

An Effective Virtual Laboratory Approach for Chemistry

¹Norasiken Bakar, ²Halimah Badioze Zaman, ¹Massila Kamalrudin, ³Kamaruzaman Jusoff and
⁴Noorli Khamis

¹ Department of Multimedia Interactive, Faculty of Technology and Communication, Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

²Department of Information Science, Faculty of Technology and Information Science, Universiti Kebangsaan Malaysia (UKM), 43600 Bangi, Selangor Darul Ehsan, Malaysia

³Department of Forest Production, Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

⁴Centre for Languages and Human Development, Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

Abstract: Virtual laboratories, currently used as an approach to virtual learning, have long been adopted in the teaching and learning process in many schools. The objectives of this paper are to develop a multimedia virtual reality laboratory for Chemistry (VLab-Chem) and to conduct an effectiveness testing on the virtual laboratory approach. The VLab-Chem was developed based on the Cognitivist-Constructivist-Contextual Life Cycle Development model (KHK³-VLab-Chem). The effectiveness testing of the virtual laboratory VLab-Chem was conducted based on the quasi-experimental approach, adopting the ethnographic observational technique, through a case study of a Smart School in Melaka. The study involved two groups, Control (K) and Experimental (E) groups, and the t-test measurement was adopted. Results indicated that the Experimental group (E), who underwent the teaching and learning process using VLab-Chem had a higher achievement level in comparison with the control group (K), who experienced the conventional approach to teaching and learning. This paper implies the effectiveness of the VLab-Chem in a chemistry classroom. For future work, it is recommended that the instructional design (ID) model of VLab-Chem includes the three-dimensional (3D) setting through immersive technology during an experiment by using Data Glove or Head-Mount Display (HMD). This would allow users to experience touching the equipment and materials with their own hands.

Key words: Virtual Learning, Virtual Laboratory, Chemistry Education, Cognitivist-Constructivist-Contextual Approach

INTRODUCTION

Virtual Learning is a new learning generation for the computer-based education system. In consequent, there arises a need to conduct studies on the effectiveness of the computer-based education system in comparison with the conventional teaching method. Most courseware for virtual learning are developed to overcome problems of teaching conditions which demand high imagination, high cost, resourceful learning materials and long hours. Virtual laboratories are designed to overcome problems encountered in conventional classes and to conduct dangerous chemical experiments. They have been seen as a new teaching method which is less expensive and less demanding, but capable to retain the students' interest in learning (Mark, P. and E. Marris, 2006; Morozov, M., 2004). However, system experience plays a significant role in moderating the effect of enjoyment on continuous intentions, and it also has a significant direct relationship with intentions (Stuart J. Barnes, 2011). This paper covers the teaching and learning theories from which this virtual laboratory VLab-Chem is derived – the Cognitivist, Constructivist and Contextual. The cognitivist theory describes the thinking process involved in a person when teaching and learning takes place (Bloom, B.S., 1992). It entails the short and long term memory. This theory suggests that during a learning process, the learner forms a mental cognitive structure (Reed, S.K., 2000). As learning takes place, the learner manages all the information and stores them in his memory. The learner will retrieve this information, once needed, to assist his learning process (Ee, Ah Meng, 2000).

The constructivist approach claims that a learner learns by forming continuous constructs, making deductions, and adapting his knowledge by making reality checks and direct interactions with the surroundings (Jonassen, D.H., 1991). On the same note, Roziyah (2004) asserts that in a constructivist-based classroom, learners are actively involved in their learning process, and they are given the opportunity to form their

Corresponding Author: Norasiken Bakar, Department of Multimedia Interactive, Faculty of Technology and Communication, Universiti Teknikal Malaysia, Melaka (UTeM), 1200, Ayer Keroh 75450 Melaka, Malaysia.

Tel: +6013-6301757, E-mail: norasiken@utem.edu.my

knowledge based on their respective backgrounds. On the other hand, the contextual teaching and learning concept allows the teachers to disseminate teaching contents based on real situations or the learners' real experience, by relating the new information with real life scenario (Sears, S.J., 1999). Through this contextual learning, learners are able to relate new concepts with their life more effectively (Ketter, C.T. and J. Arnold, 2003). This approach also emphasizes the practical aspect of learning which suggests that learners should experience hands-on learning with the lab apparatus (Hardy, T.C., 2003). It has been shown that interactive multimedia environments (i.e. control over features of the presentation) positively influence user attitudes (Haseman, W.D., 2002; Kettanurak, V., 2001). Also, it is shown that information complexity interacts with the multimedia environment to influence learning outcomes (Andres, H.P., 2004). In addition, more vivid (e.g. sensor ally rich, such as animation and narration) and more interactive multimedia environment will increase the satisfaction and interest of the users. Task complexity is also found to be interacting with vividness and interactivity to affect performance and perceived mental effort (Nicholson, J., 2008; Nicholson, J. and D.B. Nicholson, 2010).

The conventional teaching in a chemistry lab exposes the learners to the use of various harmful chemical substances. In addition, a careful preparation needs to be done prior to the use of all the apparatus and substances for the experiments. This preparation procedure is normally very demanding, in terms of time, equipment and materials, especially if the experiments need to be reconducted due to failure in getting the expected results. Occasionally, improper preparation and carelessness lead to mishaps. A Form Five student had his left body paralysed and lost his ability to speak after an accident during a science experiment in the school (Utusan Malaysia, 2005). Experiments conducted conventionally in schools cannot be done by individual student due to the high cost of the materials (Allwright, D., 1991). Therefore, the experiments have to be conducted in groups. An interview survey carried out with the chemistry teachers in the pre-analysis stage revealed that the topic *Acid, Base and Salt* is the most difficult topic for the students, along with the many subtopics to be covered (Norasiken, B. and B.Z. Halimah, 2005). The teachers have to speed up their teaching to cover the syllabus on time. As the result, only important experiments are selected to be conducted in the class. This is in lined with the age of 21st century. Shifting education must be parallel with 21st century as it is important to prepare student to face real world outside classroom (Norrizan Razali, 2011).

To overcome these various problems in the teaching and learning of Chemistry, this study, which deals with the design and development of a virtual laboratory, was carried out to allow the students to do harmful experiments repeatedly, as many times as they wish. This virtual laboratory also offers the learners the opportunity to relate their learning with the real situation through the use of videos, which provide more meaningful and effective Chemistry lessons. An effective way of using simulations is as preparation for laboratory activities (Nico, R., 20122). Therefore, the general objective of this study is to develop a virtual laboratory for the Chemistry class based on the cognitivist-constructivist-contextual approach (VLab-Chem). The specific objectives are two-folds, namely (a) to develop a virtual laboratory (VLab-Chem) for the teaching of Form IV Chemistry topics of *Acid, Base and Salt*, and (b) to evaluate the effectiveness of this VLab-Chem with science students of a public school.

METHODS AND MATERIALS

The construction of VLab-Chem:

The developmental design of the virtual laboratory was based on a Life Cycle Model, which comprises of five phases, namely: analysis, design, development, implementation, evaluation. This model is known as the Cognitivist-Constructivist-Contextual VLab-Chem Life Cycle Model (KHK³-VLab-Chem). The assessment on the effectiveness of the VLab-Chem was conducted based on a case study through a quasi-experiment method at the school. This method appeared to be the most suitable to evaluate the effectiveness of the virtual lab, because a comparison of the teaching and learning process between the virtual lab and the conventional classroom method on the same topic can be performed.

The selection of the topic *Acid, Base and Salt* from the New Secondary School Curriculum (KBSM) Chemistry syllabus was based on the needs analysis carried out prior to the study. This early analysis was a document analysis of the Malaysia Certificate of Education (MCE) Performance Report as produced by the Ministry of Education, on the topic *Acid, Base and Salt* (Lembaga Peperiksaan Kementerian Pendidikan Malaysia, 2002; 2003; 2004). Several interview sessions were also conducted with the Chemistry teachers and form five students. The evaluation was carried out with the samples of the case study from the public school. It took six weeks to carry out the whole procedure of evaluation. The sample consisted of two form four classes, taught by the same chemistry teacher.

The selected samples were the groups who obtained excellent results in two subjects for the 2006 Lower Secondary Examination (PMR). They obtained at least Grade B for their science subject. The evaluation adopted the quasi-experiment method, with 30 students as the Experiment Group (E) and 31 students as the Control Group (K). The design of the effectiveness testing involved the collection of data through the

ethnographic-based observation by utilising the check list and interview scheduling. In addition, the data was also collected through a case study using the quasi-experiment method. The samples were selected from two classes with about the same number of students. One of the classes was assigned as the Experiment Group (E), while the other was the Control Group (K). The Experiment Group was given the treatment with the teaching and learning of the topic *Acid, Base and Salt* using the VLab-Chem. Meanwhile, the Control Group (K) was exposed to the conventional teaching and learning method of the same topic.

Table 1 shows the distribution of the students for the study. A total of 31 students formed the Control Group (K), and another 30 represented the Experiment Group (E). The pre and post test questions were constructed to assess the performance of the students, which was later used to determine the effectiveness of the VLab-Chem. The results were compared with the results of the students who were exposed to the conventional method. These two tests consisted of two parts: Part A comprised 20 objective questions, which carried 20 marks. Part B contained structured questions with another 20 marks. Part A was designed to assess the students' general range of cognitive level. The items included questions on facts, application, analyses and syntheses. Part B, on the other hand, assessed the highest level of thinking skills which are application, analyses, syntheses and assessment. The measurement was considered from the improvement of the students' performance in the pre and post tests.

Table 1: Distribution of students.

Group	Girls	Boys	Total
Control (K)	15	16	31
Experiment (E)	18	12	30
Total	33	28	61

The Cognitivist-Constructivist-Contextual VLab-Chem Life Cycle Model (KHK³-VLab-Chem):

The Cognitivist-Constructivist-Contextual VLab-Chem Life Cycle Model (KHK³-VLab-Chem) is shown in Figure 1. It emphasises the aspects of target groups, teaching and learning objectives, syllabus, prototype, implementation and modification. Several entities were employed to determine the needs of the software development. These include the target groups, teaching and learning objectives, students' backgrounds, students' current knowledge, contents management (e.g. teaching and learning materials), virtual laboratory design, Acid, Base and Salt module, limitations, moral values, and assessment preparation. The analysis was conducted with the assistance of Chemistry teachers, Form V students and lab assistants. The main purpose of developing the virtual lab is to offer diversity in teaching and learning Chemistry, specifically, on the topic Acid, Base and Salt.

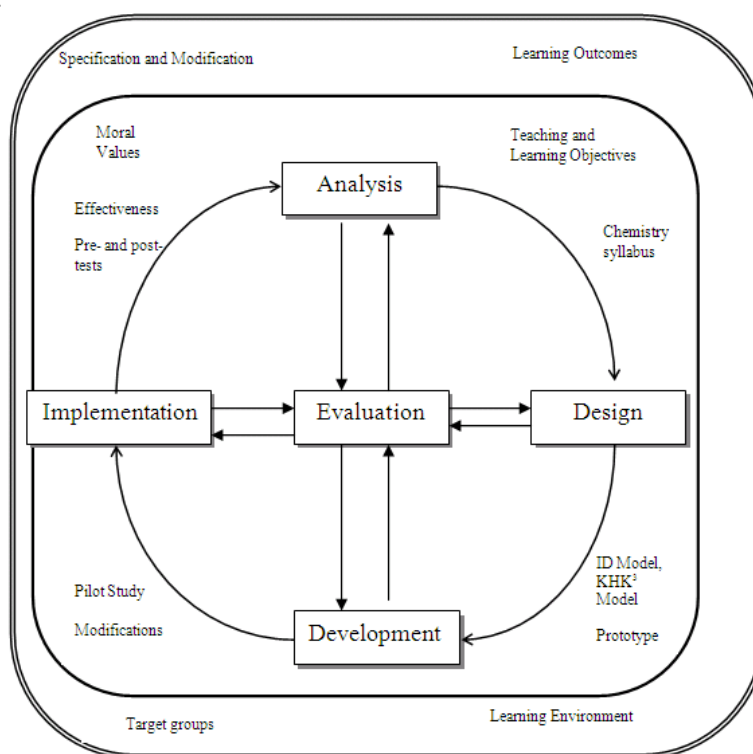


Fig. 1: The Cognitivist-Constructivist-Contextual VLab-Chem Life Cycle Model (KHK³-Lab-Chem).

The design phase encompasses the elements applied in the virtual laboratory based on the constructed conceptual model. This phase involved the activity of designing processes, such as designing the VLab-Chem architecture, Conceptual ID Model, and teaching and learning contents. The development phase of the VLab-Chem Life Cycle Model entailed three main process activities such as the development of the virtual laboratory, the Electronic Reports, and the Work Sheets. The implementation phase covered the aspects of the case study on the application of VLab-Chem based on the cognitivist-constructivist-contextual approach for the teaching and learning of Chemistry lessons. This phase dealt with the evaluation of each unit and element developed for the teaching and learning process through VLab-Chem, which was electronically and conventionally constructed. These two applications provided the opportunity to the teachers to incorporate the electronic-based teaching and learning (through the VLab-Chem) into the conventional method (Electronic Reports and Work Sheets).

The ID model of the VLab-Chem Virtual Laboratory:

The ID Model for the development of the VLab-Chem virtual laboratory in Figure 2 adopted the cognitivist-constructivist-contextual approach in the teaching and learning of Chemistry, specifically, on the topic *Acid, Base and Salt*. This virtual lab was constructed based on sound learning theories and pedagogical principles. Contextual learning approach is based on the notion that learning can only occur when students are able to connect content with context. That is, student must be able to relate the lesson presented in a classroom setting to something familiar in his or her daily life (Berns, R.G. and P.M. Erickson, 2001). These learning theories provide a pedagogical basis for understanding on how students learn (Rozie Ezrina, 2012).

The ID Model was designed taking into account several important aspects of Chemical Science teaching concepts, such as the methodology of chemical science teaching and learning, the system of chemical science teaching process, and the development of the students. These aspects were interpreted into systematic interactive multimedia modules.

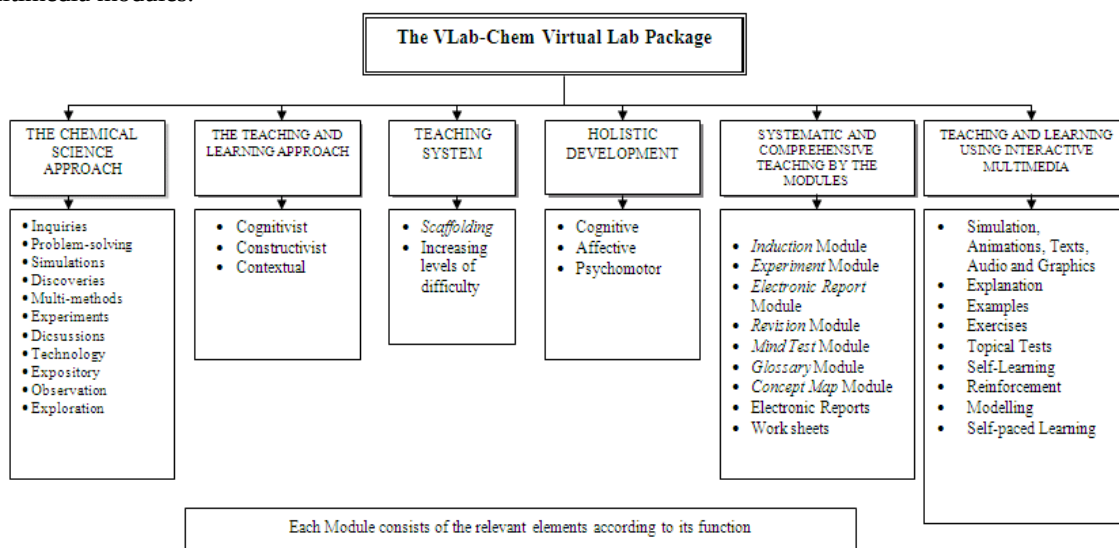


Fig. 2: The Conceptual ID Model of the VLab-Chem Virtual Lab Development.

The Screen Design of the VLab-Chem Based on the ID Model:

The VLab-Chem virtual lab consists of seven main modules, which are the Induction, Experiment, Electronic Report, Revision, Mind Test, Concept Map, and Glossary. The VLab-Chem prototype entails 46 virtual experiments in the Experiment module. This module comprises five video clips on the daily used salt, such as for medical, agricultural and dietary purposes. It reports on the various scientific names of salt, before proceeding with the experiments to enhance the students' comprehension. Figure 3 shows the video clip on the uses of salt for medical purposes under the topic *Acid, Base and Salt in Plaster of Paris*. In tandem with the contextual learning theory and problem-based science teaching, this method assists the students to associate the lesson with the realistic aspect of chemical use in the real world.

RESULTS AND DISCUSSION

Based on the experiments, it is found that the average score for group (K) in Section B of the pre-test, which assessed the higher thinking skills, was 3.39%, while for group (E) was 4.00%, with a very little difference, that was 0.61%. For the post test, group (E) obtained an average increased score of 52.83% in this same section, while group (K) showed an average increase of 17.58%. This finding illustrates that the students

from group (E) had a higher average increase in scores for the higher thinking skills test in comparison with group (K).

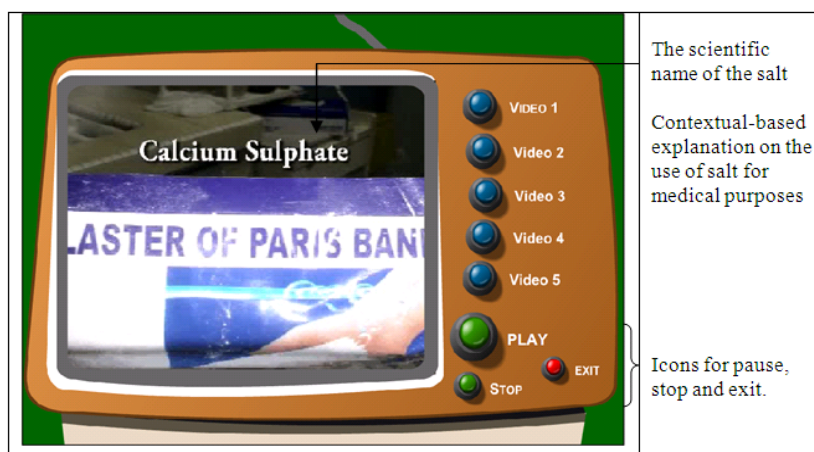


Fig. 3: Video: *Acid, Base & Salt in Plaster of Paris*.

The finding also reveals that the percentage of students passing Section B of the tests is 40%. 83.33% of students from group (E) passed the tests, and this value is higher than group (K), which had only 9.68% of passing students. Next, the scores from Section B of the post test for both groups were analysed according to the SPM grading system as shown in Table 2.

Table 2: Grade categories for Chemistry in SPM.

Scores	Grades	
0 - 39	9F	} Fail
40 - 44	8E	
45 - 49	7D	} Pass
50 - 54	6C	
55 - 59	5C	} Credit
60 - 64	4C	
65 - 69	3C	} Distinction
70 - 79	2B	
80 - 100	1A	

Table 3 and Figure 4 show the distribution of Section B post test scores obtained by both groups according to the MCE grades. Majority of the students from group (K) did not possess higher thinking skills, with 28 out of 31 students from the group failed with grade F. Unlike group (K), group (E) demonstrated an even distribution of achievements in grades. This proves that the use of the VLab-Chem with its cognitivist-constructivist-contextual approach is able to assist the students to have more effective and meaningful command of the topic *Acid, Base and Salt*. Table 3 displays the difference in the performance in Section B post test according to the MCE grades.

Table 3: Distribution of Section B post test scores: Groups (K) and (E)

Scores/ Grade	Group (K)		Group (E)		TOTAL	
	Freq.	%	Freq.	%	Freq.	%
0 - 39(9F)	28	90.32	5	16.67	33	54.10
40 - 44(8E)	1	03.23	0	00.00	1	01.64
45 - 49(7D)	2	06.45	7	23.33	9	14.75
50 - 54(6C)	0	00.00	5	16.67	5	08.20
55 - 59(5C)	0	00.00	2	06.67	2	03.28
60 - 64(4C)	0	00.00	3	10.00	3	04.92
65 - 69(3C)	0	00.00	1	03.33	1	01.64
70 - 79(2B)	0	00.00	4	13.33	4	06.55
80 - 100(1A)	0	00.00	3	10.00	3	04.92
TOTAL	31	100.0	30	100.0	61	100.0

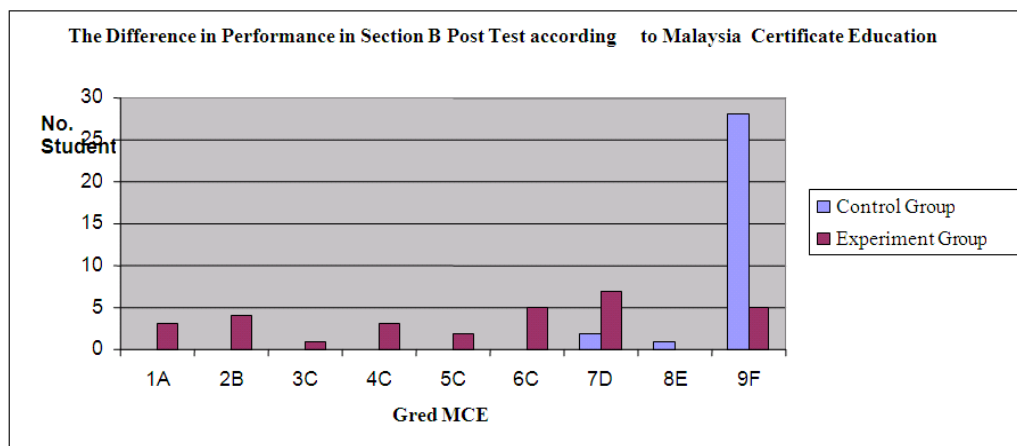


Fig. 4: The Difference in Performance in Section B Post Test according to MCE Grades.

The paired T-Test was carried out to analyse the difference in performance between the pre and post tests scores to determine the level of higher thinking skills of group (K) students, who went through the conventional method of teaching and learning process. Similarly, the T-Test was used to determine the level of higher thinking skills of group (E) students, who went through the virtual lab teaching and learning process. The test showed that t value = 7.160, with the t -tailed significance value $p = 0.000$; because p value is less than 0.05, statistically, there was a significant increase in scores for Section B between the pre and post tests, which tested the higher thinking skills of group (K) students. This means that the null hypothesis is rejected. The test also showed that the t value = 15.518, with the t -tailed significance value $p = 0.000$; because p value is less than 0.05, statistically, there was a significant increase in scores for Section B between the pre and post tests, which tested the higher thinking skills of group (E) students. This means that the null hypothesis is rejected.

The comparison of higher level thinking skills during the pre test were carried out based on Section B question set between the Control group (K) and the Experiment group (E) using the T-Test. The findings showed that the mean score of group (K) is 3.39, while group (E) is 4.00, with t value 0.42, and two-tailed significance $p = 0.67$. p value is larger than 0.05. Thus, the null hypothesis is accepted. In other words, there is no significant difference in the higher level thinking skills between students from group (K) and group (E) in the pre test. The comparison of higher level thinking skills during the post test were carried out based on Section B question set between the Control group (K) and the Experiment group (E) using the T-Test. The findings showed that the mean score of group (K) is 17.58, while group (E) is 52.83, with t value 8.96, and two-tailed significance $p = 0.00$. p value is smaller than 0.05. Thus, the null hypothesis is rejected. Group (E) who used the VLab Chem virtual lab in their teaching and learning process obtained higher performance than group (K) who used the conventional method.

Conclusion:

This study concludes that the use of the cognitivist-constructivist-contextual- based VLab-Chem virtual lab was able to enhance the higher level thinking skills of students from group (E), who used the VLab-Chem in comparison with the students from group (K), who conducted their experiments in conventional labs. It can be implied that the VLab-Chem model tested is very effective in a chemistry classroom. It is recommended that the instructional design (ID) model of VLab-Chem should include the three-dimensional (3D) setting through immersive technology during an experiment by using Data Glove or Head-Mount Display (HMD) since it allows users to experience touching the equipment and materials with their own hands.

ACKNOWLEDGMENT

This research has been supported by Universiti Teknikal Malaysia Melaka (UTeM).

REFERENCES

- Allwright, D., 1991. Autonomy and individualization in whole-class instruction. In A. Brookes and P. Grundy (eds.) London: Modern English Publications & The British Council.
- Andres, H.P., 2004. Multimedia, information complexity, and cognitive processing, Information Resources Management Journal, 17(1): 63-78.
- Berns, R.G. and P.M. Erickson, 2001. Contextual teaching and learning: Preparing students for the new economy. Columbus, OH: National Dissemination Centre for Career and Technical Education.

- Bloom, B.S., 1992. Taksonomi Objektif Pendidikan: Domain Kognitif. Terj. Mohd Isha Awang & Azizi Publicist. Kuala Lumpur: Dewan Bahasa & Pustaka (*In Malay*).
- Ee, Ah Meng, 2000. Psikologi Dalam Bilik Darjah. Kuala Lumpur : Fajar Bakti Sdn. Bhd. (*In Malay*).
- Hardy, T.C., 2003. Contextual Teaching In Science. Retrieved 2005, from: <http://www.kennesaw.edu/english/ContextualLearning/2003/Bartow/TeraHardy.pdf>.
- Haseman, W.D., V. Polatoglu and K. Ramamurthy, 2002. An empirical investigation of the influences of the degree of interactivity on user-outcomes in a multimedia environment, *Information Resources Management Journal*, 15(2): 31-48.
- Jonassen, D.H., 1991. Objectivism versus Constructivism: Do We Need a New Philosophical Paradigm? *Educational Technology Research and Development, Educational Technology & Society Journal*, 39(3): 5-14.
- Kettanurak, V., K. Ramamurthy and W.D. Haseman, 2001. User attitude as a mediator of learning performance improvement in an interactive multimedia environment: an empirical investigation of the degree of interactivity and learning styles, *International Journal of Human-Computer Studies*, 54(6): 541-83.
- Ketter, C.T. and J. Arnold, 2003. Implementing contextual teaching and learning: case study of Nancy, a high school science novice teacher. Retrieved 2005, from: <http://www.coe.uga.edu/ctl/casestudy/Arnold.pdf>.
- Lembaga Peperiksaan Kementerian Pendidikan Malaysia, 2002. Laporan Prestasi SPM 2002. Kuala Lumpur: KPM (*In Malay*).
- Lembaga Peperiksaan Kementerian Pendidikan Malaysia, 2003. Laporan Prestasi SPM 2003. Kuala Lumpur: KPM (*In Malay*).
- Lembaga Peperiksaan Kementerian Pendidikan Malaysia, 2004. Laporan Prestasi SPM 2004. Kuala Lumpur: KPM (*In Malay*).
- Mark, P. and E. Marris, 2006. How dangerous is chemistry? Retrieved 2007, from: <http://blogs.nature.com/thescpticalchymist/>.
- Morozov, M., A. Tanakov, A. Gerasimov, D. Bystrov and V. Cvirco, 2004. Virtual Chemistry Laboratory for School Education. The 4th IEEE International Conference on Advanced Learning Technologies (ICALT), pp: 605-608.
- Nicholson, J. and D.B. Nicholson, 2010. A stream runs through IT: using streaming video to teach information technology, *Information Technology and Education Journal*, 27(1): 17-24.
- Nicholson, J., D. Nicholson and J. Valacich, 2008. Examining the effects of technology attributes on learning: a contingency perspective, *Journal of Information Technology Education*, 7(11): 185-204.
- Nico, R., W.R. van Joolingen and J.T. van der Veen, 2012. The learning effects of computer simulations in science education, *Computers & Education*, January 2012, 58(1): 136-153.
- Norasiken, B. and B.Z. Halimah, 2005. Analisis Awal Makmal Maya Bagi Pengajaran Kimia (Asid, Bes dan Garam). *Inovasi Teknologi Instruksional Dalam Pengajaran Dan Pembelajaran. Convention Technology Education 8th*, pp: 809-816. Terengganu: Persatuan Teknologi Pendidikan Malaysia (*In Malay*).
- Norrizan Razali, 2011. ICT Pupuk Kemahiran Abad ke-21. Portal Pendidikan Utusan Malaysia (*In Malay*).
- Reed, S.K., 2000. Cognition: theory and applications. 5th Ed. Stanford, CT: Thomson Learning.
- Roziah Abdullah, 2004. Pembangunan dan Keberkesanan Pakej Multimedia Kemahiran Berfikir Bagi Mata Pelajaran Kimia. Thesis Doktor Falsafah. Fakulti Teknologi Dan Sains Maklumat Universiti Kebangsaan Malaysia, Bangi, Selangor (*In Malay*).
- Rozie Ezrina, 2012. The effect of Course Management System (CrMS) on achievement, satisfaction and acceptance to secondary school in Johor. Master thesis. Faculty of Technology and Communication, Universiti Teknikal Malaysia Melaka (UTeM), Malaysia.
- Sears, S.J., 1999. What is contextual teaching and learning? Retrieved 2005, from: <http://www.contextual.org/>.
- Stuart J. Barnes, 2011. Understanding use continuance in virtual worlds: Empirical test of a research model, *Information & Management Journal*, 48(8): 313-319.
- Utusan Malaysia, 2005. Pelajar lumpuh selepas cedera lakukan eksperimen di sekolah. Sabtu 7 Mei 2005 (*In Malay*).