The Effectiveness of Learning Objects as Alternative Pedagogical Tool in Laboratory Engineering Education

Yong-Wee Sek, Check-Yee Law, and Siong-Hoe Lau

Abstract—**This study aims to analyse the effectiveness of learning objects as alternative pedagogical tool in laboratory engineering education. 160 undergraduate students who enrolled in a Digital Systems course were randomly assigned to either a control group or an experimental group. This study utilised pre-test, post-test, postponed-test, and questionnaires as the basis of data collection to measure the effectiveness of learning objects. Before the experiment began, both groups were given pre-test. During the experiment, the students in the control group took a regular course without learning objects while the students in the experiment group took a regular course with learning objects. After 7 weeks of the experiment period, all students were given the post-test followed by distribution of questionnaires to the experiment group. Four weeks after the post-test, both groups were given postponed-tests. The results show that the post-test and postponed-test mean scores of the experiment group students are better than control group students. Further analysis with the three sub-groups (low-achiever, medium-achiever and high-achiever) reveals that the experimental group performed better especially the low-achiever and medium-achiever sub-groups benefited more in increase and retention of knowledge and concept compared to the same sub-groups in the control group.**

Index Terms—**Engineering education, interactive learning environments, learning objects, post-secondary education.**

I. Introduction

In recent years, with rapid development of information communication technologies, drastic changes in education in terms of instructional content and delivery medium to complement the traditional face-to-face teaching and learning have taken place [1]. One of the most important breakthrough in this field has come from the reusable object-based learning approach, referred to as "learning object" [2]. It is an idea to decompose existing course materials into smaller instructional components that can be reused in different learning contexts [3]. An exponential growth of learning objects available through the Internet is creating opportunities and offers the potential of cost and time savings for educators in course development and delivery [4]. Polsani [5] suggests that educators can effectively employ object-based learning approach to course design by using learning objects from a variety of repositories to produce a sound curriculum. They can be used as a single learning unit or combined to form larger educational interactions to allow teaching and learning to be centred on the needs and interests of the learners [6].

The Digital Systems course at our institution is a core subject for first year undergraduate students who come from a variety of backgrounds with different levels of learning experience. The students have very little conceptual understanding of logic circuit which led to hours of wasted time spent on understanding and applying the concepts incorrectly. In order to bring all students to a common understanding of the fundamental concepts in a short period of time, an effective learning approach is important to provide accurate, relevant, and just enough content at the right time to assist the students to gain the correct concepts and apply them well in the early stage. Based on some of the previous related studies [7]-[9], it was hoped that some of these issues could be addressed by using learning objects to facilitate the process of knowledge transfer between the educators and the students.

Although many assumptions have been made about the learning objects' contribution in the process of teaching and learning, few empirical study has been done to support this claim [10]. More independent study on the effectiveness of learning objects need to be conducted to provide new insights to the field [11]. The main objective of this study is to examine the impact of learning objects towards student's academic performance in engineering education. This study is designed to answer the following research questions:

1. What are the differences in students' learning achievements of the two study groups?
2. How do high-, medium- and low-achievers' learning achievements change over time?

This paper will provides a background of the use of learning objects in education which is then followed by the methods and results section. A discussion and the implications of the findings will be presented before concluding the paper with some suggestions for future research.

II. Theoretical Background

The growth of ICT has significantly changed the nature of teaching and learning at all levels of education [12]. Many higher education institutions have made substantial investments in educational technologies to augment the traditional face-to-face teaching and learning [13]. More and more instructional content is being developed specifically to be deployed as learning objects in various contexts [14], [15] because of the potential for reusability, interoperability,

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Y.-W. Sek is with the Universiti Teknikal Malaysia Melaka, Melaka, Malaysia (e-mail: ywsek@utem.edu.my).

C.-Y. Law is with the Multimedia University, Melaka Campus, Malaysia (e-mail: cylaw@mmu.edu.my).

S.-H. Lau is with the Multimedia University, Melaka Campus, Malaysia (e-mail: lau.siong.hoe@mmu.edu.my).

discoverability, and manageability [16]. They are housed in a database containing metadata describing the objects that educators and students can search and access to support different learning contexts [17]. Course design by using learning objects assembly approach increases the efficiency of learning content design, development and delivery [18] and offers potential cost saving for educators [4]. Each learning object focuses on well defined learning objective so that it will be relatively small with self-sufficient of knowledge for the development of the effective lesson plans and integration strategies to provide flexible, individualized learning [19].

Some researchers have argued that learning objects, if carefully designed, have a considerable potential creating effective integration instructional strategies and accessibility to aid student learning in the classroom [20]-[23]. Additionally, Shepherd [6] suggested that learning objects can be used in the course structure as: (1) mini-tutorials, case studies and simulations, (2) overview, applications, examples and summaries and (3) review, practice and assessments. A reviewed of previous research articles that studied the individual differences in terms of learning ability revealed that primary and secondary school students who used learning objects as supplementary learning materials showed significant improvement on academic achievements [22], [24], [25]. Nurmi and Jaakkola [22] found that students' learning performance was dependent on how the learning objects were used. Students involved in a blended learning environment with mixed learning object and lab-based lesson performed significantly better than in traditional learning environments. Medium and high ability mathematics students outperformed low ability mathematics students when using learning objects [24].

To date, although learning objects offer many possibilities to change educational practices, there are no scientifically based systematic recommendations enabling educators to find the best learning objects for different students' achievement. The effectiveness of learning objects for the students of different learning ability is still insufficiently examined [10], [11]. The collage of results reported to date with respect to individual differences and learning objects suggests that a more systematic effort is needed to develop a clearer knowledge base of what influence attitudes and performance when learning objects are used [10], [11]. Heinich *et al.* [26] suggested that an analysis of the learners' attributes must be conducted for the educational technologies to be used effectively. In line with this, this study seeks to explore this area of endeavour to provide new insights to the field of engineering education, focusing on the Digital Systems laboratory tasks.

III. Research Methodology

A. Participants

160 undergraduate students who enrolled in Digital Systems course were randomly assigned to either the control group or the experimental group, forming 80 students for each group. All subjects' ages were in the range of 20–24; they were experienced online learning users who are familiar with web technologies in a general sense and had the basic ability to use online learning system.

B. Measurement Scales

For demographic data, four items were used to collect participants' gender, learning object experience, computer and Internet skills. Two open-ended questions were also used to collect the experiences and views of learners involved in the use of the learning objects. Three types of tests were used to measure and compare the learning achievements. The pre-test aimed to ensure that both groups of students had the equivalent basic digital electronic knowledge required for taking the course. The post-test was intended to compare the learning achievements of the two groups of students after taking the course. The postponed-test was used to measure the knowledge retention by the students after the post-test. The same test sheet was used for all the tests, which covered parts of Digital Systems subjects with 30 questions, including 10 multiple-choice questions (10 marks), 10 fill-in-the-blank questions (10 marks) and 10 structure questions (30 marks). The maximum test score was 50 marks and the test time was 40 minutes.

C. The Learning Objects

The Digital Systems was the subject of choice in the experiment. In this study, relevant learning objects for this course were retrieved from various general repositories which provide higher education level learning objects. In order to produce cohesive and pedagogically sound learning materials and to effectively search for relevant learning objects, the researchers designed a generic structure of the Digital Systems course consisting of a series of electronic folders, similar to the traditional course hierarchy (chapters, lessons and topics) to hold the retrieved learning objects as shown in Fig. 1. There were four topics learned by the students including: (1) Numbering systems. (2) Logic gates. (3) Combination logic circuits. (4) Arithmetic circuits. When students needed to use the learning objects, they used the browsers to login to the learning system via local area network or Internet.

D. Research Design and Procedures

The main design for this study was a quasi-experiment with an experimental group and a control group. Two types of teaching instruction were applied: (a) Using learning objects to teach four units of Digital Systems course to the experimental group. (b) Using traditional methods with PowerPoint slides to teach four units of Digital Systems course to the control group. The same pre-test, post-test and postponed-test were administered to both the control and experimental groups. An instructor was involved in this study, and researcher provided all resources needed for this study.

Before the experiment began, both groups were given pre-test at the first week of the semester. During the 7 weeks of experiment, the students in the experimental group through the availability of learning objects in the intranet and internet, they could modify their cognition and develop digital systems concepts in accordance with individual conditions by adjusting the pace of their own learning progress. On week 9, after the experiment period, all students were given a post-test followed by the distribution of questionnaires to the experimental group. At the end of the semester (week 13), both groups were given postponed-tests.

Fig. 1. Learning objects sequencing by chapters, lessons and topics.

IV. Data Analysis and Results

A. Sample Demographics

Of the 160 students, a total of 148 respondents (experimental group = 76 and control group = 72) completed the surveys with a response rate of 92.5% because 7 students dropped the Digital Systems subject during week 4 and 5 participants didn't complete the postponed-test at the end of the semester. There were 81 (54.7%) male students and 67 (45.3%) female students. The participants have about 3 to 4 years of computer and Internet experience and reported spending an average of 3 to 4 hours on the computer and Internet everyday.

B. Independence of Samples

Although the participants were randomised into two samples, the two groups were analysed using an independent samples t-test on the pre-test scores to provide additional verification that the two samples were equal. We observed that Levene's test for equality of variances ($F = .282$, $p > .05$) was not significant as shown in TABLE I. We therefore assumed equal variances for experimental and control groups and the two groups of students had statistically equivalent abilities in learning the Digital Systems course.

TABLE I: Equality Test of Variances of Two Groups

	Levene's Test for Equality of Variances		*t*-test for Equality of Means				
	F	Sig.	*t*	df	Sig.	Mean Diff.	Std. Error Diff
Equal variances assumed	.282	.596	.047	146	.963	.034	.7324
Equal variances not assumed			.047	145.97	.963	.034	.7316

C. Comparison of Post-Test(PT) and Postponed-Test (PP) Scores

In order to compare whether learners' achievements change and how do they change over time, we compared the mean scores (*M*) pair-wise via a series of t-tests within and across the group.

A paired-samples t-test on the control group learners' achievements revealed a significant differences in the post-test and postponed-test, $t(71) = 2.74$, $p < .05$. The postponed-test mean score ($M = 28.02$) was significantly lower than the post-test mean score ($M = 28.55$). For the experimental group learners' achievements, the mean score of the postponed-test ($M = 30.64$) is slightly higher than that of the post-test mean score ($M = 30.32$). Pairwise t-test result in TABLE II shows there is no significant differences between post-test and postponed-test, $t(75) = -1.16$, $p > .05$). The outcome indicates that the effect of learning objects is significantly retained the knowledge much longer than the traditional class.

TABLE II: Comparison of Post-Test and Postponed-Test Mean Scores Within Group

Group	PT		PP		Diff. PT-PP		t.	p-value
	M	*S.D.*	*M*	*S.D.*	*M*	*S.D.*		
CG	28.55	4.65	28.02	4.99	.535	1.65	2.74	.008
EG	30.32	4.13	30.64	3.94	-.322	2.43	-1.16	.250

Note: *M*-Mean, *S.D.*-Standard deviation, PT-Post Test, PP-Postponed-Test, CG-Control group, EG-Experimental group

Further analysis was conducted to compare the post-test and postponed-test scores across two groups. From TABLE III, a paired-samples t-test revealed a significant differences in the post-test scores, t (71) = 2.89, $p < .05$. This indicates that the mean post-test score for experimental group (M = 30.18) was significantly higher than the control group (M = 28.56). The average postponed-test score of the experiment group (M = 30.48) is also better than that of the control group (M = 28.02). The pairwise t-test results show that the postponed-test score of the experiment group is significantly higher than the control group t(71) = 4.76, $p < .001$. The outcome indicates that the effect of learning objects is significantly positive to the effect of the traditional class.

TABLE III: COMPARISON OF POST-TEST AND POSTPONED-TEST MEAN SCORES ACROSS GROUPS

Test	EG		CG		Diff. (EG-CG)		t	p-value
	M	*S.D.*	*M*	*S.D.*	*M*	*S.D.*		
PT	30.18	4.14	28.56	4.65	1.63	4.77	2.89	.005
PP	30.48	3.98	28.02	4.99	2.46	4.38	4.76	.000

D. Comparison of Learning Achievements across Three Sub-Categories

Besides the comparison of the overall learning achievements of the two groups, in order to gain more details about how each group students' learning achievements change, further analyses of learning achievements with three sub-categories for experimental and control groups were conducted. This study divided students of each group into three sub-categories, high-achiever (HA), medium-achiever (MA), and low-achiever (LA) based on their pre-test scores. Students who earned A grade were assigned to the high-achiever category. Students who earned D or F grades were assigned to the low-achiever category. The rest of the students who earned B and C grades were assigned to the medium-achiever category.

For the experimental group, a 2 (Test) x 3 (Sub-group) mixed-model ANOVA in TABLE IV reveals that the main effect for the three sub-group of achievers (LA, MA and HA) were significant, F (2, 73) = 72.10, $p < .001$, Eta-squared = .66. Thus, there were overall differences in the mean test scores of the LA (M_{LA} = 25.85), MA (M_{MA} = 31.38) and HA (M_{HA} = 33.79). However, a not significant main effect for Test was obtained, F (1, 73) = 1.44, $p > .05$. The overall mean of the postponed-test score (M = 30.51) was not significantly higher than the post-test score (M = 30.17).

Further analysis, a not significant of the Test x Sub-group analysis was also obtained, F (2, 73) = .11, $p > .05$. Examination of the cell means indicated that each sub-group (LA, MA & HA) maintained the level of achievement after the post-test with slightly increase of postponed-test scores for high-achiever (M_{HA} = 34.05), medium-achiever (M_{MA} = 31.47) and low-achiever (M_{LA} = 26.02) as shown in TABLE V.

While for the control group, a 2 (Test) x 3 (Sub-group) mixed-model ANOVA also revealed that the main effect for the three sub-group of achievers (LA, MA and HA) were significant, F (2, 69) = 75.79, $p < .001$, Eta-squared = .69 (TABLE VI). Thus, there were overall significant differences in the mean test scores of the LA (M_{LA} = 22.80), MA (M_{MA} = 28.60) and HA (M_{HA} = 33.28). A significant main effect for Test was also obtained, F (1, 69) = 5.86, $p < .05$, Eta-squared = .08. The postponed-test scores (M = 28.01) were slightly lower than the post-test (M = 28.45).

TABLE IV: TESTS OF BETWEEN-SUBJECTS EFFECTS OF EXPERIMENTAL GROUP

Group	*M*	Std. Err.	95% Confidence Interval Lower Bound	Upper Bound	*F*	Sig	Partial Eta Squared
Sub-group							
LA	25.85	.483	24.89	26.81			
MA	31.38	.400	30.57	32.17			
HA	33.79	.483	32.83	34.75			
					72.10	.000	.664
Test							
PT	30.17	.319	29.53	30.80			
PP	30.51	.279	29.95	31.06			
					1.44	.235	.019

Note: LA-Low Achiever, MA-Medium Achiever, HA-High Achiever

TABLE V: TESTS OF SUB-GROUP X TEST WITHIN-SUBJECTS EFFECTS OF EXPERIMENTAL GROUP

		M	Std. Err.	95% Confidence Interval Lower Bound	Upper Bound	*F*	Sig	Partial Eta Squared
LA	PT	25.68	.585	24.51	26.84			
	PP	26.02	.511	25.00	27.04			
MA	PT	31.28	.485	30.31	32.24			
	PP	31.47	.424	30.62	32.31			
HA	PT	33.55	.585	32.38	34.71			
	PP	34.05	.511	33.02	35.06			
						.11	.899	.003

TABLE VI: TESTS OF BETWEEN-SUBJECTS EFFECTS OF CONTROL GROUP

Group	*M*	Std. Err.	95% Confidence Interval Lower Bound	Upper Bound	*F*	Sig	Partial Eta Squared
Sub-group							
LA	22.80	.603	21.59	24.00			
MA	28.60	.477	27.65	29.55			
HA	33.28	.603	32.07	34.47			
					75.79	.000	.687
Test							
T1	28.45	.351	27.74	29.14			
T2	28.01	.325	27.35	28.65			
					5.86	.018	.078

A significant Test x Sub-group was also obtained, F (2, 69) = 8.65, $p > .001$, Eta-squared = .20. Examination of the cell means (Table VII) indicated that although there were significant decrease in test scores for all LA and MA from post-test (M_{LA} = 23.28, M_{MA} = 29.11) to postponed-test (M_{LA} = 22.33, M_{MA} = 28.09), but the HA managed to retain the level of achievement with a significant increase of postponed-test score (M_{HA} = 33.60) compared to post-test score, M = 32.95.

TABLE VII: TESTS OF SUB-GROUP X TEST WITHIN-SUBJECTS EFFECTS OF CONTROL GROUP

				95% Confidence Interval				
		M	Std. Err.	Lower Bound	Upper Bound	*F*	Sig	Partial Eta Squared
LA	PT	23.28	.649	21.97	24.57			
	PP	22.33	.602	21.12	23.52			
MA	PT	29.11	.513	28.08	30.13			
	PP	28.09	.476	27.14	29.04			
HA	PT	32.95	.649	31.65	34.24			
	PP	33.60	.602	32.40	34.80			
						8.65	.000	.200

V. DISCUSSIONS

The comparison of overall learning achievements of the two groups indicates that the effect of learning object is significantly superior to the traditional class. The control group learners' postponed-test mean score was significantly lower than the post-test mean score. But the experimental group learners' mean score of the postponed-test is slightly higher than the post-test mean score. Further analysis to compare the post-test and postponed-test mean scores across two groups revealed significant differences. The post-test and postponed-test mean scores for experimental group were significantly higher than the control group. The outcome indicates that the use of learning objects significantly increase and retain the knowledge much longer than the traditional class.

In addition, significant differences are also observed between experimental group and control group when the students' post-test and postponed-test mean scores are compared within the sub-groups (LA, MA and HA). For experimental group, each sub-group managed to maintain the level of achievement after the post-test with slightly increase of postponed-test scores. However, for control group, the LA and MA sub-groups' postponed-test mean score significantly decrease compared to post-test mean score. But the HA managed to retain the level of achievement with a significant increase of postponed-test mean score.

The scores suggest that the all students who participated in object-based learning environment are benefiting more than students with conventional learning environment. The learning objects used by the experimental group did produce much of a change in terms of the students' learning achievements and retain the knowledge much longer compared to the control group, especially the LA and MA sub-groups.

The reasons for such results could be attributed to many factors. Based on the participants' responses from the open-ended questions, one main factor is connected to the learner control over the learning process as quoted by the students:

> "I can easily move from one stage to another stage and reverse back within the learning object"
> "I get to do what I want, it is so useful"
> "I could go at my own pace, step by step"
> "I can proceed at a pace that is appropriate for me"

In general, the interactivity of the learning objects facilitated their learning. Learning objects allowed them to control the learning process and learn at their own pace. They had the opportunity to explore learning modules and access to the relevant information that they needed to practice. The ability to engage with self-contained and self-paced task is especially valuable for certain students who do not accommodate easily to the fixed period lessons common in the traditional classroom. It is in line with the study conducted by Liu and Bera [27] that the accessibility and concept-focused learning objects help address a number of obstacles student face including ineffective cognitive strategies and limited working memory to retain the knowledge for long term.

Secondly, feedback from students was generally very positive and indicated that they felt that they were able to learn from the learning objects. They found that many of the learning objects were interesting, engaging and motivating.

> "Quick and easy to find appropriate learning objects for reference"
> "Gives me quick access to the useful materials"
> "Animation and simulation explain the complex concept better than traditional learning approach"
> "Graphics are clearly visible and help me to understand the subject matter better"
> "Learning objects are fit in my learning context"
> "Can access to use for practice and exam preparation"
> "Learning objects can be used as supplemental materials for lab practice"
> "Using learning objects improve traditional class atmosphere for learning"
> "Learning objects arouse my curiosity about the topic being studied"

Overall, learning objects are useful, helping students to learn, and are valuable components in their learning. The students like having learning objects that they can access when they want to, and they particularly like the learning objects as alternative learning strategy that provide just enough content for their learning. Many of the students were using the learning objects for revision, test, or exam preparation. Having such materials enables them to take more control over their own learning, allowing more flexible study patterns at times that suit them and support personalised learning to facilitate the process of knowledge transfer and helping students attain and retain the concepts they acquired. The study has demonstrated that learning object is applicable in the classroom and is consistent with previous research on instructional design [28], [29].

Thought should be given to the functionality of the learning objects and any interactions should be carefully designed as the interactivity is influenced by the degree of the availability of learners' control [30], [31] as well as the availability of the functional features that encourage users to actively learn [32], [33] and key student weaknesses like limited working memory, difficulty in retrieving long term memory, and ineffective cognitive strategies [27].

VI. Conclusions

Learning objects are opening up new potentials for learning in innovative ways in various contexts. This study compares the learning achievements within two groups. Statistical analyses outcomes reveal that the post-test and postponed-test mean scores of the experiment group students who utilised the learning objects for learning Digital Systems is better than that of control group students, who learned through the conventional classroom lecture. The low-achiever and medium-achiever categories tend to benefit more with the learning objects by obtaining in-depth information. High-achiever category is equally benefited in increased knowledge, as measured by differences in the pre-test and post-test scores. They also enjoy good retaining effect.

However, we should not generalize from the study on the effectiveness of learning objects in one learning area for one group of learners to all learning objects in all learning areas for all learners. Future study designs should consider a longitudinal study across a larger and more diverse set of subject matters and users.

VII. Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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Yong-Wee Sek, M.Sc., a former lecturer at Multimedia University, currently attached to Universiti Teknikal Malaysia Melaka (UTeM). He teaches a variety of undergraduate courses, including courses in Algebra and Trigonometry, Calculus, Probability, and Statistics. Mr Sek’s research and publications have focused on user modeling, User affect, e-portfolio, and technology acceptance model. He holds a B.Sc. from University Kebangsaan Malaysia and M.Sc. degree from University Putra Malaysia.

Check-Yee Law, M.Ed., a Lecturer at Multimedia University, teaches a variety of pre-university mathematics courses, including Pre-calculus, Calculus, and Statistics. Ms Law’s research and publications have focused on e-learning, mobile learning, and issues related to computer education. Prior to her academic appointment, she spent several years working in the electronics industry. She holds degrees from University Kebangsaan Malaysia.

Siong-Hoe Lau, Ph.D. serves as a principal lecturer in Faculty of Information Science and Technology, Multimedia University of Malaysia, actively doing research in Human-computer Interaction (HCI) focusing on the new interfaces and interaction techniques by developing new design methodologies, models and theories of interaction and the evaluation of interactive computing systems (hardware and software) in educational contexts.