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Application of IIRS in Mathematics Instruction to Promote Pupils' Decimal Concept

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ABSTRACT

The purpose of this research was to investigate the learning effects on pupils' decimal concept in IIRS (Integrated Interactive Response System) educational environment. IIRS was gradually adopted in classroom and few researches discussed its effects in mathematics instruction. Besides, S-P chart (Student Problem Chart) was one approach of cognitive diagnosis and it aimed to reveal the learning effects of examinee. Therefore, S-P chart will be adopted to analyze the learning types in this research. One way quasi-experiment design of mathematics instruction was conducted to investigate the learning effects of IIRS. In order to detect students' decimal concept structures, the researchers developed S-P chart software to analyze assessment data. According to S-P chart, this study explained the caution index and classified students into proper styles of mathematics learning. By this way, we could realize the erroneous decimal concepts and misconception. Based on the findings, one was concluded that students who used the IIRS in classroom had higher performance on decimal learning. Besides, results of S-P chart also showed that students taking the IIRS had less misconception in decimal. In conclusion, the study found the positive effects of IIRS used in the mathematics instruction. Based on the conclusions, some recommendations and suggestions for mathematics instruction and future investigation were provided.

Keywords: Integrated Interactive Response System, Learning Technology, Mathematics Instruction, Student Problem Chart

Introduction

Digital technology is widely used in the educational environment. One benefit of digital technology is the interaction between teachers and students. Especially, the digital technology may bring positive influence to help students construct correct mathematics concepts. Hence, it is prospective to investigate its effects. IIRS (Integrated Interactive Response System) is a learning technology and it has been gradually adopted in classroom. However, few researches discuss its effects in mathematics instruction. This study is to investigate the effects on pupils' decimal concept in IIRS environment. Besides, S-P chart (Student Problem Chart) is one approach of cognitive diagnosis and it aims to reveal the learning effects of examinee. This study will also adopt S-P chart to detect decimal concepts.

Literature Review

Learning Technology and Application in Mathematics Instruction

The influx of leaning technology into classrooms reveals that learning technologies are powerful tools for learning mathematics. Kinney & Robertson (2003) provides the viewpoints that teachers and students have access to technologies will improve the convenience and interaction in the mathematics classrooms. Based on the digital learning theory, interactive learning environments are vital components of a high-quality mathematics education. Interaction between peers and teachers could promote the learning achievement. Christensen (2002) finds that needs-based technology integration education is shown to have positive effect on teacher attitudes and student achievement. Roschelle, Pea, Hoadley, Gordin, & Means (2000) point out that computer technology can help support learning and develop the higher-order skills of critical thinking and analysis. They explore the various ways of computer technology used to improve how and what children learn in the classroom. Their conclusions indicate several examples of computer-based applications to illustrate technology can enhance how children learn. These examples are: (1) active engagement, (2) participation in groups, (3) interaction and feedback, and (4) connections to real-world contexts. These examples illustrate technology can expand what children learn by helping them to understand core concepts in mathematics. Their research suggests further research is needed to identify the cognitive process required for successful implementation.

As to this point, IIRS (Integrated Interactive Response System) is a powerful technology that is feasible and helpful in mathematics classroom. However, little is known about its empirical effects in mathematics instruction. Therefore, one purpose of this study is to adopt IIRS in the mathematics classrooms and investigate its effects on students' achievement. Garofalo, Drier, Harper, Timmerman, & Shockey (2000) discuss the issue in the National Council of Teachers of Mathematics (NCTM) in which identifies the "Technology Principle" as one of six principles of high quality mathematics education. The technology principle states: "Technology is essential in teaching and learning mathematics and it influences the mathematics that is taught and enhances students' learning".

There exists widespread agreement that mathematics teachers are the key agents to refine mathematics teaching with technology. Many literatures indicate well-organized technology could provide students and teachers with access to instructional technology and effects. These technologies include appropriate computers, software, Internet devices, handheld data-collection devices. Niess (2005) investigates pedagogical content knowledge (PCK) development with respect to integrating technology. Four components of PCK were adapted to describe technology-enhanced PCK (TPCK). According to this research, it shows the importance of instructional technology. Seymour (2002) emphasizes the technology utility in science, mathematics, engineering, and technology. He describes some features in the changing landscape of activities intended to improve both quality and access. Mathematics curricula and courses should incorporate instructional technology in learning outcomes and assessments of students' progress.

However, it is a complex task to help teachers to use technology appropriately. The adoption of technology requires professional knowledge that focuses on both conceptual and pedagogical issues and desire to change from within the profession. Jiang & McClintock (2000) consider that mathematics

educator should make the best use of multiple representations those enhanced by the use of technology to encourage students to apply multiple strategies in mathematical problem solving and creative thinking.

Based on the motivation of this study, most literatures indicate the necessity to explore the utility of new technologies blended in classroom instruction. IIRS is a new technology which could improve the interaction among teacher and students. In the IIRS environment, the classroom teacher could realize the thinking and answer from students so that the teacher understands their concept construction and grasps the discussion among students. As to students, they can respond and record immediately whenever they have ideas. In addition, students could discuss through the IIRS device. However, instruction technology cannot replace the role of teachers and it also can not replace the required process of understanding, computational fluency, or problem-solving skills in individual learning. In the IIRS environment, teachers must be a knowledgeable helper in determining when and how their students can use technology most effectively. The strategic usage of technology will enhance mathematics teaching and learning.

Cognitive Diagnosis and S-P Chart

Cognitive diagnostic modeling has become an effective methodology to detect the concept structure of learners. Huebner (2010) indicates that cognitive diagnosis aims to diagnose examinees' mastery status of a group of discretely defined skills or attributes. Therefore, cognitive diagnosis provides detailed information regarding specific strengths and weaknesses of learning achievement. Combining approach of cognitive diagnosis with adaptive clustering has emerged as an important part of assessment. S-P chart is one branch of cognitive diagnosis which focuses on the analysis of response pattern. S-P chart was proposed by Sato and it provides disparity index, student caution index and problem caution index which help teachers diagnose student learning conditions. Based on the student caution index and their score ratio, all students could be classified into six learning types.

According to the issue above, this article aims to investigate the learning achievement on decimal concept by comparing IIRS instruction and traditional instruction in mathematics classrooms. Two classes, which are experimental class and control class, are conducted in the mathematics course. As to the experimental class, IIRS device is established so that the teachers and students could adopt IIRS in learning decimal concepts. On the contrary, the control class is conducted in traditional mathematics instruction. The teacher explains and interprets decimal concepts to students. One way quasi-experiment design of mathematics instruction is to investigate the learning effects. In addition to the one way covariance analysis, S-P chart is to diagnose the decimal concept and classify students into six learning types. With combing the statistical covariance analysis and diagnostic S-P chart, it is prospective to inspect further information about the utilities of IIRS in promotion of mathematics learning.

As to the IIRS adopted in the mathematics classroom, it is prospective to help teachers organize effective mathematics instruction. Students at different levels can use IIRS device to construct and extend mathematical content, reasoning, sense making and problem solving. IIRS is a well-articulated technological learning device to help students in computation, construction, reflection and representation as they explore mathematics problems. Therefore, it is feasible and necessary to investigate the mathematics learning outcomes in IIRS

environment. One possible way is to design the experimental teaching and assess students' achievement.

Ayers, Rabe-Hesketh, & Nugent (2013) consider one major purpose of cognitive diagnosis models are often used for diagnosis. That is, it is to classifies students into the different skill set profiles. Magidson & Vermunt (2001) also indicates that graphical displays for diagnostic clustering could help understand further cognitive assessment. Methodologies of assessment are important related to experimental instruction. Paris & Paris (2001) consider that a proper assessment will help explain the learning achievement. Self-regulated learning (SRL) in classrooms is suitable for technology usage learning. Three major aspects of SRL are strategies for reading and writing, cognitive engagement in tasks, and self-assessment. In IIRS environment, SRL is viewed as a set of skills that can be taught explicitly or as developmental processes that emerge from interaction. A suitable assessment can provide information and opportunities to students that will help them become strategic, motivated, and cooperative learners. As to this point, Dineroa, Sonia & Blixtb (1988) state that S-P chart should a prospective assessment. S-P chart can not only provide diagnostic information for caution index of students, but also its result shows the classification of learning type for remedial instruction. S-P chart reveals that this analysis will detect misconceptions as to all levels learners. Therefore, this study will adopt S-P chart to analyze assessment data from experimental teaching.

Research Design

Subject and Mathematics Instruction

Dufresne, Gerace, Leonard, Mestre, & Wenk (1996) and Beatty & Gerace (2009) support the iterative cycle in classroom response systems by technologies. These cycle are question posing, answering, and discussing, aided by technology. This cycle will form a scaffold for structuring whole-class interaction. This study also adopts this cycle in IIRS environment. The objectives of this study are to investigate the effects of IIRS adopted in mathematics course. Topic of this mathematics instruction is the decimal concepts. In order to compare the effects of IIRS device with traditional instruction, two groups of fourth graders are chosen to accept these two kinds of mathematics instruction respectively. One group is the experiment class, which includes 69 students, in IIRS environment. Those students take IIRS decimal teaching with peer cooperation and game-based learning. The other group is control group, which has 68 students. This group is conducted by traditional teaching.

Experiment Design and Data Analysis

This paper adopts two methods to analyze the assessment data. One is statistical method which is one way ANCOVA (one way analysis of covariance). The covariate is final mathematics exam of the previous semester. The other one, which is S-P chart, is psychometric approach to diagnose the misconceptions and learning types. As shown in Table 1, it is the brief illustration of the research design.

Table 1
Brief Illustration of Research Design

Group	Covariate	Treatment	Dependent Variable
Experiment Group	The Final Mathematics Exam of Previous Semester	IIRS Teaching with Peer Cooperation and Game-based Learning	Achievement Test of Decimal Concept
Control Group		Traditional Teaching with Explanation and Exercise by Black Board	

IIRS Environment and S-P chart

There are 10 hours of decimal instruction. After these two kinds of decimal instruction are finished, students take achievement test of decimal concept. These are total 30 items in this test.

IIRS environment is easy to establish in classroom. As shown in Figure 1, it is the graph of illustration for IIRS and the relationship among components. Each student in the classroom has his own feedback receiver, which can receive wireless signal from the computer in classroom. Similarly, the feedback can also send signal to the computer. Therefore, by the individual feedback receiver, high interactions between students and teachers are real-time. The computer in the classroom is connected to the server which provides lots of resources and applied software for instructions. In addition, the equipment of screen and LCD projector will show the instruction materials, problem posing and all the instructional process. In addition, all the responses among students will also be displayed on the screen.

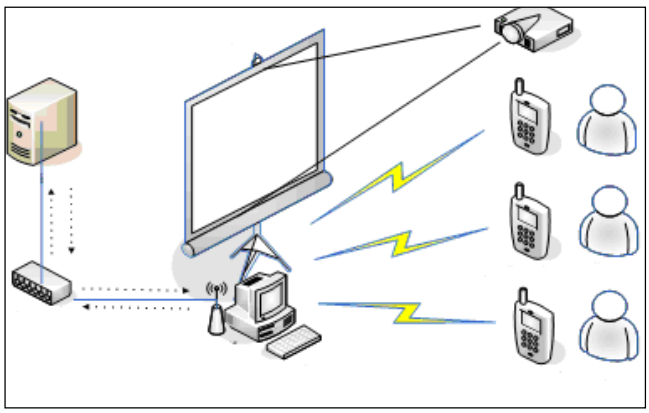

Figure 1. Illustration of IIRS Environment in Mathematics Classroom

Figure 2. Feedback Receiver of IIRS

As to S-P chart, suppose there be N ($n = 1,2,...N$) students and M ($m = 1,2,...M$) dichotomous items in the test. The response data matrix is $Y = (y_{nm})_{N \times M}$ with $y_{nm} = 1$ or $y_{nm} = 0$. $y_{nm} = 1$ means student n responds item m correctly and $y_{nm} = 0$ means student n answers item m incorrectly. $Y = (y_{nm})_{N \times M}$ with $y_{n\bullet} = \sum_{m=1}^{M} y_{nm}$ and $y_{\bullet m} = \sum_{n=1}^{N} y_{nm}$ has been sorted by $y_{1\bullet} \geq y_{2\bullet} ... \geq y_{N\bullet}$ and $y_{\bullet 1} \geq y_{\bullet 2} ... \geq y_{\bullet M}$. Let $u' = \sum_{m=1}^{M} y_{\bullet m} \Big/ M$ and the student caution index CS_n is

$$CS_n = 1 - \frac{\sum_{m=1}^{M} (y_{nm})(y_{\bullet m}) - (y_{n\bullet})(u')}{\sum_{m=1}^{y_{n\bullet}} y_{\bullet m} - (y_{n\bullet})(u')}$$

Student caution can help diagnose aberrant response of students. The higher student caution index students have, the greater aberrance response students have. Based on the two dimensions of caution index for students and correct ratio on items, all students could be classified into six learning types, which are A, A’, B, B’, C, and C’. It is depicted in Figure 3.

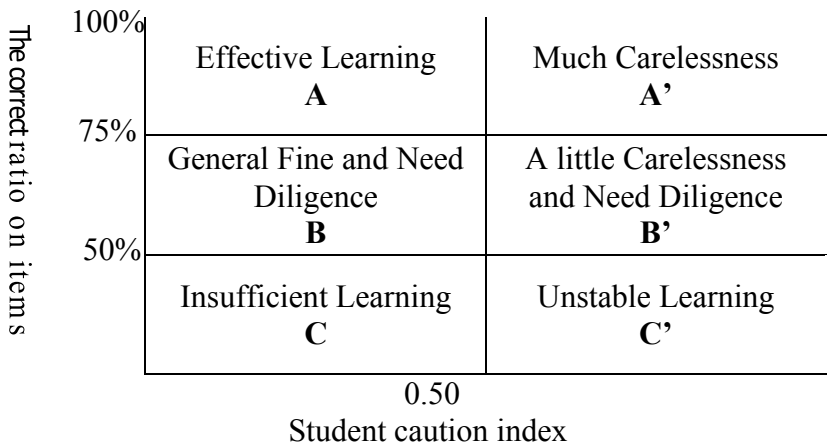

Figure 3. Classification of Learning Types for Students

In Figure 3, all students could be classified into six learning types. Type A means students have good performance and high stability on test. Type B means students have generally good stability but should work a bit harder. Type C shows students have poor learning capability and must work harder a lot. Type A' means students have almost good performance on test but sometimes give incorrect response due to carelessness. Type B' shows students have fair mastery on contents and sometimes respond incorrectly due to carelessness. Type C' indicates students have quite low stability and they have poor mastery. As to these six learning types, Lin and Chen (2006) indicate type C and type C' need more remedial instruction.

Result and Discussion

One Way ANCOVA for Learning Achievement

It is required to test the assumption of regression homogeneity in advance. As shown in Table 2, the statistical test shows that F= .124 (p> .05). Hence, it is feasible to do the next step of one way ANCOVA. As to the one way ANCOVA, the result is depicted in Table 3. Table 3 shows that F=30.765 (p<.01), this result explains these exists significant difference on decimal learning achievement. Adjusted mean of experiment group and control group are 23.232 and 21.309 respectively. It indicates experiment group has higher score than control group.

Table 2
Test of Regression Homogeneity

Source	SS	df	MS	F
Group*Covariate	1.574	1	1.574	.124
Error	1686.028	133	12.677	

Table 3
Analysis of Covariance

Spource	SS	df	MS	F
Group	387.459	1	387.459	30.765**
Error	1687.601	134	12.594	

** p<.01

S-P chart for Cognitive Diagnosis

S-P chart is to cognitive diagnosis of decimal concept. Table 4 is the frequency of learning type based on two groups. As to experiment group, percent of type A is 20.4%. On the contrary, percent of type A in control group is only 15.3%. Similarly, percent of type C' is 0% but percent of type C' in control group is 4.4%. All the information above indicates experiment group perform better than control group.

Table 4
Frequency Analysis of Learning Type

Group	Learning Type	A	A'	B	B'	C	C'
Experiment Group	Number	28	24	10	5	2	0
	%	20.4%	17.5%	7.3%	3.6%	1.5%	0%
Control Group	Number	21	17	13	6	5	6
	%	15.3%	12.4%	9.5%	4.4%	3.6%	4.4%
Total	Number	49	41	23	11	7	6
	%	35.8%	29.9%	16.8%	8.0%	5.1%	4.4%

Conclusions and Recommendations

Conclusions

The study is to investigate the effects to improve decimal concept under IIRS environment. In order to compare the effects between IIRS environment and traditional environment, the method is quasi-experimental design of decimal instruction. Two methodologies are to analyze the assessment data. One is statistical approach of one way ANCOVA and the other is psychometric approach of S-P chart analysis.

According to the results, it shows the experiment group with IIRS environment has significantly better performance than control group. Moreover, IIRS in mathematics classroom could promote better learning type. To sum up, the assumption that IIRS has positive effects on mathematics learning is proved.

Recommendations

The feature of this research is to discuss the empirical IIRS environment as to its effects on education. Little is known about the effects of IIRS. Therefore, this research has its own characteristics. The results support the utility of IIRS environment in mathematics classroom. The consequence also coincides with the utility of other technologies in educational environment. Future research could explore the effects on students' attitudes and interest as to the IIRS environment. Further investigations on effects of IIRS as to other subjects or high school students are also prospective.

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