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Use of Animation to Display Math Problems on Computer-Based Test

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Abstract: This research is an attempt to use animation to display complex math problems on computer-based testing. To translate math problem into mathematical expression is one of the key factors in math. However, examinees who cannot understand the literal meaning of the sentence will not be able to express it mathematically, even if they have the necessary mathematical skills. To solve this problem, this research explores the possibility of using animation for delivering math problems to examinees. This paper describes an experiment carried out with 19 college students using 4 different complex math problems, delivered either in all-text mode or in all-animation mode, to examine whether the modes affects in understanding the math problems. The result indicates that although the students felt it easier to understand the math problem from the all-animation mode, there were no significant differences in the test scores, between 2 modes.

Background

Math vocabularies are not commonly used in daily settings (Fillmore 2007), and sometimes they are highly complex and very specific (Brown 2005). According to the research based on No Child Left Behind Act (NCLB) yearly progress, the performance difference between ELL (English Language Learner) students and FEP (Fully English Proficient) student was greater for tests of analytical math that contained linguistically complex items than for computational math (Abedi 2004).

These researches indicate that students who cannot understand the literal meaning of the sentence will not be able to express it mathematically, even if they have the necessary mathematical skills. There are approaches such as using automated language translation specific for math to provide the same math problems in multiple languages (Caprotti 2006), or prepare linguistically simple items to solve the language differences and difficulty (Abedi & Lord 2001). However, a new method of delivering math problems should be considered to measure mathematical literacy independently from reading literacy.

Use of Animation in Math

As computer-based testing has been widely spread for various ages, this research focused on an animation-based explanation to set math problems, as an alternative to text. Animations or movies are often used in mathematics education to share the scenario of the math problem (e.g. Grincewicz, Diehl & Zydney 2009), or to visualize the formula for better understanding (e.g. Poohkay & Szabo 1995). These researches and approaches use animations for teaching supplements, and rarely used for testing. Therefore, they are not required to explain everything about the math problem with animation, often with teacher's explanations or some sentences.

The goal of this research is to display math problems only with animation, without depending on sentences. To examine whether the modes affects in understanding the math problems, the following experiment had measured examinees' cognitive loads while solving the test by questionnaire, and the score differences between the modes.

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Experiment

Prepared Math Problems

For the experiment, 4 math problems, Q1 to Q4, were prepared in both Japanese text and in short animation, as shown in figure 1. The math problems prepared for this experiment are as follows:

Q1: Solid figure: drawing a solid figure and measuring the depth of water inside.
Q2: Speed: moving balls in counter directions in different speed ratio.
Q3: Multiplications: amount of 2 different thicknesses of papers foldable in a binder.
Q4: Plain figure: drawing and tracking the movement of a plain figure.

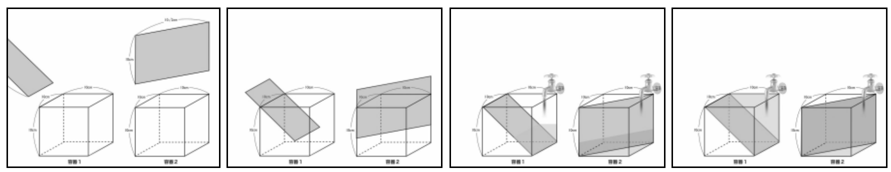
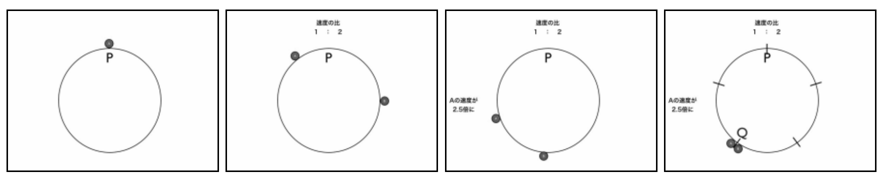
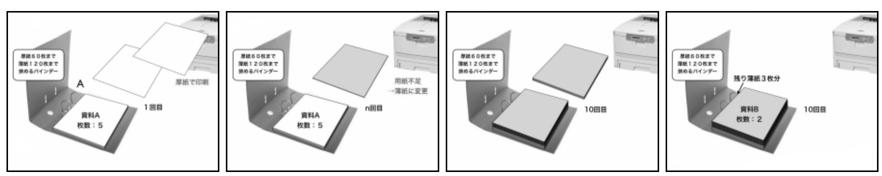
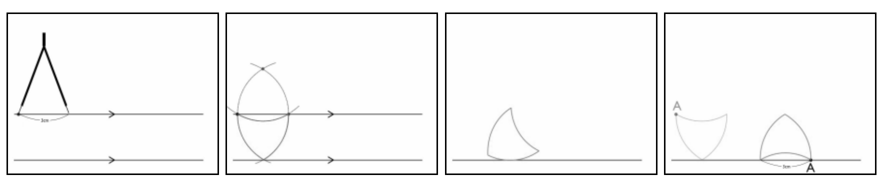
Text	Animation
2432 characters	 8.40 seconds
185 characters	 11.26 seconds
224 characters	 25.20 seconds
205 characters	 18.06 seconds

Figure 1: Math Problems

While many researches (e.g. Taylor *et al.* 2009) have shown the importance of interaction to the contents, or some mechanism to force learners to watch the contents actively, this research focused on one-way animation without any playback controlling functions such as pausing, during its playback. The reasons for this decision are; 1) because the contents are used for testing, and not for educational materials to support learners' understand, their main goal is to let the examinees to understand what was described, or shown, to start solving the math problem, and 2) to evaluate the characteristics of animation that shows multiple phenomena simultaneously, while text shows multiple phenomena linearly.

Experiment Settings

Subjects were 19 college students (10 males and 9 females). Each subject has a 15-inch notebook PC with Windows XP Professional SP2 and QuickTime 7.6, and a set of papers for answer sheet and questionnaire for each math problem (see figure 2). Animation was created with Keynote '09, a slideshow application by Apple, which has a simple animation function. Both text-based and animation based math problems are combined as a QuickTime Presentation File for each subject, and shown on the computer screen.

Subjects were given 4 math problems, 2 animation-based and 2 text-based in combinations, alternately with no overlap among subjects. Subjects have 7 minutes for each math problem, and were required to draw or write down; 1) how they understand the math problem, 2) answer to the math problem. As the latter part, answering the math problem depends on each subject's math knowledge, this experiment focuses on the former part, how they understand the math problem, to see how display modes effect when the math problems were provided.

When the animation mode was given, subjects are allowed to playback the animation twice, whenever they click on "play" button on the screen, in the given 7 minutes. And for the text mode, the text is shown on the screen for the whole 7 minutes.

	7 min	3 min	7 min	3 min	7 min	3 min	7 min	3 min
Animation first	Q1 (animation)	Questionnaire	Q2 (text)	Questionnaire	Q3 (animation)	Questionnaire	Q4 (text)	Questionnaire
Text first	Q1 (text)	Questionnaire	Q2 (animation)	Questionnaire	Q3 (text)	Questionnaire	Q4 (animation)	Questionnaire

Table 1: Experiment Timeline

Figure 2: Experiment Environment

Results

Questionnaire Results

In the questionnaire, which was given after the exam, subjects were asked about their impressions for each math problem. As shown in Table 2, there were no significant differences in cognitive loads (pace making, load of eyes, concentration, comfort) between the display modes and the math problems.

Source	df	SS	MS	F
Display Mode (D)	1	0.46	0.0234	0.8789
Math Problem (Q)	3	128.12	2.1530	0.1015
D x Q	3	60.72	1.0205	0.3890
Residual error	69	1368.64	19.84	

** $p<0.01$, * $p<0.05$.

Table 2: The results of a two-way ANOVA: cognitive loads

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Table 3 shows that the subjects felt more difficult when they solve the problems in text ($F(1,69) = 4.7707$, $p<.05$), and there were no significant differences in impression of difficulty between the problems. Figure 3 shows the impression of difficulty between the modes in each problem. There are significant differences in Q1, Q2 and Q4 and no significant difference in Q3 when compared between the modes.

Source	df	SS	MS	F
Display Mode (D)	1	45.95	45.95	4.7707*
Math Problem (Q)	3	31.67	10.56	1.0959
D x Q	3	26.94	8.98	0.9323
Residual error	69	664.66	9.63	

** $p<0.01$, * $p<0.05$.

Table 3: The results of a two-way ANOVA: impression of difficulty

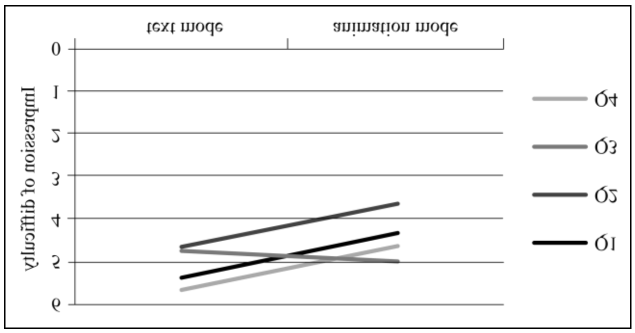

Figure 3: Differences in impression of difficulty by display mode

Score Results

Rubric scoring sheet for each math problem were created for rating the subjects' answers. The rubric covers the cognitive process of understanding the math problem, which is done before start solving the math problem mathematically. Taking Q3 as an example, the following sentences shows the text-based mode of the math problem and its scoring rubric for the rating.

Given math problem:

Two balls, A and B, start moving along the circumference of a big circle. Ball A moves counter-clockwise and Ball B moves clockwise from the same point P. The relative speed ratio of Ball A and Ball B is 1:2. On the way, Ball A increases its speed by 2.5 times, and met Ball B in one minute at the point Q. Towards the point Q, Ball B moved a distance of 3/5 of the circle. You can assume that two balls have negligible quantity. Obviously the point P and the point Q is on the circumference of a big circle.

Given questions:

(1) Read the sentences and describe how these two balls moved, by words or figures.
(2) How long did it take for Ball B to move from point P to point Q?

Scoring rubric for question (1):

(1) 2 balls are moving counter directions along the circumference of a big circle.
(2) Ball A moves counter-clockwise and Ball B moves clockwise
(3) Ball A increases its speed by 2.5 on the way.
(4) The relative speed ratio of Ball A and Ball B is 1:2.
(5) Ball B moved a distance of 3/5 of the circle when Ball A and Ball B meets on the way.

Based on the score rated with the rubric, Q4 has marginal significance ($t(17)=-1.723, p<.1$), and Q1- Q3 have no significant difference between 2 modes (Table 4).

	Text		Animation		Differences
	X	SD	X	SD	
Q1	0.352(n=9)	0.183	0.333(n=10)	0.307	-0.019
Q2	0.733(n=9)	0.189	0.66(n=10)	0.369	-0.073
Q3	0.633(n=10)	0.194	0.667(n=9)	0.36	0.034
Q4	0.429(n=10)	0.394	0.73(n=9)	0.319	0.301 +

+ p<0.1.

Table 4: Score differences

Discussion

An experiment shows the result which indicates that although the students felt it easier to understand the math problem in all-animation mode, there were no significant differences between all-text mode and all-animation mode, from the test score.

As the animation mode allows subjects to pass the cognitive process to translate from text into image, a hypothesis was set that the animation mode has an advantage in both impression of difficulty and the score result. On the contrary to this assumption, the result shows no significant differences between 2 modes. This may relate to the characteristics of animation, which is often said when they are used for teaching; animations are more understandable compared to texts, however, they tend to remain learners passive.

The animation of Q3, which didn't show a significant difference in impression of difficulty between the modes, may occurred because of the longer duration, and the structure of the animation was relatively similar to the linearity of the text mode.

Conclusion and Future Works

This research is an attempt to use animation to display complex math problems on computer-based testing. An experiment was carried out to examine whether the modes affects in understanding the math problems. The result indicates that although the students felt it easier to understand the math problem in all-animation mode, there were no significant differences from the test score, between all-text mode and all-animation mode.

Although the results show no significant differences in understanding, it might depend on subjects' attitudes or the characteristics of the math problems. However, the experiment indicates the possibility of displaying math problems in animation as an alternative to text.

As future works, 1) classification of math problems that are suitable for animation mode, 2) animation player with playback controlling function for interactivity and active watching, and 3) relations between the subjects' characteristics and the display modes, can be considered.

References

Abedi, J. (2004) "The No Child Left Behind Act and English Language Learners: Assessment and Accountability Issues", *Educational Researcher*, vol.33(1), pp.4-14

Abedi, J. & Lord, C. (2001) "The Language Factor in Mathematics Tests", *Applied Measurement in Education*, vol.14(3), pp.219-234.

Blyth, B. & Naim, A. (2000) "Problem Solving using Maple Animations" Mathematics Subject Classification", in *Proc. 6th Asian Technology Conference in Mathematics*, pp.273-281.

Brown, C.L. (2005) "Equity of Literacy-Based Math Performance Assessments for English Language Learners", *Bilingual Research Journal*, vol.29(2), pp.337-363.

Caprotti, O. (2006) "WebALT! Deliver Mathematics Everywhere", in *Proc. Society for Information Technology and Teacher Education International Conference 2006*, pp.2164-2168

Fillmore, L. W. (2007) "English Learners and Mathematics Learning: Language Issues to Consider", in Schoenfeld, A. S. Ed., *Assessing Mathematical Proficiency*, Cambridge University Press.

Grincewicz, A., Diehl, L. & Zydney, J.M. (2009) "Learning from Examples: Animated Help Tools within a Mathematical Learning Game", in *Proc. World Conference on Educational Multimedia, Hypermedia & Telecommunications 2009*, pp.3592-3596.

Poohkay, B. & Szabo, M. (1995) "Effects of Animation & Visuals on Learning High School Mathematics", *Annual Meeting of the Association for Educational Communications and Technology*, (ERIC NO: ED380122)

Taylor, D. S., Lurie, A. F., Horstmenn, C. S., Johnson, M. B., Sharma, S. K., & Yin, E. C. (2009) "Predictive vs. passive animation learning tools", In Proc. *40th ACM technical symposium on Computer science education*, pp.494-498.