY

Research Sample

This study took 96 undergraduate students from the Department of Business Management as a demonstration sample, who participated in the performance evaluation of the second author's classes.

Two classes of students with similar academic achievements were selected, and randomly assigned one class as the experimental group (n=46) and the other one as the control group (n=50). The experimental group received incorporated instruction in multimedia technology, while the control group received regular textbook instruction.

Research Tools

This study included various achievement post-tests of conceptual problems and a learning attitude questionnaire. The achievement post-tests of content validity were established by the College Entrance Examination Center in Taiwan and three well-regarded professors. The post-test was composed of ten concept questions in the College Entrance Examination Center. The contents of the post-test included three knowledge questions, five rationalisation questions and two application questions. The reliability of achievement test was assumed from the observation of consistency in the examination scores from the different semesters. This gave a judgement of the learning results from the two groups. A short, simple test was created for this study to investigate students' performance in the experimental and control groups on mathematical limitations for conceptual and problem-solving questions.

The learning attitude questionnaire was headed and developed by Dr Su [6]. This questionnaire took the score of five Likert-type grades, with each item given plus scores [25]. The questionnaire indicates both good validity and high reliability, and included the following six aspects:

- Learning attitude towards incorporated courses (S_1);
- Learning attitude towards teachers (S_2);
- Learning environment towards multimedia (S_3);
- Attitude towards students (S_4);
- Attitude towards self-evaluations (S_5);
- Learning results (S_6).

The questionnaire employs a Cronbach's α coefficient (internal consistency) to check reliability. Table 1 lists the results of the reliability analysis, with all six α coefficients between 0.89 and 0.92. As such, this questionnaire has higher reliability compared to average pedagogical reports [26].

Table 1: Reliability of the questionnaire.

Aspect	S_1	S_2	S_3	S_4	S_5	S_6
Cronbach's α	0.91	0.91	0.90	0.89	0.89	0.92

Treatments

The supplementary materials for the multimedia learning environment were developed by the authors of this article.

Figures 1-6 show the conceptual limit animations, with graphs of function *f*(x) at point *a*,

$$\lim_{X \to a} f(x) = L \quad .$$

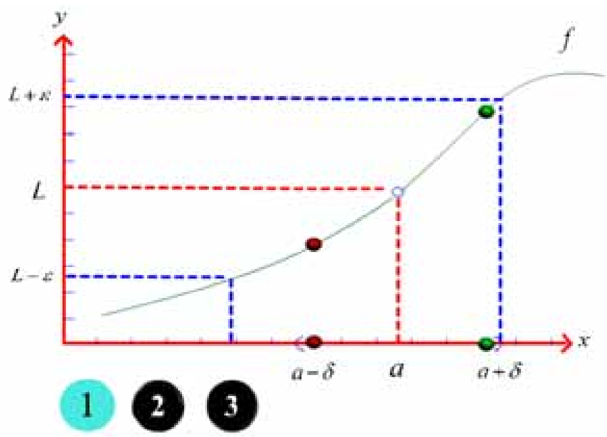

Figure 1: Conceptual limit animation with graph (a).

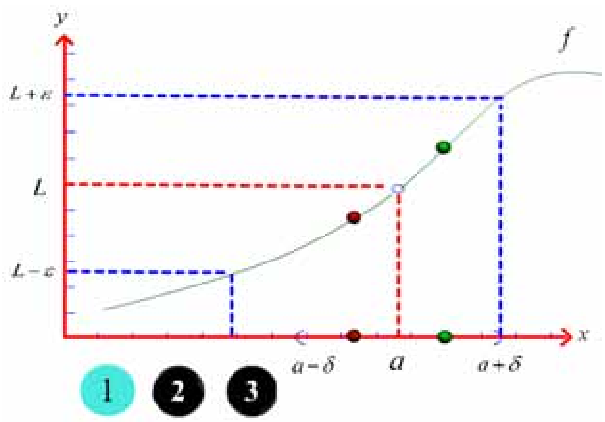

Figure 2: Conceptual limit animation with graph (b).

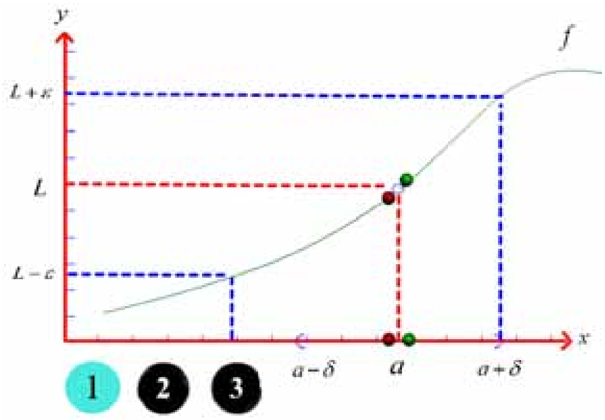

Figure 3: Conceptual limit animation with graph (c).

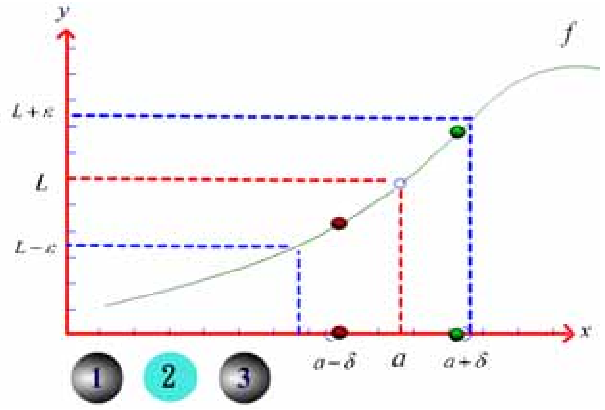

Figure 4: Conceptual limit animation with graph (d).

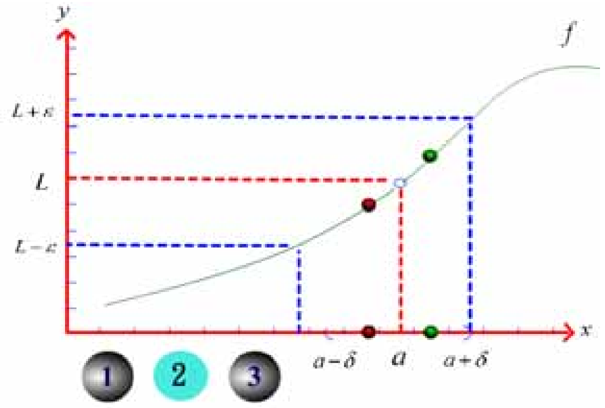

Figure 5: Conceptual limit animation with graph (e).

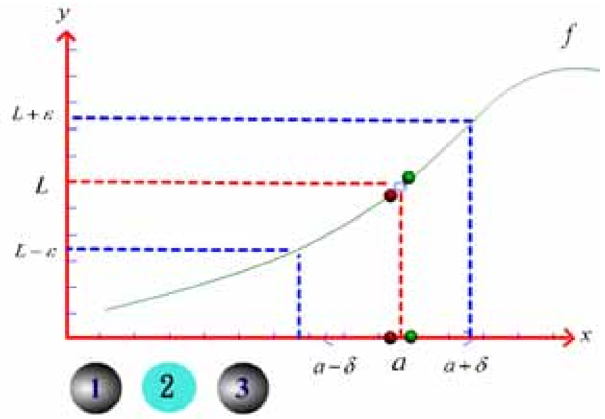

Figure 6: Conceptual limit animation with graph (f).

The computer animations figures were devised using *Flash MX* (Macromedia) and static figures generated by using *Mathematica 4.2* (Wolfram Research), with demonstrations presented in *PowerPoint* bulletins and *e-plus* software in the classroom. An attempt was made to emphasise the development of mathematical concepts for the experimental group's instruction. The conceptual animations in Figures 1-6 were treated using Adobe *Photoshop* 7.01.

Data Management and Analysis

All statistical information was analysed using *SPSS* software for Windows 10.0, with the significance levels of each test being the 0.05 level. Various statistical methods were utilised, such as mean value, standard deviation, one-way ANCOVA and Scheffe post comparison.

RESULTS AND DISCUSSIONS

In order to examine the differences between the experimental group and control group, the focus was on the post-test achievements on the effect of multimedia learning. Table 2 shows that the mean achievement is quite different for the two groups. The experimental group average score was 80.33, while the control group averaged 72.00. The standard deviation showed about 19% difference.

Table 2: Means and standard deviations of the post-test.

Group	Person	Mean	Standard Deviation
Experimental	46	80.33	14.31
Control	50	72.00	14.29

To examine the efficiency of multimedia learning, an analysis of covariance was used to compare the different post-test scores between the two groups. Table 3 shows the ANCOVA results. A significant difference was found in the test results for multimedia learning efficiency ($p<0.05$) between the experimental group and the control group.

Table 3: ANCOVA results of the post-test.

Source of Variance	df	SS	MS	F	P
Section	1	1660.88	1660.88	8.12	0.005
Intersection	94	19220.11	204.46		
Total	95	20880.99			

An analysis of ANCOVA was used to investigate the multimedia learning attitude of the experimental group students. Table 4 represents different degrees of *fondness* of multimedia technology; the mean value of each aspect indicates a positive learning attitude. Table 4 yields values for four different aspects: namely:

- Students' learning attitude (S_1) ($F=4.225$, $p<0.05$);
- Teacher's attitude (S_2) ($F=3.563$, $p<0.05$);
- Attitude towards students (S_4) ($F=3.819$, $p<0.05$);
- Attitude towards self-evaluation (S_5) ($F=3.995$, $p<0.05$).

All four aspects show significant differences, where *very like* is better than *dislike* for aspects S_1, S_2, S_4 and S_5 in Scheffe's post comparison. Other aspects do not show any significant differences. In addition to *fondness*, the other co-variants – enrolments, master computer multimedia and attend class or not – no obvious difference was found in the one-way ANCOVA analysis. These results imply that multimedia may help students acquire a better understanding of targeted mathematical limit concepts, and that the learning attitude should be a further catalyst.

The fruitful result of integrating multimedia into mathematic teaching in this study is encouraging and helpful. Previous research has found that the abundance of multimedia materials and significant efforts to help students to have a better conceptual understanding of chemistry and physics [3][8][9].

This study explored the level of efficiency in integrating multimedia technology into mathematical teaching. It was found that this study created a significant positive contribution towards students' learning in, and understanding of, mathematics.

Table 4: ANCOVA of the experimental students' fondness of multimedia learning attitude.

Aspect	Variant*	N	M	SD	Analysis of Variance					
					Source	Df	SS	Ms	F	Scheffe
S_1	1.00	5	29.40	4.72	Section	3	322.05	107.35	4.225**	1>4
	2.00	19	22.68	5.87	Intersection	36	914.72	25.41		
	3.00	12	22.33	3.53	Total	39	1236.77			
	4.00	4	17.75	4.79						
	Total	40	22.92	5.63						
S_2	1.00	5	18.60	2.88	Section	3	110.97	36.99	3.563**	1>4
	2.00	19	15.74	3.57	Intersection	36	373.80	10.38		
	3.00	12	14.42	2.57	Total	39	484.78			
	4.00	4	12.00	3.56						
	Total	40	15.32	3.53						
S_3	1.00	5	10.00	1.23	Section	3	11.83	3.94	0.655	
	2.00	19	8.79	2.84	Intersection	36	216.58	6.02		
	3.00	12	8.67	2.35	Total	39	228.40			
	4.00	4	7.75	1.26						
	Total	40	8.80	2.42						
S_4	1.00	5	18.40	1.34	Section	3	150.27	50.09	3.819**	1>4
	2.00	19	16.26	2.86	Intersection	36	472.13	13.12		
	3.00	12	15.75	4.92	Total	39	622.40			
	4.00	4	10.50	4.12						
	Total	40	15.80	3.99						
S_5	1.00	5	17.60	2.88	Section	3	122.88	40.96	3.995**	1>4
	2.00	19	15.00	3.50	Intersection	36	358.87	10.25		
	3.00	12	14.92	3.00	Total	39	481.74			
	4.00	4	10.25	2.50						
	Total	40	14.82	3.56						
S_6	1.00	5	22.60	4.22	Section	3	109.65	36.55	1.109	
	2.00	19	21.58	6.51	Intersection	36	1186.25	32.95		
	3.00	12	20.83	5.39	Total	39	1295.90			
	4.00	4	16.25	3.30						
	Total	40	20.95	5.76						

*1.00 shows *very like*, 2.00 shows *like*, 3.00 shows *insensitive*, and 4.0 shows *dislike*.
** $p<0.05$.

As mentioned above, this study is exploratory in nature, regarding the potential benefits of integrating multimedia in the teaching of mathematics. Despite the statistical significance of the results, readers are reminded that the samples in this case study are limited and the researchers cannot implement an extremely wide scope. Continuing efforts are needed to confirm this further approach in order to fulfil the benefit of this teaching in the future.

CONCLUSIONS

In summing up this study, the following conclusions were obtained:

- It is helpful for student learning that animations, literature, images and sounds be combined with teaching, and to have a concrete understanding from the abstract limit of purely text;
- The incorporation of multimedia teaching is validated by more effective learning.

Generally speaking, it was found in this study that only by incorporating multimedia technology into mathematics teaching can students' learning abilities be enhanced and their performance in multimedia technology be upgraded.

ACKNOWLEDGEMENT

A short but sincere thank-you must be given to the patronage of the Ministry of Education, research project No. B-91-FDE9-3, without whose help this study could not have otherwise been completed.

REFERENCES

1. Moore, R. and Miller, I., How the use of multimedia affects student retention and learning. *J. of College Science Teaching*, February, 289-293 (1996).
2. Rieber, L.P., Animation as feedback in a computer-based simulation: representation matters. *Educational Technology Research and Development*, 44, 5-12 (1996).
3. Su, K.D., An assessment of multimedia as effective learning tools – dynamic factors in students' learning attitudes of general chemistry. *Inter. J. of Instructional Media*, 34, **4** (in press).
4. Mayer, R.E., Bove, W., Bryman, A., Mars, R. and Tapangco, L., When less is more: meaningful learning from visual and verbal summaries of science textbook lessons. *J. of Educational Psychology*, 88, **1**, 64-73 (1996).
5. Lin, H.S., Hung, J.Y. and Hung, S.C., Using the history of science to promote students' problem-solving ability. *Inter. J. of Science Educ.*, 24, **5**, 453-464 (2002).

6. Solomon, J., Duveen, J., Scot, L. and McCarthy, S., Teaching about the natures of science through history: action research in the classroom. *J. of Research in Science Teaching*, 29, **4**, 409-421 (1992).
7. Chang, K.E., Sung, Y.T. and Chen, S.F., Learning through computer-based concept mapping with scaffolding aids. *J. of Computer Assisted Learning*, 17, 21-33 (2001).
8. Ardac, D. and Akaygun, S., Effectiveness of multimedia-based instruction that emphasizes molecular representations on students' understanding of chemical change. *J. of Research in Science Teaching*, 41, **4**, 317-337 (2004).
9. Kiboss, J.K., Impact of a computer-based physics instruction program on pupils' understanding of measurement concepts and methods associated with school science. *J. of Science Educ. and Technology*, 11, **2**, 193-198 (2002).
10. Mayer, R.E., Systematic thinking fostered by illustrations in scientific text. *J. of Educational Psychology*, 81, 240-246 (1989).
11. Mayer, R.E., A generative theory of textbook design: using annotated illustrations to foster meaningful learning of science text. *Educational Technology Research and Development*, 43, 31-43 (1995).
12. Mayer, R.E. and Anderson, R.B., The instructive animations: helping students build connections between words and pictures in multimedia learning. *J. of Educational Psychology*, 84, 444-452 (1992).
13. Russell, J.W., Kozma, R., Jones, T., Wykoff, J., Merx, N. and Davis, J., Use of simultaneous-synchronized macroscopic, microscopic, and symbolic representations to enhance the teaching and learning of chemical concepts. *J. of Chemical Educ.*, 74, 330-334 (1997).
14. Burke, K.A., Greenbowe, T.J. and Windschitl, M.A., Developing and using conceptual animations for chemistry instruction. *J. of Chemical Educ.*, 75, 1658-1661 (1998).
15. Thompson, S.V. and Riding, R.J., The effect of animated diagrams on the understanding of a mathematical demonstration facilitates the understanding in 11-14 year old pupils. *British J. of Educational Psychology*, 60, **1**, 93-98 (1990).
16. Rieber, L., Using computer animated graphics in science instruction with children. *J. of Educational Psychology*, 82, 135-140 (1990).
17. Sperling, R.A., Seyedmonir, M., Aleksic, M. and Meadows, G., Animations as learning tools in the authentic science materials. *Inter. J. of Instructional Media*, 30, **2**, 213-221 (2003).
18. Lin, C.L. and Dwyer, F., Effect of varied animated enhancement strategies in facilitating achievement of different education objectives. *Inter. J. of Instructional Media*, 31, **2**, 185-194 (2004).
19. Lai, S.L., The effects of visual display on analogies using computer-based learning. *Inter. J. of Instructional Media*, 25, **2**, 151-160 (1998).
20. Lai, S.L., Influence of audio-visual presentations on learning abstract Concepts. *Inter. J. of Instructional Media*, 27, **2**, 199-206 (2000).
21. Malcolm, C., Trends in school science curriculum and their implications for teacher education. *Discipline Review of Teacher Educ. in Mathematics and Science*, 3, 163-169 (1989).
22. Koarndt, U., Hypermedia in vocational learning: a hypermedia learning environment for training management skills. *Inter. J. of Instructional Media*, 31, **2**, 175-184 (2004).
23. House, J.D., Motivational qualities of instructional strategies and computer use for mathematics teaching in Japan and the United States: Results from the TIMSS 1999 assessment. *Inter. J. of Instructional Media*, 32, **1**, 89-101 (2005).
24. Mayer, R.E., Multimedia aids to problem-solving transfer. *Inter. J. of Educational Research*, 31, 611-623(1999).
25. Likert, R., A technique for the measurement of attitudes. *Archives of Psychology*, 140, 5-53 (1932).
26. Katerina, S. and Tzougraki, C., Attitudes toward chemistry among 11th Grade Students in High Schools in Greece. *Science Educ.*, 88, 535-547 (2004).