Available online at www.sciencedirect.com
ScienceDirect
Procedia - Social and Behavioral Sciences 176 (2015) 588 – 595
Procedia
Social and Behavioral Sciences

IETC 2014

Effective Assessments of Integrated Animations to Explore College Students' Physics Learning Performances

King-Dow Su [a]*, Shih-Chuan Yeh[b]

[a]*Department of Hospitality Management1 and Center for General Education De Lin Institute of Technology, NO.1, Lane 380, Ching-Yun Road, Tu-Cheng Dist., New Taipei City 236, Taiwan, ROC
[b]Department of Hospitality Management1 and Center for General Education De Lin Institute of Technology, NO.1, Lane 380, Ching-Yun Road, Tu-Cheng Dist., New Taipei City 236, Taiwan, ROC

Abstract

This study dealt with effective assessments of physics animations to upgrade college students' learning performance. All participants were taken from engineering departments who joined this physics course. All statistic results demonstrated that the physics animated instruction would be to enrich physics texts, to advance positive learning achievement, and to promote the validity of the revised physics instruction with regard to learning attitudes. Assessments of applied animations in this study contributed much to learning results of students' performance which uplifted students' physics concepts understanding and learning attitudes indicated by different variances of gender and dispositions.

Peer-review under responsibility of the Sakarya University.

Keywords: physics animations, college students, concepts understanding, learning attitudes

1. Introduction

Many scholars have pointed out that students rarely build a complete physics knowledge because they underestimate the complexity and relationships between prior knowledge and new knowledge without interactive animations or signaling functions (Feltovich, Coulson & Spiro, 2001). Some physics instruction of promising strategies have already been successfully explored, such as visual animations for communicated environment (Tao, 2004; Su, 2008a, 2008b, 2013; Su & Yeh, 2014), in their advanced concepts of science history (Wang & Marsh, 2002) to help students achieve more effective physics learning. Several constructivists' strategies of integrated animations were included in the overall physics learning process, such as multimedia texts and hands-on inquiry experiences for students to learn fundamental physics conceptual developments.

Peer-review under responsibility of the Sakarya University.
doi:10.1016/j.sbspro.2015.01.514

1.1. Purposee

This research focuses on dynamic applications of physics assessments implemented by 2D animations highlighted with physics conceptions o. Three fundamental prospects of college students' physics learning purposes will be conducted as follows:
(1) Integrated physics animations will enhance students' learning conceptions for physics assessments.
(2) Effective assessments of integrated animations can improve students' physics learning performances.

2. Literature Review

Many researches (Becerra-Labra, Gras-Martı & Torregrosa, 2012; Su & Yeh, 2014) reveal that college students' learning towards physics is declining not in their lack of interest, but in lack of integrated animations for instruction environment nowadays. Thus, efforts towards integrated animations are needed for positive physics learning concepts to increase students' interest and motivation. Many contemporary strategies of physics learning are based on constructive integrated animations related to the authentic nature of physics instruction. There are several potential advantages for this study to get effective assessments of rich integrated animations which closely parallel with new technologies of physics instruction. This study also offers physics teaching activities including integrated animations in the learning environment suitable for a constructive assessment of students' learning performances.

2.1. Construct Physics Learning Performances

Constructivism would be an interactive epistemology which defined students' constant competence and demonstrates their understanding of real knowledge. Tenenbaum, Naidu, Jegede, and Austin (2001) presented seven key constructivist factors for students' physics learning environment: (1) dealing with arguments, discussions, debates; (2) meeting conceptual conflicts and dilemmas; (3) sharing ideas with others; (4) measuring targeted materials toward solutions; (5) organizing reflections and conceptual investigations; (6) fitting students' needs; and (7) making meaningful, real-life examples. All seven factors emphasized students' dynamic fulfillment that real knowledge was actively constructed in learners' mind step-by-step. For last few decades, the importance of the constructivist perspective has been stressed by educators for improving students' learning performances. Ausubel (1968) indicated that the fundamental principle of constructivist instruction was to assess what students knew and then to design activities and assessments of their performances accordingly. Constructivist principles had been interpreted in a variety of scientific ways ranging from information processing, interactive and social constructivist to physics instruction (Yore, 2001). Both constructivist principles and students' conceptual changes were influential in physics instruction, and they were inseparable from any physics instruction. This study explored the constructivist-based physics instruction which had been in accordance with the conceptual change models (Posner, Strike, Hewson, and Gertzog, 1982) to help students modify their misconceptions and develop better learning performances.

2.2. Technology Enrichment Physics Learning Environment

Students who face rapid changes in the modern world will be in great need of technological instruction with effective animated learning environment. More than one decade, Gilbert (1999) proposed a new strategy of integrated animations to enhance students' science learning environment. He said that much scientific learning was too abstract to interpret, and those complicated ideas would prevent students from constructing mental models and their subsequent learning performances. Several means of physics instruction had been dealt with, such as models, analogies, equations, graphs, diagrams, pictures, mathematical operations, and visual and action images (Lemke, 1998). All these could be functional with integrated animations for different effects of a single representation compared to multiple representations (Yore & Treagust, 2006). Several multiple representations (Spiro & Jehng, 1990; Paivio, 1971 &1991) could be in collation with Ainsworths' (2006) learning frameworks of the ubiquitous DeFT (design, functions, and tasks) for students' physics learning environment. A common justification for using multiple representations responded to the fact that they captured students' interest and, in doing so, played an important role in promoting animated environment for students' learning performances.

2.3. Learning Theory and Physics Animated Environment

Verbal and visual inputs would construct multi-functions of dual-coding theory (Paivio, 1971 & 1991) in students' integrated animations of physics learning environment (Butler & Mautz, 1996). Both verbal and visual systems could be linked and inter-communicated for the cueing combination of one system to the other, which in turn facilitated students' integrated animations of physics instruction. Theoretical principles from this multimedia-orientated environment would offer fundamental presentations as texts and animated sequences which all interacted together to enhance students' learning performances (Mayer, 1997; Moreno & Mayer, 1999). The contiguity principles for computer-based instruction gave students effective impact when words and pictures were presented contiguously in time or space (Mayer & Anderson, 1991; Mayer & Sims, 1994).

3. Methodology

The overall research methodology was comprised of three effective assessments, including pretests, posttests and questionnaire for non-major college students in the required physics courses.

3.1. Participants

Assessments of statistical samples for group surveys were taken from college students in the present researcher's physics classes. All participants (N = 193) were recruited as tentative samples from both civil engineering and mechanical engineering departments by a stratified procedure to eliminate voids in the sampling frames.

3.2. Tools

There were four major assessment tools in the data collection and analyses stages: namely, (a) pretests, (b) physics instruction of three integrated animation units, (c) posttests, and (d) a follow-up questionnaire. Several pretests and posttests appropriate to three integrated physics units were developed to assess students' learning achievements and learning attitudes. All tests with computer-based analyses were focused on three categories: knowledge, comprehension, and applications (Bloom et al., 1956). Both pretests and posttests for three physics units were administered by local physics professors of the Entrance Examination Center in Taiwan to assess different test validities. The reliability of students' achievement tests was analyzed in Cronbach's alpha coefficients for the pretests and posttests, which were 0.78 and 0.79 respectively. Kline (2005) posited that the α value up 0.70 was considered acceptable. The same test validities were combined together with pretests and posttests to detect students' differential physics learning performances. Effective assessments of students' learning attitudes in the questionnaire were devised by the author (Su, 2008a, 2008b, 2011). The Likert 5-point scale was used to evaluate students' physics learning attitudes. Each test item had five responsive categories, ranged from item 1 (strongly disagree) to item 5 (strongly agree). The questionnaire included six aspects as the following descriptions:

(S1) Learning Attitude towards Integrated Physics Units
(S2) Learning Attitude towards Physics Instructors
(S3) Learning Attitude towards Integrated Physics Learning Environment
(S4) Learning Attitude towards Students' Interactions
(S5) Learning Attitude towards Self-evaluations
(S6) Learning Attitude towards Integrated Physics Learning Results

Effective attitude assessments of the questionnaire were evaluated according to the content, constructive validity and internal consistency reliability. Three specialists were asked to set up the validities of the questionnaire content. Pilot versions of the questionnaire were examined using principle component factor analyses to verify the structure and alignment given the designed constraints. Reliability was explored in terms of Cronbach's α coefficient to determine the internal consistency of total subscales. The analyses of six subscales separately yielded different coefficients ranging from 0.92 to 0.96 (S1=0.96, S2=0.92, S3=0.93, S4=0.94, S5=0.94, and S6=0.96). Compared to the previous report of average reliabilities, this questionnaire had a higher reliability than statistical data by most other researchers (Katerina & Tzougraki, 2004).

3.3. Treatments

Three integrated physics units were conducted for effective learning assessments. These integrated physics units normally involved 3 hours of lecture demonstrations and 3 hours of laboratory hand-work each week. The lecture demonstrations programs were redesigned to be enriched with supplemental programs. The supplementary materials (such as animations and slides), lectures, and demonstrations all combined within an integrated learning environment in well-equipped facilities. These component programs were developed by the author drawn from the literature (Ainsworth, 2006; Yore and Treagust, 2006) and constructivist perspectives. Six integrated features of physics courses were covered in the instructional designs and computer animations as the following way:

1. Three integrated animation units were employed for specific visualizations of physics instruction.
2. The recognition of integrated environment determined the important priority of meaningful physics instruction.
3. Concrete creative images and mental assemblages facilitated students' memory and understanding.
4. Integrated interactions of physics learning between teachers and students were reinforced and encouraged in this study.
5. Guided learning with the integrated environment as a catalyst would achieve greater physics instruction goals and overcome students' learning obstacles.
6. Integrated physics presentations and demonstrations proposed opportunities and activities for students' real-life learning.

Three integrated animation units were produced in Flash MX (Macromedia Inc.), static visuals were made with Mathematica 4.2 (Wolfram Research, Inc.), and classroom demonstrations were presented by PowerPoint or e-plus software. The conceptions, ideas and dynamic processes were operated in Adobe Photoshop 7.01. Three integrated animation units were separately indicated from [Figure 1] to [Figure 3].

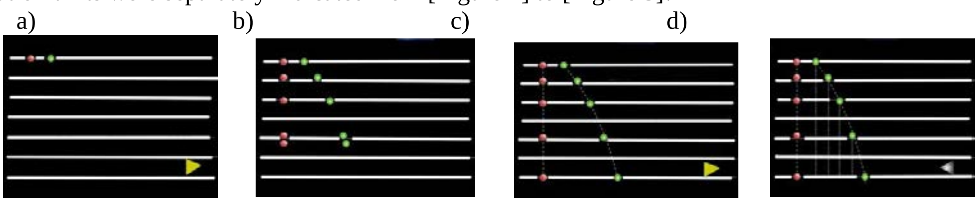

Fig. 1. Selected illustrations and corresponding conceptions from the integrated physics courses with kinematics animations conducted by Photoshop 7.01, as shown in the sequence from slides (a) to (d)

[Figure 2] indicated the passing movements of a ray from one medium V_1 into another medium V_2. The angle of refraction was different from that of incidence. This case would always be the same during reflections when the ray entered a medium at a speed less than the speed of light. Snell's law was the basic requirement of refraction derived from light theory. The sequence presentations of integrated animations, as seen from pictures (a) to (d) in [Figure 2] step by step, provided an effective domination for the conception of the incident wave and the refracted wave. Most students who came from a vocational school background did not have much advanced concepts of abstract physics and dynamic processes; therefore, these animated documents helped students build a sound, basic recognition of refractions and avoid the difficulty and confusion of physics geometric optics as encountered in their daily lives. The principal animations for the conservation of mechanical energy could be seen in [Figure 3] -- as a pendulum swung in a motion system, and the energy was transferred back and forth between kinetic energy K and gravitational potential energy U, as shown from pictures (a) to (f) in [Figure 3], with the sum K+U being constant, as shown in [Figure 3]. The slides indicated a vivid physics illustration of the conservation energy. Any energy that did not serve the intended purpose must be subtracted from the total sum in order to obtain the amount of useful energy. This physics application was very straightforward. This experiment of integrated physic mechanical energy saved students from the misunderstanding of interpreting the abstract conceptions of mechanical energy. These animations were available for solving conceptual problems related to the principle of the conservation energy.

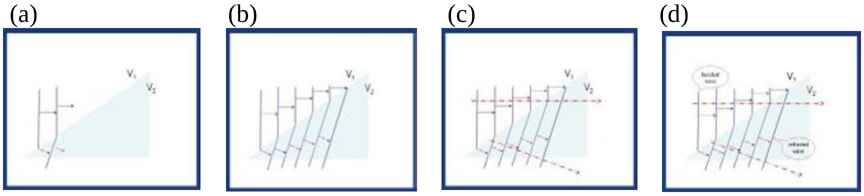

Fig. 2. Selected illustrations and conceptions from the integrated physics courses with corresponding animation arrangements and movements for the ray passing from medium V_1 into medium V_2, conducted by Photoshop 7.01, as shown in different sequences from slides (a) to (d).

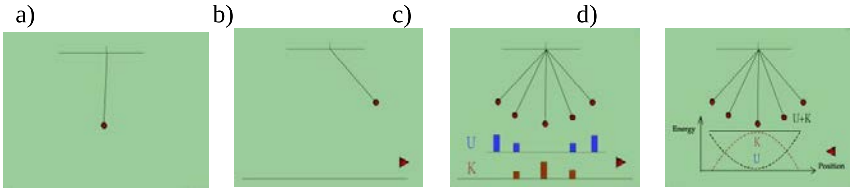

Fig. 3. Selected illustrations and concepts from the integrated physics courses with corresponding animations for the conservation principle of mechanical energy, conducted by Photoshop 7.01, as shown in sequences from slides (a) to (d).

3.4. Data Management and Analyses

All quantitative data were employed for statistical analyses functioned by the SPSS of Windows 10.0 software. Descriptive statistics (sample sizes, means, and standard deviations) were calculated for two comparative groups, and the significant levels for one-way analyses of covariance (ANCOVA) were set at 0.05 to examine main effects. In cases where *p*-values were less than or equal to 0.05, Scheffe's post hoc comparisons were conducted on different significant effects. Regarding students' changes in achievements and attitudes, the differential effects were explored and identified by the categories of blocking variables for the integrated physics learning.

4.Results

This study focused on three physics units with integrated animations available for Taiwan technical college students. Blocking variables for the data analyses corresponded to differentiated requirements of students' learning performances in implemented conditions and learning attitudes. The design principles and study developments had already been described in the above sections. Next this study examined students' learning performances before and after attending instruction tests in these integrated physics programs. Students' learning performances were documented and analyzed by means of pretests and posttests; the means and standard deviations were calculated by descriptive statistics, and improvements brought about by three physics units. Average performances throughout pretests and posttests for three physics units indicated students' different scores from 10 to 20 points. These scores corresponded to percentage improvements of 35.8% in the kinetic energy and work unit, 30.3% in the optics unit, and 16.5% in the kinematics unit. The total improvement for three physics units was 26.5%, and effect size found by one-way ANCOVA testing was $f = 0.279$, the above medium effect. The effect size was used as the factor or index to differentiate variations in students' learning behaviors. Cohen (1994) pointed out that the effect size had more research efficiencies than the *p*-value. The testing results of statistical significance revealed occurrence rates. The effect size put important emphasis on the measurements of the relative magnitude for the experimental results. Although both testing results of statistical significance and effect size showed the size of the experimental effect, effect size became especially influential when comparing the magnitude of experimental treatments to other experimental effects. Cohen noticed that, "the effect size of one-way ANCOVA was represented by $f = [\eta^2 / (1-\eta^2)]^{½}$, in which η^2 indicated Eta square to show different efficient, $f = 0.1$ as the smaller effect size, $f = 0.25$ as the medium effect size, and $f = 0.4$ as the higher effect size" (Cohen, 1988). Inspective results of students' attitude survey (with four subscales) indicated reasonable attitudes towards physics learning.

Detailed statistics of variances and covariances were analyzed to examine the differential effects of integrated instructions on civil and mechanical engineering students' physics learning achievements and attitudes. The main effects of the integrated physics courses for students' achievements (for the given variables) were tested by a series of ANCOVAs in which the pretest results were utilized as the covariances. All ANCOVA results revealed that when students' performances of posttests were adjusted by performances of pretests, different significant main effects appeared. The statistical parameters, *F*-ratios, *p*-values and effect sizes (*f*) for each of 12 ANCOVAs for gender, major, dispositions towards computers and orientation attendance (for each of three physics courses and four blocking variables). All ANCOVA results revealed significant main effects between mechanical and civil engineering students in kinematics ($F = 4.209$, $p = 0.044$, $f = 0.259$) and kinetic energy and work content achievements ($F = 22.100$, $p = 0.001$, $f = 0.593$), with above medium or higher effects, but not in the optical units ($F = 1.328$, $p = 0.254$, $f = 0.153$). Non-significant ($p > 0.05$) main effects were found for gender, disposition towards multimedia, and attendance at computer orientation classes for all three integrated physics units. All effect sizes were below the medium effect ($f < 0.25$).

The questionnaire results showed students' differential physics learning attitudes. The four survey subscales indicated positive attitudes toward integrated physics units, with the statistical mean responding > 4.00 for all learning attitudes. The descriptive statistical mean and standard deviations for students' learning attitudes (for six subscales and the total survey) were indicated in [Table 1]. Differential effects of the integrated physics units were explored for taking a variety of students' characteristics into consideration. The main effects of the integrated physics units (with six attitude subscales for the six blocking variables) were tested by a series of ANCOVAs. The final testing was done on the combined samples since each student had to complete the same attitude survey. [Table 2] provided a brief summary of the *F*-ratios, *p*-values and effect sizes (*f*) in 24 ANCOVAs for gender, major, disposition towards integrated physics courses, and students' attendance.

Table 1. Descriptive statistics for the mean scores (M) and standard deviations (SD) for students' integrated physics learning attitudes for six subscales and the total survey.

Scores	Attitude			Measurement			
	S_1	S_2	S_3	S_4	S_5	S_6	Total
M	4.22	4.15	4.03	4.08	4.03	4.14	4.11
SD	0.17	0.20	0.07	0.17	0.16	0.24	0.33

The statistic ANCOVAs revealed significant main effects of gender on students' learning attitudes, favoring males over females (S_4) ($F = 3.885$, $p = 0.050$, $f = 0.143$), and self-evaluation (S_5) ($F = 4.621$, $p = 0.033$, $f = 0.157$). The effect sizes ranged between 0.1 and 0.2, indicating small and medium effects. Students demonstrated a non-significant gender effect of attitudes towards integrated physics units (S_1), attitude towards the physics instructors (S_2), attitude towards integrated physics learning environment (S_3), and attitude towards integrated physics learning results (S_6). These effect sizes were all below 0.14, only a small effect. Non-significant ($p > 0.05$) main effects were found for student's major (either mechanical or civil engineering) on all six attitude subscales.

The main effects of ANOVAs significance testing showed that students who attended the learning activities had a favorable attitude towards integrated physics units (S_1) ($F = 8.694$, $p = 0.004$, $f = 0.215$), attitude towards the physics instructors (S_2) ($F = 7.509$, $p = 0.007$, $f = 0.199$), attitude towards students' interactions (S_4) ($F = 4.590$, $p = 0.033$, $f = 0.153$), and attitude towards integrated physics learning results (S_6) ($F = 4.059$, $p = 0.045$, $f = 0.146$); all effect sizes ranged from small up to medium. Non-significant ($p>0.05$) main effects were found for two other subscales: learning attitude towards integrated physics learning environment (S_3) and self-evaluation (S_5).

Significant positive main effects were found for dispositions towards integrated physics units for all attitude subscales: attitude towards integrated physics units (S_1) ($F = 18.943$, $p = 0.001$, $f = 0.446$), learning attitude towards the physics instructors (S_2) ($F = 21.131$, $p = 0.001$, $f = 0.472$), attitude towards the integrated physics learning environment (S_3) ($F = 10.439$, $p = 0.001$, $f = 0.331$), attitude towards students' interactions (S_4) ($F = 12.067$, $p = 0.001$, $f = 0.357$), attitude towards self-evaluation (S_5) ($F = 14.741$, $p = 0.001$, $f = 0.393$), and attitude towards integrated physics learning results (S_6) ($F = 20.378$, $p = 0.001$, $f = 0.464$). The effect sizes ranged between 0.331 and 0.472, indicating medium and higher effects. Scheffe's post hoc comparison results revealed that S_1, S_2, and S_5

students' attitudes reporting 'positive' were superior to those reporting 'neutral' and 'negative', and attitudes reporting 'neutral' were superior to those reporting 'negative.' The results of Scheffe's post hoc comparisons revealed the same integrated physics learning results that S_3, S_4, and S_6 students' attitudes reporting 'positive' were superior to those reporting 'negative', and attitudes reporting 'neutral' were superior to those reporting 'negative.'

Table 2. Summary of *F*-ratios, *p*-values and effect sizes (*f*) for each of the ANCOVAs

Blocking Variable	Analyses of Variance	Attitude Measurement					
		S_1	S_2	S_3	S_4	S_5	S_6
Gender (male, female)	*F*-ratio	2.718	1.642	3.771	3.885	4.621	3.133
	p-value	0.101	0.202	0.054	0.050*	0.033*	0.078
	f	0.119	0.095	0.139	0.143	0.157	0.128
Major (civil, mechanical engineering)	*F*-ratio	1.004	0.001	0.524	0.727	1.898	2.859
	p-value	0.318	0.977	0.470	0.395	0.170	0.092
	f	0.071	0.071	0.055	0.063	0.101	0.123
Disposition toward multimedia (positive, neutral, negative)	*F*-ratio	18.943	21.131	10.439	12.067	14.741	20.378
	p-value	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
	f	0.446	0.472	0.331	0.357	0.393	0.464
Attendance (yes, no)	*F*-ratio	8.694	7.509	1.652	4.590	3.286	4.059
	p-value	0.004*	0.007*	0.200	0.033*	0.071	0.045*
	f	0.215	0.199	0.095	0.153	0.132	0.146

Note: * $p < 0.05$

5. Conclusions

It would be a favorable strategic teaching for this research to integrate both animations and physics instruction into upgrading students' learning performances. The validity of this study exemplified many characteristics of integrated animations and animated environment in previous research results (Su, 2008a, 2008b, 2011, 2013; Kiboss, 2002; Tao, 2004), which contributed much to students' scientific learning competence and proficiency. As an effective integrated study, all the statistical physics learning results discussed above were consistent with most recent advanced researches (Tenenbaum, et al., 2001; Kiboss, 2002; Tao, 2004). In order to present students' better targeted programs of physics understanding and promote a more positive attitude towards physics learning, all ANCOVAs findings of students' characteristics such as gender, dispositions toward integrated physic courses, and attendance at the integrated physics learning programs had a major significant ($p < 0.05$) influence on their attitudes, with higher effect sizes than other variants considered.

Three major animation principles concerning the properties of physics learning environment such as kinematics, the movement of a ray and the conservation of mechanical energy (indicated in Figure 1, Figure 2 and Figure 3) gave students to organize reflections on the effective learning of physics conceptions. Based on the analyses of statistical responses, students were able to identify fundamental concepts between animations environment and physics learning. The integrated texts and physics learning environment helped to develop more unifying principles and meaningful higher-level skills which would enhance students' physics understanding and facilitate their learning performances. The integrated animations environment of physics learning provided a powerful means for fostering physic principles because it could illustrate multi-level physics conceptions (Galili, 1996; Kiboss, 2002). All results of three major animations supported and facilitated students' physics conceptions learning and attitudes.

The integrated statistic results of three animation units in this study were well-organized and helpful for most college students' effective physics learning. It would significantly make a positive contribution to students' physics learning attitudes. The results gave more reliable implications to previous researches (Barton, 2005; Tao, 2004; Kiboss, 2002) in relation to integrated physics materials and demonstrated applications which could encourage students to construct a better physics conceptual understanding. As stated by Ainsworth (2006), the DeFT (Design, Functions, Tasks) learning framework needed to integrate the cognitive representations and constructivist theories of education into multiple research programs. He proposed that the effectiveness of multiple representations could best be understood by considering three fundamental learning aspects: the design parameters that were unique to learning environment; the functions that supported integrated physics learning; and the cognitive tasks that must be undertaken by learners' interactions with multiple representations. All three major animations increased students' learning perspective and cultivated physics conceptions. Through the availability of three principal animation texts, students were capable of more effective performances for developing physics conceptions and learning environment.

Acknowledgements

The author would like to thank the journal editors and the anonymous reviewers of this paper for their kind assistances and helpful suggestions. A short but sincere thank must also be given to the patronage of the National Science Council, R.O.C. in Taiwan (under Grant No. NSC 101-2511-S-237-001 & NSC 102-2511-S-237-001). Without their help, this study could not have been completed in present form. Finally, thanks must also be given to all the instructors and students who participated in this research study.

References

Ainsworth, S.E. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction, 16(*3), 183-198.

Ausubel, D.P. (1968). *Educational psychology: A cognitive view.* New York: Holt, Rinehart & Winston.

Barton, R. (2005). Supporting teachers in making innovative changes in the use of computer-aided practical work to support concept development in physics education. *International Journal of Science Education, 27,* 345-365.

Becerra-Labra, C., Gras-Martı, A. & Torregrosa, J. M. (2012). Effects of a Problem-based Structure of Physics Contents on Conceptual Learning and the Ability to Solve Problems. International Journal of Science Education, 34(8), 1235-1253.

Bloom, B. S. Englehart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: Handbook 1, The cognitive domain.* New York: David Mckay Co.

Butler, J.B. & Mautz, R.D., Jr. (1996). Multimedia presentations and learning: A laboratory experiment. *Issues in Accounting Education, 11*(2), 259-280.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd Ed). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Feltovich, P. J., Coulson, R. L. & Spiro, R. J. (2001). Learners' understanding of important and difficult concepts: A challenge to smart machines in education. In P. J. Feltovich & K. Forbus (Eds.), Smart machines in education (pp. 349–376). Cambridge, MA: MIT Press.

Galili, I. (1996). Students' conceptual change in geometrical optics. *International Journal of Science Education, 18(7)*, 847-869.

Gilbert, J. (1999). On the explanation of change in science and cognition. *Science and Education, 8*, 543-577.

Katerina, S. & Tzougraki, C. (2004). Attitudes toward chemistry among 11th grade students in high schools in Greece. *Science Education, 88,* 535-547.

Kiboss, J.K. (2002). Impact of a computer-based physics instruction program on pupils' understanding of measurement concepts and methods associated with school science. *Journal of Science Education and Technology, 11,* 193-198.

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2nd Ed.). New: York: Guilford Pres.

Lemke, J.L. (1998). Multimedia meaning: Visual and verbal semiotics in scientific text. In J.R. Martin & R. Veel (Eds.), *Reading science* (pp. 87-113). London: Routledge.

Mayer, R.E. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist, 32*, 1-19.

Paivio, A. (1971). Imagery and Verbal Processes. New York, NY: Holt, Rinehart & Winston.

Paivio, A. (1991). Dual coding theory: retrospect and current status. *Canadian Journal of Psychology*, 45, 255-287.

Su, K. D. (2008a). An integrated science course designed with information communication technologies to enhance university students' learning performance. *Computers & Education*, *51*, 1365-1374.

Su, K. D. (2008b). The effects of a chemistry course with integrated information communication technologies on university students' learning and attitudes. *International Journal of Science and Mathematics Education*, *6*, 225-249.

Su, K. D. (2011). An intensive ICT-integrated environmental learning strategy for enhancing student performance. *International Journal of Environmental and Science Education*, *6*(1), 39-58.

Su, K. D. (2013). Validity of problem-solving skills: Exploring dynamic reaction figures in acid and base chemical learning. *Journal of Computer Engineering Informatics*, *1*(1), 1-12.

Su, K. D., & Yeh, S. C. (2014). Effective assessments of integrated animations -- Exploring dynamic physic instructions for college students' learning and attitudes. *The Turkish Online Journal of Educational Technology*, *13*(1), 88-99.

Tao, P.K. (2004). Developing understanding of image formation by lenses through collaborative learning by multimedia computer-assisted learning programs. *International Journal of Science Education*, *20*, 1171-1197.

Tenenbaum, G., Naidu, S., Jegede, O. & Austin, J. (2001). Constructivist pedagogy in conventional on-campus and distance learning practice: an exploratory investigation. *Learning and Instruction, 11,* 87-111.

Wang, H. A. & Marsh, D. D. (2002). Science instruction with a humanistic twist: teachers' perception and practice in using the history of science in their classrooms. *Science & Education, 11,* 169-189.

Yore, L.D. (2001). What is meant by constructivist science teaching and will the science education community stay the course for meaningful reform? *Electronic Journal of Science Education, 5*(4). Online journal: http://unr.edu/homepage/crowther/ejse.

Yore, L.D. & Treagust, D.F. (2006). Current realities and future possibilities: Language and science literacy—empowering research and informing instruction. *International Journal of Science Education, 28*, 291-314.