Using Computer Animation in Science Instruction for the Study of Misconception Correction

Ming-Gong Lee
mglee@chu.edu.tw
Department of Applied Mathematics
Chung Hua University, Hsin Chu, Taiwan, R.O.C

Hui-Hua Gu
huihua_069@yahoo.com
Chung Hua University, Hsin Chu, Taiwan, R.O.C

Abstract: The effect of computer animation developed by Interactive Physics – an easy-to-use computer software with friendly graphic user interface, was studied in a science lesson involving 201 ninth grade students. Both pre-test and posttest problems were chosen mostly from the Force Concept Inventory with emphasis in the fields including, Kinematics, the Newton Second Law, superposition principle, and gravitation. Results show three conclusions: a. Students given by traditional instruction and computer animation instruction do not have significant difference of the statistics in the pre-test.; b. Students given by computer animation instruction perform much better at the posttest than students instructed by traditional teaching; c. Students instructed by traditional teaching do make progress at the posttest and makes significance difference in the statistics, but the progress is very limited compared with student instructed by computer animation instruction. These results suggest that instructions by computer animation can promote learning, and they also demonstrate a successful application of interactive physics in the design of cognitively based practice activities.

1. Introduction

Application of current modern information technology in education, “learning” has been transformed from directly transported from teachers to student into a multiple interactive knowledge construction as interaction between students and teachers, among colleagues, and learning environment. This learning process has been transformed from passive acceptance into active exploring learning process. In the current 9-years straight education policy, a fundamental ability of learning for student is the basic requirement. As for teachers, simplified curricula with a moderate content, in addition, to give the idea for student to know how to apply the material is the goal. What kind of teaching methodology fits for these goals? There are a lot research on this topics have been proceed, among them, a concept teaching, mastery learning, and cooperative learning could be helpful. In the concept teaching, there are two different methods, one is concept-attainment teaching, and the other is concept-change teaching. The former is to try to teach students correct concept, and the latter is to make students have the opportunity to correct their original misconception, and in turn to learn more correct knowledge from the process of misconception correction strategy. In this paper, a misconception correction study is implemented. A sequence of misconceptions-change computer simulation lectures which is made by Interactive Physics [5] are given during lectures and statistical analysis is used to prove the effectiveness of this methodology. The topic is focused on some general principles of Newton First Law, Second Law, and some specific forces, such as gravitation and friction in the junior high school physics course.

2. Misconception

Student's conceptual difficulties with situations of force and motion appear to persist over a wide range of educational levels [8]. What are the essential misconceptions in the subject of rectilinear motion? We have collected several cases given as follows:

1. Most students think velocity and speed are the same, and sometimes they do know velocity is something to do direction, but they still have doubt with a negative velocity.
2. In [11], some college students think the average velocity is nothing to do with the ratio of displacement within some period of time. They think if two moving objects, if they are at the same position during some certain time, or if one object catches another object during a certain time, then they will have the same average velocity.
3. In [12], some college students think if at the same period time, if object A travels longer distance than object B, then object A will have bigger acceleration than object B. In addition, some students think if two objects have the same velocity at some certain time, then they will have the same acceleration, since they think $acc = \frac{\Delta v}{\Delta t}$, i.e., they do not have any idea of the instantaneous rate of change of velocity is the acceleration.

Among above three subjects, though, they happened in college students, we believe that the same misconception should be happening in junior high school students too. How these student misconceptions can be changed? What teaching materials should be developed, and what should the teaching approach be? In the "constructive" view, students are seen as active learners, who make sense of the world by constructing meanings and linking new information with past experience. Thus, learning involves the generation and restructuring of students' conception [3]. A process of conceptual change is only likely to occur if students are dissatisfied with their current concepts and feel the need for a new concept. Constructivist approaches to science teaching have been outlined by [1] and [2]. As Driver [2] puts it "Teaching is not the transmission of knowledge but the negotiation of meaning. It involves the organization of the situations in the classroom and the control of tasks in a way which promotes intended learning outcomes.

The object of this study is to evaluate the effectiveness of implementing computer-aided simulation materials in the lecture to determine if this will reduce misconceptions regarding learning courses about general principles of Newton First Law, Second Law, and some specific forces in the Junior high school physics course. There are several hypotheses: (a) Animated visuals would be more effective in correcting misconceptions than static or no visuals, (b) Animated visuals would be benefit to the learning for female student than male students.

The outliner of this paper is given as follows: Section 3 will elaborate general methods, including pretest, posttest, and result of the posttest. Section 4 will give general discussion of results of this experiment and direction of further research.

3. Research Method

3.1 Subjects

The subjects consisted of 201 ninth grade junior high school students, among them 98 students is the group whom were lectured by the instructor without any additional computer-aided tool, and the other 103 students were instructed not only by instructor but also with the aid of computer animation. They are chosen from a public junior high school in TaoYuan County, Taiwan.

3.2 The computer animation made by Interactive Physics

In recent years, several studies have shown that computer-aided instruction can provide useful materials for student and in turns can enhance student interest in the subject [13]. Computer-aided instruction performs better than traditional lecture [6, 7]. If computer-aided instruction is joined with traditional lecture, the effectiveness is much significant [10].

Because of the effectiveness of implementing computer during instruction is being verified, it is why authors choose the software Interactive Physics [5] to be the animation tool in this experiment. The reason is there are so many physics laws given in the junior high school physics course are considered in the perfect condition, that is, without air resistance, no friction, etc., but it is difficult to set up these condition in the usual experiment. In other words, these conditions can be set up easily in the computer software to reveal these physics laws results. Students can also perform this simulation by changing some parameters or variables to observe the different outcome, as a result to verify these physics laws or theorem. These observations are difficult when students are performing by usual lectures.

The following figure 1 is a sample given in the experiment to explain the fallen location of this skating boy when he slides by different velocity. The misconception of some students will think he will fall closer to the edge if he is heavier or not. But it turns out that the distance is nothing to do with his weight. In the simulation, there are two parameters that students can alter to observe the outcome of this skating boy will be fallen. Eventually he will understand it only depends on his initial velocity.

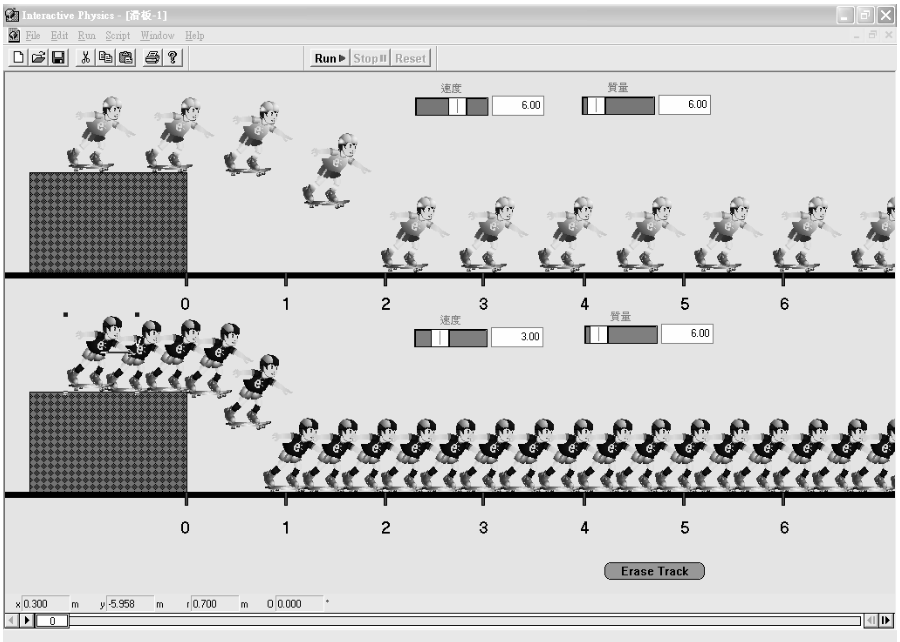


Figure 1 A Computer Animation Model Made by Interactive Physics

3.3 Pretest

The pretest consists of 15 problems that are used to evaluate the learning of the subject and if there is misconception for the subject. Some questions were selected based on the Force Concept Inventory [4] and some are from [14]. The problems in the Force Concept Inventory [4] have been given to more than 1500 high school students and more than 500 university students. Though, it was used to high school or university level student in the test, as a result, only 15 questions were selected from the inventory. In [4], taxonomy of misconception by the inventory provides us the presence of misconception if suggested by selections of the corresponding inventory items. That gives us a clue that what misconceptions our students may have. Some of the possible misconceptions are referenced from [4] and is shown partially in the Appendix.

In the pretest, all questions are given by multiple-choice (one answer and four distracters), and an explain column has to be answered by the students to give what is their thought about answering that specific answer. That will give us an idea the answer is not given by just guess. Some questions are given in Appendix. The pretest measured students performance on the following few items, which they have learned at the previous semester's physics course.

1. Newton First Law- with no force; with canceling force
2. Newton Second Law- Impulse force
2. Kind of Forces-Friction; air resistance; gravitation
3. Superposition principle – Cancelling forces; vectors sum

3.4 Procedures

Since these students already have learned the subject at the previous semester, they will have some idea from the traditional lecturing. This questions are only used to test if the misconceptions are still carried even they have learned the same subject. By the experiment design, there are two groups of student were formed. One is the experimental group, and the other is the comparative group. In the experimental group, students were instructed again by PowerPoint with some computer simulation made by Interactive physics. The utmost goal is to see if implementing computer simulation that we designed will help to correct some misconception. The comparative group students were instructed by the standard lecture just like they were given before to refresh their memory. All instructions were given within 90 minutes, including a 20 minutes posttest. Since there is not enough time to cover all the subjects within that short of time, some of the contents have to be bypassed. But students showed strong interest in the computer simulation, even have the interest to try themselves. But due to short of software, they were not able to implement the simulation themselves. We do believe in the next experiment, the practice will be a major factor to be considered. After the demonstration, the posttest was given. Since they were informed this exam is nothing to do with their grade in the subject, nevertheless, there were students do not take this test serious.

4. Results and Discussion

The grade of the pretest and posttest are all 15 points, i.e., every problem counts one point. Means and standard deviation of the comparative and experimental group students pretest scores are given in Table 1. All the statistics are implemented by SPSS [9].

Table 1: Pretest result 1

Pretest Group Statistics

Group	N	Mean	Std. Deviation	Std. Error Mean
Experimental	98	4.18	2.286	.231
Comparative	103	4.61	2.348	.231

An F test is used prior to the t test and the p-value = 0.553 $> \alpha = 0.05$ indicates the t test assumption of equal variance appears valid. Then a student t test is used to test the hypothesis of no significant difference between the mean scores for the two groups. The p-value = 0.192 $> \alpha = 0.05$, the hypothesis can not be rejected. Thus, we can not conclude that a significant difference between the mean scores for the two groups.

Means and standard deviations of male and female students in individual comparative and experimental group, in addition, total male and female pretest scores are all given in Table 2.

Table 2: Pretest result 2

Comparative Group Statistics

Sex	N	Mean	Std. Deviation	Std. Error Mean
Male	53	4.66	2.594	.356
Female	50	4.56	2.082	.294

Experimental Group Statistics

Sex	N	Mean	Std. Deviation	Std. Error Mean
Male	53	4.19	2.646	.363
Female	45	4.18	1.800	.268

Total Sample Statistics

Sex	N	Mean	Std. Deviation	Std. Error Mean
Male	106	4.42	2.618	.254
Female	95	4.38	1.953	.200

The results from all three F tests indicate that male and female students have same variances of pretest scores in the comparative group, in the experimental group and in the total population. Also, the results from all three student T tests show that there is no significant difference between the pretest mean scores for male and female students in the comparative group, in the experimental group and in the total population.

Four conclusions can be obtained from the pretest are given in the following,

a. **The pretest mean scores do not have significant difference between the experimental and the comparative groups.**

b. **Male and female students in the comparative group do not have significant difference in the pretest mean scores.**

c. **Male and female students in the experimental group do not have significant difference in the pretest mean scores.**

d. **Male and female students in the whole group do not have significant difference in the pretest mean scores.**

These results mean the pretest is fair and it can show that students were about the same level before they took the computer experiment. Though, the score are a little bit of low, the reason maybe the content is much harder than the usual questions than they usually handle. The concept inventory questions indeed quite challenge to most of the students here. As a result, to reinforce the concept during lecture should be one thing that instructors should notice.

Bases on the hypothesis of this experimental design, we should focus on if the score of the experimental group is higher than Comparative group after the computer visual lecture. Means and standard deviation of male and female students in individual comparative and experimental group, in addition, total male and female posttest scores are all given in Table 3.

Table 3: Posttest results

Posttest Group Statistics

Group	N	Mean	Std. Deviation	Std. Error Mean
Experimental	98	6.67	3.302	.334
Comparative	103	5.19	2.578	.254

An F test is used prior to the t test and the p-value = 0.003 < α = 0.05 indicates the T test assumption of unequal variance appears valid. Then a student t test is used to test the hypothesis of a significant difference between the mean scores for the two groups. The p-value = 0.001 < α = 0.05, the hypothesis can be rejected. Thus, we can conclude that a significant difference between the mean scores for the two groups.

Do students have progress among the experimental group and comparative group after computer visual instruction and traditional lecturing? Some results are given in Table 4 and Table 5, and the following analysis is to verify this question.

Table 4: Comparative group results

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	**Pretest**	4.63	103	2.360	.233
	Posttest	5.19	103	2.578	.254

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	**Pretest & Posttest**	103	.632	.000

Paired Samples Test

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Pair1 Pretest-posttest	-.56	2.127	.210	-.98	-.15	-2.687	102	.008

From Paired Samples Test, the difference of the mean scores between pretest and posttest is -0.56, it means, after traditional lecturing, the comparative group average score increases 0.56. From the paired t test, a p-value = 0.008 <α = 0.05. That means the average scores between pretest and posttest of comparative group have significant difference, though, the progress is not much.

Table 5: Experimental group results

Paired Sample Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	**Pretest**	4.18	98	2.286	.231
	Posttest	6.67	98	3.302	.334

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	**Pretest & Posttest**	98	.707	.000

Paired Samples Test

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Pair1 Pretest-posttest	-2.49	2.334	.236	-2.96	-2.02	-10.560	97	.000

From Paired Samples Test, it shows that the average score has difference -2.49，it means the average score of the experimental group increases 2.49 after computer visual simulation lecture.

From the paired T test, a p-value = 0.000 $< \alpha = 0.05$, it means the average score of the experimental group increases and makes significant difference after giving computer visual lecture. This result shows that our hypothesis is verified by giving students suitable computer visual lectures, though, the progress is not that big, but, within 60 minutes lecture, a limited progress is expected. Further research should be carried on to verify consecutive implementing computer visual simulation lectures, in addition, to have a chance to let students can perform and do practice of these simulation.

Overall results are given as follows:

a. **The posttest score does have significant difference between the experimental and the comparative group.**

b. **Though, there is progress in both groups, but the experimental group has much more progress than the comparative group. It means a computer visual simulation lecture do help to correct students misconception in this subject.**

Regarding to another hypothesis, if female students do have more benefit after computer visual simulation lecture than traditional lecturing? A further analysis is given as follows:

Table 6: Female traditional lecturing results

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	**Pretest**	4.56	50	2.082	.294
	Posttest	4.82	50	2.292	.324

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	**Pretest & Posttest**	50	.484	.000

Paired Samples Test

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Pair1 Pretest-posttest	-.26	2.230	.315	-.89	-.37	-.825	49	.414

From Paired Samples Test, it shows the average score of the female students in the comparative group has difference -0.26. It means the average score increases 0.26 after giving traditional lecture.

The paired t test shows that a p-value = $\frac{0.414}{2} > \alpha = 0.05$. It means the average score of the female comparative group has no significant increase after giving the traditional lecture.

Table 7: Female computer visual lecture results

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	**Pretest**	4.18	45	1.800	.268
	Posttest	6.67	45	2.985	.445

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	**Pretest & Posttest**	45	.489	.001

Paired Samples Test

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Pair1 Pretest-posttest	-2.49	2.625	.391	-3.28	-1.70	-6.360	44	.000

From Paired Samples Test, the average score of the experimental group has difference -2.49. It means the average score of female students in the experimental group increases 2.49. A p-value = 0.000 < 0.05, it means the female students in the experimental group have significant improvement after giving the computer visual lecture.

The result shows that by implementing suitable computer visual lecture to female student may increase their interest and help them to learn correct physics. This may be a way to lift the interest of female student in Taiwan to learn Physics.

Acknowledgements The author would like to thank my colleague Dr. Chi Lo, Department of Applied Mathematics, Chung Hua University, for her valuable comments and inputs in statistics analysis.

References:

[1] Champagne, A.B., Gunstone, R.F., and Klopfer, L.E. (1985a), "Instructional Consequences of Students' Knowledge About Physical Phenomena," In L.H.T. West & L. Pines (Eds.), Cognitive structure and Conceptual Change, Orlando, FL., Academic Press.

[2] Driver, R. (1989). “Changing Conceptions”, In P. Adey, J. Head, & M. Shayer (Eds.), Adolescent Development and School Science. New York, Falmer Press.

[3] Driver, R. and Oldham V. (1986), "A Constructivist Approach to Curriculum Development in Science," Studies in Science Education, 13, pp. 105-122.

[4] Hestense, D. & Wells, M. and Swackhamer, G. (1992). “Force Concept Inventory”, Physics Teacher, 30, pp.141-158.

[5] Interactive Physics version 3.0.2 (1992). San Mateo, USA：Knowledge Revolution.

[6] Kulik, J. A., Bangert-Drowns, R. L., & Williams, K. J. (1983). Effects of computer-based teaching on secondary school students. Journal of Educational Psychology, 75, 19-26.

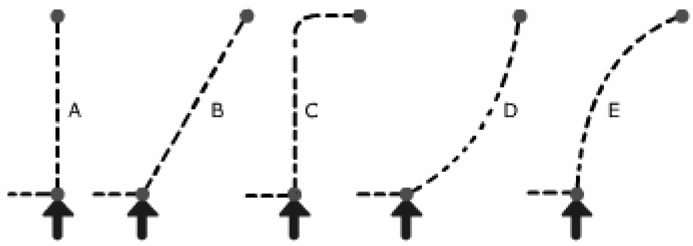
[7] Khalili, A., & Shashaani,L. (1994). The effectiveness of computer applications: A meta-analysis . Journal of Research on Computing in Education, 27, 48-61.
[8] Licht, P. and Thijs, G.D. (1990),"Method to Trace Coherence and Persistence of Preconceptions", International Journal of Science Education," 12(4), pp.403-416.
[9] SPSS for Windows version 6.1.3 (1995). Chicago, USA： SPSS Inc.
[10] Tobias, S. (1985). Test anxiety ： Interference,defective skills,and cognitive capacity.Educational Psychologist,20(3),135~142.
[11] Trowidge, D.E. and McDermott L.C. (1980), "Investigation of Student Understanding of the Concept of Velocity in One Dimension", American Journal of Physics, 48(12), pp.1020-1028.
[12] Trowidge, D.E. and McDermott L.C. (1981),"Investigation of Student Understanding of the Concept of Acceleration in One Dimension", American Journal of Physics, 49(3), pp.243-253.
[13] Woodward, J. P.（1988）. Antecedent Knowledge and Intelligent Computer Assisted Instruction. Journal of Learning Disabilities, 21（3）, 131-139.
[14] Chen, C-C (2002), http://www.hle.com.tw/bookmark/nature/03/03-02.asp

Appendix:

A ball slides with an equal velocity along a frictionless surface from a to b. It was hit suddenly when it arrives at point b.
(ps: The figure is read by x-z direction)

( ) 1. In the following figures, which will be the path of the ball after it was hit?

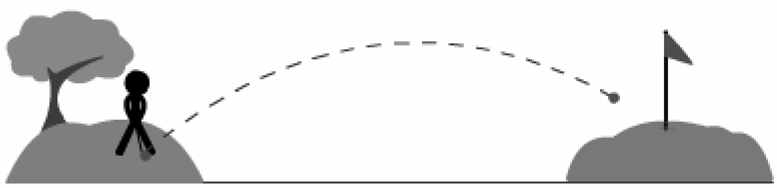
(1) A
(2) B
(3) C
(4) D
(5) E



Reason Why：

<u>Possible Misconceptions by answering</u>
<u>(A): Last force to act determines motion</u>
<u>(D): gradually impetus builds up</u>

( ) 2. In the following graph, it shows the flying path of a golf ball after it was hit. Please supply what kind of forces it involves during its flight?



A、Gravitation B、The impetus hit by the club C、air resistance

(1) Only force A
(2) Force A and B
(3) Force A、B、C
(4) Force A and C
(5) Force B and C

Reason Why：

<u>Possible Misconceptions by answering</u>
<u>(A) only active agents exert forces</u>
<u>(B)Impetus supplied by hit</u>