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The Effectiveness of Creative Inquiry Model on Experimental Teaching

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The purpose of this study was to explore the effectiveness of the creative inquiry model (CIM) in experimental teaching of the natural science course for eighth graders and to analyze the causal path model that affects the performance of scientific inquiry-based learning. It was a study of quasi-experimental design and the subjects, four classes of eighth graders from three junior high schools were divided into an experiment group ($N = 103$), in which CIM teaching was implemented, and a control group ($N = 95$), in which cookbook experiment teaching was employed. A number of research instruments were used including what is happening in this classroom (WIHIC), science process skill test (SPST), Williams' creativity assessment packet (WCAP), performance test of scientific inquiry-based learning (PTSIL), and students' monographic study theses. The resulted data were subjected to statistical analysis with *t*-test, analysis of covariance (ANCOVA), and path analysis (PA). It was found that: 1. Students in the experiment group had better perception of a supportive inquiry-based learning environment than their counterparts in the control group; 2. There was no difference among the experiment group and the control group in terms of students' performance in SPST and WCAP; 3. Students in the experiment group had better performance in monographic study theses than their counterparts in the control group; 4. Students in the experiment group had better performance than their counterparts in the control group in terms of monographic study theses; 5. Perception of science classroom environment had both direct and indirect effect on students' scientific inquiry-based learning and the total effectiveness value was 0.349; and 6. Science process skills had direct influence on students' scientific inquiry-based learning performance and its effectiveness value was 0.655. According to the results, the CIM developed in this study has substantial value and deserves promotion.

Keywords: creative inquiry model (CIM), experimental teaching, scientific inquiry

Introduction

It has been pointed out in *National Science Education Standards* (National Research Council [NRC], 1996, p. 113) that compared to previous inquiry-based teaching, the emphases of inquiry should be placed more on activities that investigate and analyze science questions and less on activities that demonstrate and verify science content, more on science as argument and explanation and less on science as exploration and experiment. Moreover, emphases should be placed less on private communication of students' ideas and conclusions to teacher and more on public communication of students' ideas and work to classmates. This

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changing of emphases indicates that the transmutation of inquiry-based teaching nowadays is centered on exploration, explanation, and communication.

Moreover, it has been proposed in *Inquiry and the National Science Education Standards* (NRC, 2000) that inquiry-based teaching consists of the following five common components:

1. Students engage with a scientific question, event, or phenomenon. This connects with what they already know, creates dissonance with their own ideas, and/or motivates them to learn more;
2. Students explore ideas through hands-on experiences, formulate and test hypotheses, solve problems, and create explanations for what they observe;
3. Students analyze and interpret data, synthesize their ideas, build models, and clarify concepts and explanations with teachers and other sources of scientific knowledge;
4. Students extend their new understanding and abilities and apply what they have learned to new situations;
5. Students with their teachers review and assess what they have learned and how they have learned it.

However, the above five common components of inquiry-based teaching are not adequate to reflect the afore-mentioned emphasis of "public communication of student ideas and work to classmates." The fifth one is a key point of value and is included in this study for evaluation.

Literature Review

Based on the above analyses and summary, it can be inferred that the core of inquiry-based teaching lies in exploration, explanation, communication, and evaluation. However, what is the optimal operational relationship among these four components? Treffinger, Isaksen, and Dorval (1994) had developed a creative problem-solving (CPS) approach, which has four core elements, i.e., understanding the problem, generating ideas, planning for action, and task appraisal. In this study, a creative inquiry model (CIM) was proposed using analogs of the four elements and their networked structural relationship. The method, proposed with reference to the networked structural pattern of CPS, uses exploration, explanation, communication, and evaluation as the core elements instead of the original understanding the problem, generating ideas, planning for action, and task appraisal in CPS. Furthermore, the application of the analogy and substitution of the networked structural relationship and elements in the scientific inquiry model of this study requires the clarification of a problem, i.e., Is scientific inquiry functionally identical with problem-solving? If the answer is yes, then, why not use CPS for classroom teaching? Regarding this problem, Marzano et al. (1988) had in their book *Dimensions of Thinking: A Framework for Curriculum and Instruction* discriminated scientific inquiry from problem-solving.

The scientific inquiry differs from problem-solving in that its purposes are explaining and predicting (Halpern, 1984) rather than simply finding a correct answer. Although scientific inquiry uses both problem-solving and decision-making (indeed, all the other processes are involved in one form or another), it is primarily directed toward understanding how something works and how to use this understanding to predict phenomena (p. 52).

Therefore, explanation and prediction should receive more attention than finding the correct answer for a problem in a scientific inquiry-emphasizing classroom. In light of this, it is both necessary and rational to apply the analogy and substitution of the networked structural relationship and elements of CPS to the CIM of this study. As a result, a CIM as shown in Figure 1 was developed in this study.

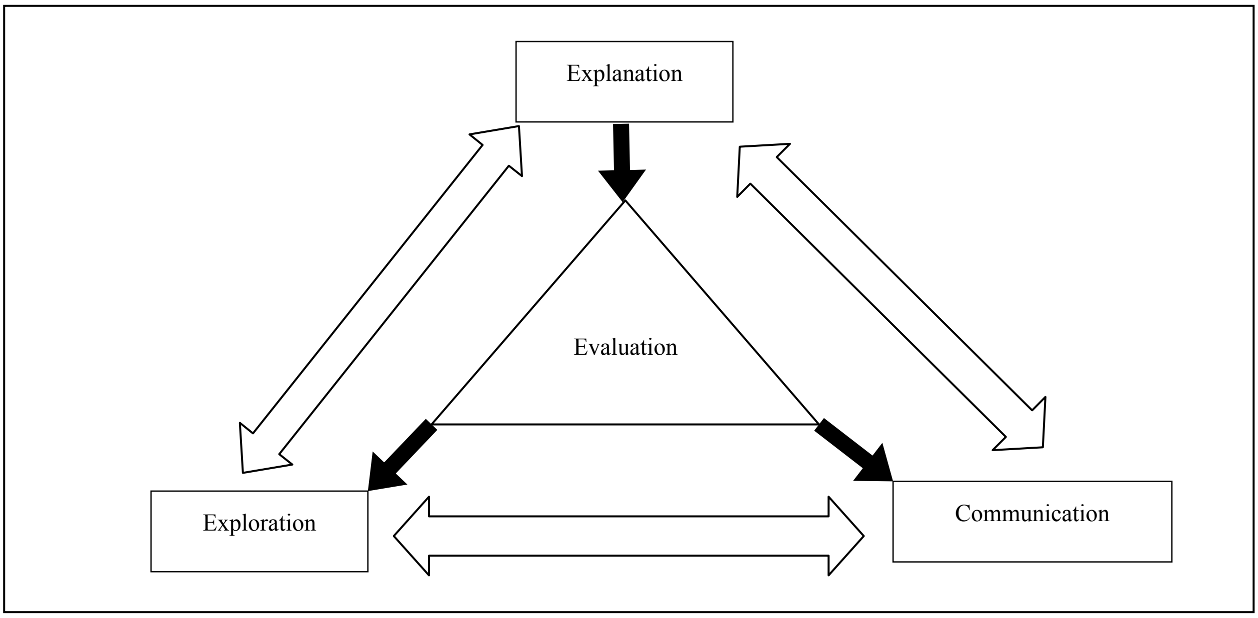

Figure 1. Networked cyclical pattern of CIM.

A CIM teaching model consists of the following seven components:

1. Students engage with a scientific question, event, or phenomenon, which connects with what they already know. The teacher, on the other hand, manages to give rise to resonance with the students' own ideas, motivates them to reflect, and abstract the potential causes and hypotheses;
2. Students through designed experiment explore into the question and test their hypotheses;
3. Students analyze data, identify pattern, and integrate their viewpoints to build a model;
4. Students expound (provide causes and conclusion) on the question with scientific knowledge from their teacher or other sources;
5. Students communicate their explanations during the argumentation;
6. Students by making comparison with other explanations, especially those embodying scientific reasoning, evaluate their own explanations;
7. Students, with their teachers, review and assess what they have learned and how they have learned it.

Phases 1 and 2 are components of exploration, Phases 3 and 4 are components of explanation, Phase 5 is component of communication, and Phases 6 and 7 are components of evaluation.

How do the above seven phases work in the CIM architecture? The following operational strategies were used to convert the characteristic CPS model of Treffinger, Isaksen, and Dorval (1994) into the CIM of this study:

1. Divergent thinking (i.e., creative thinking) was applied first, and then, followed by convergent thinking (i.e., critical thinking) for every phase;
2. The convergent thinking was for evaluating, clarifying, and focusing on the results of the divergent thinking in order to get ready for the inquiry and thinking in the next phase;
3. No phase had to follow a linear procedure and all phases interact with and set off each other in a spiral up way;
4. The CIM was suitable for inquiry by a group of students and/or an individual.

The CIM was designed such that it coincided with the key points emphasized by Taiwan's science education goal. In fact, it was pointed out in "The objectives, status quo, and outlook of science education," which was the top agenda of the first session of National Science Education Conference of Taiwan,

> One of the essential objectives of science education in primary and secondary schools is to develop students' inquiry ability. … Able to use their inquiry ability and learned scientific knowledge and concepts to propose hypotheses, design experiments, and/or solve problems. In contrast, the current situation of scientific experiment classes is that the experiment part of natural science teaching materials and textbooks in primary and secondary schools nowadays is stuffed with apparatuses, materials, chemicals, and experiment procedures, so that students have to do nothing but following the cookbook to verify the results. (Ministry of Education, 2002)

It is thus evident that the present cookbook like teaching simply deprives students of the opportunity to propose hypotheses and design experiments, which require creative thinking and critical thinking ability. The CIM-based teaching, on the contrary, provides in-depth development of habits of mind in these essential scientific process skills and creativity in inquiry.

On the ground of the above, it was hypothesized in this study that students' perception of classroom learning environment may differ between the CIM-based teaching and cookbook experiment teaching, which difference may in turn affect students' science process skills, creative tendency, and scientific inquiry-based learning performance. Moreover, science process skills and creative tendency also affect students' scientific inquiry-based learning performance, respectively. A causal path model that affects scientific inquiry-based learning performance can be obtained.

Based on the above literature review, a CIM-based teaching model was proposed in this study and its effectiveness in experiment teaching of natural science in eighth grade students was discussed. The effectiveness was determined by a comparison of the experiment group students' and the control group students' performance in terms of perception of science classroom environment, science process skills, creative tendency, scientific inquiry-based learning, and monographic study theses. Furthermore, the influence of the causal path model on scientific inquiry-based learning performance was also analyzed. In light of this, the research questions of this study were as the following:

1. Would there be any difference between the experiment group and the control group in terms of perception of science classroom environment after experiment treatment?
2. Would there be any difference between the experiment group and the control group in terms of performance in science process skills after experiment treatment?
3. Would there be any difference between the experiment group and the control group in terms of performance in creative tendency after experiment treatment?
4. Would there be any difference between the experiment group and the control group in terms of performance in scientific inquiry-based learning after experiment treatment?
5. Would there be any difference between the experiment group and the control group in terms of performance in monographic study theses after experiment treatment?
6. Would all direct causal paths be significant in the causal path models that have impact on the performance in scientific inquiry-based learning?
7. What would the total effectiveness values of the individual independent variables on the dependent variables?

Research Design

This is a quasi-experimental study of non-equivalent group pre- and post- test design. The designed model was as shown in Table 1.

In Table 1, the O_1 denotes science process skill test (SPST), O_2 denotes Williams' creativity assessment packet (WCAP), O_3 denotes performance test of scientific inquiry-based learning (PTSIL) on relevant teaching content, O_4 denotes students' performance in monographic study theses, and O_5 denotes what is happening in this classroom (WIHIC). Experiment classes were done by CIM teaching (X) in the experiment group and cookbook teaching (C) in the control group. A pre- and post- test was arranged in the first week and the last week of the semester for both groups.

Table 1

Research Design for the Study

	Control variable (pre-test)	Treatment	Dependent variable (post-test)
Experiment group	O_1 O_2	X	O_1 O_2 O_3 O_4 O_5
Control group	O_1 O_2	C	O_1 O_2 O_3 O_4 O_5

Subjects

All subjects were from three small primary schools (total number of classes < 10) in non-metropolitan area and two classes of eighth grade students were selected and arranged into the experiment group ($N = 103$) and the control group ($N = 95$). As shown in Table 2, approximately 20% of the students graduated from the three schools were admitted to regular senior secondary schools, 70% to vocational schools, and 10% went to the job market after graduation.

Table 2

Number of Subjects in the Experiment Group and the Control Group

CIM	Experiment group	Control group	Subtotal
Male	48	52	100
Female	55	43	98
Total	103	95	198

For the experiment group, the teachers are seed teachers who had been trained for the study. As regards the control group, in School A, the responsible teacher was the one who taught the experiment group students, while in Schools B and C, the responsible teachers were teachers of similar seniority other than the ones in charge of the control group.

Treatment

The study was carried out in the first semester of Grade 8, using Volume 3 of the natural science textbook.

Since it was impossible to carry out CIM teaching activities for all teaching modules of the semester because of the impracticability of scheduling and considering that it was hoped that the study would last throughout the semester, an experiment was selected from each chapter and converted to CIM teaching activities for the experiment group. During the experiment activities, in both the experiment group and the control group, the students were divided into six groups with five to six subjects.

For the control group, the teaching process was carried out based on the cookbook experiment activities of the design in the textbook. Students in the control group were taught by traditional lecture teaching, that is, the teacher would explain to the students the content in the textbook, experiment operation instructions including apparatuses, materials, and procedures, in thorough details. After the teacher's explanations, the students would carry out the experiment step by step according to the instructions on the textbook and record the results in their experiment records, which would be submitted to the teacher for grading.

The teaching process in the experiment group would follow a list of learning activities designed with CIM. The activities would start with an event, for example, the students would be asked to think it over why we cannot hear the wing fluttering sound of a butterfly, but we can here the buzzing sound of a flying mosquito. This was to find out students' preliminary concept of sound wave. Then, the students would be asked to prepare a ruler, pluck it to make it vibrate, and hear the sound. Later, the students would be asked to discuss the factors that contribute to the sounding difference of the ruler. During this experiment, the students would be allowed to explore all such factors including the material, thickness, length, and the magnitude of the plucking force, in order to figure out the three elements of sound (tone, loudness, and timbre).

The CIM-based exploration, explanation, communication, and evaluation activities would be carried out by students in individual and/or in groups by virtue of divergent and convergent thinking throughout the experiment. All experiment activities would be discussed and designed by students themselves. Unlike students in the control group, who simply would submit their experiment results to the teacher for grading, students in the experiment group would communicate their inquiry results to the whole class and exchange ideas with their classmates at the end of the experiment. The teacher would play the role of an assistant in the experiment and help students in their experiment activities for identifying their desired inquiry patterns and might introduce the scientific terms and relevant concepts to students to help them establish scientific concepts (Lawson, 1995).

Instrument

The WHISC. Students' perception of science classroom environment would be assessed with the WIHIC, a scale developed by Fraser, McRobbie, and Fisher (1996), which modified by Huang, Aldridge, and Fraser (1998). The scale consists of 56 questions covering seven dimensions, i.e., student cohesiveness, teacher support, involvement, investigation, task orientation, cooperation, and equity. With Cronbach α-value in the range of 0.90-0.96 for the dimensions and a total scale Cronbach $\alpha = 0.95$, the scale's discriminate validity value was 0.41-0.58 and its factor analysis values were ideal. When scoring with the scale, a positive question would yield a score of 1, 2, 3, 4, and 5, while a negative question would yield a score of 5, 4, 3, 2, and 1. The total score can be 280 at most or 56 at least. With an individual dimension, the score can be 40 at most and 8 at least. In this study, the full-scale Cronbach α-reliability coefficient was 0.96, the subscale Cronbach α-reliability coefficients were 0.89, 0.89, 0.86, 0.92, 0.83, 0.90, and 0.93 for student cohesiveness, teacher support, involvement, investigation, task orientation, cooperation, and equity, respectively.

The SPST. It was prepared by Jiun-Hwa Lin (1986) on the basis of test of integrated process skills II (TIPS II), a test designed by Okey, Wise, and Burns (1982) with reference to relevant Taiwan and foreign documents. It consists 38 questions, 22 of which are for basic process skills sub-test (variable processing and inference) and 16 are for integrated process skill sub-test (proposing hypotheses, designing experiment, and processing data). The test uses multiple-choice questions. For each question, only one of the four candidate answers is correct. One correct answer will secure one point. With a Cronbach α-reliability coefficient being 0.83 and a retest reliability confidence value being 0.83 for full test, a Cronbach α-reliability coefficient was 0.75 and a retest reliability confidence value was 0.78 for basic process skills sub-test. A Cronbach α-reliability coefficient was 0.68 and a retest reliability confidence value was 0.72 for integrated process skill sub-test, meaning that the SPST has ideal reliability and a correlation coefficient of 0.67 with TIPS, and a good concurrent validity during the study. The test yielded correlation coefficients in the range of 0.20-0.50 for the individual skills, suggesting it had satisfactory discriminate validity. The results of factor analysis revealed two factors that had a characteristic value greater than 1 (5.27 and 1.14, respectively), indicating a good construct validity. In this study, SPST's full test Cronbach α-reliability coefficient was 0.87, basic process skills sub-test's Cronbach α-reliability coefficient was 0.81, and integrated process skills sub-test's Cronbach α-reliability coefficient was 0.73.

The WCAP. A modified WCAP prepared by Lin and Wang (1994) was used in the study. It covers the factors of risk-taking, curiosity, imagination, and challenge, which consists of 40 positive questions and 10 negative questions. Among the 50 questions, 12 are about risk-taking, 12 are about challenges, 13 are about curiosity, and 13 are about imagination. This WCAP had been subjected to confidence testing on Grades 5-10 students. The correlation coefficients of its retest reliability were in the range of 0.489-0.810 ($p > 0.05$), suggesting a significant correlation. Its scores' Cronbach α coefficients were in the range of 0.401-0.780 and total score's Cronbach α coefficients were in the range of 0.765-0.877. Its validity had been tested on Grades 8 and 10 students with a revised Pennsylvania assessment of creative tendency (PACT) as validity criterion. The results showed its correlation coefficients with PACT were in the range of 0.682-0.806 ($p > 0.05$) in junior secondary school students and in the range of 0.590-0.736 ($p > 0.05$) in senior secondary school students. In both cases, its correlation with PACT was significant. In this study, the Cronbach α-reliability coefficient was 0.91 for full-scale and the Cronbach α-reliability coefficients for such subscales as risk-taking, curiosity, imagination, and challenge were 0.60, 0.78, 0.81, and 0.68, respectively.

The PTSIL. It is an in-house developed tool designed on the basis of the content of the modules involved in the experiment teaching. It consists of 10 questions covering parameters, such as density, amount of heat, pressure and frictional force, and element categorization, and a number of skills including processing variables, deduction, proposing hypothesis, designing experiment, and processing data. It is designed by the authors and reviewed and finalized by three science teachers who have a master's degree in science education. The PTSIL was not applied at the end of the semester and it was integrated into stage exam papers for testing students depending on the schedule and content of the schools' stage exams.

Monographic study theses. In this study, according to the content of the modules involved in the experiment teaching, students in the experiment group and the control group had chosen a subject that intrigues them for monographic study. The monographic study theses were reviewed and assessed by a former senior high school teacher who had a doctorate degree in science education and four senior high school natural science teachers. The theses were assessed and graded with a 5-point Likert scale and the grading criteria were novelty and effectiveness (Mayer, 1999), which were further broken down into four items, i.e., novelty of subject, novelty of method, effectiveness of study design, and validity of logical deduction to facilitate the grading. The itemized scores of students in each of the two groups were the weighed mean of the scores by the five reviewers and the total score of a group in the monographic study was the sum of the four itemized scores.

Data Analyses

Statistical analysis was carried out with statistic package for social science (SPSS) 17.0. The *t*-test was performed on Questions 1 and 5 and the analysis of covariance (ANCOVA) was done on Questions 2, 3, and 4. The critical value α was set to 0.05. If the statistical analysis results reached significant level ($p < 0.5$), then the effect size (ES) of the experiment should be calculated and judged by Cohen's (1988) (If $d > 0.8$, it has large effect; if $0.5 < d < 0.8$, it has medium effect; and if $0.2 < d < 0.5$, it has small effect). Research Question 6 was subjected to path analysis (PA) by analysis of moment structures (AMOS).

Findings and Discussions

The Experiment Group's and the Control Group's Perceptive of Science Classroom Environment

It can be inferred from the analysis results in Table 3 and Figure 2 that the experiment group's perceptive tendency, which has large ES ($p > 0.8$), is superior to the control group's in three subscales, i.e., inquiry, task orientation, and cooperation. This result after experimental processing shows that:

1. The experiment group students' perception of science classroom environment tends to be more inquiry skills and process oriented than the control group's students and can be used for problem-solving ($p < 0.05$);

2. The experiment group students' perception of science classroom environment tends to be more focused on completing the expected activities and on study than the control group students ($p < 0.05$);

3. When it comes to learning, the experiment group students' perception of science classroom environment tends to be more cooperation-oriented rather than competition-oriented than the control group's students ($p < 0.05$).

Table 3

The t-Test of the Experiment Group's and the Control Group's Perceptive Tendency of Science Classroom Environment

Science classroom environment subscale	*M*		*SD*		*t*	*p*	*d*
	Experiment group	Control group	Experiment group	Control group			
Student cohesiveness	29.53	29.83	6.05	6.22	-0.341	0.367	
Teacher support	22.91	23.40	6.64	6.10	-0.537	0.296	
Involvement	23.33	22.78	6.23	6.09	0.628	0.265	
Investigation	23.63	21.83	6.61	6.80	1.888^*	0.030	0.265
Task orientation	27.48	25.77	5.75	5.31	2.164^*	0.016	0.322
Cooperation	29.10	27.57	6.04	6.22	1.754^*	0.041	0.246
Equity	25.97	26.58	7.69	7.57	-0.560	0.288	
Total scale	181.95	177.76	32.74	31.94	0.911	0.182	

Note. $^* p < 0.05$.

Performance of the Experiment Group and the Control Group in SPST

It can be inferred from the analysis results of Table 4 that there is no significant difference between the experiment group and the control group in terms of SPST performance ($p > 0.05$).

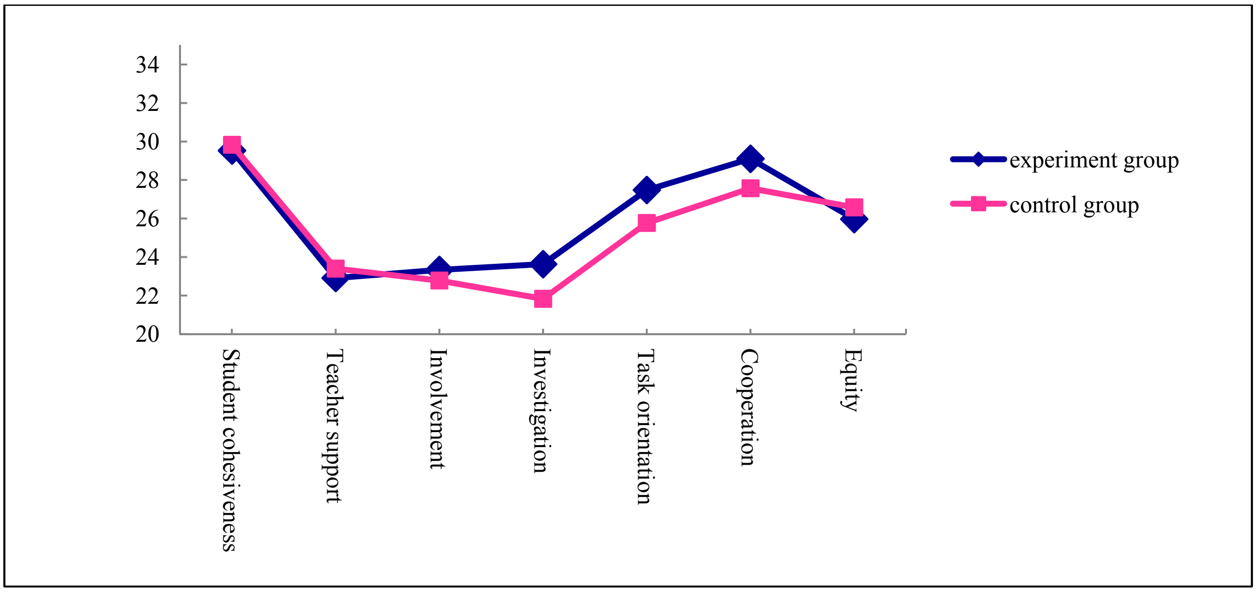

Figure 2. Line chart of the experiment group's and the control group's perception of science classroom environment

Table 4

Summary of the ANCOVA of the Experiment Group's and the Control Group's SPST Results

Title of subscale	Source of variation	*SS*	*df*	*MS*	*F*	*p*
Processing of variable	Group	6.08	1	6.08	0.687	0.408
	Error	1,698.15	192	8.84		
Deduction	Group	0.19	1	0.19	0.242	0.623
	Error	149.11	192	0.78		
Proposal of hypothesis	Group	2.74	1	2.74	1.107	0.294
	Error	474.57	192	2.47		
Design of experiment	Group	0.49	1	0.49	0.631	0.428
	Error	148.73	192	0.77		
Processing of information	Group	0.07	1	0.07	0.068	0.795
	Error	185.78	192	0.97		
Total scale	Group	12.94	1	12.94	0.503	0.479
	Error	4,942.16	192	25.74		

Table 5

Summary of the ANCOVA of the Experiment Group's and the Control Group's WCAP Results

Title of subscale	Source of variation	*SS*	*df*	*MS*	*F*	*p*
Risk	Group	17.93	1	17.93	0.661	0.417
	Error	5,285.84	195	27.11		
Curiosity	Group	2.26	1	2.26	0.049	0.826
	Error	9,051.9982	195	46.42		
Imagination	Group	58.18	1	58.18	0.951	0.331
	Error	11,933.30	195	61.20		
Challenge	Group	36.33	1	36.33	1.204	0.274
	Error	5,881.74	195	30.16		
Total scale	Group	268.48	1	268.48	0.610	0.436
	Error	85779.11	195	439.89		

Performance of the Experiment Group and the Control Group in WCAP

It can be inferred from the analysis results of Table 5 that there is no significant difference between the experiment group and the control group in terms of WCAP performance ($p > 0.05$).

Performance of the Experiment Group and the Control Group in PTSIL

It can be inferred from the analysis results in Tables 6 and 7 that the ANCOVA results of scientific inquiry-based learning performance which takes science process skills as its covariant reveal that the experiment group has better performance than the control group in terms of scientific inquiry-based learning ($F = 11.154$, $p < 0.05$). The experiment's ES reached 0.353, suggesting a medium experiment effect.

Table 6

Summary of Descriptive Statistics of Scientific Inquiry-Based Learning Performance With Science Process Skills Pre-Test Performance as its Covariant

Group	*N*	*M*	*SD*	*AdjM*
Experiment group	103	20.23	8.39	20.42
Control group	92	17.24	9.51	17.03

Table 7

Summary of ANCOVA of Scientific Inquiry-Based Learning Performance With Science Process Skills Pre-Test Performance as its Covariant

Source of variation	*SS*	*df*	*MS*	*F*	*p*	*d*
Group	559.41	1	559.41	11.154^*	0.001	0.353
Error	9629.20	192	50.15			

Note. $^*p < 0.05$.

Table 8

The t-Test of the Experiment Group's and the Control Group's Monographic Study Theses Performance

Item	Group	*M*	*SD*	*t*	*P*	*d*
Novelty of topic	Experiment group	2.81	0.86	2.023	0.051	0.69
	Control group	2.24	0.82			
Novelty of approach	Experiment group	2.44	0.71	2.083^*	0.045	0.76
	Control group	1.99	0.60			
Effectiveness of research design	Experiment group	2.84	0.83	3.106^*	0.004	1.10
	Control group	2.03	0.74			
Validity of logical deduction	Experiment group	2.47	0.78	2.043^*	0.049	0.70
	Control group	1.94	0.75			
Total score	Experiment group	10.57	2.73	2.672^*	0.011	0.92
	Control group	8.21	2.56			

Note. $^*p < 0.05$.

The Experiment Group's and the Control Group's Performance in Monographic Study Theses

It can be inferred from the analysis results in Table 8 that the experiment group out-performed the control group in three scoring criteria of monographic study theses, i.e., novelty of method, effectiveness of study design, validity of logical deduction, and the experiment group also out-performed the control group in total score ($p < 0.05$). Moreover, although the experiment's effect as judged by the scoring criterion of novelty of subject failed to achieve significant level, the ES nonetheless reached 0.69. This may be attribute to the limited groups in the experiment ($N = 18$), this result remains to be further explored in follow-up studies.

Analysis of the Influence of the Causal Path Model on Scientific Inquiry-Based Learning Performance

Figure 3 is the causal path models that have impact on the performance in scientific inquiry-based learning. It has the $\chi^2 = 9.045$ ($p = 0.003$), the goodness-of-fit index (GFI) = 0.978, the normal fit index (NFI) = 0.952, and the incremental fit index (IFI) = 0.957, all of which are greater than 0.9, suggesting that the overall model fit is acceptable (Hoyle, 1995).

It can be inferred from Figure 3 that of the paths that have effect on scientific inquiry-based learning performance, there are three paths of significant effect, i.e.,

1. Perception of science classroom environment → scientific inquiry-based learning performance;
2. Perception of science classroom environment → science process skills → scientific inquiry-based learning performance;
3. Science process skills → scientific inquiry-based learning performance.

It is noted as the following:

1. Perception of science classroom environment had significant direct effect on scientific inquiry-based learning performance, its path coefficient was 0.118 ($p < 0.05$). Its indirect effect via science process skills on scientific inquiry-based learning performance was also significant, with an indirect effect value of $0.352 \times 0.655 = 0.231$. However, its indirect effect via creative tendency on scientific inquiry-based learning performance was not significant. Therefore, perception of science classroom environment had a total ES of $0.231 + 0.118 = 0.349$.
2. Science process skills had significant direct effect on scientific inquiry-based learning performance, with a path coefficient of 0.655 ($p < 0.05$).
3. Creative tendency had insignificant direct effect on scientific inquiry-based learning performance, with a path coefficient of -0.067 ($p > 0.05$).

It can be inferred from the above that perception of science classroom environment had both direct and indirect effects on scientific inquiry-based learning performance with a total ES = 0.349. Science process skills had direct effect on scientific inquiry-based learning performance with an ES = 0.655.

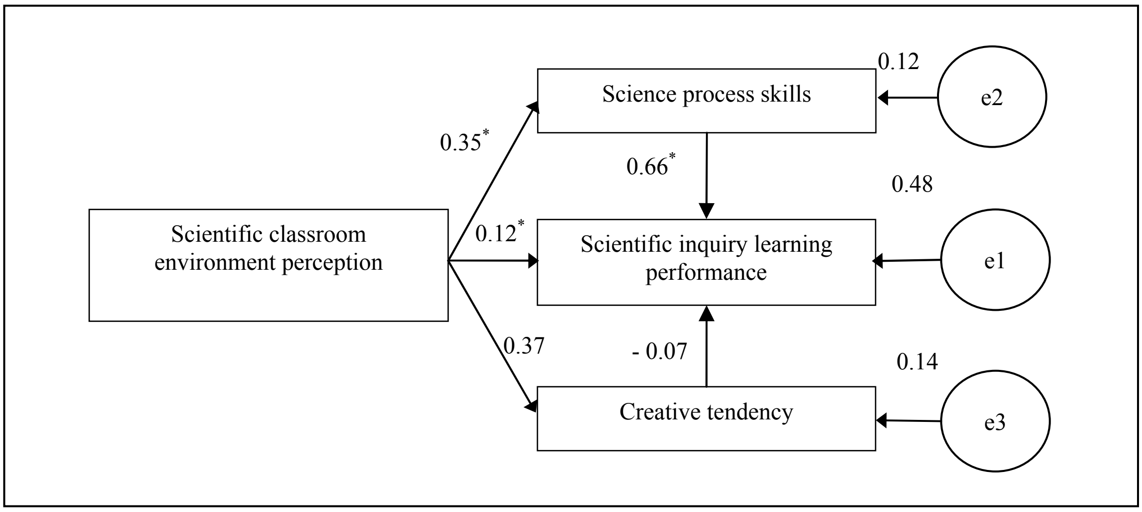

Figure 3. The causal path models that have influence on scientific inquiry-based learning performance. (*Note.* * $p < 0.05$)

Conclusions and Implications

The study results revealed that:

1. The experiment group students' perception of science classroom environment tends to be more inquiry skills and process oriented than the control group's students and can be used for problem-solving, more focused on completing the expected activities and on study than the control group's students, and more cooperation-oriented rather than competition-oriented than the control group's students;

2. There is no difference between the experiment group and the control group in terms of SPST and WCAP performance;

3. The experiment group out-performs the control group in terms of scientific inquiry-based learning performance, and with large experiment ES;

4. The experiment group is superior to the control group in terms of monographic study theses and with large ES;

5. Perception of science classroom environment has both direct and indirect effect on scientific inquiry-based learning performance, with a total ES = 0.349. Science process skills, on the other hand, had direct effect on scientific inquiry-based learning performance, with an ES = 0.655.

Firstly, it can be inferred from the above results that there is a difference between the experiment group's and the control group's students in terms of perception of science classroom environment in three out of seven dimensions of WIHIC, i.e., inquiry, work orientation, and cooperation. As regards the other four dimensions, i.e., student cohesiveness, teacher support, involvement, and equity, there is no perception difference between students of the two groups. This fully reflects that there is an essentially radical difference between CIM teaching and cookbook teaching.

Secondly, the experiment group out-performed the control group in terms of scientific inquiry-based learning performance and monographic study theses. The ES was large in the former group and medium in the latter group. The experiment group also had better performance than the control group in terms of novelty of method, effectiveness of study design, and validity of logical deduction, suggesting that the CIM teaching in this study because of its emphases on the four elements of exploration, explanation, communication, and evaluation, its networked cyclical structure-based operational strategy for inquiry-based teaching, and its application of divergent think first and subsequent convergent thinking, promotes significant learning more effectively by group cooperation based inquiry than cookbook teaching and is more WCAP able of applying the learned scientific knowledge for case studies.

Furthermore, there was no difference between the experiment group and the control group in terms of SPST performance. Maybe, this is because SPKT tests process skills, such as processing variables, deducing, proposing hypotheses, designing experiment, and processing data separately rather than appraise the overall performance of process skills in an identical inquiry scenario, and as a result, the merits of the CIM teaching in this study failed to be manifested on its current SPST performance. Moreover, there was also no difference between the experiment group's and the control group's students in WCAP performance. The possible cause for this phenomenon might be that, creative tendency is a habit of mind that needs development for a long time. In this study, however, only an experiment had been chosen from the six modules of the textbook for teaching research, and as a result, the boosting effect of creative tendency might not be significant enough to help the experiment group out-perform the control group.

Finally, it can be inferred from the analysis of causal path models that have effect on scientific inquiry-based learning performance that the direct effect of creative tendency on scientific inquiry-based learning performance is not significant. Two factors may contribute to this result:

1. The causal path models assumed to be with effect on scientific inquiry-based learning performance might be in need of revision and correction;

2. The PTSIL designed for this study might fail to help students display their risk-taking, curiosity, imaginative faculty, challenging, and other habits of mind. It is speculated that the second reason is more likely and revisions and discussions can be carried out in follow-up studies.

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