EFFECTS OF TECHNOLOGY DRIVEN PEDAGOGY APPLICATIONS ON THE COMPREHENSION OF COMPLEX AND ABSTRACT CONCEPTS OF CHEMICAL EQUILIBRIUM

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ABSTRACT

Chemistry students often regarded abstract and complex Chemistry concepts as difficult to learn (1; 2) and this prevents many of them from continuing studies in pure chemistry courses. This study investigated how students develop their comprehension of complex topics of chemistry with the aid of Technology Driven Pedagogy (TDP) by using animation, simulation and video integrated with student-centered learning in visualizing complex and abstract concepts of chemistry. TDP technique in the chemistry classroom was used to promote effective learning. A chemist can view a chemical reaction at the macroscopic level, what the reaction will look like to the student's eye, and at the particulate level, what changes are taking place among the particles. TDP is used to create mental images and displays on the macroscopic level. It also enables students to present information in a more dynamic, compelling and interactive way, engaging the environment prepared for learning by doing. To apply TDP in supporting student-centered learning activities, one week training on how to operate the computer with the experimental software was carried out on the experimental students of this study. This was followed by four weeks teaching and learning of chemical equilibrium topics for first-year undergraduate students with art technology flash and micro media player for 15 male and 15 female students who were conveniently grouped into control and experimental groups. A particular focus group of this investigation was used to determine to what extent the use of TDP can influence learning in Chemistry. This study employed sequential embedded mixed case study design. Pre and Post tests were administrated to the target groups. The quality of the learning strategy was evaluated by administrating open and closed ended questions containing schedule, focused group discussion, and observations. The results obtained from the tests, participants` responses to the questionnaire schedule, focused group discussion and observation showed that TDP greatly improves the comprehension ability and performance of students in the subject. Therefore, TDP technique is a promising tool for simplifying and clarifying complex and abstract concepts of Chemistry and hence it is conclusively recommended by the researchers for a wider use. *[AJCE, 3(2), June 2013]*

INTRODUCTION

Applications of chemistry are ubiquitous, growing all over the world. It can be used in various aspects of societal needs. However, the wide spread applications of Chemistry do not translate to the survival of the discipline in the school system with the number of chemists on a steady decline. It is becoming clear that Departments of Chemistry in many institutions are getting absorbed into other natural science fields.

Learning Chemistry at higher education level is complicated and difficult for students because it contains indistinguishable and intangible particulate concepts as it pertains to visualizing the atom, molecule, ions, and the interaction of these particles (3; 4; 5; 6; 7). Many researchers have done several researches to alleviate this problem but it is still exists (8).

Learning is about how we perceive and understand the world, involve mastering complex principles, understanding proofs, remembering factual information, acquiring knowledge, skills and developing intended behavior suitable to specific situations; it is about change(8). Excellence in learning involves achieving and maximizing effective teaching which encourages deep and high quality student learning, and active engagement with subject content (7). This helps them to respectfully see the world in a different way and establishing the kind of climate that will optimize appropriate interactions among students (9; 8; (10).

Therefore, chemistry students are expected to understand the scientific ideas at particulate level of matter in the manner that can be used to explain the properties of matter and different types of changes that take place in a vast array of chemical phenomena. The particulate nature of matter is fundamental to almost every topic of chemistry. This is the basis of explanations of atomic structure, bonding, molecules, chemical reactions, chemical equilibrium and chemical kinetics. Chemical change involves the rearrangement of the constituent particles that make up the reactants, to give new configurations and characteristics of the products.

On the other hand, constructivism says that learning occurs by fitting new understanding and knowledge into and with, extending and supplanting old understanding and knowledge (11). Students are active rather than passive if they are exposed to increased amounts of information; their ability to solve problems, retain and transfer knowledge becomes very successful. But this is impossible without well prepared appropriate learning environment (12). Students of Chemistry are always thought *what* changes in a chemical reaction, i.e. the identities of the reactants and products involved. However, this simple view does not provide them with a comprehensive understanding of a universal phenomenon that is central to life, its maintenance, and continuation (13).

Teachers are expected to consider how to bring this changes or transformation to the pre-existing knowledge of their learners. Chemistry learning largely depends on students' ability to understand the microscopic descriptions: how substances are formed and what are the functions of the substances. These microscopic worlds are usually not related to the students` everyday experiences. Therefore, external representations are the only way, that can overcome these barriers (14), enable students to *visualize and understand* chemical reactions from a particulate point of view, to see *why* and *how* the change takes place. Such visualization would include not only the nature of the substances involved but also other aspects of the mechanism by which the reaction takes place. For example, the extent of the reaction, the rate at which it takes place and the factors that influences these aspects (13). The systematic use of carefully designed external representations such as technology driven pedagogy can make the microscopic world be familiar enough for students to be able to imagine and discuss the behavior of particles (15).

The Nature and Importance of Technology Driven Pedagogy?

For the purpose of this paper, we have used Technology Driven Pedagogy (TDP) as learning of abstract and complex content chemical equilibrium by means of visualizing software involving animation, simulation and video integrated with student-centered learning. Animation and simulation are systems that emulate the actual idea about the system being animated and simulated and its chemical phenomena are defined as artificial material object created or adapted for this intention. Whereas Video is the system of recording, reproducing, or broadcasting moving visual images on or from videotape, film or other recording on videotape (16). Students are to use computer animation, simulation or video according to their requirements to have clearer vision of complex and abstract chemical equilibrium concepts during their studies and interact with their group members to internalize the concepts.

The uses of animation and simulation techniques are strong on visualizing intangibles events, materials and facts to education and such are comparatively recent formats and standards that the teacher and students need to utilize to achieve a rapid development (17). Animation and simulation are powerful techniques that can enhance teaching about some aspects of the real world by imitating or replicating it. Learners are not only motivated and interested with these techniques but learn by interacting with them in a manner similar to the way they react in a real situation (16; 17).

The combined effects Animation, simulation and video integrating with appropriate student- centered learning or Technology Driven Pedagogy (TDP) have diverse advantages over other instructional modes of teaching. Students often participate more interestingly, intrinsically motivated with the use of TDP. It is very flexible in that both students and instructor have high degree of control and get closer to real world experience (18; 19).

TDP allows students to experience phenomena which could be dangerous, expensive, intangible, and even impossible to observe in the real world situation (20; 21; 22). Mental model exists in a learner’s mind, conceptual models are devices presented by teachers or instructional materials. Computer diagrams, animations, and video presentations have all been suggested as means of providing conceptual models that help develop learners’ mental models.

For the reason that TDP makes clear and simple the real-world phenomena, it facilitates learning by omitting what would otherwise be distracting elements in a real-world situation (18; 21). Finally, TDP can accommodate a wide range of instructional strategies, including micro worlds, scientific discovery learning, virtual reality, laboratory simulations, role playing, case-based scenarios, and simulation gaming (20; 15).

The purpose of this study was to determine how Technology Driven Pedagogy supports students’ comprehension of a complex and abstract concepts in university chemistry learning, such as the atom, molecule, ions, and the interaction of these particles in chemical. Thus, the objectives of this study were to:

- determine the effect and advantages of the use of TDP environment over student-centered technique learning on students` comprehension of abstract and complex topics,
- identify which learning concepts of *chemical equilibrium* require TDP environments,
- discuss the implication of Technology Driven Pedagogy as a tool for teaching and learning.

Animation, simulation and video are concerned with *External Representation,* the systematic and focused display of information in the form of pictures and diagrams. There are several ways in which animation, simulation and video technology are expected to assist learning. Animation, simulation and video are building a computer-generated” virtual” world. These features provide support for visualizing (22).

TDP not only provides rich learning patterns and teaching contents, but also helps to improve learners’ ability by clarifying complexity and exploring new concepts. These technologies are now maturing, and they enable even more complex and authentic interactions not only with regard to physical and cognitive fidelity but also the ability to integrate learning and training experiences into the real world to make learning more fun, interactive, effective, relevant and powerful(18). Significantly they are more successful at solving problems that required visualization. They promote current educational thinking that students are better able to master, retain, and generalize new knowledge when they are actively involved in constructing that knowledge in a hand on learning environment (15), allow students to explore, manipulate computer-generated, three-dimensional multimedia environments in real time. The TDP environment is suitable for illustrating ***indistinguishable*** concepts that involve spatial relationships, since the virtual world objects can be manipulated in a three dimensional space and viewed from multiple perspectives. It is a potentially powerful learning technology, which offers teachers a means to concretize particulate concepts for students and provide them with opportunities to learn by doing what they might otherwise encounter only in a textbook (16).

Designers and evaluators of animation, simulation and video systems express some ideas concerning how animation, simulation and video can facilitate learning. However, we should pay attention about information the animation, simulation and video best feet feature for enhancing understanding or how to customize those affordances for different learning environments. The design and development of effective educational chemistry software requires an expert approach.

It should be pedagogically appropriate technology and software development enables to acquire true knowledge based on the needs and difficulties of students' chemistry learning (23, 24).

RESEARCH METHODOLOGY

The researchers used the sequential embedded mixed case study design to investigate the TDP approach compared to student centered approach because they believed that such a mixed method enhances the production of richer information that helps in thinking out of the box and provides comprehensive and full information.

In this research, data were collected mainly by adopting quasi-experiment and observations, while the data obtained by schedules and focused group discussions were used to support the information obtained by the quasi experiment and observations. In order to successfully conduct this study, a software, computer operation and focused group discussion training were given to students in the experimental group; a training process that lasted for one week. The training was set up to cover the various technological and pedagogical issues involved in the study. 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 the application of the technology in the classroom.

Population and Sample of the Study

The population for the study was all the 70 first year Chemistry students and 14 Chemistry lecturers of Debre Berhan University. First year Chemistry students were selected because most times they are more troubled and faced with the problem of poor concepts understanding in Chemistry.

First year students are busy with their courses; therefore, to get important data from willing participants a convenient (nonequivalent) sampling technique was employed to pick a sample size of 30 first year chemistry students and 5 lecturers.

Data Gathering Instruments, Their Validity and Reliability

The instruments of the study included observation check list, two types of schedules, containing open and closed ended semi structured questions and open-ended, focused group discussion prepared and administered by the researchers to the respondents. They were meant to examine the awareness, perception of students and lecturers, the students` interaction and comprehension ability in Chemistry with special interest in Chemical Equilibrium.

Before distributing the tests, the instruments of the study were validated and discussed with the advisors and experts (22). The content validity index of the schedule for both lecturer and students similarly was 0.79 whereas the content validity index of the test was 0.81.

Reliability tests of the instruments were determined with Cronbach Alpha using the data collected from the Debre Berhan University lecturers and students who were not part of the main study with 0.86 and 0.88 reliability values respectively. The instruments were therefore used as such.

Method of Data Analysis

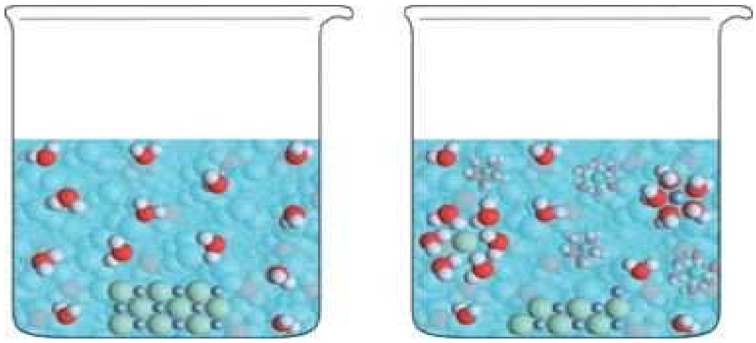
The researchers used t-test and the ANCOVA tools to compare the performance of the control and treatment groups of 1^{st} year students using SPSS-20 statistical software (23) to analyze the quantitative data generated. On the other hand, the qualitative data obtained from open ended questionnaires, focused group discussions and observation were analyzed using thematic and content analysis techniques. It involved categorizing the responses and classifying the ideas generated with appropriate data analysis done.

RESULTS AND DISCUSSION

Among the sample 27 (90%) of the first year Chemistry students and 5 (100%) lecturers who responded to the schedule and participated in the focused group discussion considered Chemistry as a difficult subject and not interesting because of its abstract, indistinct, and complex nature. Most of the time students face difficulties when they are exposed to such complex concepts. Moreover, both the students and the lecturers believed that student-centered and traditional way of teaching was not appropriate for all lessons of chemistry. But if students learn these concepts with TDP environment, it enables them to see those invisible, complicated processes and activities because the learning environment made the concepts clearer in meaning, sustaining effort and academic motivation.

TDP increasingly plays important roles both in learning and teaching. The fundamental principle of using TDP for learning was to create trust and clarity to all students of chemistry. This is because it is not wise to deliver as usual for students who have difficulty of learning complex and abstract concepts to learn more (1).

Individual students working with TDP had better class activities and skills than those who worked in a group without it. This shows clearly that there are times when individual work is necessary and when students should work alone under a quiet condition. Calm and quiet classrooms can lead to the production of very good work and can lead to effective learning. On the other hand, there is also a need for sharing and working together. Students who work in groups have better comprehension and communication ability, and they had deep and clear concept understanding than individual students. Most of responses to the study schedules and the observations made suggest that TDP as an alternative way of learning is needed in domains where the interpretation of complex and /or abstract information is more demanding, as it happens in particulate level of clarification (Fig. 1).



a b

Figure 1: (*a*) When solid LiF is added to water, initially there are no ions in solution. (*b*) At equilibrium, cations and anions are present.

The reason for the above interesting observation is clear: it is easier to obtain understanding from a three-dimensional model than from the simple reading or hearing of lecture. The *Chemical Equilibrium experiment* aims at the conception of an educational environment, joining particulate illustration with three dimensional Technology Driven Pedagogy representations.

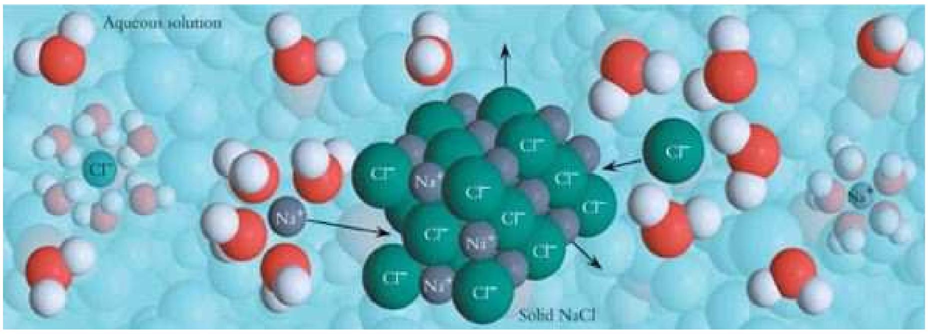


Figure 2: A view of sodium chloride solution's solubility equilibrium in water.

At equilibrium, ions dissolve from the crystal surface at the same rate as they are captured, so the concentration of ions in the solution remains constant. Visualization is thus, in the first instance, concerned with the formation of an internal representation from an external representation (see figure 2) such that the nature and temporal/ spatial relationships between the entities of which it is composed are retained. An internal representation must be capable of mental use in the making of predictions about the behavior of a phenomenon under specific conditions (17).

The Statistical Analysis

Table 1: The pre and post test performance of students

No	Control group			No	Experimental group		
	Pre test	Post test	Gain		Pre test	Post test	Gain
1	6	9	3	1	4	10	6
2	5	8	3	2	5	15	10
3	6	10	5	3	5	15	10
4	5	7	2	4	5	14	9
5	5	8	3	5	6	12	6
6	4	8	4	6	5	14	9
7	7	12	5	7	4	13	9
8	5	9	4	8	6	15	9
9	6	10	4	9	6	14	8
10	5	9	4	10	5	15	10
11	5	10	5	11	5	14	9
12	5	7	2	12	7	15	8
13	5	9	4	13	4	15	11
14	4	7	3	14	5	14	9
15	5	10	5	15	4	14	10
Total	78	133	57	Total	76	209	133
Mean	5.20	8.85	3.73	Mean	5.07	13.93	8.87
Std	0.775	1.407	1.033	Std	.884	1.387	1.407

Table 2: Independent sample t-test result of pre test performance

Test	F	P	t	P (2-tailed)
Pre test	.123	.729	.439	.664

This study assumed that there was no statistical difference ($p< 0.05$) between the mean chemical equilibrium 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 environment) group during the pretest. Chemical Equilibrium performance pre-test analysis, for control and experimental group given in Table 2, illustrates that no significant differences was found between the two groups, p value 0.646 is greater than 0.05. The pre-test mean scores and their corresponding standard deviation for both control and experimental groups given in Table 1, 5.20 (.775) and 5.07 (0.884), 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 0.439 and two tailed p- value 0.664 in Table 2, also supported the initial assumption that there was no significant difference between the two groups at the pre-test ($p>0.05$) at $\alpha = 95\%$

Table 3: Paired Samples Correlations of pre test post test for each group

		N	Correlation	Sig.
Pair 1	Post_test_C & Post_test_E	15	-.071	.803
Pair 2	Pre_test_C & Post_test_C	15	.747	.001
Pair 3	Pre_test_E & Post_test_E	15	-.049	.862

Table 4: Paired Samples t-test of pre-post test for each group and post-post test comparison

Pair 1		Paired Differences		t	df	Sig. (2-tailed)
		Mean	Std. Deviation			
Pair1	Post-test-C – Post-test-E	-5.067	2.154	-9.112	14	.000
Pair 2	Pre-test-C – Post-test-C	-3.667	.976	-14.552	14	.000
Pair 3	Pre-test-E – Post-test-E	-8.867	1.807	-19.000	14	.000

According to the assumption that there is a significant difference (p<0.05) between the mean pre-test and post test score on Chemical Equilibrium performance, in both the control and experimental group, as shown in Table 3, there were no correlation between the post and pre test performance of two groups though there was a significant correlation between pre and post test performance of the control group which illustrates that there were no enhanced change in conceptual understanding in the control group, whereas there were higher levels of understanding of chemical equilibrium concepts in experimental group**.** The mean scores difference and corresponding standard deviation 5.067(0.2.154) at t-value -9.112 p-value is 0.000 for post tests, and -3.667(0.976) at t-value -14.552 the p- value is 0.000 and-8.867(.467) p-value 0.000 for control and experimental group, respectively also suggest that there was significant improvement in students performance in both groups though the improvement is greater in the experimental group.

Table 5: Paired Samples Test of the performance gain of control and experimental group

Pair 1	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Gain of control group - Gain of experimental group	-5.133	1.356	.3500	-5.884	-4.383	-14.66	14	.000

Comparing the gain scores of control and experimental group students, there was a significant difference between them (P < 0.05) as is shown in the Table 5 above. The table illustrates that experimental groups have better understanding of complex and abstract concepts of chemical equilibrium having been taught with the TDP and thus have better performance.

Prior to running the ANCOVA, the assumption that both experimental group and control group were not related was initially tested with homogeneity test. The ANCOVA test for homogeneity in Table 6, below shows the results for homogeneity *slops*, the interaction between pre-test and teaching method was not significantly related(p-value 0.664 >0.05) and the results allowed the use of ANCOVA.

Table 6: Homogeneity slop test between pre test and method of instruction

Post test	Mean Square	f	Sig.
Method of instruction pre test	.133	.193	.664

Table 7: ANCOVA test for post-test (N=30)

Source	Type III Sum of Squares	df	Mean Square	f	Sig.	Partial Eta Squared
Corrected Model	208.084(a)	3	69.361	39.973	.000	.822
Intercept	45.899	1	45.899	26.452	.000	.504
Teaching_style	27.658	1	27.658	15.939	.000	.380
Teaching_style * Pre_test	9.885	1	9.885	5.697	.025	.180
Pre_test	7.683	1	7.683	4.428	.045	.146
Error	45.116	26	1.735			
Total	4152.000	30				
Corrected Total	253.200	29				

R Squared = .822 (Adjusted R Squared = .801)

Table 8: Estimated marginal means from ANCOVA (N=30)

The teaching style	Mean	Std. Error
student centered	8.776[a]	.341
virtual reality integrated with student centered	13.928[a]	.341

Covariates appearing in the model are evaluated at the following values: The pre test = 5.13.

Table 9: The Univariate Tests of ANCOVA (N =30)

	Sum of Squares	df	Mean Square	f	Sig.	Partial Eta Squared
Contrast	197.644	1	197.644	113.902	.000	.814
Error	45.116	26	1.735			

f - tests for the effect of the teaching style. This test is based on the linearly independent pair-wise comparisons among the estimated marginal means.

Investigating whether there is evidence for greater improvement in the experimental group than the control group on the mean post test score of Chemical Equilibrium performance, after the pre-test, it was evident that teaching the abstract and complex topics of Chemical Equilibrium with Technology Driven Pedagogy environment shows a significant improvement gains over the control group as shown in Tables 1 and 7. The effect size index rating (i.e. 0 = no effect up to 1(greater effect)) the eta-squared value in Table 9, and estimate marginal means in Table 8, also substantiated that the teaching method (η^2 =0.814) had greater effect on a post test performance based on Cohen et-squared value (0.01 very small, 0.06 medium, and 0.14 and above is greater (23).

This study results have shown that Technology Driven Pedagogy provides rich forms of learning and teaching processes. Almost 90% of Schedule responding and focused group participants in the study said that a lecturer who uses Technology Driven Pedagogy environment at Debre Berhan University can encourage intellectual inquisitiveness that can help students engage actively and open new channels for success and provides opportunities for students to share their ideas (24).

When asked to compare this study`s approach with normal student-centered approach, 24(80%) of the students stated that student-centered supported with animation, simulation and video made the greatest contribution in terms of improving educational clarity, quality and students' performance. Moreover, from the results of schedules, observation, focused group discussion and experimental results, Technology Driven Pedagogy learning environment encourages individually paced learning and mutual interaction of students and it enables to make clear learning and to improve academic performance of students. Thus, the combined effects of technologies such as animation simulation and video learning environment improve the attention level, activities and conceptual understanding of students. On the other hand, implementing this type of teaching and learning technique described in this paper:

- makes the learning process of complex chemistry topics clearer and simpler.
- improves the comprehension level of students
- enhances student's ability to acquire concepts within a short period of time.
- helps students to attend their lessons with greater interest.

Collectively, such improvement in learning style may lead to profound changes in the way concepts 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 concepts together with students mutual interactions facilitate the internalization of the difficult topics of chemistry.

CONCLUSIONS AND RECOMMENDATIONS

Chemistry and technology are interdependent and advances in chemistry often lead to new technological discoveries. Therefore, if Chemists use appropriate technology, the learning of chemical phenomena and concepts becomes easy. The aim of this study was to indentify and determine how Technology Driven Pedagogy supports students' understanding of complex and abstract concepts in chemical equilibrium learning.

The research took place at Debre Berhan University that caters for different students from diverse backgrounds and employs both traditional and student centered technique of teaching. In order for students to become qualified professionals in Chemistry they should receive clear and quality teaching. In dealing with these issues there must be appropriate learning environment.

The results of Chemical Equilibrium post-test indicated that students, who were taught by Technology Driven Pedagogy approach, were more successful than the students who were taught by student-centered method. Students' interest and comprehension ability were increased. Moreover, students clearly understood complex concepts of Chemistry because of using 3D, dynamic picture scheme, sketch and films. It can be concluded that computer based education is more effective than student centered on students' perception towards Chemical Equilibrium. Complexity is a key factor in casting a shadow for students' understanding of chemical equilibrium; we need to be alert to concepts that are subject to misinterpretation by our students.

Therefore, the development and application of TDP learning environments is feasible based on expertly engineering development of methodologies and is highly recommended for use by Chemistry lecturers in particular and science educators in general.

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