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ABSTRACT

The purpose of this study was to investigate the changes of the teachers' teaching practices through a collaborative action research project. The researcher and eight elementary science teachers established a collaborative relationship. The Constructivist Rationale and Teaching Model was introduced to the participant elementary science teachers. Then these teachers worked in-group to design, implement, and evaluate their curriculum. Data were collected mainly by means of classroom observations, teacher interviews, document reviewed, and the survey of a classroom climate questionnaire to investigate the changes of teaching practices. The qualitative data was transcribed and sorted to form tentative assertions. The teaching videotapes were checked according to "Teaching Practices Checklist." The t-test was used to analyze the data from the questionnaire. The findings indicated that: (1) the teachers adopted the teaching sequence as suggested and they showed some constructivist behaviors instead of non-constructivist behaviors during each stage; (2) all teachers reflected on their planning and classroom actions to induce their professional development; and (3) seven teachers' building classroom climate was as good as or more positive than before on seven of the questionnaire. (Contains 27 references.) (Author/ASK)

Improving Elementary Science Teaching through a Collaborative Action Research

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Abstract

The purpose of this study was to investigate the changes of the teachers' teaching practices through a collaborative action research. The researcher and eight elementary science teachers established a collaborative relationship. The Constructivist Rationale and Teaching Model was introduced to the participant teachers. Then these teachers worked in-group to design, implement, and evaluate their curriculum. Data were collected mainly by means of classroom observations, teacher interviews, document reviewed, and the survey of a classroom climate questionnaire to investigate the changes of teaching practices. The qualitative data was transcribed and sorted to form tentative assertions. The teaching videotapes were checked according to "Teaching Practices Checklist". The t-test was used to analyze the data from the questionnaire. The findings indicated that (1) the teachers adopted the teaching sequence as suggested and they showed some constructivist behaviors instead of non-constructivist behaviors during each stage, (2) all teachers reflected on their planning and classroom actions to induce their professional development, (3) seven teachers' building classroom climate was as good as or more positive than before on seven scales of the questionnaire.

INTRODUCTION

Education in Taiwan is highly valued and centralized. Parents, school principles, teachers, and students all have relied on test scores to vale the quality of teaching and learning. Tests have become one of the major factors influencing the teaching practices and quality of learning in school in Taiwan. Because the tests are textbook driven, teachers always cover all the content of the textbooks and put emphasis on repeated exercises that aid the retention of facts to help students get high scores on tests. Students' learning life is full of memorization of facts from textbooks.

People have begun to reflect on the quality of teaching and learning in schools and call for educational reform in Taiwan. Increasingly, people believe that the purpose of science education includes facilitating students' understanding of science knowledge. Facing this changing era, the teacher cannot to be a textbook interpreter only as before. The teacher has to change his or her role into a curriculum designer. How can elementary science teachers improve the effectiveness of their teaching and increase student learning of science concepts?

The constructivist perspective is becoming a dominant paradigm in the field of cognitive psychology. Research findings resulting from this perspective have profound implications for the way in which science instruction is carried out. The science education research community is also contributing greatly to the nature of meaningful learning process. Findings from the research efforts have generated important insights about how students acquire meaning and understanding of science concepts both in and out of school and on how prior knowledge can interfere with or enhance students understanding. Unfortunately, a vast majority of science teaching in Taiwan is textbook driven and thus often fails to capitalize upon more effective instructional practices stemming from these insights into the cognitive process.

Constructivism educators believe that "Meaning is constructed by the cognitive apparatus of learner"(Resnick, 1983). In other words, meaning is created in the mind of the student as a result of the students' sensory interaction with her or his world. Students make sense of what we present to them by associating the new information with prior knowledge (von Glasersfeld, 1989, 1992; Appleton, 1989). The students must construct it in their mind. The teacher cannot convey or transmit meaning (Saunders, 1992). From the research findings (ex.Champagne, Klopfer, & Anderson, 1980; Whittrock, 1985) it has shown that cognitive structures are sometimes highly resistant to change, even in the face of observational evidence and/or formal classroom instruction to the contrary. When the learner's expectations or predictions do not coincide with experience the result is disequilibration. Disequilibration can result in the modification of one's schema. In summary, learners construct knowledge through a psychologically active process. These knowledge structures are sometimes highly resistant to change. Finally, disequilibrating experiences can result in modification of these cognitive structures and hence give rise to increases in the learners understanding of the world.

Yager (1991) states that, with constructivism, peers are very important in the learning process. Learning is an interpretive process, involving constructions of individuals and social collaboration. Knowledge is created through social interaction as individuals test the fit of usefulness of their conceptual understandings in interactions with others and in contexts in which the knowledge is applied (Tobin, Briscoe, & Holman, 1993). The focus is language and the group. Emphases in constructvist thought include considerations of constructs and processes seen to be internal to the learned (Freyberg & Osborne, 1985) as well as the influence of the social context and social interactions (Tobin, 1990).

In response to this perspective, science educators have been focusing attention on approaches to teaching science, which take account of students' alternative conceptions. Summarizing the research literature on alternative conceptions in science, Wandersee, Mintzes, and Novak (1994) pointed out that students harbor a wide variety of alternative conceptions about objects and events when they enter formal instruction in science. Moreover, the origin of these conceptions lies in students' diverse personal experiences, which include observation, perception, culture, language, prior teachers' explanation, and prior instructional materials. Students hold tenaciously onto these alternative conceptions in the face of traditional formal instruction. Finally, all of this prior knowledge interacts with whatever is presented in formal instruction, resulting in a variety of unintended learning outcomes by students. There is considerable evidence in the literature, which suggests that discarding or restructuring one's schema does not come easily.

What are important features of effective science program in light of the constructivist perspective? Several models of teaching in science based on constructivist theories have been proposed, such as Sauders (1992). He showed us four instructional features, which stemmed directly from the constructivist perspective. The features include the use of hand-on investigative activities, a classroom environment which provides learners with a high degree of active cognitive involvement, the use of cooperative learning strategies, and the inclusion of test items which activate higher level cognitive processes. In addition, Appleton (1993) outlined nine interventions related to the constructivist perspective to guide practice. A key and necessary change was for teachers to consider the preconceptions of children before they selected activities. In planning activities and links between them, the interventions would have to be become a new planning frame which would be considered alongside other frame such as time and management.

However the models tend to be limited in scope and provided few clear indications for what a teacher might do to help students learn. An important consideration for teaching practices is the identification and articulation of aspects of constructivism, which provided clear directions for teacher. Bybee, Buchwaid, Crissman, Heil, Kuerbis, Matsumoto, and Mdnerney (1989) proposed a teaching format called the 5 E model. This model suggested a teaching sequence which was engagement→exploration→explanation→elaboration→evaluation. It also provided charts that would help teachers identify their own and students behaviors that supported or contradicted the various phases of the instructional model (IMPACT, 1994).

Research findings on student's conceptions in science are gaining more attention and science teachers and researchers are asking questions about possible implications for teaching in the recent years in Taiwan. The study reported here was grounded in the realities of teaching and learning science in elementary school classroom in Taiwan and involved researcher from a teachers college working with a group of local science teachers. The overall strategy was to work with teachers as collaborators in exploring ways of improving students' conceptual understanding in science. This study had two aims: (1) to help the elementary science teachers to develop curriculum and pedagogy by adopting a constructivist teaching approach for improving practices and promoting student conceptual understanding, and (2) to investigate the changes of participant teachers' practices.

THE PROJECT

A Collaborative Action Research

An initial open meeting with local science teachers was held at the Pingtung Teachers College in 1999 August to outline and discuss the central aim of this project. The researcher and participant teachers all agreed that the aim was to devise, implement, and evaluate teaching materials and strategies which attempt to promote understanding in science concepts and to base teaching on a constructivist view of learning. It was emphasized that the theoretical perspective might be brought to bear on the design and development of teaching schemes, which would be practicable in Taiwan elementary schools. It means that when developing curriculum the participant teachers would take into account factors such as class size, available equipment, and lesson time allocation also. Therefore, it was decided to adopt an interventionist approach to match the aim of the project. During the study the researcher had responsibility for setting the aims of the project, for providing a theoretical framework, for providing guidance in developing curriculum materials, and for monitoring and evaluating classroom practices. The teachers who worked with each other were centrally involved in developing the materials, which they tested in their own classrooms. So the collaborative relationships described here represented both the teacher-teacher and teacher-researcher situations. Based on the constructivist view on learning, it was free for the participant teachers to reject the constructivist approach to teaching or to refine it to make it more useful in their teaching context.

Theoretical Perspectives

Individuals construct their personal knowledge through social interaction and experiences with the physical environment (Tobin, Briscoe & Holman, 1993; Tobin & Tippins, 1993). Learning, therefore, is a purposive activity on the part of the learner and requires active engagement. Furthermore, individuals' existing conceptions influence the meanings which they construct in a given situation, and what is learned results from an interaction between the learner's existing conceptions and the various linguistic and sensory experiences provided. Designing teaching schemes to support science learning requires some appreciation of the prior knowledge that students are likely to bring with them to the learning situation, while recognizing that individual learners make sense of learning experiences in personal ways. This perspective confers the learners both the power and responsibility to take control of their own leaning, aware of their personal epistemological commitments, represent conceptions to their peers and teacher, and monitor their interpretations of scientific phenomena and expressed views of others (Hewson, Beeth & Thorley, 1998).

Teaching Format

There are several constructivist formats one can use. The one the researcher choose was developed by Biological Sciences Curriculum Studies (BSCS) and is called the "5E" model. The chief developer of the model, Rodger Bybee, bases the constructivist teaching plan on five instructional phases: the Engagement, Exploration, Explanation, Elaboration and Evaluation. According to Bybee *et al* (1989) the Engagement is presented to the students to initiate interest and excitement in the topic; the Exploration encourages students to investigate and discuss different aspects of the topic in small cooperative groups; the Explanation gives students chance to describe to others what their team has discovered; the Elaboration provides the opportunity for the students to expand and investigate the topic further; and the Evaluation allows the students and the teacher to assess what students have learned.

The Teachers and School Context

The eight teachers, Jou, Lu, Sueng, Dai, Yang, Tzu, Shiu, and Tsai had been elementary teacher for 3 to 25 years. They all worked in public schools in the middle social-economic class areas near Pingtung or Kaohsung City in Taiwan. The teachers taught the third, fourth, fifth or sixth grade science. In the eight teachers' classrooms, the children were seated in-groups. The classroom climate was warm, humorous, and purposeful. Three to four teachers with different years of teaching were arranged in one group. Groups of teachers would provide the professional and social support to both within and across the schools. In addition it was anticipated that this number of teachers would bring a breath of ideas and skills to the task of curriculum development and also would offer a range of different kinds of schools in which the materials might be tried out.

Design and Implementation of the Project

The project was divided into two parts, the preparatory and intervention phases.

Preparatory Phase

The purpose of the preparatory phase was to help both researcher and teachers to understand the characteristics of teaching and to frame the curriculum problems by reflecting systematically on existing practice. The preparatory phase of this study focused upon existing teaching practices. The teachers taught the units in their usual way. The lessons of the teachers' one class were observed and videotaped. The researcher held discussions with the teachers and their students after the lessons. Within group meetings, questions were raised about current approaches to teaching each topic, how students responded to those approaches, the particular problems that students encountered, and how teaching approaches might be revised to address those perceived problems. The Constructivist Rationale and Teaching Model was introduced to the teachers during the meetings. Reviewing findings form the preparatory phase, the teachers in-groups worked with the researcher to discuss the constructivist view of learning and generate teaching plans based on the teaching format. The teachers would use these plans in the Intervention Phase.

Intervention Phase

During the intervention phase, the teachers in their classes tried the new plans. The lessons of the teacher's one class were observed and videotaped. During these trials, regular meetings allowed teachers and the researcher to review each instructional activity in the light of Teaching Practices Checklist (IMPACT, 1994) and the problems that they had encountered.

METHOD

This was an interpretive case study consisting of eight elementary teachers' implementation of science topics over a year period. Classroom observations, interviews, documents, and a classroom climate questionnaire were used to collect related data. The researcher provided some support for all eight teachers, both as a source of ideas and suggestions during the study. During classroom observation, the researcher acted as a silent observer sitting at the back of classroom. The researcher and teachers constructed the vignettes of this study.

Data Collection

The data sources including classroom observations, interviews, documents, and a classroom climate questionnaire were collected. Data were recorded in a variety of ways: observational field notes, video recording of classroom teaching, tape recording of interviews with teachers, and teaching documents. Data were collected over a year period. My Science Class (MSC)(Lin, 1998) was administrated to assess students' perception of actual learning environment in the end of the preparatory and intervention phase. MSC contained 8 items of simple Yes-No response format measuring each of eight different dimensions (Satisfaction (S), Difficulty (D), Involvement (I), Teacher Support (TS), Participation (P), Investigation (IV), Student Negotiation (SN), and Shared Control (SC)). Items from the different scales were arranged in a cyclic order. In order to score items 3 was given for the Yes response and 1 was given for the No response. Underline items were scored in the reverse manner. Omitted items were given a score of 2. To obtain scale total the five items scores for each scale were added.

Analysis

A chronological vignette of the development of the topics was constructed from the various data sources by the researcher. Video and tape recordings were transcribed The framework of the study guided selection of data. The Teaching Practices Checklist (IMPACT, 1994) helped researcher and participant teachers to identify student and teacher behaviors that supported or contradicted the various phases of the instructional model. The data of the MSC was scored and analyzed. Interpretations were feed back to the eight teachers for their comment.

RESULTS

Results presented the changes in eight teachers' science teaching practices during the study in terms of three categories: development of curriculum, professional development, and classroom climate.

Curriculum Development

Analyzing the eight teachers' existing teaching practices, it was found that they would introduce concepts or provide definitions and answers then provided activities for students to verify it. For example, Jou showed the micrographys of cells of Elodea and onion first, explained the structure of cell, taught students how to use light microscope, then asked students to use light microscope to find cells of Elodea and onion, and share students finding with whole class. Evaluation appeared once per unit not per concept for time saving.

After the reviewing meeting the eight teachers played a central role in planning and curriculum development based on Constructivist Rationale and Teaching Model. They did spend a lot of time and energy developing and trying curriculum material. The topics identified by them as a focus for the group to develop were Lenses, O_2 and CO_2, Rust on Iron, Inheritance, and Light and Heavy. As showed in the table 1 the eight teachers followed the suggested instruction sequence of "5E" (E1→E2→E3→E4→E5).

A range of instructional activities was used in the teaching formats as considering the nature of the learning differed in different topic areas and these were listed in the following paragraph.

In the engagement the instructional activity was designed to involve students in learning and to explore students' existing conceptions. Teachers did good job in creating interest, generating curiosity, and raising questions as preparatory phase. The researcher encourage the teachers to explore students' existing conceptions that can offer a starting point, which can be extended in coming to the scientific view. The teachers seemed be aware of some of the ideas their students' already had especially Lu, Jou, Sueng, and Dai those who had gained the students' knowledge during over past ten years on teaching. However most of the teachers did not elicit responses that uncovered what the students knew or thought about the concept when teaching each concept in the class. During teacher interviews the teachers indicated that they always omit the exploration of their student's ideas during the class time for time saving. The teachers also thought that the exploration of students' ideas would make students confused. Such as Jou said:

> If the teacher explicitly encourages students to tell about their own personal ideas on the conception and not provide following instruction, it would make a contradictory effect. Students always remember strongly or insist the misconception and not the scientist's ideas that the teacher or textbook describes.

For all of the teachers, they put more energy on creating interest and generating curiosity for keeping students attention on the concept. They all indicated that if students did not keep attention on the activity they would learn nothing.

The second phase, the exploration, involved building experiential bridges to a new conception. The teachers designed activities to encourage students to investigate and discuss different aspects of the topic in small cooperative groups. The teachers observed and listened to the students as they interacted. In some cases, students did not have the necessary or enough experiential evidence to allow them to make sense of a particular scientific idea. In such a case, the teachers would provide additional experience. The teachers learned hard to give up the role of an information provider who told or explained how to work through the problem or the role of a judge to tell the students that they were right or wrong. They tried to be a consultant for students. For example, Jou said that,

> "I always tell myself that do not provide the answers or do not tell my students that they are wrong directly. Acting more like a constructivist teacher, I must try to design activities or ask questions to direct or redirect my student learning."

The third phase aimed to construct new conceptions. The teachers gave chance for students to describe to others what their group had discovered during the exploration. In some cases, because students' prior ideas were incommensurate with what they had observed, students' ideas are acknowledged and discussed with their peers. Teachers then indicated that scientists had a different view and presented an alternative model. Sometimes students could not induce rule from evidence. For example, in Tzu's class on "O_2 and Co_2", students could not induce characteristics of oxygen and carbon dioxide from learning activities. Tzu told her students about what the scientists had found. However, Tzu was disappointed about that her students still could not conclude the rules of gases from the previous activities after spending so much time on the exploration.

The fourth phase, the elaboration, aimed to provide the opportunity for the students to expand and investigate the topic in everyday or new situation. For example, after learning the characteristics of gases, Yang asked his students using what they had learned to design a fire extinguisher with gases. In other teachers class since the curriculum were not well planned for the students to utilize new ideas in a range of contexts, the teachers were still the key speakers who lectured or explained how to work through the problems.

Students were expected to have the opportunities to evaluate what they had learned in the evaluation. Jou and Lu had used teacher-made multiple assessment to evaluate their students for three years. The other teachers learned on theory and practice of multiple assessment during this research. Most of the time the teachers used multiple assessments to test vocabulary words, terms, and isolated facts, to assess students' knowledge and /or skills, and to look for evidence that the students had changed their thinking or behaviors. However, students still had few opportunities to actively assess their own learning and group-process skills. The same results were also shown in the result of "My Science Class". This practice was compatible with teachers' view on assessment. Except Lu and Dai the other teachers did not wholly agree the view that their students had the competence to assess their own learning progress. In Lu and Dai's class students had more opportunities to assess their classmates' learning in whole class discussion. In others' classroom the teachers controlled the assessments and students had few opportunities to learn how to assess their own progress.

Teacher Professional Development

The central aim of this team was to devise, implement and evaluate teaching materials and strategies which attempted to promote understanding in science concepts and to base teaching on a constructivist view of learning. All participant teachers reflected on their planning and classroom actions and adopted the suggested theory and the teaching format to generate new learning activities for subsequent trial, evaluation, and modification.

In general, the participant teachers showed positive attitude toward the new approach. In addition, the insights offered by research provided teachers with a rationale for thinking about teaching and learning. For the participant teachers, it was the first time since their initial teacher training that they had looked at practice from a reflective and theoretical stance.

Within the new approaches, the teachers planed teaching to take account of students' thinking offered both problems and rewards. The aspects which teachers considered problematic involved the fundamental issue of developing lessons in a way, which was more responsive to students' understandings. Indeed eight teachers found the move away from pre-set lesson planning stressful. They tried very hard to involve their students in planning their work. In particular the young teachers, Yang, Tzu, and Shiu, lacked confidence and expertise in allowing the direction and development of lessons to be set, at least in part, by the questions and contributions of the students. The experienced teachers, Dai, Jou, Lu, and Sueng, were more prepared to move in this direction but found it intellectually much more demanding as it required not only being aware of a range of different ways in which students conceptualize given tasks, but also responding appropriately in each case.

The management of whole-class discussions in ways that respected the contributions of individuals while maintaining a clear direction was seen as particularly demanding. It also was recognized that low-achievement and quiet students tended to be less comfortable than others were in contributing to this phase of lessons. As well, the teachers identified aspects of students' small-group discussion work as being potentially problematic. Teachers were not sure that their students all involved on the task. The teachers found that some students were off-task and that some were always the leaders. They hoped that their students could cooperate with each other and learned in discussion time. All the teachers indicated that individual difference was still an unsolved problem in a 35 students class. This often resulted in lessons coming to an end without the teacher sensing that 'effective' had been achieved around every student with the task in hand. As teachers gained experience with the approach, they became more confident about giving student freedom and supports to learn concepts.

Assessment was one of the key concerns between teachers and researcher. Most the teachers in Taiwan used paper and pencil tests to assess students in their class. The items of tests were the same in the same grade in one school. Considering teachers' assessment competence needs the researcher designed a curriculum on multiple assessment to help teacher to be familiar with. Jou and Lu had used teacher-made multiple assessment to evaluate their students for three years. The others work hard to design and use multiple assessment in their schools. However, their students perceived that they played passive role instead of active participants in monitoring their own progress in learning (see table 2). Some teachers doubted that it was proper for the student to assess his/her own learning? Sueng said that:

> "I don't think my students have the ability to monitor their own learning. For students to assess their own learning is not common around existing teaching context. It was impossible for both teachers and students to change their roles in assessment during such a short time in existing teaching contexts. "

Lu and Dai were the only two teachers who thought that it was practicable to provide more opportunities for students to learn how to actively evaluate their own learning. Both of them attended some assessment classes, observed other successful teachers' practice, and got some students worksheets. These two teachers just planned the new curriculum and would like to make some changes in the assessment.

For each teacher, this study was a personal journey of professional reconstruction. It was a process of change, development, and modification of their personal teaching theory and practice. The central focus of each teacher was unique. Overall, eight teachers felt that the development of the schemes had been a worthwhile exercise.

Classroom Climate

The MSC was administered to the students in eight teachers' one classes in the preparatory phase (pretest). Student responses were scored and mean scores of the class were shown in Table 1. The teacher generated feedback information based upon the data of pretest. The teachers thought about the response of MSC and discussed them with each other. They found that there existed low scores on Student Negotiation and Shared Control in all eight teachers' class. The researcher encouraged the teachers to make an effort to increase the level of Student Negotiation and Shared Control in the new teaching approach. The intervention consisted of a variety of strategies, some of which originated during meetings between teachers, and others of which were suggested by examining ideas contained in individual MSC items. For example, the strategies used to enhance classroom student negotiation involved the teachers in leading students to ask other students to explain clearly, inviting students to explain their ideas to others, encouraging peer interaction, and providing opportunity for students to ask for justification and clarification from students.

The questionnaire was reassessed in the end of the year to see whether students perceived their classroom environments differently from before. Comparison of the pretest scores with the posttest scores indicated that with the exception of Sueng, seven teachers built the same or somewhat more positive climate on Satisfaction, Difficulty, Involvement, Teacher Support, Participation, Investigation, and Student Negotiation. Sueng's students perceived the learning environment was less Satisfaction and Involvement. Analyzing the fieldnotes of teaching, Sueng's class was less order and more off-task than before. His students seemed lost directions in the explore phase. During the interviews, Sueng said that his students seemed not knowing what to do without teacher's leading step by step.

The lowest score was still on "Shared Control" in all eight teachers' classes. Three teachers, Lu, Shiu, and Tsai, built more Shared Control, and two teachers, Jou and Dai, built less one. Reviewing the data the teachers were not surprising at all. They indicated that the notion of Shared Control was inconsistent with traditional roles of teacher and students. It took time for both teachers and students to learn how to change. The teacher needed to know how to open more freedom for inviting students to design the curriculum. The students had to learn to participate actively in the learning activity in the same time.

CONCLUSION

Teachers possessed a range of knowledge, skills, attitudes, values, and personal aspirations that created and determined a personal practice. The top-down curriculum always overlooked these teachers' personal traits and failed. The collaborative approach viewed teacher as the key person in the class, who brought to their curriculum their own perceptions, ideas, values, and experiences. The teacher adapted the planned-curriculum to his or her teaching style and classroom practice. This approach made the planned curriculum implemented successfully.

In this study. all eight teachers expressed a desire to improve their science teaching practice or to learn how to teach and to develop theories about teaching and learning. The participant teachers with over three to twenty years of teaching experience reflected and learned how to plan and how to teach through this action research. It was the group activities and the consequent sharing of perceptions and ideas, the mutual criticism and negotiation, the support, and the pooling the resources, that produced the changes in ideas and opinions and created the conditions for the production of the usable curriculum material. For each teacher it was a process of change, development, and modification of each teacher's personal theory and professional practice. This personal practice developed over time. Collaboration in teaching offered a more powerful path toward educational change.

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Table1. Teaching practices of leader teachers

Teacher	Teaching Unit (Vol.)	Concept or Activity	Instructional Sequence	Teaching Behavior	
				CON	INCON
Jou	Lenses (10)	Function of Lenses	E1→E2→E3	9	0
		Focusing	E1→E2→E3→E5	11	0
		Image	E1→E2→E3→E4	9	0
		Kinds of lenses	E1→E2→E3→E4→E5	9	0
Lu	Inheritance (12)	Likeness of Relatives	E1→E2→E3	7	0
		Genotype	E2→E3→E4	8	0
		Q & A	E1→E2→E3→E5→E4	12	0
Sueng	Lenses (10)	Functions of Lenses	E1→E2→E3	18	0
		Images	E1→E2→E3→E4→E5	7	0
		Converting Lenses	E1→E2→E3→E4→E5	7	0
Dai	O_2 and CO_2 (8)	O_2	E1→E2→E3	8	0
		Produce O_2	E2→E3	7	0
		Finding O_2	E2→E3→E2→E3	7	0
		CO_2	E2→E2→E2→E2→E3→E4→E5→E5→E4	11	0
Yang	O_2 and CO_2 (8)	O_2	E2→E3	3	0
		O_2 Oxygen	E1→E2→E3	4	0
		O_2 in Air	E1→E2→E3	4	0
		CO_2	E2→E3	3	0
		CO_2 in $Ca(OH)_2$	E1→E2→E3→E4→E5	5	0
		CO_2 in BTB Sol.	E2→E3→E4	3	0
		Extinguisher	E2→E3→E4→E5	6	0
Tzu	O_2 and CO_2 (8)	CO_2	E1→E2→E3→E4	10	2
		O_2	E1→E2→E3→E4→E5	8	0
		Test of Gases	E1→E2→E3→E4→E5	10	0
Shiu	Rust on iron (12)	Rust on iron	E1→E2→E3	4	0
		Factors induce rust	E1→E2→E3→E4→E5	6	0
Tsai	Light and Heavy (6)	Light and Heavy	E1→E2→E3→E4→E5	5	0
		Measurement of Weight	E1→E2→E3→E4→E5	8	0
		Why Things Weight	E1→E2→E3	9	0
		Throw Sand Bags	E1→E2→E3	4	0

* CON means consistent with 5E instructional model

INCON means inconsistent with 5E instructional model

Table2. T-test of "My Science Class"

Teacher	Scale	Satisfaction	Difficulty	Involvement	Teacher Support	Participation	Investigation	Student Negotiation	Shared Control
Jou	1st	2.82	2.76	2.74	2.61	2.63	2.78	2.57	2.09
	2nd	2.78	2.84	2.83	2.70	2.64	2.92	2.70	1.66
	T-test	-0.64	1.28	1.28	0.80	-0.31	2.49	1.59	-4.05
Lu	1st	2.99	2.86	2.76	2.83	2.68	2.85	2.34	1.58
	2nd	2.84	2.79	2.85	2.76	2.71	2.88	2.63	1.81
	T-test	-3.47	-1.14	1.55	-1.15	0.37	0.56	3.21	2.30
Sueng	1st	2.95	2.78	2.67	2.79	2.67	279	2.52	1.77
	2nd	2.52	2.65	2.41	2.79	2.54	2.78	2.35	1.86
	T-test	-6.83	-1.93	-3.08	-0.25	-1.65	-0.24	-1.80	0.93
Dai	1st	2.83	2.76	2.76	2.77	2.39	2.73	2.43	2.26
	2nd	2.93	2.83	2.84	2.75	2.62	2.90	2.41	1.75
	T-test	1.84	1.08	1.76	-0.63	2.49	2.79	-0.29	-4.99
Yang	1st	2.50	2.63	2.35	2.71	2.23	2.59	2.43	1.73
	2nd	2.65	2.59	2.23	2.65	2.33	2.46	2.37	1.85
	T-test	1.81	-0.47	-1.19	-0.77	1.05	1.55	-0.63	1.14
Tzu	1st	2.57	2.39	2.36	2.54	2.31	2.66	2.28	2.02
	2nd	2.56	2.54	2.54	2.57	2.42	2.65	2.25	1.73
	T-test	-0.10	1.47	0.84	0.38	1.05	-0.21	-0.34	-2.63
Shiu	1st	2.49	2.44	2.38	2.40	2.36	2.65	2.27	1.46
	2nd	2.53	2.61	2.41	2.51	2.44	2.68	2.35	1.66
	T-test	0.50	1.99	0.28	1.23	0.95	0.34	0.83	2.22
Tsai	1st	2.94	2.76	2.72	2.71	2.52	2.67	2.33	1.59
	2nd	2.79	2.82	2.71	2.78	2.59	2.82	2.51	2.02
	T-test	-1.95	0.85	-0.16	0.95	0.72	2.07	-1.67	3.43

p.s.: ▒ means .05 significance

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