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A Pedagogical Development Model on Chemistry Teaching Through Computer-Assisted and Guided Inquiry

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Abstract: The present research has been undertaken to develop a pedagogical model for teaching chemistry through computer-assisted and guided inquiry for Iranian high school, 11th grade. A naturalistic qualitative study was adopted by triangulation method for data collection (mixed-methodology). Observations and semi-structured interviews were conducted by participants to collect date. The obtained data were analyzed using transcriptions to evaluate the current practice in classroom. Descriptive and inferential statistics were applied to analyze the quantitative data. About 52% of high school students declared that the computer implemented studying system was a potential method for learning chemistry. Triangulating data showed that the perception of teachers, students, principals and the ICT team about the use of computer in teaching process was significantly different. The findings revealed that out of the 20 expert respondents, 100% agreed on developing intranet, 95% agreed on establishing inquiry, 90% insisted on use of computer at home and 80% supported constructive ICT coordinator and computer facilities.

Key words: Pedagogical model · Teaching chemistry · Computer-assisted and guided inquiry · High school

INTRODUCTION

The advance computer use represents great changes in technology, politics and global economic developments. In such progress, education is not an exception and may face to drastic changes. In fact, school curriculum needs to be adjusted according to "information age". Computer aided instruction (CAI) and computer assisted learning (CAL) are accepted methods in teaching and learning processes. The Information and Communication Technology (ICT) can support the learning process [1]. Furthermore, the consensus is that the use of ICT will enhance the quality of teaching and learning techniques [2].

It is believed that, computer alone is insufficient and must be accompanied by technical and pedagogical supports [3]. In order to use ICT in education, three-way interaction pattern between learners, teachers and computers should be considered [4]. Besides, the success or failure of any pedagogical practice at school context is influenced by external factors, which need to be closely considered [5]. Therefore, a pedagogical model is important in prescribing computer as a tool to seek and process the information. This model reflects thinking processes, individual understandings and beliefs [6].

Computer enriched learning environments support the learning process [7]. Use of computer in teaching and learning processes is quite new. Hence, a crucial factor contributing to the development of the novel method is based on availability of infrastructure resources. These foundational resources consist of hardware, in terms of number of computers available in the school for students and teachers for educational purposes, the quality and functionality of the equipment (speed of processors, operating systems, peripherals and access to internet); as well as the availability of software [8].

An integrated study of ICT in teaching science consists of some obstacles such as 1) insufficient material resources 2) inadequate new information and communication technologies 3) inappropriate technologies in the scientific fields and specific areas and 4) misconceptions, especially where teachers would be considered less important and the idea that the use of ICT is a waste of time [9]. However, ICT includes some restrictions such as 1) lack of pedagogic and didactic information about use of ICT in classrooms 2) lack of appropriate infrastructures 3) resistance to the change from teachers concerning the use of new strategies and methodologies justified by didactic research in science and 4) lack of technical support to organize ICT area [10].

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For instance, Volland has stated that Le Châtelier's principle and chemical equilibrium are considered as the most difficult topics in chemistry for high school students [11]. Development of numerous simulations and software solutions, have created an environment to understand these cases. Some researchers have clearly expressed the use and application of ICT and its elements in learning process are: a) difficulty of access, b) less control over learning and monitoring progress, c) different classroom organization, d) change of relationship from transmitter to enabler of knowledge, e) lack of proficiency in the use of ICT, f) less autonomy, g) change in work habits, h) pupils questioning of received knowledge may undermine the traditional method and i) the authoritarian role of teacher [12]. Biggs has argued that, there is no single, all-purpose best method of teaching such as available resources, students' abilities and individual strengths and weaknesses as a teacher. It depends on how the process of teaching using ICT to produce learning resources and provide successful learning experiences for students in the future was conceived [13].

The office for the standards in education (OFSTED) declared that good teaching in ICT includes clear objectives. This is to be followed by thoughtful planning and collaboration between teachers in integrated ICT into a scheme of work. Teacher's intervention is required to ensure that pupils do not become distracted by the technology and let pupils know that teachers have high expectations. OFSTED mentioned some weakness in this kind of teaching such as 1) unclear objective: ICT is used where other modes of learning would be inappropriate, 2) the potential of the application is not fulfilled, for example, individual work on a computer would be more appropriately conducted as a group discussion, or vice versa, 3) glossy computer graphics are used with no real purpose, 4) there is a failure in use of the full potential of particular ICT applications, for example, use of the data handling power or graphic facilities and 5) teachers fail to intervene in children's learning in this way [14].

According to Cuban's investigation, many innovations were rejected, since teachers didn't have sufficient understanding of the principles behind the innovations and the functions that they were expected to carry out. Also, teachers didn't have sufficient training in the skills needed to use the technology [15]. More importantly, they often would not see compatibility between the technology and their aims and intentions as teachers. In an independent investigation entitled "The Impact of Roshd Network from the views of students and teachers in the high school Tehran Urban" that was conduct by Satari, it was found that ICT often does not fit in the existing teaching culture and may even undermine the teacher's sense of efficacy. Satari stated that teachers using the technology tend to domesticate applications so that they conform to the prevalent practice [16]. Such studies clearly showed that there is a gap in the literature on chemistry teaching through computer at international level. Inadequate information and lack of research based literature constitute the present research study.

The purpose of the present study was to develop a pedagogical development model on chemistry teaching through computer assisted and guided inquiry for Iranian high school, 11th grade. The objectives of this research are as follows:

- To deepen the understanding of chemistry teaching with the use of computer based activities at 11th grade.
- To describe and examine the important factors involved in computer based instructional activities.
- To identify the essential features of chemistry teaching through computer in Iranian high schools.

Theoretical Based Model for the Guided Inquiry: Since late 1980s, inquiry based learning has been one of the new approaches in scientific education. Students in all grades and at any scientific domain should have an opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry [17]. This point of view requires students to combine processes and scientific knowledge to develop their understanding in chemistry. Inquiry is a term used in teaching science that refers to a way of questioning, seeking knowledge and information or finding out about phenomena. Moreover, it is believed that inquiry is a combination of behaviours involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious [18]. From a pedagogical perspective, inquiry oriented teaching is often contrasted with traditional expository methods and reflects the constructivist's model of learning, often referred to as active learning. It has been believed that, learning is the result of ongoing changes in our mental frameworks as we attempt to make meaning out of our experiences [19]. Thus, in classrooms where students are encouraged to make meaning, they are generally involved in developing and restructuring their knowledge schemes through experiences with phenomena, through exploratory talk and teacher

intervention [20]. Therefore, we could define scientific inquiry as the ways in which scientists study the natural world and propose explanations based on evidences derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. There are various pedagogical models for inquiry to support meaningful learning, for example, structured inquiry, guided inquiry and open inquiry. Guided Inquiry is found on belief that learning is a process of personal and social construction. A view of learning as a process of social and personal construction is deeply embedded in the American educational tradition and has been developed by influential 20th century thinkers [21]. Also, guided inquiry consists of the ability of using technological tools like spreadsheet, word processor, database and so on. In this definition, sum of the characteristics of the guided inquiry process are as follows:

- Students learn by being actively engaged in and reflecting on that experience,
- Students learn by building on what they already know,
- Students develop higher order of thinking through guidance at critical points in the learning process,
- Students' developments occur in a sequence of stages,
- Students have different ways of learning and
- Students learn through social interaction with others.

Research Objective and Research Methodology: The purpose of present research is to conduct a study of teaching computer aided chemistry in an Iranian high school. It consist findings useful to teachers, principals, ICT team and students who are involved in the development of pedagogical models for teaching chemistry through computer assisted guided inquiry. This study was organized into three phases. In the first phase, the teachers sample contained 10 persons; teachers with bachelor degrees and teachers who hold master degrees. In the second phase, the ICT team consisted of 10 technicians and 10 principals who were all female. In the third phase, the students sample for the t-test consisted of 30 girls in 11th grade. In order to conduct the research, ten schools were visited and one chemistry class of 11th grade in each school was observed. However, schools had been visited and observed the chemistry classes for ten times and the duration of six month. All of the schools were located in Tehran. The teachers' and students' interactions and their use of ICT in practical classes were videotaped. The observations were later transcribed. Multiple methods of data collection and data analysis were carried out in which it strengthened the reliability and the internal validity of the current research which corresponds to the literature [22]. Data collection was conducted according to a well developed and devised plan. A range of activities such as planning the research trend, interviewing the teachers, the ICT team and the principals were carried out. These sources of information made the triangulation possible and of course fruitful. The guided inquiry survey with students was analyzed. For the first step in the current report, the outline of ICT pedagogical practice in class was summarized. A framework for understanding of the whole chemistry curriculum structure and pedagogical practice was proposed. Following this phase, findings of activities observed in classes by focusing on the chemistry classes of 11th grad in high schools for the purpose of developing the pedagogical model was described.

ICT Pedagogical Practice Classes: Through data analysis collected in ICT practical classes, the following factors inside classrooms were summarized:

- ICT capability factors; teaching, understandings and learning concepts
- Teaching and learning module (educational plant)
- Individual or collaborative learning factors
- Interaction between teacher, student and educational technology (tools)
- Teacher/student mediating factors
- Student/teacher centered activities
- Technology or tools factors.

Based on the above factors, the framework for understanding of the whole ICT pedagogical practice has been constructed as illustrated in Figure 1. The pedagogical model is based on three subdivisions with prefix of "syn".

The other parameters affected data collection and use of ICT outside classroom as follows:

- Views/plan principal
- Role of ICT coordinator
- ICT-Infrastructure

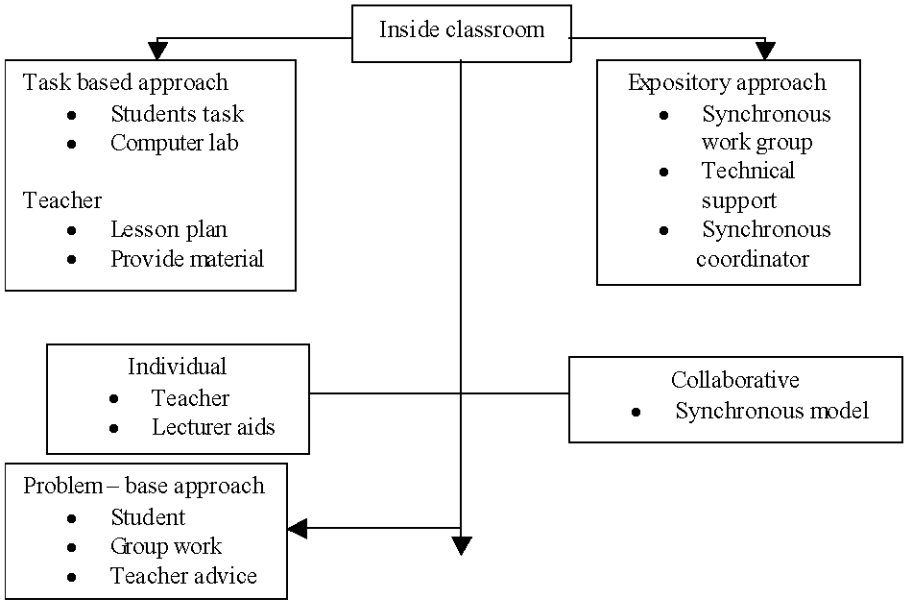

Fig. 1: Various ICT pedagogical practices inside classroom

Procedure for Data Analysis: Since the study was naturalistic type, it required utilization of triangulation method for collection and analysis of the data. Triangulation strategy as a reliable methodology was validated by other investigators [23]. The pedagogical model as mentioned above is described in three phases.

In the first phase, the observations were recorded and transcribed later. In the second phase, semi-structured interviews were conducted with the ICT team and the principals. These interview protocols were transcribed. In the third phase, semi-structured interviews were performed with the experts. Delphi technique was used in this phase [24]. Throughout the study (Phases 1 to 3), learning environment, teachers and students collaboration was designed to serve the present investigation. T-retest method was used for the development of the pedagogical model. Before the t-retest phase, two ICT expert and chemistry curriculum designer were asked to evaluate the questionnaire in order to comment on question fitness with research objectives. Questionnaire was approved by experts. After the approval of the experts, the questionnaire was t-rested across a sample of 30 students. Descriptive and inductive statistics were used for data analysis. The statistical indices and tests consisted of mean, standard deviation, z-score and distribution of significant respondents as depicted in Table 4 represents respondent themes and Willcoxson test.

RESULTS

ICT pedagogical practice between teachers and students was investigated. Data were collected from different sources and analyzed. Triangulation model was used to validate the obtained data.

Phase 1: Observation: The ICT pedagogical practices at classroom as follows:

I) Individual in classroom -teacher

Example 1: Teacher explains topic in the class.

Example 2: Teacher talks to students who are doing the tasks collaboratively without software application. Because of the limited familiarity with the new styles of teaching, they tried to use the computer connected to the projector for presentation to promote students' question and answer activities. This type of interaction is often seen in chemistry classes, due to convenient use.

II) Collaboration in classroom - student

Example 3: Students do assignment together without using software in the classroom.

Example 4: Students provide result of group work using their notebooks. Under the circumstance of the classroom LAN, student cannot work together with classmates.

Table 1: Respondent themes for pre observation based on student-teacher interaction

No	Area	Chemistry teachers
1	Learning goals/objective	Poor lesson plan
2	Teaching-learning method	Poor pedagogical model
3	Tools	Lack of tools
	Assessment	Lack of evaluation software

Table 2: Respondent themes for post observation based on student-teacher interaction

No	Area	Chemistry teachers
1	Educational software	Required educational software
2	Evaluation software	Required evaluation software
3	Data base	Required data base
4	Toolkit	Required training toolkit
5	Courseware	Required training courseware

Table 3: Respondent themes based on interview with principals and ICT teams

No	Area	Respondent Theme Principal
1	Plan/ policy school	•Poor support from leadership for development of equipment •Budget obstacle for improving sites •Persuade teachers to use computers in their classes •Poor developed plan
2	Teacher support	•Poor human development in teacher training •Limited time •Limited examination system •poor skilled ICT teachers
3	ICT-infrastructure	Respondent Theme, ICT team •Limited computer facilities •Lack of budget •Limited educational software •Lack of internet •Limited intranet •Poor ICT team's skills

This style was often observed in daily chemistry classes. The concept of collaboration in the classroom seems to be acceptable in the chemistry classes. It was observed that, either they are not trained, how to use the computer, or the provided training was not sufficient.

The interviews with teacher were preformed as pre and post observation in the classroom.

Pre Observation: The interviews with selected teachers were performed for lesson plan, assessment, teaching and classroom management. The following objectives were investigated:

- What are the learning objectives?
- What are the teaching and learning methods?
- What would be the role of computer in teaching?
- What would be the outcomes of ICT?

The interviews were conducted using a set of open ended questions. The interviews were recorded and later transcribed. Table 1 concludes the respondent themes for pre observation based on student-teacher interaction. It was found that nearly 99% of teachers used traditional models with the aid of computer.

Post Observation: The interviews with the appointed teacher were performed to investigate the problems in preparing lesson plan and kind of training/professional development. The discussed items were associated with problems in preparing the lessons, further professional developments they may need. Table 2 summarizes the respondent themes for post observation based on student-teacher interaction.

It was found that about 99% of teachers in teaching and learning processes need educational software, evaluation software and data base. Furthermore, all teachers (100%) need to train toolkit and courseware.

Phase 2: Interview: The interviews were conducted with principal and ICT team. It took approximately one hour to examine thoroughly the plan, policy and ICT tools used in the school curriculum. The interviews were performed using a set of open ended questions. The interviews were recorded and later transcribed.

The three themes that emerged from the responses of principal and ICT team to questionnaires are tabulated in Table 3. The researchers have classified the three themes into three areas for further consideration.

Almost all the respondents indicated that the computer facilities in school were inadequate. There was only one computer site which had network facilities in weekend. That means, many teachers did not use computer in teaching and learning process. Maintenance was poor and allocation of budgets and funds from the Ministry of Education was delayed and limited. On the question plan/policy, teacher professional development and infrastructure, there was no real plan to be implemented.

During the interviews, it was realized that the school leadership did not propose a plan and/or a strategy to support their schools. It was found that many principals wished to use computers in the school curriculum. But, they were faced to many challenges such as limitation of

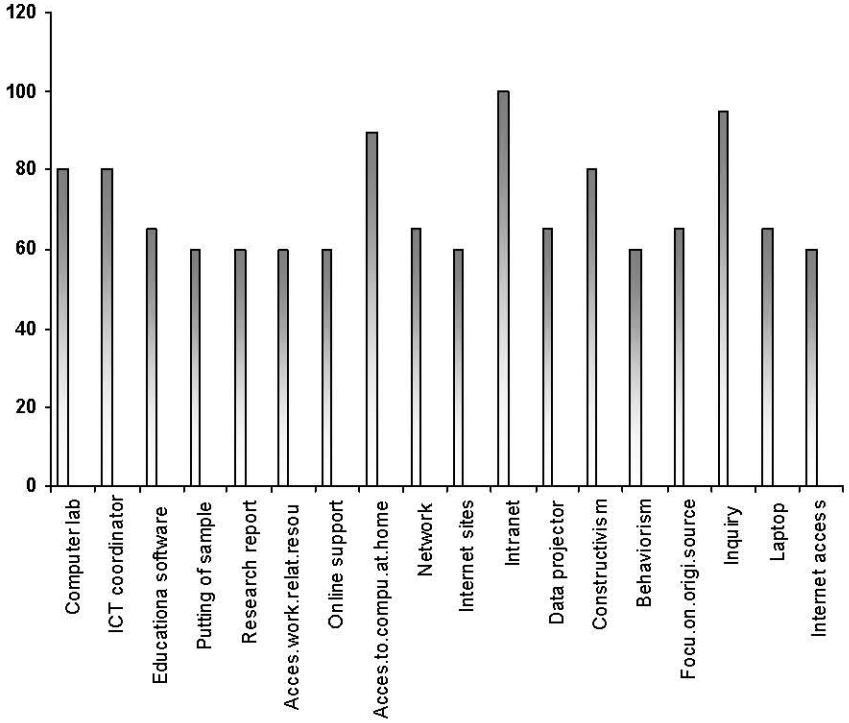

Fig. 2: Consensuses in round 3 based on environment and pedagogical features

Table 4: Students views of learning chemistry with computer use

Statement	*M**	*S. D**	*M***	*S. D** *	*Z*	*Sig. (2-tailed)*
1. Use of computer is useful for team work	3.150	0.670	4.050	0.825	-4.025	0.000
2. Use of computer is useful for increasing responsibility/self-esteem independence	3.150	0.875	4.050	1.145	-3.338	0.001
3. Team work is a suitable method for encouragements	3.166	0.785	4.000	0.973	-2.853	0.004
4. Feedback is applied to correct any mistakes in chemistry learning process	3.150	0.875	3.900	1.252	-2.686	0.007
5. I'd like team work in studying chemistry, it's an investigation work	3.105	0.737	4.050	1.356	-2.682	0.007
6. Investigation enhance understating of chemistry phenomenon	3.450	0.604	3.950	1.190	-2.013	0.044
7. Collaboration upgrade my knowledge and skills in chemistry	3.100	0.788	4.050	0.944	-3.477	0.001
8. Practical work with computer is a suitable method	3.300	0.801	4.250	1.251	-3.100	0.002
9. I enjoy team work as I can work with other students	3.300	0.864	4.200	1.151	-2.933	0.003
10. Teacher's help is adequate to improve chemistry learning	3.000	0.858	3.750	1.019	-2.829	0.005
11. Use of computer in chemistry lesson	3.200	0.695	4.100	0.911	-3.350	0.001
12. Technology tools that I used in chemistry class were friendly	3.263	0.805	4.100	1.071	-2.925	0.003
13. Computer can be quite useful in chemistry concepts	3.150	0.812	3.900	1.119	-3.120	0.002
14. Computer establish communication with others	3.050	0.825	4.050	1.190	-3.233	0.001
15. Overall, I have found chemistry lesson with computer is interesting.	3.100	0.788	3.650	1.268	-1.883	0.060

Note. There were five choice ranging from strongly agree (=5) to strongly disagree (=1) in each statement. *means before guided inquiry, ** after guided inquiry. *** z, p> 0.05 (not significant,), p<0.05 (almost significant), p<0.01 (significant), p<0.001 (very significant). Wilcoxson singed ranks test was calculated.

budgets and lack of sufficient funds. The principals provided the initial steps for utilizing computer in their schools. However, it was found out that the ICT team in the school was inexperienced and needed to be trained.

Phase 3: Delphi technique: Delphi Panel identified results of research outputs. The results of the third phase were obtained by use of inputs, pedagogical and environmental features. For the pedagogical area, teaching chemistry through computer was described by use of the descriptive

Table 5: Analyzes of students' views by studying description indicators

Item	*Strongly Agree*		*Agree*		*Disagree*		*Strongly Disagree*		*No opinion/know*		
Use of computer	#	%	#	%	#	%	#	%	#	%	*Mean*
	10	50%	9	45%	1	5%	-	-	-	-	1.550
	1 year		1-2 years		2-3 years		3-4 years				
Duration of computer usage	#	%	#	%	#	%	#	%			
	-	-	1	5.0	3	15%	16	80%			3.750
	every day		per week		once per week		Monthly, rarely or never				
Use of computer in their study	#	%	#	%	#	%	#	%			
	10	50%	5	25%	5	25%	-	-			1.750
	#	%	#	%	#	%	#	%			
Cooperative	7	35%	5	25%	6	30%	2	10%			2.150
	I do		I would need				I have never				
Items	#	%	#	%			#	%			
word-processor	18	90%	2	10%			-	-			1.100
spreadsheet	9	45%	11	55%			-	-			1.550
email program	15	75%	2	10%			3	15%			1.400
database	10	50%	8	40%			2	10%			1.600
graphics program	10	50%	7	35%			3	15%			1.650
web authoring program	9	45%	5	25%			6	30%			1.850
presentation manager	7	35%	10	50%			3	15%			1.800
web browser	8	40%	9	45%			3	15%			1.750

Note: # (frequency), % (percentage)

analysis and descriptive statistics. These statistical measurements were frequency, mean and standard deviations. The results obtained from the comparison of expert's consensuses in round 2 and 3 based on environment and pedagogical features are shown in Figure 2. The respondents ranked the statement on "intranet" as “strongly agree” by 100%. Moreover, more than 95% of the respondents depicted that they either agree or strongly agree with the implementation of inquiry approach. Furthermore, between 80 to 90% of the respondents were rated the access to computer site, ICT coordinator, access to computer at home and constructivism as important features to include in a pedagogical model of teaching chemistry.

The Willcoxson test of no-parametric variables (singed ranks test) was used to evaluate the differences exist between before and after use of computer in classroom. This test shows that there exists a meaningful difference between before and after computer use in chemistry learning. The analysis of results is presented in Table 4. Before utilizing computers in teaching chemistry, students rarely worked cooperatively with others (35%). Table 5 shows analyzes of students' point of views which was investigated by descriptive indicators.

At the end of their inquiry, result showed that many students were agreed; "The use of a computer in chemistry class helped them to understand the concepts of chemistry." (Refer to statement 13, Table 4). Also, many students responded that "The use of a computer in a chemistry lesson helps them to study" (Refer to statement 15, Table 4).

DISCUSSION

Nearly 99% of the teachers stated that the lack of ICT resources and infrastructure facilities in schools is the reason that they cannot carry out the integration of ICT tools in the chemistry teaching. In fact, computer site is available in school for teachers and pupils, but the observations of findings revealed that teachers need to be

trained to use computer in their education. This is a serious problem where upgrading and improving facilities are drastically slow. There are some schools still uses Windows 98 Operating System. It is suggested that they should be replaced by Windows XP Operating System. However, there is a need to employ authenticated and licensed software. Many urban schools need ICT coordinator. Observation showed that the ICT team in school needed to be trained. However, computer infrastructure facilities in schools are still at the bare minimum.

Out of a total of 10 observations at classroom practice, it was realized that teachers do not integrate ICT tools in their chemistry teaching. Training ICT skills is crucial in implementing ICT integration in the teaching of chemistry science. Some teachers become competent in use of basic ICT tools. Besides, there are emerging needs for training how to integrate ICT in their classroom activities. This would enhance the chemistry teaching. The interviews with the chemistry teachers, the ICT team, principals and the experts revealed that, they need ICT skills, infrastructure, plan/policy and resources. These findings showed that the Ministry of Education should provide a strategic planning for ICT skills training for chemistry teachers, students, ICT teams, principals and schools supported by the necessary equipment.

It was found that infrastructure facilities and resources, ICT team and teacher ICT skills would of course provide a learning climate and environment rich in authentic interaction [25]. Findings have shown that schools which have very good ICT resources achieved better results in chemistry than schools with poor ICT [26]. However, it is not good enough to increase the number of computer laboratories in the schools. In this way, schools needs a training program to have skilled personal to encourage ICT application. Also, schools should be seriously looked at long term plan for use of integration of ICT in education [27].

CONCLUSION

The observations and informants' responses did provide an insight into the impediments ICT integration in teaching and learning chemistry. This study reveals that the lack of infrastructure facilities was one of the causes for poor ICT integration in the teaching chemistry. Observations in the classrooms and the analysis of the results obtained from interviews showed that the teachers and ICT teams need to be trained in ICT skills. Some of the obstacles like administrative burden were seriously addressed.

The observations showed that the ICT skilled teachers were not qualified but, they tried to improve their skills for the benefit of pupils. The school principals and ICT team urge the teachers to integrate ICT tools in the teaching and learning of chemistry but, they need to have budget, resource and plan/policy. The expert's opinion is that the successful implementation of ICT integration in chemistry teaching needs the pedagogical model, rich learning environment. The finding shows that students believed the use of computer helpful to understanding concept chemistry. The full cooperation and support from the school principal, positive attitude of chemistry teachers, continuous training to update teachers' ICT skills when and how ICT tools appropriately could be used in classroom practice is necessary to fully realize the benefits of ICT integration.

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