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Investigation of effects of virtual reality environments on learning performance of technical skills

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ABSTRACT

Practical training is what brings imagination and creativity to fruition, which relies significantly on the relevant technical skills needed. Thus, the current study has placed its emphasis on strengthening the learning of technical skills with emerging innovations in technology, while studying the effects of employing such technologies at the same time. As for the students who participated in the study, technical skills had been cultivated in the five dimensions of knowledge, comprehension, simulation, application, and creativity, in accordance to the set teaching objectives and the taxonomy for students learning outcome, while the virtual reality learning environment (VRLE) has also been developed to meet different goals as the various technical skills were being examined. In terms of the nature of technology, operation of machines, selection of process parameters, and process planning in technical skills, VRLE has also designed the six modules of "learning resource", "digital content", "collaborative learning", "formative evaluation", "simulation of manufacturing process", and "practical exercise" in particular for providing students with assistance in the development on their technical skills on a specific, gradual basis. After assessing the technical skills that have been developed for the time period of one semester, the students have reported finding VRLE to be a significantly effective method when considering the three dimensions of "operation of machines", "selection of process parameter", and "process planning", though not so much so when it came to the dimension of "nature of technology". Among the six modules, "simulation of manufacturing process" and "practical exercise" were the two that were most preferred by students for the three dimensions considered.

1. Introduction

The technology of virtual reality (VR) is a product generated by the intertwining applications of image editing, graphic designing, and multimedia (Knott, 2000). It is capable of making simulations of the reality in cyberspace and creating three-dimensional images that possess highly educational values (Johari, 2005; Saleeb & Dafoulas, 2011; Wasson, 1997). Virtual reality enables a learning environment in cyberspace that is more versatile than the traditional "chalk-and-blackboard" classrooms in that learning takes place as individuals make exchanges of technological interactions either with other individuals or with whatever systems/softwares used; the application of virtual reality in education is a great leap of teaching methods after the multimedia, computers, and the Internet. The most commonly used formats of such virtual teaching environment include virtual technical skill training, virtual laboratory, virtual instructions, virtual campus, and virtual distance learning.

1.1. Study on virtual-reality learning environment & core theories

In distinguishing the teaching styles, the core of the first generation of computing-assisted learning lies in analyzing how to build a virtual learning system, environment, and content just so to better have knowledge spread (Gordin & Pea, 1995). The core of the second generation of computing-assisted learning focuses more specifically on ways of building appropriate learning styles as well as ways of allowing learning processes to be outlined with the convenience that comes with informative technologies available, and this is so that the learner is able to have the newly acquired knowledge internalized (Dede & Lewis, 1995). The design of virtual-reality learning environment being investigated in the present study places even a higher premium on context-aware computing, with its concentration transformed from spread of knowledge to formation of knowledge, and then to "one-on-one" style of learning, while the theories on learning have been transformed simultaneously.

The transformation of computer-assisted learning from "resources" to "competency" has been a complex and difficult process that went through five phases (Beckman, 1997) (see Table 1).

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Table 1
The five layers of knowledge (Beckman, 1997).

1. Data	Original text, fact, coding, image, sound
2. Information	Organized and systemic information that has been interpreted and summarized
3. Knowledge	Case study, rule, equation, model
4. Expertise	Timely and accurate suggestions; interpretation and defense of results
5. Capability	Organizational skills, knowledge base, comprehensive production-driven system support, core capabilities

Advancing to one level up at each of the stage requires a certain degree of cognitive machining. For instance, the realization of transformation of information into knowledge requires reasoning, abstract thinking, formation of associations, and practical applications. It should be pointed out that the cognitive activities outlined by Beckman are usually carried out on campuses in different formats, and they appear to be closely associated with teacher–student interactions. As a study on cultivating the higher order functions has found, when the cognitive capabilities and social interactions are integrated sensibly it is when learning effects are the greatest. In fact, the sociocultural theory has explicitly specified that dialogues that take place in a learning environment play a significant role in defining the sociological viewpoints that a learner internalizes. Consequently, it is not just the effects that are produced on formation of meaning by cognition that deserves more attention than it has been getting but also even more so would be the values that the external social world places on the transformations of knowledge.

This point of view has also gained tremendous support from Brown, Colins, and Duguid (1989) and other scholars. Such practical knowledge as skills and concepts is situational and its formation is most effective and meaningful when such formation takes place in a setting where social and physical situations and interactions intertwine. Brown et al. has proposed that through cognitive apprenticeships the learner's skill becomes honed and perfected to an expert level. The effectiveness of the cognitive apprenticeship model emphasizes on learning in context and this is highly corresponsive to what in cognitive psychology has been termed "distributed cognition", which places its emphasis on the coordination between individuals, artifacts, and the environment (Dede & Lewis, 1995), and this supports the development of an environment that is based on information communication technology.

1.2. The virtual reality learning environment and technical skills education summarized

Studies conducted on virtual learning environments in recent years have focused increasingly on sciences of learning, by looking at the studies that have been done internationally there seem to exist issues in the following five aspects: The fundamental theories that the virtual reality environments are based on, for one (E.g. Burdea & Coiffet, 2002; Furlong, Vance, & Larochelle, 1999; Rickel & Johnson, 1998); secondly would be the teaching and learning of the virtual reality environments (E.g. Johari, 2005; Moreno & Mayer, 2000; Salzman, Dede, Loftin, & Chen, 1999); third, the initiatives taken on the use of the different kinds of virtual-reality based environments (E.g. Alvarez & Su, 2009; Bierbaum et al., 2001; Elliott & Bruckman, 2002); four, the assessments done on the learning outcomes made possible in virtual reality environments (E.g. Antonya & Talaba, 2007; Chen, Chen, & Kinshuk, 2009; Rizzo et al., 2000); five, the multi-faceted cultural elements and the sexual equality that are involved in the learning processes (E.g. Cromby, Standen, & Brown, 1995; Smedley & Higgins, 2005); and six, studying of the students' emotions and affections, cognitions, and behaviors (E.g. Amorim, Trumbore, & Chogyen, 2000; Patera, Draper, & Nael, 2008; Yee & Bailenson, 2007).

In sum, the following conclusions may be made: (1) theories that are used are fundamentally based on structuralism and situational constructions, meaning to analyze the principles of designs along with the relative computer programming of the virtual reality environments in the lights of sciences of learning; (2) the methods for teaching and learning are largely based on situational constructing, and such methods are compared against the traditional teaching methods, as well as against the virtual reality teaching–learning environments of various types; (3) the discussions on virtual reality environments have been oriented basically toward the desktop virtual-environment type, the advanced virtual-reality environment type, the immersive virtual-reality type, and finally, the distributed virtual-reality type of such environments; (4) the measurements taken for assessments conducted on virtual reality environments applied to the students have been based on the students' cognition, emotions and affections, and the changes that they have made in their concepts or behavior; (5) the cultural elements and sexual equality concerned are relatively innovative fields of study for scrutiny, with the emphasis mainly focused on special education; and (6) emotions and affections, cognition, along with behavior of the students are also what are being concentrated on for the current thesis. Some researchers (Patera et al., 2008) created a virtual reality environment (VRE) to stimulate motivation and creativity in imaginative writing in students. The impact of VRE on the educational activity was evaluated through a formal assessment of the stories by an independent marker, with quantitative and qualitative analysis of the stories conducted; observations and interviews had also been given jointly with the teachers. As the results of the study have shown, while the students have displayed high levels of motivation and interest as they were situated in a virtual-reality driven learning environment both the teachers and the students are in the stage where they still need to acquire better adaptability on such applications.

Concerning the professing of technical skills, technology education has been defined by Yang (1992) as: "a rational education plan, by which learners can develop technical skills, learn technical principles, and intelligently apply these skills and knowledge in modern life". In this way, learners can also develop the ability to make appropriate value judgments of contemporary and future technology, which can help them easily adopt future highly-developed technology. Therefore, we have to first verify the content of technological literacy and then teach this content through a well-planned curriculum and activities (Lee & Yang, 1999). They developed the tool to be used for quality control on the testing skills and the relative index system, which includes the scope of technology, the evolution of technology, the process of technology, the application and evaluation of technology, and the impact of technology.

2. Research method

2.1. Objectives and Issues

The several issues that are scrutinized in a more concrete form in this research are the following: (1) Whether virtual-reality learning environments are facilitating to college students' training of technical skills; (2) The effects produced by the taxonomy designed for this study on the students in their senior year of college; (3) the various levels of proficiency of technical skills cultivated; (4) the different modules that make possible of the technical skill proficiencies.

2.2. Instruments

To find out the most accepted module for use by the students, one set of means of measurement used was paper-and-pencil

Table 2
Comparisons of pre-and post-test scores for the undergraduate students.

	Control group ($n = 53$)					Experimental group ($n = 52$)				
	Pre-test		Post-test			Pre-test		Post-test		
	M	SD	M	SD	t	M	SD	M	SD	t
Nature of technology	2.28	1.69	2.44	1.77	0.47	2.19	1.67	2.42	1.62	0.71
Operation of machines	2.16	1.86	2.51	1.46	1.06	2.27	1.59	3.03	1.89	2.22**
Selection of process parameters	2.18	1.75	2.92	2.06	1.98*	2.20	1.72	3.74	1.84	4.41**
Process planning	1.96	1.53	2.56	1.72	1.88*	1.93	1.84	3.59	1.52	5.01**

* $p < .05$.
** $p < .01$.

assessments along with practical exercises, while the other set was the questionnaires administered. Three multiple-questions were asked in the aspect of "rationale" and three open-ended questions were administered in the aspect of "Control of Variables", and consent on grading of the measurements taken was sought on the judge panel, which was comprised of three coders. On the scale of 0 to 4, "0" indicates weakest in strength and "4" indicates strongest.

Two sophomore classes with a total of 105 undergraduate students were randomly selected to participate in the study. One class ($n = 52$) were randomly selected to receive VRLE instructions, while the other class ($n = 53$) received traditional instructions. The two classes were taught by the same instructor and the time frame was one semester.

2.3. Research method

The quasi-experimental research design was used to examine the effects that VRLE has on students' performance in learning, with one class receiving instructions given in the traditional manner, whereas the other class receiving instructions with the VRLE model implemented. The independent variable in the design was the use of instructions provided by the same teacher at the same pace. Questionnaires were administered to also observe the effects generated by the six learning modules and the results were coded to allow for analysis; knowledge, comprehension, imitation, and application were measured on the scale from 0 to 4 to evaluate the strength of the students' technical skills.

Forty participants took the preliminary test before the conduct of the study and the software SPSS 19.0 was used as a measurement of reliability test. The Cronbach's Alpha value was 0.763, as Nunnally (1978) suggested the alpha value to be at above 0.7 with DeVellis (1991) suggested the range to be between 0.65 and 0.70 in order for the value to be considered as indicative of "reliable validity".

Validity and reliability of the 12 sub-categories where 105 students were examined after the research has been conducted. The Cronbach α value was 0.821 which translates into strong reliability, while the alpha if item deleted value were above 0.7 for all of the 12 sub-categories – with that of ten sub-categories being above 0.8. The value produced after the SPSS19.0 was applied was 0.887.

3. Results and discussion

For the two classes of the experimental group and the control group, t-tests were performed to observe the differences that there might have been produced before and after the students participated in the two classes; the four dimensions observed were "nature of technology", "operation of machines", "selection of process parameters", and "processes planning". On the overall basis, performance displayed in pretest has been apparent to have been overtly improved in the three dimensions of "nature of technology", "operation of machines", and "selection of process parameters ", as the opposite holds true for the averaged score of the dimension of "processes planning" (see Table 2). The traditional teaching approach did not seemingly deliver observable differences in performance when considering the controls placed on the process parameters in the two dimensions of "nature of technology" and "operation of machines". As for the students in the experimental group, differences in their learning performance were detected in all four dimensions but the dimension of "nature of technology".

Covariance (ANCOVA) was applied to further study the differences observed in grades before class and after class in the four dimensions outlined (see Table 3). There were no observable differences in learning performance generated by the two classes in pretest. The posttest that was given after the students have received instructions suggests that there is a difference of 0.01 scale in

Table 3
Summary of covariance analysis for the undergraduate students of pre-course.

Source	SS	df	MS	F
Nature of technology				
Between groups	0.34	1	0.34	0.69
Within groups	50.75	103	0.49	
Operation of machines				
Between groups	1.29	1	1.29	1.18
Within groups	112.60	103	1.09	
Selection of process parameters				
Between groups	0.21	1	0.21	0.22
Within groups	98.32	103	0.95	
Process planning				
Between groups	0.38	1	0.38	0.34
Within groups	115.12	103	1.12	

Table 4
Summary of covariance analysis for the undergraduate students of post-course.

Source	SS	df	MS	F
Nature of technology				
Between groups	2.97	1	2.97	1.15
Within groups	371.54	103	3.61	
Operation of machines				
Between groups	15.62	1	15.62	5.34*
Within groups	301.28	103	2.93	
Selection of process parameters				
Between groups	16.53	1	16.53	5.97*
Within groups	285.19	103	2.77	
Process planning				
Between groups	18.74	1	18.74	8.34**
Within groups	231.11	103	2.25	

* $p < .05$.
** $p < .01$.

Table 5
Pre-and post-test mean scores for the undergraduate students.

Categories	Items	Control group		Experimental group	
		Pre-M	Post-M	Pre-M	Post-M
Nature of technology	Structure of technical skills	2.30	2.56	2.12	2.61
	Function of technical skills	2.02	2.23	2.09	2.32
	Relationship between technology and manufacturing	2.42	2.53	2.36	2.69
	Operation of machinery	2.37	2.44	2.43	3.02
Operation of machines	Operation of multi-function machinery	2.10	2.63	2.20	3.09
	Comprehensive operation of machinery	2.00	2.46	2.18	2.98
Selection of process parameters	Identify the parameters	2.35	3.18	2.34	3.86
	Rationale	2.21	2.85	2.27	3.79
	Control of parameters	1.98	2.73	1.99	3.57
	Introducing of the issues	2.13	2.67	2.05	3.71
Process planning	Proposition of solutions	2.02	2.58	2.00	3.58
	Optimization and completion of manufacturing	1.73	2.43	1.74	3.38

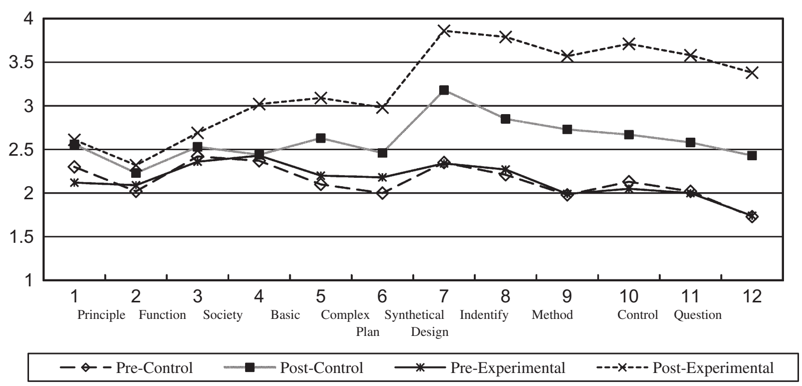

Fig. 1. Pre-and post-test mean scores for the undergraduate students.

learning performance between the two classes (see Table 4) in the dimension of "Process Planning" and a difference of 0.05 scale in the dimensions of "Selection of Process" and "Operation of Machinery", whereas no differences were found in "Nature of Technology". To have the four dimensions and the 12 sub-categories analyzed in more explicit terms, the mean value scores collected from both the pretest and posttest phases were listed in Table 5.

In order to have the research results presented in a straightforward fashion, the learning performances on the 12 sub-categories in the pretest phase of the two classes have been illustrated in Fig. 1. The levels of performance were similar. During the posttest phase, the mean value score for both classes have been illustrated to have improved, with such improvements being made at a greater scale for those who received VRLE-oriented instructions, namely the students in the experiment group. As the mean value scores produced by the VRLE-oriented instructions have demonstrated, significant improvements were made in process parameters, selection of manufacturing methods, selection of appropriate processing parameters, troubleshooting, optimization of planning in manufacturing, and completion of the designing process, as no such findings were made in the nature of technology dimension. On the overall basis, neither classes saw improvements in "Nature of Technology". This is reminiscent of the recent findings made in education of nature of science (Lederman, 2007); teaching approaches that are explicit in nature are much more motivating as teaching methods and the effectiveness of tacit teaching approaches have found to be less apparent. The same findings also apply to the education of nature of technology.

The students were able to embrace a comprehensive learning approach towards the four dimensions by applying the six modules of "learning resource", "digital content", "collaborative learning", "formative evaluation", "simulation of manufacturing process", and "practical exercise". The contents of the six modules have been so designed to allow the students to obtain a comprehensive understanding of how VRLE-oriented instructions on each of the module might be facilitating to their learning of the various technical skills that are taught. Questionnaires and interviews were administered as tools for collecting results on the students' learning performance. Percentages were calculated in proportion to the population size of the students as shown in Table 6. Data displayed in the chart reflects the preference conveyed towards the certain modules, the number of persons conveying the preferences, and the relative percentages after the respective data has been converted.

As shown in Fig. 2, in the learning in the dimension of "Nature of Technology", 75% of the students conveyed preferences in learning resources, digital content, and collaborative learning; for the

Table 6
Preferences conveyed by students for the four dimensions in percentage.

	Resources	Digital content	Collaborative learning	Formative evaluation	Simulation	Practical exercise
Nature of technology	14(27%)	13(25%)	12(23%)	2(4%)	5(10%)	6(11%)
Operation of machines	1(2%)	1(2%)	4(8%)	3(6%)	22(42%)	21(40%)
Selection of process parameters	8(15%)	5(10%)	6(11%)	10(20%)	11(21%)	12(23%)
Process planning	1(2%)	1	2(4%)	5(10%)	11(21%)	33(63%)

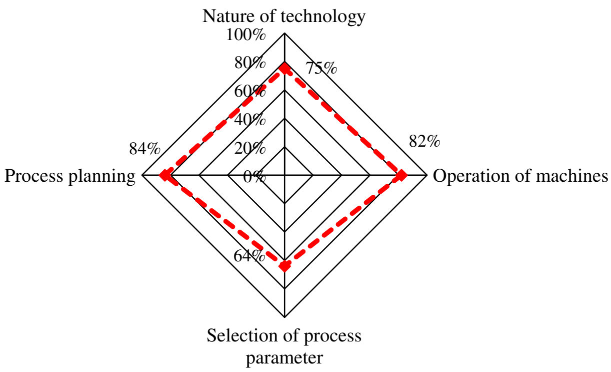

Fig. 2. Preferences of VRLE conveyed by students for the four dimensions in percentage.

dimension of ‘‘Operation of Machinery’’, 82% of the students conveyed preference in simulation of manufacturing and practical practice; 64% of the students preferred practical exercise, simulations of manufacturing, and evaluation for the dimensions of ‘‘Selection of Process Parameters’’, and 74% of the students, for the dimension of ‘‘Process Planning’’, prefer simulation of manufacturing and practical exercises.

4. Conclusion

In this study, technical skills in students are cultivated in the five dimensions of knowledge, comprehension, simulation, application, and creativity in accordance to the teaching objectives that have been set and the taxonomies for students learning outcome proposed by Blooms (1956) and Gagne (1968). A three-dimensional analysis of the virtual-reality learning environment has been developed based on the teaching experiences and research basis that are already acquired, and the five dimensions have been assessed on the scale of 0 to 4, with ‘‘0’’ being the weakest in strength and ‘‘4’’ being the strongest. The virtual reality learning environment (VRLE) has also been developed to meet different goals as the various technical skills are being examined. For the four dimensions of ‘‘nature of technology’’, ‘‘operation of machinery’’, ‘‘selection of process parameters’’, and ‘‘process planning’’ in technical skills, VRLE has also designed the six modules of ‘‘learning resource’’, ‘‘digital content’’, ‘‘collaborative learning’’, ‘‘formative evaluation’’, ‘‘simulation of manufacturing process’’, and ‘‘practical exercise’’ particularly for providing students with assistance in the development on their technical skills on a specific, gradual basis. The four dimensions were further broken down into three subgroups, which makes a total of 12 sub-categories of ‘‘structure of technical skills’’, ‘‘ function of technical skills’’, ‘‘relationship between technology and manufacturing’’, ‘‘operation of machinery’’, ‘‘operation of multi-function machinery’’, ‘‘comprehensive operation of machinery’’, ‘‘identify the parameters’’, ‘‘rationale’’, ‘‘control of parameters’’, ‘‘introducing of the issues’’, ‘‘proposition of solutions’’, and ‘‘optimization and completion of manufacturing’’.

The students have reported finding VRLE a significantly more effective method when considering the three dimensions of ‘‘operation of machinery’’, ‘‘selection of process parameters’’, and ‘‘process planning’’, though not so much so when it comes to the dimension of ‘‘nature of technology’’. The performance of the students who were given traditional teaching instructions showed no significant differences in the dimensions of ‘‘nature of technology’’ and ‘‘operation of machinery’’, while showing a 0.05 value of a difference in ‘‘control of parameters’’ and ‘‘process planning’’. The performance of the students who were offered teaching instructions with VRLE showed no difference on just ‘‘nature of technology’’, as changes in their performance have been detected: a 0.05 in value of a difference in ‘‘operation of machinery’’; a 0.01 in value of a difference in ‘‘control of parameters’’ and ‘‘process planning’’. No changes were found between the two classes of students during the pretest period in all four of the dimensions examined. After having participated in the course, performance of the students from the two classes displayed a difference of 0.01 in value in ‘‘process planning’’ and a 0.05 in value in ‘‘selection of process parameters’’ as well as in ‘‘operation of machinery’’.

In the learning of ‘‘operation of machinery’’, it has been found that students find the modules of ‘‘simulation of manufacturing process’’ and ‘‘practical exercise’’ more appealing, as they are more fond of the modules of ‘‘learning resource’’, ‘‘digital content’’, and ‘‘collaborative learning’’, in terms of learning on ‘‘nature of technology’’. In the studying of ‘‘selection of process parameters, they have found ‘‘practical exercise’’, ‘‘simulation of manufacturing process’’, and ‘‘formative evaluation’’ more interesting and so are ‘‘simulation of manufacturing process’’ and ‘‘practical exercise’’ for process planning. As can be seen, the different modules designed satisfy the different learning needs that students might have.

It has also been observed that in terms of learning of the nature of technology, teaching approaches such as formative evaluation and collaborative learning that are embedded in situational operation were not producing high performance in student learning, rather, it is teaching approaches that are apparent that most motivate learning to occur in students. This is what subsequent research initiatives will be focusing on.

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References

Alvarez, J. C., & Su, H. J. (November 2009). VRMDS: An intuitive virtual environment for supporting the conceptual design of mechanisms. *Virtual Reality*. SI: Manufacturing and Construction. http://dx.doi.org/10.1007/s10055-009-0144-z.

Amorim, M. A., Trumbore, B., & Chogyen, P. L. (2000). Cognitive repositioning inside a desktop VE: The constraints introduced by first- versus third-person imagery and mental representation richness. *Presence: Teleoperators and Virtual Environments, 9*(2), 165–186.

Antonya, C., & Talaba, D. (2007). Design evaluation and modification of mechanical systems in virtual environments. *Virtual Reality, 11*(4), 275–285.

Beckman, T. A. (1997). Methodology for knowledge management. Canada, Banff: International Association of Science and Technology for Development AI and Soft Computing Conference.

Bierbaum, A., Just, C., Hartling, P., Meinert, K., Baker, A., & Cruz-Neira, C., (2001). VR juggler: A virtual platform for virtual reality application development. In: Virtual Reality Conference, IEEE, pp. 89, IEEE Virtual Reality Conference 2001 (VR 2001).

Blooms, B. S. (1956). *Taxonomy of educational objectives, the classification of educational goals handbook I: Cognitive domain*. New York: McKay.

Brown, J. S., Colins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32–42.

Burdea, G., & Coiffet, P. (2002). *Virtual reality technology second edition*. Hoboken, New Jersey: John Wiley & Sons Inc.

Chen, Y. L., Chen, N. S., & Kinshuk (2009). Examining the factors influencing participants' knowledge sharing behavior in virtual learning communities. *Educational Technology and Society, 12*(1), 134–148.

Cromby, J., Standen, P., & Brown, D. (1995). Using virtual environments in special education. *VR in the Schools, 1*(3), 1–4.

Dede, C., & Lewis, M. (1995). *Assessment of emerging educational technologies that might assist and enhance school-to-work transitions*. Washington, DC: National Technical Information Service.

DeVellis, R. F. (1991). *Scale development theory and applications*. London: SAGE.

Elliott, J., & Bruckman, A. (2002). Design of a 3D interactive math learning environment. Paper presented at the DIS 2002 (ACM conference on designing interactive systems). London, UK.

Furlong, T. J., Vance, J. M., & Larochelle, P. M. (1999). Spherical mechanism synthesis in virtual reality. *ASME Journal of Mechanical Design, 121*(4), 515–520.

Gagne, R. M. (1968). *Learning research and school subjects*. F.E. Peacock.

Gordin, D. N., & Pea, R. D. (1995). Prospects for scientific visualization as an educational technology. *The Journal of Learning Sciences, 4*, 249–279.

Johari, A. (2005). International review of a feasible constructivist instructional development model for VR-based learning environments: Its efficacy in the novice car driver instruction of Malaysia. *Association for Educational Communications and Technology, 53*(1), 111–123.

Knott, A. (2000). Learning route and survey representations from a virtual reality environment. The Catholic University of America, Washington, DC: Unpublished doctoral dissertation.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831–880). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Lee & Yang (1999). A study on the infusion of technological literacy education content at the elementary school level. Proc. Natl. Sci. Council. ROC(D), vol. 9(2), pp. 25–31.

Moreno, R. & Mayer, R. E. (2000). A learner-centered approach to multimedia explanations: Deriving instructional design principles from cognitive theory. *Interactive Multimedia Electronic Journal of Computer Enhanced Learning*. <http://imej.wfu.edu>.

Nunnally, J. C. (1978). *Psychometric theory* (2nd ed.). New York: McGraw-Hill.

Patera Draper & Nael (2008). Exploring magic cottage: A virtual reality environment for stimulating children's imaginative writing. *Interactive Learning Environments, 16*(3), 245–263.

Rickel, J., & Johnson, L. W. (1998). STEVE: A pedagogical agent for virtual reality. In K. P. Sycara & M. Woolridge (Eds.), *Proceedings of the 2nd international conference on antonomens agents (Agents '98)* (pp. 332–333). New York: ACM Press.

Rizzo, A. A., Buckwalter, J. G., Bowerly, T., van der Zaag, C., Humphrey, L., Neumann, U., et al. (2000). The virtual classroom: A virtual environment for the assessment and rehabilitation of attention deficits. *Journal of Cyberpsychology and Behavior, 3*, 483–500.

Saleeb, N., & Dafoulas, G. (2011). Effects of virtual world environments in student satisfaction. *International Journal of Knowledge Society Research, 2*(1), 29–48.

Salzman, M., Dede, C., Loftin, R., & Chen, J. (1999). A model for understanding how virtual reality aids complex conceptual learning. *Presence: Teleoperators and Virtual Environments, 8*, 293–316.

Smedley, T. M., & Higgins, K. (2005). Virtual technology: Brining the world into the special education classroom. *Intervention in School and Clinic, 41*(2), 114–119.

Wasson, B. (1997). Advanced educational technologies: The learning environment. *Computers in Human Behavior, 13*(4), 571–594.

Yang, S. K. (1992). The philosophical analysis of technological literacy education. The 7th Meeting on Research of Technological Literacy Education. Taipei: National Science Council.

Yee, N., & Bailenson, J. N. (2007). The proteus effect: Self transformations in virtual reality. *Human Communication Research, 33*, 271–290.