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THE IMPACT OF THE CBR INTEGRATED WITH ICT ON LEARNING OUTCOMES OF MATHEMATICAL MODELING AT UNIVERSITY LEVEL

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Abstract

This study investigats the instructional impact of case-based reasoning (CBR) instruction integrated with information and communication technology (ICT) on students' learning outcomes of mathematical modeling curriculum at university level. Total 118 students in Hunan University of Technology fulfilled the curriculum demand of 13-weeks instruction time with three hours per week and total 45 hours. The two-way analysis of variance, Levene's test of equality of error variance and nonequivalent posttest were employed for the collected statistical data. The obtained results indicate that the case-based reasoning instruction integrated with information and communication technology presents notable effects on students' learning outcomes in mathematical modeling curriculum and is potential to yield better learning performance than that instructed by either case-based reasoning or information and communication technology alone. However, excessive CBR use in modeling curriculum might not contribute to further enhancement of students' learning gains.

Keywords: Case-based reasoning, Information and communication technology, Mathematical modeling, Learning outcomes, Analysis of variance

Introduction

In current highly developed society, mathematics is becoming an essential and unavoidable tool for investigation in various fields such as finance, business, engineering, biology, information technology, medicine, military and the social science etc (Cai et.al, 2014). Today's social elites require a lot of professional knowledge to manage their complexly interdisciplinary industries. Each of these industries demands more or less the facility with mathematical model to make sense of related phenomena. Such a modeling process involves observing a phenomenon, conjecturing relationships, applying mathematical analyses (equations, symbolic structures, etc.), obtaining mathematical results, and reinterpreting the model (Swetz & Hartzler, 1991).

Today's undergraduates majored in various disciplines, even in science and engineering, however often do not know how to apply their learned mathematical knowledge into the real-world and lack corresponding abilities to construct the mathematical model in practices. This is partly due to the nature of mathematical instruction, which mainly dwells on abstract concepts, well-defined theories and rigorous proofs going through textbook and exercises. On the other hand there exists a substantial gap between the forefront of mathematical research and development in the mainstream of mathematics modeling instruction (Blum 1994).

As for the historic reason, previous mathematical modeling in China was mainly instructed by traditional method such as lecturing with blackboard and chalks. Some difficulties in such instructions might be the lack of vivid and detailed exhibition of mathematical models and the long time range exhausted for teaching merely several models. Students also tend to master the abstract concepts, tedious formula, self-contained examples and patterned calculation methods rather than explore the origin of models and their applicable scope (Chen, 2013; Wu, 2015). Although for now traditional lectures in mathematical modeling have been dramatically evolved as the high-speed development of information and communication technologies (ICTs), huge obstacles still exist as most instructors are still accustomed to traditional instruction ways. Meanwhile, students in current universities are also immersed by the tremendous complex information when accessing the internet freely in classroom. Therefore how to select meaningful information for interpreting and communicating with students and develop their problem-solving skills becomes a primary task for instructors in teaching mathematical modeling knowledge.

In general, good principles in mathematical modeling instructions should include use of technology that helps students learn real-life problems, enhancement of communication that connects students effectively with the teacher, active involvement that encourages students to be flexible in problem thinking, and systematical evaluation that contributes to students' self-assessment (Grandgenett et.al 2000). To satisfy such principles, the student-targeted instructions are unavoidable. Rather than teaching merely abstract concepts and self-contained examples in traditional lectures, student-centered instructions allow students to use their discipline's conceptual tools and see connections to real world applications (Prince&Felder, 2007). It will be helpful for students to see how successful professionals develop higher conceptual understanding, critical thinking and problem-solving skills by coping with emergent and ill-defined problems (Brown et al., 1989, Das, 2006). The case-based reasoning (CBR) instruction is one of the learner-centered instructional approaches. It aims at, via incorporated cases, making encountered problems connected to real-world and applying obtained knowledge for solving authentic problems (Kolodner, 1993, Kolodner et al., 2003). Especially, it emphasizes adopting past lessons in unknown situations to tackle new problems and playing authentic roles within realistic complex scenario to implement targeted reasoning to succeed (Kolodner, 2003, Prince & Felder, 2006).

As models in mathematics are closely similar to practical cases, it is proper to incorporate CBR into modeling instructions. There has been some qualitative investigations such as questionnaires, interviews, together with quantitative surveys associated with one-way analysis of variance to support the effectiveness of CBR instruction (Prince & Felder, 2006). However the relationship between students' learning outcomes and the CBR instruction at different degrees is still unclear. Especially, the quantitative study on how CBR instruction integrated with ICT use affect students' learning outcomes, as compared to traditional lecture, is rarely explored. Therefore, the goal of this paper is to examine the influence of matching various CBR instruction degrees with ICT use on students' learning outcomes in the mathematical modeling curriculum.

Use of information and communication technology

The information and communication technology refers to the means of unified communications and the integration of telecommunications, computers as well as necessary software, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information (Foldoc, 2008). The rapid development of ICT in recent years has brought education huge changes and shaken the traditional teaching and learning paradigms. There are lots of social and economic advantages of using ICT in education such as reducing the costs of education, supporting the computer industry, preparing students for work and for living in a society permeated with technology, and making the school more attractive to its potential clients (Pelgrum, 2001). Nevertheless, the basic function of ICT as a medium for teaching and learning was identified as the most important objective among all usages of ICT in education (Plomp et.al 1996). In fact, efficient ICT use in classrooms could effectively save curriculum time to provide students with more substantial content and change the interactive teaching environment between instructors and learners (Jeremy et.al. 2001; Ertmer, 2005). There are also some scholars definitely believed that ICT use could bring positive benefits to mathematical education. For example, use of ICT provides lots of information enriching students' mathematical vision and changing their attitudes towards mathematics learning (Goos & Bennison, 2008; Pierce & Ball, 2009); ICT integrated teaching way can make students more clear about abstract mathematic concepts, familiar with proper representation of problems, accustomed to independent thinking ability, and finally increase their mathematical gains (Goos & Bennison 2008).

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It is generally accepted that the development of ICT is often constrained by people's beliefs and economic fundamentals. For example, Agyei and Voogt (2011) reported a study conducted to explore ICT use in mathematics teaching, which revealed that major barriers to ICT use were lacks of sufficient training opportunities for ICTs integration knowledge acquisition and of effective instruction ways to integrate ICT in classrooms. Even in developed areas with well enough ICT devices, including scientific calculators and computers, graphing projector, internet networks and sophisticated teaching software, available for teaching and learning in classrooms, ICT instruction obstacles still exist as some instructors are used to the traditional teaching ways dominated by working only with blackboard and chalks or pen and papers (Ertmer et al., 2012; Pierce & Ball, 2009). Especially, ICT use is regarded by some teachers as a relay in the reproduction of traditional ways of teaching and learning (Cararina 2013) and even strongly believed to, in contrast to traditional instruction way, be less efficient to develop the necessary mathematic abilities such as the computing power and the induction and reduction ability (Goos & Bennison, 2008; Pierce & Ball, 2009). This could be interpreted, in some degree, as "culture clashes" in technology use between subject areas and these clashes are frequently attributed to core features, values and beliefs held in the subject area cultures (Howard et.al 2015). Therefore, it is the teachers' attitudes but not the ICT itself that matter and can be considered as a major predictor of ICT use during the whole educational settings (Albirini, 2006). Their attitudes toward ICTs can play an important role in the acceptance of actual ICT use and then to determine usage frequency of technology and usage amount of the technology (Kluever, Lam and Hoffman, 1994).

Case-based reasoning instruction

Case-based reasoning (CBR), roughly described, is the process of solving new problems based on similar solutions of past problems. It is known as the case-based learning when only one case is provided but emphasizes reasoning about multiple cases and how prior solutions can be adapted to new problems or how prior cases are related to new cases (Merseth, 1991; Jarz et.al. 1997). CBR traces its roots to the work of Roger Schank and his students at Yale University in the early 1980s (Schank 1982). Schank's model of dynamic memory laid the basis for the earliest CBR system, which simulated the problem-solved style of professional experts, such as fire commanders, car mechanics and system designers. In this model, cases based on past experiences were more heavily depended on than those on abstract principles when making decisions with a high degree of uncertainty (Klein and Clderwood 1988, Lancaster and Koloder,1988, Merseth 1991).

The whole CBR process relies upon the constructed cases libraries and could be divided into three parts: recalling old experiences, interpreting the new situation and adapting the old solution to meet the requirement of new situation (Kolodner,1992). It was subsequently developed by Aamodt and Plaza (1996) into a more detailed four-step CBR cycle as Figure 1 described.

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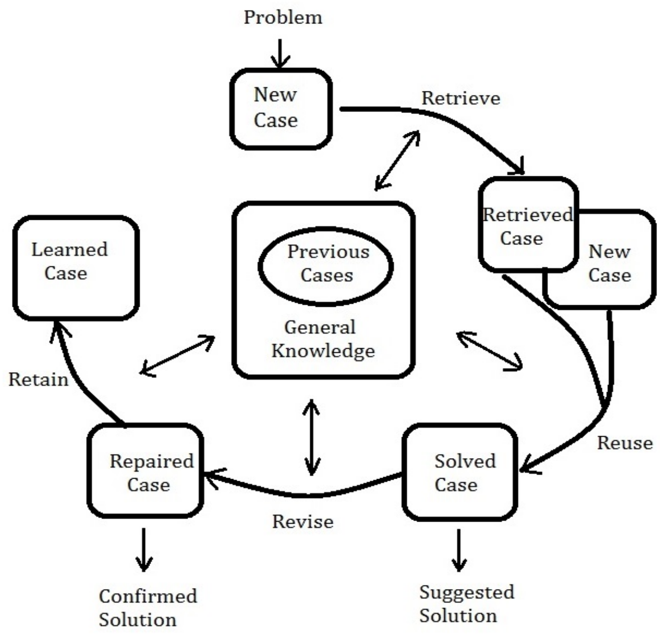

Figure 1. Four-step CBR Process

For a new target problem given in Figure 1, the CBR mode starts retrieving from memory relevant to the current case. This step consists of rapid indexing similar old problems, finding corresponding solutions, and, typically, developing annotations about how the solution was derived. Then the CBR reuses as the nearest as possible case to the target problem. This step might suggest a solution trying to fit the new problem. If the mapped solution is the desired, then the CBR model will turn to next step. Otherwise, the old and new cases are revised to satisfy the required demand. After the solution has been successfully adapted to the target problem, the learned case is retained in memory for later use (Aamodt and Plaza 1996).

The CBR process has wide range applications in the real-world, ranging from knowledge-rich situations where construction of solutions is complex to knowledge-poor situations where cases provide the only available knowledge (Kolodner 1993). It allows the reasoner to propose feedbacks to the problems rapidly, to reason in domains that are not well understood, to evaluate solutions when algorithmic methods are not available and to focus on important parts of a new situation. Such relative concrete steps make it fit well with the artificial intelligence areas (Aamodt & Plaza, 1996; Zouag & Nkambou, 2010). Besides, the CBR method is also a good instructional strategy that engages students in active discussion about issues and problems inherent in practical applications. It can highlight the centre position of students and provide a format for role playing within controversial scenarios. For example, Janet et.al (2003) designed a project-based inquiry instruction approach by using the CBR, with the goal to lay the solid foundation for students to be successful thinkers, learners, and decision-makers throughout their lives. David and Julian (2002) described how stories can be used as a task analysis tool and as an instructional aid in the form of CBR instruction. Kassirer (2010) thought that the optimal medical care derived from various level of CBR medical education, which finally resulted in clinicians' skills to make the right diagnosis and to recommend the most appropriate therapy. Bacca et.al (2012) applied the CBR technique, together with multilingual–tiny as a web authoring tool, to bilingual training programs for indigenous students and Yadav (2014) employed CBR to improve students' conceptual understanding ability and found a significant increase as compared to traditional lecture.

From the practical point-views of solving mathematical problems, CBR could be further divided into two different basic kinds: the precedent-based CBR (PBCBR) and the problem-solving CBR (PSCBR) (Rissland, 2010). Here PBCBR uses past cases not only to create a new solution, but also

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to justify it and explain its rationale, while PSCBR only emphasizes a detailed problem solution via past cases without offering justifications. Both types of CBR share many elements such as the need for a significant memory or corpus of cases and ways to index them. Major differences between them include the indispensability of justification in PBCBR and the central role of detailed plans in PSCBR. In other words, the relevant precedents or citations are all woven into the solution in PBCBR while the relevant cases contribute information but are not necessarily cited explicitly in PSCBR. As mathematical modeling instruction requires not only accurate construction of the model but the careful verification of its rationality to be applicable into the real-world, we implemented each step of PBCBR in teaching and denoted it concisely by CBR henceforth.

Research Methodology

Research hypothesis

CBR instruction is usually promoted in many universities since it is able to teach important concepts and facts within the context of authentic or real-world situations. One advantage of CBR is that it has the potential for reducing "inert" knowledge which is some kind of information in "chunked" fashion, typically out of all context and hard to be applied to realistic situations (Jarz, et.al, 1997). When learning mathematics, for example, simply "crunching" formula may leave a student with "inert" knowledge concept. CBR also has some disadvantages in instruction, including the increased time to design and develop quality cases, the heavy workload in collecting of sufficient resources for students to understand cases and the complicated team-work consisted of content specialists, instructional designers and programmers. Fortunately, such weaknesses of CBR seem to be compensated in some degree by use of ICT. Possible reasons are that for teachers, ICT use facilitates sharing of educational resources and advices so that planning and preparing lessons or designing materials become easier, brings greater temporal and regional flexibility so that instructional tasks could be carried out when required, obtains more gains in technical literacy skills so that instructors' confidence and enthusiasm could be enhanced (Suraksha & Emmanuel, 2016). Besides, ICT use can provide students with higher-quality lessons through greater collaboration between teachers in planning and preparing resources, ultimate flexibility of access, huge encouragement of independent and active learning. There are some qualitative reports showing CBR integrated ICT use could influence instructors' beliefs about teaching with ICT and make students feel more successful in school so as to increase their self-confidence and find learning in a technology-enhanced setting more stimulating than in a traditional classroom (Otto & Albion, 2003; Li & Wang, 2012; Yadav et.al, 2014). However, quantitative research of CBR integrated with ICT use on students' learning outcomes of mathematical modeling, especially at the university level is still rare. So in this study, the following hypotheses are proposed to analyze the impact of the CBR integrated ICT on students' learning outcomes:

H1: CBR reveals remarkable effects on learning outcomes of mathematical modeling.
H2: ICT use shows notable effects on learning outcomes of mathematical modeling.
H3: The CBR integrated with ICT use presents significant effects on learning outcomes of mathematical modeling.

Research objects

The mathematical modeling curriculum at university level was elective for all students in Hunan University of Technology during the spring semester of 2016, spanning 13-weeks with three hours per week total 45 hours. The instructional content contained the linear programming model, the differential equation model and the stochastic model. Total 118 students majored in Applied Mathematics, Physics, Information and Computation, Mechanical Engineering, Communication Engineering and Civil Engineering constitute the sampled subject and 111 students fulfilled the curriculum demand. So the ratio of effective objects included in statistics data reaches about 94.

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0%.

Among all effective participants, there were 81 (73%) Year 3 and 30 (27%) Year 4 students, and 68 (61%) male and 43 (39%) female students. Meanwhile, students taken this curriculum all had required knowledge of calculus, linear algebra and probability and statistics which are compulsory in their first two years according to the nationwide curriculum specifications for science and engineering majors.

Research design

To efficiently test the proposed hypothesis in this paper, all participated students were randomly divided into six classes for instruction, three of them employing ICT (ICT2) the other three using no ICT (ICT1). Meanwhile in each group, the cost CBR time during the whole curriculum was classified as three various degrees (i.e. CBR1, CBR2 and CBR3 represents 0%, 50% and 100% time used in instruction). Here the time "0" means CBR method is unused. Students' learning outcomes are determined by examinations consisted of 60% theoretical tests and 40% experimental tests.
In the implementation of CBR integrated with ICT use, we not only laid stress on the content of cases, but also emphasized students' discussion process. Moreover, all concepts, methods in mathematical models were elicited or discussed through cases and procedures for assessing students' achievements or their work on cases were quantitatively recorded as scores from theory and experiment.

Analysis method

Besides the basic descriptive statistics analysis, the two-way analysis of variance (ANOVA) was applied to discuss the effects of use of ICT integrated CBR on mathematical modeling learning outcomes. Meanwhile the impacts of respective use of ICT and CBR were also conducted. Before the two-way ANOVA, the homogeneity of variances, however, should be assumed for each combination of the groups of the two independent variables (ICT and CBR), which will be validated by using Levene's test in the practical implementation. Also, to efficiently ensure a strong level of internal validity and further understand the effects of CBR integrated with ICT use on learning outcomes, the post hoc analysis was also introduced by assigning participants randomly between two groups (i.e. use of and not use of ICT).

Analysis of Data and Findings

Test of homogeneity of variance

The equality of error variances across groups was validated by the Levene's test and the results are listed in Table 1. As seen "P=0.106" which recalls that a non-significant result is indicative of the homogeneity of variance assumption being met.

Table 1. *Levene's Test of Equality of Error Variance*

F	df1	df2	P
1.901	5	105	0.106

** stands for p<0.05, ** for p<0.01*

ANOVA of CBR use on mathematical modeling learning outcomes

By applying analysis of variance to evaluate the effect of CBR use on learning outcomes, the obtained result is listed in Table 2, displaying that the significant difference exists between the CBR instruction and the traditional lecture on learning outcomes. Also the CBR instruction appears higher learning outcomes than traditional instruction does and H1 is supported.

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Table2. *ANOVA of CBR use*

Variable		df	Mean Square	F	P
Use of CBR	Lerning outcomes	2	163.974	7.324	0.001**

** stands for p<0.05, ** for p<0.01*

ANOVA of ICT use on mathematical modeling learning outcomes

The analysis of variance was also conducted to discuss the effects of ICT use on learning outcomes and obtained results were pulled out into Table 3, from which we are able to see that ICT use presents remarkable differences on learning outcomes with and traditional lecture. Moreover, ICT use shows higher learning outcomes than traditional lecture does and H2 is supported.

Table 3. *ANOVA of ICT use*

Variable		df	Mean Square	F	P
Use of ICT	Lerning outcomes	1	592.991	26.486	0.000**

** stands for p<0.05, ** for p<0.01*

ANOVA of CBR integrated with ICT use on mathematical modeling learning outcomes

To investigate the effect of CBR integrated ICT use on mathematical modeling learning outcomes and their interactive effects for the promotion of learning outcomes, the two-way analysis of variance is utilized for the collected data. Derived results were listed in Table 4 from which we can see a statistically significant interaction at the value **p** = .008, presenting that CBR instruction integrated with ICT use was able to yield remarkable interaction on mathematical modeling learning outcomes. Then H3 is supported.

Table 4. *ANOVA of ICT*CBR use*

Variable		df	Mean Square	F	P
Use of CBR*ICT	Learning outcomes	2	114.632	5.120	0.008**

** stands for p<0.05, ** for p<0.01*

Analysis of effects of cost CBR time at different level on learning outcomes

As stated as above, the CBR instruction was classified into three different levels (in terms of the cost time 0%, 50% and 100%) to test their respective effect on learning outcomes. The descriptive statistics was tabulated in Table 5 which showed that the CBR2 (i.e 50% cost time) instruction got the highest learning outcomes.

Table 5. *Descriptive statistics*

CBR	ICT	Mean	Std.Dev.	N
1	1	67.94	3.780	18
	2	68.53	5.920	19
	Total	68.24	4.935	37
2	1	68.88	5.439	16
	2	75.26	4.798	23
	Total	72.64	5.927	39
3	1	68.18	4.531	17
	2	75.17	3.417	18
	Total	71.77	5.298	35

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To see whether such differences resulting in the statistical significance, we subsequently employed Post Hoc Tests to implement the multiple comparison. Note that Post Hoc Tests are not performed for ICT as there are only two groups (i.e. use and not use of ICT). The obtained results are listed in Table 6. Regardless of some repetitions, we can see that there is a statistically significant difference between CBR1 and CBR2, CBR1 and CBR3 but no difference between CBR2 and CBR3. As an aid to understanding these post hoc test results, homogenous subsets are also provided in this table, revealing that CBR2 and CBR3 are not different from each other and they could be reduced into the same subset.

Table 6. *Tukey HSD Post Hoc Tests and Homogenous subsets of different CBR levels*

	(I)CBR	(J) CBR	Mean Dif.	Std. Err.	P	Subset1	Subset2
Tukey HSD Post Hoc Test	1	2	-4.40*	.855	.000*	68.24	
		3	-3.53*	.850	.006*		
	2	1	4.40*	.855	.000*		71.77
		3	0.87	.845	.710		
	3	1	3.53*	.850	.006*		72.64
		2	-.87	.845	.710		
	Homogenous subsets of different CBR				**P**	1.000	.710

** stands for p<0.05, ** for p<0.01*

Lastly, a graphical illustration of different level CBR integrated with ICT are provided to describe the interactive effect which is seen as a set of non-parallel lines. We can see from this graph that the lines appear to be crossing eventually so that a statistically significant interaction is expected. Furthermore, use of ICT together with 50% CBR time in the whole course attained the best learning outcomes among all cases.

Discussion

The main research objective of this paper is to investigate the impact of ICT use, CBR instruction and the integration with both of them on learning outcomes of mathematical modeling curriculum at university level. Based on results of ANOVA as shown in Table 2, it seems that there is a statistically significant difference between learning outcomes with CBR use and without CBR use. Especially, CBR use in curriculum instruction tends to yield a higher learning outcome than that of the traditional lecture. This obtained result is consistent with findings in the previous study (e.g., Jarz, et.al. 1997) which found that students' learning outcomes could be efficiently improved when the proper and good CBR instruction are incorporated into the class.

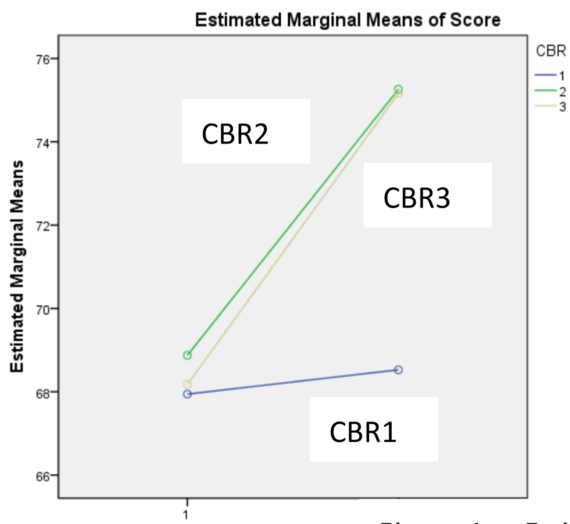

Figure 1. Estimated Marginal Means of Score

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In addition, according to the results of post-hoc tests and subsets analysis, there are various statistical significances among different CBR experimental groups. More concretely, the statistical significant difference does exist between CBR1 and CBR2 and CBR1 and CBR3, but lacks between CBR2 and CBR3. In our practices, when CBR was applied into instruction, several advantages were found as compared to the traditional lecture. On one hand, the significantly higher conceptual understanding and stronger reasoning ability were obtained by students and, on the other, more opportunities were afforded with students to develop teamwork and competency abilities. These results are consistent with earlier studies of applying CBR learning into traditional lectures (Bilica, 2004; Mayo, 2004; Yalvac al., 2007). However as the CBR cost more time in instructions, the learning outcomes conversely seemed to a small decrease. That is, the score of CBR3 is less than that of CBR2 but such a gap was not big enough to intrigue the statistical significance. Also, students in investigation also felt that more cases seemed not significantly increase their learning confidence to solve problems. In summary, proper CBR use could be regarded as an effective pedagogical tool as students feel more engaged in conceptual understanding, logistic reasoning and efficient connecting to the real world which is finally reflected by higher scores as compared to traditional lecture, but excessive CBR use might not contribute to the perceptive enhancement of learning gains. These findings seem conformed to the earlier study finding no significant difference in the students' perceptions of learning outcomes between CBR instruction and traditional lecture in a mechanical engineering course (Yadav et al., 2010). It also may be interpreted by some scholars that students actually learned more from such case studies, but not good at accurately predicting how well they learned or students achieved very low levels of accuracy in predicting their learning performance (Dunlosky & Lipko, 2007; Glenberg, Wilkinson, & Epstein, 1982).

Analogously, results in Table 3 indicated that ICT use gave rise to positive effects on students' learning outcomes in mathematical modeling curriculum. As holding active attitudes in applying ICTs, instructors under investigation found such technologies did improve students' interests and motivation, and also change students' attitudes towards learning mathematics models. However they also admitted, to a certain degree, that multifarious ICT use in practices was time-consuming for designing lesson plans and easier distracting students' mathematical concentration. Analogous researches were also found in previous studies. For example, Dogan (2012) showed that Turkish primary teachers on one hand admitted the helpfulness of computer in mathematical education but on the other hand held negative attitude to excessive usage of computer-based mathematics education.

Another main aim of this study is to examine the effect of integration of CBR use integrated with ICT on students learning outcomes in mathematical modeling curriculum. In our experiments, instructors holding relatively stronger constructivism-oriented views were assigned to implement CBR instructions. That is, ICT use was believed by them to be not just as a teaching machine to present information, reinforce students' practice and track student progress (Niederhauser & Stoddart, 2001; Teo et al., 2008), but capable of promoting students' learning outcomes via assigned multidisciplinary team-work tasks and finally guiding them to become independent learners (Ertmer et al., 2012; Yang & Leung, 2015; Teo et al., 2008). Although Table 6 suggested that there was no substantially statistical difference in CBR2 and CBR3 and they could be classified as one group, statistical results showed that students instructed by CBR integrated with ICT get a better learning performance in mathematics modeling curriculum than those by either ICT alone or CBR alone. Moreover, all of them were found superior to the traditional lecture. This conforms to some arguments proposed by previous researchers and some findings in previous research. For example, Tlhapane and S. Simelane (2010) found that students' critical thinking abilities and problem solving skills could be improved and their social space could be enhanced by the technology-enhanced CBR instruction. Besides, learners who integrate CBR with ICT in solving a problem may develop more professional content knowledge and skill than those who merely employ ICT (Karami et.al 2013). In our investigations, instructors, when implemented CBR integrated with ICT, were found more inclined to discuss problems with students and students tended to give unexpected and profound

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problem-solving methods. This is also validated by some previous studies people who hold more sophisticated epistemic beliefs about the nature of knowledge are more likely to hold constructivist-view of using ICT (Kim et al., 2013, Yang and Leung 2015).

Conclusions and Limitations

This study discusses the instructional impact of CBR integrated with ICT on students' learning outcomes of mathematical modeling curriculum at university level. The obtained results reveal that students' learning outcomes will benefit from the application of ICT provided that the instructor holds positive attitudes toward ICT. Also CBR instruction does contribute to the enhancement of student's learning outcomes of mathematical modeling. However, more CBR time cost seems not helpful to the higher learning achievement than less CBR time does, although such a difference is not big enough to intrigue the statistical significance. When instruction is integrated CBR with ICT, our findings show that students are inclined to get a better performance on learning outcomes than those instructed by either ICT alone or CBR alone. Moreover, to attain the best learning outcomes, instructors have to learn how to effectively integrate CBR with ICTs as well as concrete CBR time cost in the curriculum so as to achieve actual effects.

There are also some limitations with this study. Firstly, we only collected the objective scores from theoretical and experimental tests in the middle and the end of a semester as the statistical data. Although lots of opinions and suggestions from students about ICT and CBR were also considered after tests, they did not form a quantitative research yet. Future studies may include more than one method of data collection, such as quantitative questionnaires of interviews and reports, to achieve greater validity of the data. Secondly, although this study investigated the impact of ICT instruction integrated with different CBR time on students' learning outcomes, the proper CBR time range for yielding better efficiency in curriculum instruction is still not clear. These issues will deserve more exploring in future and contribute to deeper understanding of constructivism-view of using ICT.

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