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ICT enabled Situated Learning Model in the development of metacognitive skills

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***Abstract*—*Educational researchers have been searching for new and innovative approaches for enhancing the teaching and learning process. They have evidenced that the effective use of information and communication technologies (ICT) in developing students' cognitive skills is based on good instructional design. This article presents the attempt made by the author in promoting the understanding of the electrostatics concepts by ICT enabled dual situated learning model (DSLM) in physics education at the Middle East College, Sultanate of Oman. The results reveal significant improvement in students' cognitive skills*.**

***Index Terms*—ICT in physics education, Physics, DSLM, Interactive simulation, conceptual change, cognitive.**

I. INTRODUCTION

Learning and academic achievement are closely associated in teaching. When learning truly takes place it is reflected in students' academic achievement. However, students of science, especially physics in higher education, are facing problems due to lack of focus and motivation. This is perhaps because of traditional approach to teaching in which the level of interaction between teachers and learners is very low [1]. In addition, the traditional way of lecture-based classes transmits shallow information which does not promote learners' critical thinking ability and is not suitable for learner-centered teaching in this digital era [2]. On the other hand, integration of information and communication technology (ICT) into science education certainly motivates learners and improves the quality of teaching and learning process. Besides, ICT makes science education more versatile, and goal-oriented, and inspires learners to be more creative and active in their learning [3]-[4].

Physics is a natural science that deals with many abstract theories. The knowledge, understanding and mastery of physics concepts depend on learners' intuition of physical phenomena. Hence, it is essential to have many scientific activities in classroom-teaching to demonstrate various challenging contents for the thorough perception of the abstract nature of physics. But, in a traditional classroom environment, the teacher cannot perform real laboratory experiments [5]. In contrast, interactive computer simulations play a vital role in the science classroom by providing learners an opportunity to study different kinds of scientific phenomena in a variety of environments. Furthermore, in interactive computer simulations, learners can redesign the scenarios, get immediate feedback and observe the effects to construct their own scientific conclusions [6]-[7]. Hence, computer simulations serve as one of the essential educational tools in activity-based science education and conceptual development [8].

In the Middle East College (MEC), Oman, the engineering physics is an essential module offered in the first semester of Electronics and Telecommunication (E&TC) Engineering programme. This module has various topics including electrostatics theory which is basically abstract in nature. Hence, acquiring the concepts of static electricity, electrostatic force and electric field are essential for students in order to pursue other core modules. Even though interactive computer simulation helps learners' to visualize the concepts, it does not indicate their cognitive development [9]. Hence, in this study, the authors propose a learning model by adopting Dual Situated Learning Model (DSLM) combined with interactive computer simulations in the teaching of electrostatics theory.

II. DUAL SITUATED LEARNING MODEL FRAMEWORK

Previous research studies have suggested that conceptual change involves deep restructuring, not only in the concepts, but also in the ways of reasoning in science education [10]. Thus learners must have well defined goals and self-motivation in order to successfully learn during the process of conceptual change. Motivation and encouragement, therefore, should be emphasized during science education for conceptual change.

She [11], in 2002, has developed the Dual Situated Learning Model (DSLM) which is evidenced success in

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promoting conceptual development in science education within the classroom environment [12]. DSLM consists the following six learning/instructional stages: 1) Examining the attributes of the scientific concept; 2) Probing learners' alternative scientific conceptions; 3) Determining which mind-sets the learners lack; 4) Designing dual situated learning events; 5) Instructing with dual situated learning events; and 6) Instructing with a challenging dual situated learning event [12].

III. METHODOLOGY

A. Participants

The participants of this study are an intact cohort of 31 students enrolled in the physics module of the E & TC Programme. They are at different levels of academic proficiency and are between the ages of 20 and 30. This class was taught by the same physics teacher throughout the semester.

B. Learning Materials

Based on the six stages of DSLM described earlier, students are taught the following four learning events designed for electrostatics concepts: definition of 'electrostatics' (C1); properties of 'charged particles' (C2); knowledge of 'electrostatic force' between the charged particles placed in both medium and free space (C3); and idea of 'electric field' around the charged particles (C4). It is clear that students' misconceptions of electric charge, electrostatic force and electric field are due to the invisibility of charges and their dynamic nature, making it more difficult to construct concepts related to electrostatics.

In order to facilitate students' learning of the concepts of electrostatics through the DSLM designed learning events, two interactive simulations from the Physics Education Technology (PhET) research group are used as a conceptual tool for students. They emphasize providing students with visualizations on the movement of charges, elucidating electrostatic force and electric field for helping them build more scientific views of the concept. For example, two screenshots of the simulations used in this study are shown in Fig. 1.

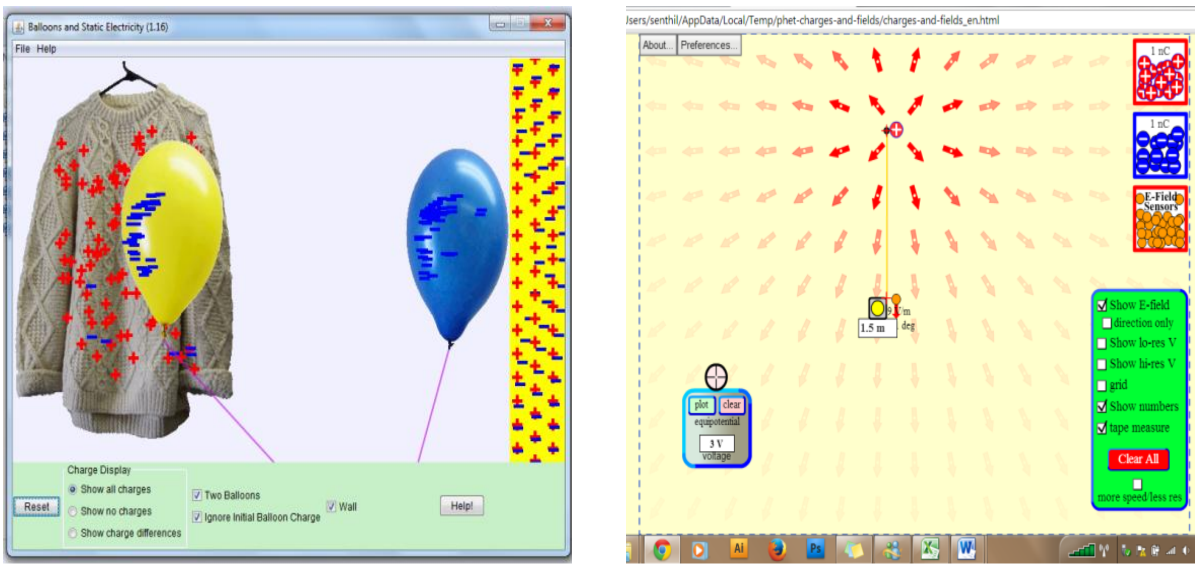

Fig. 1. (a) Shows the properties of charged particles; (b) shows how the electric field strength at a point varies while changing the magnitude of the charge

C. Data collection and Analysis

For examining students' conceptions, the pre-test which contains both multiple-choice and open-ended questions is administered before the proposed classroom delivery. The teaching of simulation-based inquiry using DSLM was employed during two lecture weeks (three hours per week). Then, the post-test (same questions) is administered to explore their conceptual understanding upon completion of teaching of the four planned events. The post-test will

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help to examine students' changes in conceptual understanding after the intervention. Finally, the test is repeated eight weeks after the post-test in order to investigate their retention of conceptual understanding.

In this study, both quantitative and qualitative analyses are used as the test contains both multiple-choice and open-ended questions. For the analysis of the students' conceptual understanding, an analytic rubric scoring method is used for the answers of open-ended questions. As results did not show normal distribution, the Friedman test and Wilcoxon sign-ranked test are used for the analysis. Further, based on She and Liao's ideas [12] the following five categories are measured to quantify the conceptual change: 1) Progress (PG), 2) Maintain-correct (MTC), 3) Maintain-partial correct (MTPC), 4) Maintain-incorrect (MTIC), and 5) Retrogression (RTG).

IV. RESULTS AND DISCUSSION

The results of descriptive statistics and comparative analysis of the students' pre-test, post-test and retention-test (by question and average) are presented in Table I.

Repeated measures of Friedman test are used to examine any increases in mean scores for the pre-test, post-test and retention-test. A significant difference between the conceptual scores of pre-test and post-test can be seen in Table 1. This implies that students made great progress in their conceptual understanding of electrostatics. Also, progression in their conceptual understanding is indicated by the high retention-test scores as compared to pre-test scores. These findings reveal that the students' understanding of concepts from the four intended learning events made progress throughout their learning. The reason for the progress in conceptual understanding from pre-test to post-test can be attributed to the intervention. The Wilcoxon sign-ranked test which is used to compare the conceptual understanding scores between the pre-test, post-test and retention-test ranked both the post-test and retention-rest higher than the pre-test. The results of the present study are consistent with the research findings which show that students' conceptual understanding improves with learning using computer simulations [5].

Table I. Statistical results of repeated measures of the Friedman test, and Wilcoxon sign-ranked test.

Concepts Questions	Pre Test (a)		Post Test (b)		Retention Test (c)		Asymp. Sig.	Pairwise comparison
	Mean	SD	Mean	SD	Mean	SD		
Q1	1.81	0.91	3.52	0.51	3.39	0.50	0.000*	b > a *; c > a *
Q2	1.71	0.69	3.58	0.50	3.48	0.51	0.000*	b > a *; c > a *
Q3	2.16	1.00	4.00	0.00	3.90	0.30	0.000*	b > a *; c > a *
Q4	2.29	1.03	4.00	0.00	3.97	0.18	0.000*	b > a *; c > a *
Q5	1.97	0.75	3.61	0.05	3.65	0.49	0.000*	b > a *; c > a *
Q6	1.32	0.98	4.00	0.00	3.94	0.25	0.000*	b > a *; c > a *
Q7	1.58	0.77	3.74	0.45	3.42	0.50	0.000*	b > a *; c > a *
Q8	1.29	1.04	4.00	0.00	3.97	0.18	0.000*	b > a *; c > a *
Q9	1.77	0.88	4.00	0.00	3.97	0.18	0.000*	b > a *; c > a *
Q10	1.00	1.10	4.00	0.00	3.84	0.37	0.000*	b > a *; c > a *
Avg.	1.69	0.92	3.85	0.15	3.75	0.35	0.000*	b > a *; c > a *

*$p \leq 0.05$

The percentage of the quantity of students' conceptual change are measured, categorized as PG, MTC, MTPC, MTIC, and RTG as mentioned earlier and presented in Fig.2.

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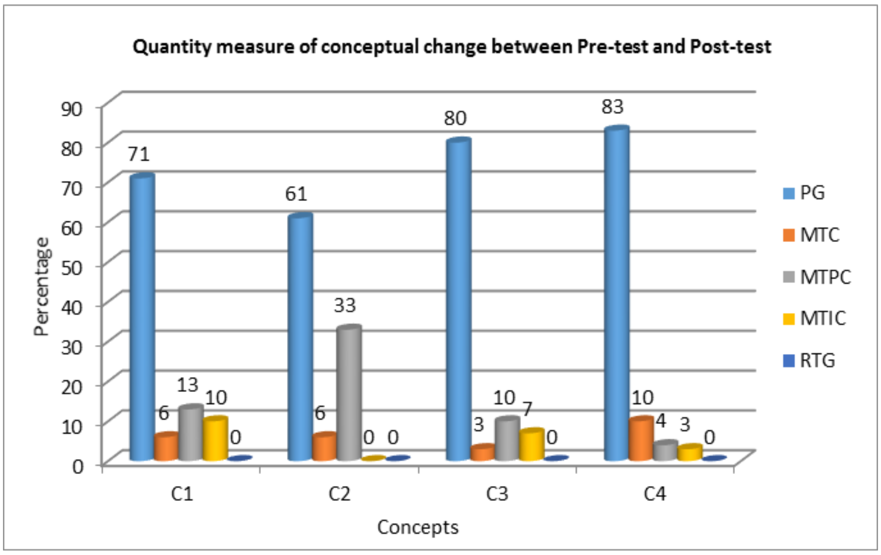

Fig. 2. Distribution of conceptual change across four concepts in electrostatics from pre-test to post-test.

Figure 2 illustrates that the percentage of PG category is higher than that of other categories in all four concepts. The highest percentage of PG category is observed from C4. The PG category ranges from 61% to 83%, the MTC category from 3% to 10%, the MTPC category from 4% to 33%, and the MTIC category from 0% to 10%. Figure 2 also shows that the percentage of RTG category in all four concepts is zero. These results demonstrate the change of the students' existing conceptual knowledge due to their learning through simulation based-inquiry with DSLM. Since most of the conceptual change occurred in the PG category, it reveals that the students' knowledge level improves through learning from simulations. Research findings from several studies [5, 11-12] support the present findings that learning through simulation with DSLM can improve students' conceptual change in physics education.

V. CONCLUSION

Many scientific concepts are invisible and abstract in nature: thus, the use of models and simulation could increase the possibility of nurturing learners' constructions or reconstructions of a more scientific view of concepts. In this study, a learning model by adopting Dual Situated Learning Model (DSLM) combined with interactive simulations in the teaching of electrostatics theory at the Middle East College, Oman, is proposed, and its effectiveness is studied. The result of the pre-test is compared with that of the post-test and retention-test of students who are taught through conceptual learning, with emphasis on computer simulations. The results of this study reveal that learning by dynamic computer simulation with DSLM develops students' conceptual understanding in physics education. This study also confirmed the hypothesis about the potential role of computer simulations in physics education. These findings suggest that the intervention of simulation based learning with DSLM can be effective in fostering students' conceptual changes. Based on the present results, the author suggest that physics teachers who use traditional methods in classroom teaching should consider integrating simulations into classroom lectures in order to develop students' cognitive skills. This study will be extended on developing metacognitive skills by the integration of ICT tools in education.

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