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Pedagogy-Based-Technology and Chemistry Students' Performance in Higher Institutions: A Case of Debre Berhan University

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Many students have difficulty in learning abstract and complex lessons of chemistry. This study investigated how students develop their understandings of abstract and complex lessons in chemistry with the aid of visualizing tools: animation, simulation and video that allow them to build clear concepts. Animation, simulation and video enable learning by doing and provide opportunity to explore the abstract and complex lessons of chemistry. They also enable to present information in more dynamic, compelling and interactive way with engaging environment. The study applied animation, simulation and video supporting, on student-centered learning activities, in electrochemistry for second year students organized with state of art technology flash and micro media player and evaluated for its effectiveness. A particular focus of this investigation was to what extent the uses of animation, simulation and video influenced student-centered learning. Pre- and post- tests were administrated on the target group and concurrent embedded mixed case study design was employed. Total quality of the developed package was evaluated by administrating a separate schedule containing open and closed ended question. The comments and ratings obtained in the learners' insights provided the basis for the learning impact of the study. The result obtained from the experiment and responses of the schedule showed that technology integrated with appropriate pedagogy improves the performance of students.

Keywords: PBT (pedagogy-based-technology), animation, simulation and video, abstract and complex lessons

Introduction

Education plays a very important and central role in the country's transformation strategy. The transition to a modern and state-of-the-art educational system is happening at all academic levels. Especially understanding chemistry plays remarkable roles in improving the society's social, economical and political way of life, since the strong commitment to disciplinary strength in chemistry, results in the development with physical, biological science and technology. So learning chemistry is a demanding task. Its abstract and complex nature continues to be challenging and unattainable to most of the students. The difficulties may lie in human learning as well as nature of the subject (McCormick & Li, 2006).

Ethiopia has an energetic and powerful young generation to fulfill the country's motive to strive for

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economic and social prosperity. Ethiopia might exercise a fast recovery from long years of economic downturn and social turmoil. Even though these positive tendencies, the country still has a long way to go to reach general social and economic welfare for all. Especially underdevelopment of the logistical, health care and education quality can be named as barriers to the healthy development of the country. On the other hand, one has to note that the government has been putting concentrated effort to develop these sectors (for example, by large investments in both education and the building of hospitals). But this does not bring the educational delivery system to the expected level (Kocsev, Hansen, Hollow, & Pischetola, 2010). One of the main challenges of the country is disseminating quality education (Negash, 2006). The present education policy of Ethiopia gives high priority on improving teachers and teaching quality in the universities to produce effective professionals. To achieve this mission, the government has built 13 new universities and increased the total number of universities to 21 (IOM (International Organization for Migration), 2008). Due to this expansion, the number of young people entering universities is increasing. But they are choosing other study fields than natural science. This lack of interest shown by young people for learning natural science is truly an issue that needs a great concern which enforces to investigate the reason. Most of the universities in Ethiopian follow traditional and student-centered way of teaching. Similarly, the Amhara Regional State in Ethiopia has five universities and the current learning and teaching process is more traditional, and in some cases student-centered approach, with this strategy, in the last few decades, the students were not clear about some abstract and complex lessons and not willing to join to chemistry department (Robinson, 2003; McCormick & Li, 2006; Sellers, Robert, Giovanetto, Fredrich, & Hammargren, 2007). The abstract nature of the subject not only causes difficulties for many students, but also makes it an unpopular subject (Tsaparils, 2003). It indicates that both traditional educational practices and newer constructivist methods appear unable to solve these problems (Taylor & Coll, 2001; Scardemalia & Bereiter, 2006). As a result, the number of students enrolling in natural science is declining (Saint, 2004). For instance, at Debre Berhan University, the nine natural and social science departments have a total of 1,457 students in the academic year of 2008/2009 of these only 50 were registered in chemistry department.

Alternatively, there have been various studies on the use of computer assisted learning. The successful integration of technology with chemistry teaching has an outstanding contribution to visualize things, making it more comprehensible and concrete and helping students correct their misunderstandings (Mahaffy, 2005; UNESCO (United Nations Educational, Scientific and Cultural Organization), 2005; So & Kim, 2009). However, no one reports about the complex and abstract nature of the subject. Technology, integrated with appropriate pedagogy, gives the student the opportunity to practice without penalty until the task is no longer difficult. It removes the geographical barriers since the Internet, CD (compacted disk) and DVD (digital video disk (optical storage disc with a 4.7 gigabyte)) can reach everywhere in the world and removes the barriers in economic status given that the price of the internet CD and DVD are affordable and students learn at their own pace. It also removes barriers in special needs, since adaptive-technology-lessons solve many impairments (O'Neil, Ray, & Perez, 2003; Mujibul, 2004; Elliton, Percival, & Race, 2005; Kargiban & Siraj, 2009). Therefore, there is a need to incorporate the PBT (pedagogy-based-technology) into chemistry learning. In line with this, this study examined the effects of PBT on student performance in Debre Berhan University.

Over the last decade of the 20th century, constructivist epistemologies ushered in the learning sciences as an alternative to the instructional sciences. The proponents of this theory believed learning as an active internal process of constructing new understandings. In some instances, a newly constructed idea fits easily into the structure of existing understanding. In other cases, the construction of new understanding catalyzes substantial revision of existing knowledge into a new, more coherent framework.

This educational philosophy posits that meaning is not imposed or transmitted by direct instruction rather it is created (constructed) by students' learning activities. This perspective diverges from the instructivist (objectivist) view of education that presumes that knowledge exists independently of the knower and that understanding is coming to know what already exists. The constructivists argued that deep learning will occur only when the learner is actively engaged in, operating upon, or mentally processing incoming stimuli and acquire knowledge, skill and attitudes actively through a process of active participation, regardless of the subject matter, students' working in small groups tend to learn more of what is taught and retain it longer than that when the same content is presented in other approaches. Students who work in collaborative groups also appear more satisfied with their classes. The activity is structured so that group members are interdependent. Besides, each member of the group must participate to succeed and be individually accountable (Davis, 1993; Cobb & Yackel, 1996; Silberman, 1996, pp. 67-69; Kanselaar, 2002; John & Staver, 2007).

There are several schools of thought within the constructivist paradigm (Cobb, 1994; Prawat & Floden, 1994). The two most prominent ones are personal constructivism and social or socio-cultural constructivism. Their major difference has to do with the locus of knowledge construction. For the personal constructivists, knowledge is constructed in the head of the individual learner (Piaget, 1970; Von Glasersfeld, 1989). For the social constructivists, knowledge is constructed in communities of practice through social interaction (Kuhn, 1996; Vygotsky, 1978). Cobb (1994) argued that the two approaches cannot be separated, because both complement each other. For the purpose of this paper, the author will follow Cobb's theoretical ideas, according to which knowledge is constructed through social interaction and in the learner's mind.

However, many researchers reported that traditional classrooms as well as the constructivist approach using a variety of technologies, such as overhead projectors, radio, periodic table, etc., were not successful in visualizing the abstract and complex lesson. In contrast, the uses of digital computers and computer software, such as simulation, animation and video, are new in most parts of the world and not yet a part of the mainstream. If they are integrated with the student-centered approach, they will play greater roles in solving such problems (So & Kim, 2009). This paper argues that knowledge is both individual and shared and would be supported by favorable environment, such as technology. Unless the socially constructed knowledge is being processed in the individual's mind and related to their experiences with the help of suitable environment, it will not be meaningful.

Learning environments should support students' active constructions of knowledge. Teachers prepare strategies that help learners recognize conflicts and inconsistencies in their thinking, as these experiences catalyze the construction of new, more coherent knowledge. Technology-enriched learning environments engage and support learners in accomplishing more complex learning activities with the goal of meaningful learning and conceptual change (Strommen & Lincoln, 1992; Boudourides, 2003).

These are indicators for that PBT is an active, ongoing process, situated in multiple contexts, bringing immediacy, interactivity and adaptability. The use of animation, simulation and video in chemistry has been related to the importance of visualizing activities in learning and interactive learning environments that associate constructivist learning with computer applications, allow students to interact with accessible dynamic representations of virtual images. Learning abstract and complex lessons is a challenge that can be helped by dynamic representations (Gao, Choy, Wong, & Wu, 2009).

PBT is an integration of pedagogy and content knowledge with technologies, such as computer animation, simulation and video integrated with the student-centered approach. Due to the advancement of new techniques and technologies, under a strong influence of computer revolution during the last decade, the traditional source of knowledge, the book, is slowly being pushed behind. At the present time, the use of computers assisted learning in school is of crucial importance. Computers first appeared in the late 1970s and the early 1980s in specialized schools, such as natural science schools and vocational schools.

The main characteristic of the computer assisted learning, as opposed to classic teaching aids, is the fact that it unites the picture, sketch, photo, scheme, television, projectors and films. Since it can easily reproduce a number of media simultaneously (sound, tone and picture), its application in teaching chemistry at higher institutions levels is becoming indispensable for a number of reasons. The most effective learning experiences are not only individualized in terms of pacing and differentiated to fit the learning needs of particular learners, but also personalized in the sense that they are flexible in contents or theme to fit the interests of particular learner (NETPTWG (National Educational Technology Plan Technical Working Group), 2010).

Thus, the skills of the teacher coupled with educational technology enable better learning and teaching process. Without substantial and extended professional development in the innovative models of learning and teaching, the instructional technology can be affordable and sustainable. Students exposed to technology that integrated with appropriate pedagogy, i.e., PBT outside the classroom in the library, home or elsewhere, may arrive at campus already imbued with some background and motivation, ripe for guided inquiry, ready for interpretation and collaborative construction of knowledge which creates the lessons' clarity, instructional variety engagements in the learning and teaching process and makes the student successful. The discipline becomes more practical and it brings the student to stay on task. It was also a concern of UNESCO stating that technology has always been a powerful tool for learning (UNESCO, 2005; Mohanty, 2007). Therefore, as the researchers reported that teaching pupils with effective multimedia may create in a pupil's mind, a proper image of a concept enabling frequent revision of acquired knowledge and skills, use of all senses to acquire new knowledge, maintain concentration in the learning process, present knowledge in an interesting and attractive way, arouse motivation and thus increasing the quality of learning (Tinio, 2002; Falvo, 2008).

The purposes of this paper are as follows:

(1) It will create awareness about the role of PBT playing in the teaching-learning process;

(2) It will point out the effects of PBT in improving the performance of chemistry students;

(3) It will bring changes in our understanding of how students learn and how this is applied to chemistry learning at the university.

Research Methodology

Under the pragmatism paradigm, the researcher used the concurrent embedded mixed case study design to investigate the animation, simulation and video integrated with the student-centered approach compared to student-centered approach, because mixed method enables to get richer information that helps to think out of the box and provides comprehensive and full information (Andrad, 2009). In this research, the researcher collected data mainly by adopting quasi-experiment, while the data obtained by schedule were used to support the information obtained by quasi experiment. In order to conduct this study successfully, software and computer operation training was given for students; a training process consisting of 80 minute sessions was set up to cover the various technological and pedagogical issues involved. The first session aimed at familiarizing the students with the technology software and its use in the development of educational context, while the second dealt with the operation and application of the technology in the classroom.

Population of the Research

The population for the study was the second year chemistry students and chemistry lecturers of Debre Berhan University. The second year students were selected because the first year students were busy with other courses and they only study chemistry at the end of the academic year. The third year students were graduate students and they would give no attention to the study.

Sample of the Study

The convenient (nonequivalent) sampling technique used to pick the required sample size of 12 second year chemistry students, three lecturers that were not included in the main study.

Variables

The independent variable of this research was PBT whereas the dependent variable is students' performances.

Data Gathering Instruments

The pre- and post- tests contain 13 choices and six short answer questions to test if there is any difference between the control and treatment groups. Two types of schedule containing open- and closed- ended semi-structured questions to examine the awareness and perception of students and lecturers, the suitability of the environment and identify areas of difficulty in learning chemistry were employed.

Validity and Reliability

Validity. Before distributing the tests and the questionnaire, the researcher has to discuss with the advisors and experts (Brown, 2000).

Reliability. The instruments, prepared in English language checked with Cronbach Alpha using the data collected from the Debre Berhan University taking some randomly selected lecturers and students were 0.94 and 0.83, respectively.

Method of Data Analysis

Quantitative analysis. After collecting and tabulating the data, the researcher used the percentage to analyze to what extent the respondents have positive or negative idea towards the given statements. The Cronbach alpha was used to check the similarity of the statistical data, the *t*-test and the ANCOVA (analysis of covarience) to compare the performances of the control and treatment groups of the second year students using PASW (predictive analytical software (applied statistical software)) 18 statistical software (Koul, 1984, p. 186).

Qualitative analysis. The qualitative data obtained from open-ended questions and focused group discussions were analyzed using thematic and content analysis techniques adapted from Gray (2004). After categorizing the responses and classifying ideas accordingly, the data analysis were done appropriately.

Result and Discussion

The results of the study represent the collective opinion of lecturers and students that participated in the schedule and 15 days experimental activities with 12 randomly selected students and three lecturers. A vast majority of registered students at the Debre Berhan University in Ethiopia have background knowledge which was required to operate computers and enable them to accomplish the tasks of operation of animation, simulation and video display on their own.

In this study, students and lecturers' perception towards electrochemistry and students' performances on electrochemistry depending on PBT and student-centered learning were examined. The computer program used in computer-based method was presented on Website http://www.educypedia.be/educationchemistryjava.htm or http://www.chem.iastateedu/group/grreebowe/sections/projectfolder/smdownload/ind4.html.

Observing the outlook, all of the chemistry lecturers (100%) who responded to the schedule believed that chemistry was not interesting because of its abstract indistinct, complex nature and which is an experimental subject that involves risk. Most of the time, students face difficulties to understand chemistry lesson when they are exposed to complex and abstract lesson of chemistry. Moreover, both the students and the lecturers have considered that student-centered as well as the traditional way of teaching are not appropriate for all lessons of chemistry. On the other hand, even though there is access to simulation, animation, video and Internet, lectures have no experience to use simulation, animation or video which obstruct the students' understandings of the abstract and complex lesson of chemistry. Nevertheless, both the students and lecturers believed that when students learn particularly those abstract and complex lessons with simulation, animation or video based on their appropriateness, integrated with suitable pedagogy enable to see those invisible, complicated process and activities. Since, computer assisted learning sustain effort and academic motivation. Technology-based learning resources can give learners choices that keep them engage in learning (Mahaffy, 2005; Falvo, 2008).

Table 1

Independent Sample T-test Result of Pre-test Performance

	The teaching technique	*N*	Mean	Std. deviation
Pre-test	Student-centered method	6	5.83	0.753
	Pedagogy-based-technology method	6	5.67	0.816

In Tables 2, 3, 4, 5, 6 and 7, *F*, *t*, *p*, $\eta 2$, *c*, *e* and *SD* are interpreted as follows:

$$F = S_1^2 / S_2^2,$$

where s_1^2, s_2^2 are the variances (S) of sample 1 and sample 2;

$$t = \frac{\overline{x_1} - \overline{x_2}}{s\sqrt{(1/n_1) + (1/n_2)}},$$

where $\overline{x_1}$ and $\overline{x_2}$ are the means of samples of size n_1 and n_2 taken from each population, and s is an estimate of the assumed common variance.

P-value: The probability of the observed data (or data showing a more extreme departure from the null hypothesis) when the null hypothesis is true; η^2: coefficient value; *c*: control group; *e*: is the treatment group; SD: standard deviation.

Table 2

Independent Sample T-test Result of Pre-test Performance (N = 12)

Test	*F*	*t*	*p*	*p* (two tailed)
Pre-test	0.25	0.368	0.646	0.721

The Statistical Analysis

To be meaningful with this study, there must not be a statistical difference ($p < 0.05$) between the mean electrochemistry performance in both the control (those who were taught through student-centered technique of teaching) and experimental (those who were taught through student-centered integrated with animation simulation and video) group during the pre-test. Electrochemistry performance pre-test analysis, for control and experimental group given in Table 2 shows that no significant difference was found between the two groups (p-value 0.646 is greater than 0.05). The mean pre-test and their corresponding standard deviation for both control and experimental groups given in Table 1, 5.83 (0.753) and 5.67 (0.816) respectively also confirms their similarity. Besides, the Levene's independent t-test for equality of covariance's for distribution of students both in the treatment and control group ($p > 0.05$) at t-value 0.368 and two tailed p-value 0.721 in Table 2 also supported the initial assumption that there were no significant difference between the two groups at the pre-test ($p > 0.05$).

Based on the assumption, there is significant difference ($p < 0.05$) between the mean pre- and post- tests score on electrochemistry performance in both the control and experimental group as indicated in Table 3. Table 4 suggests that there was a correlation between the teaching technique and students' understandings. The mean score difference and corresponding standard deviation -7.7 (0.548) at t-value -33.541 p-value is 0.000 and -10.833 (0.4080 at t-value -65.00 the p-value is 0.000 for control and experimental group respectively suggesting that there was significant improvement in students' performances in both groups. Prior to running the ANCOVA, the assumption that both experimental group and control group were not related was initially tested with homogeneity test. As the ANCOVA test for homogeneity shown in Table 5, the results for homogeneity slopes confirmed that the interaction between pre-test and teaching method was not significantly related (p-value 0.683 > 0.05) which allows to proceed the ANCOVA.

Table 3

Paired Samples Correlations of Pre- and Post- tests for Each Group

Teaching method	*N*	Correlation	Sig (p)
Student-centered pre- and post- tests	6	0.951	0.004
Pedagogy-based pre- and post- tests	6	0.934	0.006

Table 4

Paired Samples T-test of Pre- and Post- tests for Each Group

Teaching method		Paired differences		*t*	Sig. (two-tailed)
		Mean	Std. deviation		
Pair 1	Student-centered pre- and post- tests	-7.500	0.548	-33.541	0.000
Pair 2	Pedagogy-based pre- and post- tests	-10.833	0.408	-65.000	0.000

Table 5

Homogeneity Slope Test Between Pre-test and Method of Instruction

Post-test	Mean square	*F*	*P*
Method of instruction pre-test	0.069	0.180	0.683

Table 6

ANCOVA Test for Post-test (N = 12)

Source	Mean squared	*F*	*p*	η^2
Pre-test	10.378	27.196	0.001	0.773
Teaching method	36.75	96.301	0.000	0.923

Table 7

Estimated Marginal Means from ANCOVA (12)

Method of instruction	Mean	SDE
Student-centered	12.882[a]	0.254
PBT	16.600[a]	0.254

Examining whether there is evidence for greater improvement in the experimental group than the control group on the mean post-test of electrochemistry performance, comparing the mean score between the two groups after controlling the pre-test, it was evident that teaching the abstract and complex aspects of electrochemistry with animation, simulation and video shows a significant improvement gains over the control group as shown in Table 6. The effect size index rating (i.e., 0 = no effect up to 1 = greater effect) the eta-squared value in Table 6 and estimate marginal means in Table 7 also substantiate that the teaching method ($\eta^2 = 0.923$) had greater effect on a post-test than pre-test ($\eta^2 = 0.773$). According to Cohen eta-squared value (0.01 very small, 0.06 medium, and 0.14 and above is greater) (Cohen, 1988).

Accordingly, PBT provides multi-modal, spawning rich forms of learning and teaching processes. Nearly 82% of schedule responding student said that lecturer who soon teaches in more than one medium at Debre Berhan University, for instance, classroom courses shown with animation sound mixer would give clear vision as technology can inspire intellectual curiosities that help people engage actively and open new channels for success and provides opportunities for students to share their ideas (Collins & Halverson, 2009). "The course goes for first four days", said one student. "For the next sessions, students were interested in retrieving a certain topic click their computers examine the contents of the whole lessons and can view the portion that interests them".

When asked to compare with normal student-centered approach, 79% of the student respondents stated that PBT would make the greatest contribution in terms of improving educational quality and increases students' performances while 21% pointed out that the dynamic delivery of contents and software that supports individually paced learning have a profound effect on their academic performances.

It is interesting to note that despite the growing array of technology-enabled teaching tools available, nearly three-quarters of participants said that the greatest potential benefit of technology is something far more straightforward, namely the expanded access to education and reference resources that it provides.

Moreover, from the results of schedule and experimental result, PBT, software that supports individually paced learning and mutual interaction of students is among the computer assisted learning most expected to improve academics in the near future. Technologies, such as simulation, animation and video which have been influential in improving interaction among students, students and lecturers are in the universities are expected to decline wasting of time to understand complex, abstract and difficult lessons if they are in use now widely. On the other hand, 67% of lectures respondents suggested that if innovations like animation simulation and video are adopted among universities over the next years:

(1) On average, students who learned with computer assisted learning improved by 60% on their performances compared to those without computer assisted learning who improved by 40% in their performance;

(2) Students are able to acquire concepts within a short period of time;

(3) Students like more their lessons and develop interest.

Collectively, such advances may lead to profound changes in the way courses are taught. "Learning will become more outcome-based and student-centered", said all the Debre Berhan University schedule respondent lecturers. Therefore, visualizing the abstract and complex lesson together with students mutual interactions facilitate to internalize the difficult lesson of chemistry due to the fact that, students who are exposing for simulation, animation and video, enables to share and correct their idea cooperatively, observe the abstract and complex repeatedly and correct their confusions (UNESCO, 2005; Mohanty, 2007).

Conclusions

The results of electrochemistry post-test indicated that students, who were taught by animation integrated with student-centered approach, were more successful than those who were taught by student-centered. Students' interests and attentions can easily attract with application of animation and simulation in computer. In addition, knowledge is not forgotten because number of using sense organs is increased in learning process. It can be concluded that computer based education is more effective than student-centered on students' perceptions towards electrochemistry.

Thus, PBT is the most promising and attractive way of teaching to teach complex and abstract lesson of chemistry. The students in the experimental group accepted and valued science learning as being something interesting which enable them to see many hidden secret within their perception. Their antipathy has been turned. They recognized that this type of approach is different as it makes them busy and absorbed in their learning to know many things in a real sense. This change within the affective and cognitive dimensions suggested that the students need change which initiate them to learn and provide progress. On the other hand, the lecturers participating with schedule were interesting about its implementation. This indicates that teaching is really about assisting people coming to understand different, difficult, abstract, complex and new ideas. All the interactive processes that can help this to happen through constant interactive play that matches how we intuitively learn can be supported and developed through technology. That includes virtual learning environments (simulations, animation, video, etc.) activities that do not replace the need for real life teaching but enhance how it happens. Such approaches will not only facilitate more engaging learning practices but they also promote skills that are necessary for life (Bradwell, 2009).

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