Constructivist Teaching in Primary Science

Winnie Wing-Mui SO

Department of Science, Hong Kong Institute of Education

Email: wiso@ied.edu.hk

Received: 18 May, 2002

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Introduction

The present study aimed to find evidence of constructivist teaching amongst teachers in primary science lessons and to identify any changes in the extent of constructivist teaching when teachers advanced from pre-service to novice teaching. In order to make an overview of the teachers' changes in their practice of teaching from pre-service teacher education to beginning teaching, a longitudinal study was conducted with teachers for three academic years. The first two stages were the pre-professional phases during initial teacher education, and the final stage was the beginning teaching year. At each stage of the study, student teachers' teaching was observed once a year.

Constructivist Theories

Fischler (1999, p.173) stated that teaching should not be regarded as an arrangement of instructional strategies, but more a situation in which learning processes need to be recognized and supported. This important knowledge base of teaching creates demands on the teachers as they need to be sensitive to students' learning difficulties; be patient through the process of students' construction of new knowledge; take into account the students' existing knowledge; create a classroom climate in which students are willing to express and discuss their ideas; create situations in which students can present their own opinions; and, to accept a teaching role that is not so much that of a communicator and an examiner, but more as a person who advises and helps students to develop knowledge (Scott, Asoko and Driver, 1992)

Cognitive theories of learning have exerted a powerful influence on policy and research relating to the education of students (Stoddart, Connell, Stofflett & Peck, 1993). Learners are increasingly viewed as active participants in the learning process, actively constructing meaning through experience. For this reason Solomon (1997) believed that how teachers teach children is as important as what teachers teach. Since the didactic approach to teaching has been shown to be ineffective in developing students' conceptual understanding (Carin, 1993), there has been a call for a shift in the focus of instruction from mechanical drill and practice towards teaching for understanding. Learning involves the active construction of meaning by the student and is not something that is imparted by the teacher (Driver & Oldham, 1986).

The call for more ecologically valid research served to bring on the widespread acceptance of psychology's metaphor of learning as knowledge construction in the 1980s and 1990s (Mayer, 1996). The constructivist view is one of the traditions in educational psychology that rest on the views that a learner's existing ideas are all important in responding to, and making sense of, stimuli. The learner makes sense of experience by actively constructing meaning (Osborne & Wittrock, 1985). When answering the question of whether constructivism is primarily an epistemology or a pedagogy, von Glasersfeld said that constructivism confronts questions of knowledge -

what knowledge is and where it comes from. He therefore considered this is an exercise of epistemology (von Glasersfeld, 1993). However, two years later, von Glasersfeld (1995) stated that the constructivist view is an attempt to explain a way of thinking and makes no claim to describe an independent reality, and he preferred to call it an approach to, or a theory of, knowing. He tried to avoid the terms "epistemology" or "theory of knowledge" for constructivism though he had previously used both.

Constructivist theories draw heavily on the work of Piaget and Vygotsky which emphasized that cognitive change only take place when previous conceptions go through a process of disequilibrium with the new information (Slavin, 1994). Constructivist theories of cognitive development emphasize the active role of learners in building their own understanding of reality. Leinhardt (1992) stated that the essence of constructivist theory is the idea that learners must individually discover and transform complex information if they are to make it their own. The constructivist theory in education rooted in neo-Piagetain thought is Personal Constructivism (Von Glaserfeld, 1989). Solomon (1987) and Millar (1989) have taken Personal Constructivism further to Social Constructivism that believes learners internalize the interpretations in terms of their previous experience and culture. Spivey (1997) argued that the social constructivist have focused on the cognitive as well as the social. Cobb (1996) stated that although von Glaserfeld defined learning as self-organization, he acknowledges that this constructive activity occurs as the cognizing individual interacts with other members of a community. (p.37) And the sociocultural and cognitive constructivist perspectives each constitutes the background for the other (Cobb, 1996, p.48). On the one hand, an individual constructs meaning as new information should interact with one's existing knowledge, and learning should be personal and subjective and exists in one's own mind. On the other hand, though knowledge is personally constructed, the constructed knowledge is socially mediated as a result of experiences and interaction with others in that social context. And learning science was believed to involve more than the individual making sense of their personal experiences (Wilson, 2000).

Constructivist Teaching in Science

"The most conspicuous psychological influence on curriculum thinking in science since 1980 has been the constructivist view of learning." (Fensham, 1992, p.801) Tobin

(1993) remarked that as "constructivism has become increasingly popular… in the past ten years…. it represents a paradigm change in science education." (p.ix) Yeany (1991) also argued that "an unification of thinking, research, curriculum development, and teacher education appears to now be occurring under the theme of constructivism." (p.1) Their views were echoed by the words of Scott, Asoko, Driver and Emberton (1994) "science learning, viewed from a constructivist perspective, involves epistemological as well as conceptual development." (p.219)

Constructivism sees learning as a dynamic and social process in which learners actively construct meaning from their experiences in connection with their prior understandings and the social setting (Driver, Asoko, Leach, Mortimer & Scott, 1994). The constructivist view of learning argues that students do not come to the science classroom empty-headed but arrive with lots of strongly formed ideas about how the natural world works. In the view of constructivists, pupils should no longer be passive recipients of knowledge supplied by teachers and teachers should no longer be purveyors of knowledge and classroom managers (Fosnot, 1996). From this perspective, learning is a process of acquiring new knowledge, which is active and complex. This is the result of an active interaction of key cognitive processes (Glynn, Yeany & Britton, 1991). It is also an active interaction between teachers and learners, and learners try to make sense of what is taught by trying to fit these with their own experience.

Constructivist views also emphasize generative learning, questioning or inquiry strategies (Slavin, 1994). An emphasis on constructivism and hands-on inquiry-oriented instruction to promote children's conceptual knowledge by building on prior understanding, active engagement with the subject content, and applications to real world situations has been advocated in science lessons (Stofflett & Stoddart, 1994). And constructivist views emphasizing discovery, experimentation, and open-ended problems have been successfully applied in science (Neale & Smith, 1990). Wildy and Wallace (1995) believed that good science teachers are those who teach for deep understanding: "They use students' ideas about science to guide lessons, providing experiences to test and challenge those ideas to help students arrive at more sophisticated understanding. The classrooms of such teachers are learner-centered places where group discussion, exploration and problem solving are common place." (p.143)

The term 'constructivism' encompasses a variety of theoretical positions (Geelan, 1997) and has mainly been applied to learning theories, focusing on learning as a conceptual change (Driver & Oldham, 1986) and to curriculum development and teaching, mainly in science (Osborne & Wittrock, 1985). It also provides some clear pointers towards teaching strategies that might assist students in conceptual reconstruction (Hodson & Hodson, 1998), such as:

a. identifing students' views and ideas;

b. creating opportunities for students to explore their ideas and to test their robustness in explaining phenomena, accounting for events and making prediction;

c. providing stimuli for students to develop, modify and where necessary, change their ideas and views; and,

d. supporting their attempts to re-think and reconstruct their ideas and views.

Teaching methods based on constructivist views are very useful to help students' learning. The following are practices derived from cognitive psychology that can help students understand, recall and apply essential information, concepts and skills. They are used to make lessons relevant, activate students' prior knowledge, help elaborate and organize information, and encourage questioning. Important concepts from this perspective are (Slavin, 1994, p.237-239):

a. Advanced organizers: general statements given before instruction that relate new information to existing knowledge to help students process new information by activating background knowledge, suggesting relevance, and encouraging accommodation;

b. Analogies: pointing out the similarities between things that are otherwise unlike, to help students learn new information by relating it to concepts they already have; and

c. Elaboration: the process of thinking about new material in a way that helps to connect it with existing knowledge.

To explicitly build on students' existing knowledge is one of the ways to encourage deep approaches to learning (Biggs, 1995). To achieve this, teachers should have a clear idea of what students have already known and understood so that they can engage students in activities that help them construct new meanings (von Glaserfeld, 1992). Moreover, the opportunities for pupils to talk about their ideas concerning particular concepts or issues are prominent in the learning process. Teachers who employ constructivist teaching try to help pupils to learn meaningfully. They should encourage pupils to accept the invitation to learn and to take action on what they have learnt, and to provide pupils with opportunities to explore, discover and create, as well as to propose explanations and solutions.

One main purpose of using the findings of research into children's preconceptions in science is to help teachers to apply constructivist ideas about learning in the classroom (Peterman, 1991). The collaborative effort among researchers and teachers on constructivist teaching is to encourage teaching which takes account of the prior ideas and understanding of children in the development of specific concepts in science, and to stress the need to provide prospective science teachers with a model for constructivist learning situations. This lays the seeds that help prospective teachers in life-long professional growth as science educators (Anderson & Mitchener, 1994).

Though Wilson (2000) suggested science educators need to look beyond the confines of cognitive psychology in developing pupils' understanding of scientific concepts, the four immediate accessible points she suggested for practicing teachers to consider in teaching concepts to pupils also rooted with constructivist teaching, these were:

1. recognizing what pupils already know;
2. teach fewer concepts;
3. improve continuity across key stages and progression of the development of concepts. Pupils are exposed to scientific concepts at a much earlier stage in their

education; and,

4. acknowledge the diversity of learners.

Current teaching of science

Glynn, Yeany and Britton (1991) stated that school science curricula are commonly placed on a continuum from "textbook-centered" to "teacher-centered" and that the textbook is the vehicle that drives the teaching. The textbook is usually accompanied by a large bulk of resource materials, such as additional information, overhead transparencies, wall charts, cassette tapes, teaching kits, worksheets, exercises, suggested activities and experiments, and the activity cards. Besides this, there are also "very useful" teachers' handbooks prepared by the publishers, which prescribe precisely how a concept should be taught (So, Tang & Ng, 2000).

The problem of the heavy reliance on textbooks during science lessons was addressed in the American Association for the Advancement of Science Report (1989), notingthat the present science textbooks and methods of instruction emphasized the learning of answers more than the exploration of questions, memory at the expense of critical thoughts, bits and pieces of information instead of understanding in context, recitation over argument, reading in lieu of doing.

Morris (1995) in discussing the pedagogy in classrooms claimed that the major resource used by teachers and pupils in Hong Kong is the textbook. It often provides the content of the lesson and many of its learning activities. Further to this, in examining the nature of the more pupil-centered tasks used in the classrooms, such as group work, problem solving and discovery learning, Morris found that these tasks are often characterized by a high degree of teacher control and a low level of pupil involvement.

Method of Study

Participants

The participants in this study were pre-service teachers of the Certificate in Primary

Education (Chinese) (Two-year Full-time) Course. A class of 25 student teachers taking the Science Curriculum Studies module was invited to be the subjects of the present study, and was followed through their two years of study and in their first year of beginning teaching.

There were two reasons for inviting all student teachers in a class to participate in the full study. The first reason was to capture a general picture of teachers at different stages of their study and thus to have a stronger basis for generalizing the pattern of development. The second reason was to allow for the possibility of the loss of some participants from the research due to unforeseeable factors such as arrangements during school teaching experience and beginning teaching. There was a likelihood that some of the student teachers would have no science lessons during school teaching experience. As well some student teachers would be likely to further their studies after graduation or be assigned no General Studies teaching in their beginning year of teaching.

It turned out that twenty of the twenty-five participants in the first stage of study were actually involved in teaching science topics during their school teaching experience period at the second stage of the study. Only nine of the original participants were teaching General Studies in their first year of teaching in local primary schools at the third stage of this study. Possible bias due to unrepresentative dropout was analysed by comparing the first stage responses of this group with those who continued in the study.

Lesson observation

Student teachers were observed once every year throughout the three-years of the study to capture the extent of their constructivist teaching. For micro-teaching, owing to the tight schedule in teaching the method studies module, each student teacher was required to teach for about twenty minutes. For both the school teaching experience and beginning teaching year, the lesson observations were conducted in normal classroom settings, which normally lasts for thirty to thirty-five minutes. The topics chosen for lesson observations were science topics in the subject General Studies.

The lesson observation utilized an interpretative approach which is described by Erickson (1986) as focusing on "the immediate and local meanings of actions, as defined from the actors' points of views." (p.119) "Snapshots" of teachers' teaching of science topics were obtained. Data was recorded in different ways that included the researcher's observational field notes, video and tape recordings of teachers' talks with the class and discussions amongst pupils. The reason for studying teachers' teaching of primary science lesson was to find out if they were implementing a constructivist approach to learning and the extent of their constructivist teaching.

Analysis of constructivist teaching

The following researchers' work which advocated constructivist learning were studied and referred to for a more systematic and objective observation:

1. the five characteristics of constructivist teaching outlined by Appleton and Asoko (1996) to infer the use of constructivist views of learning by teachers to inform teaching;

2. Kober's (1993) picture of an emerging consensus about the knowledge and skills that science teachers should possess when enacting a constructivist approach;

3. Novodvorsky's (1997) nine components which describe the teacher's role in guiding the students construction of knowledge;

4. Yager's (1991) Constructivist Learning Model (CLM); and,

5. Novak's (1998) comparison of teaching practices under the traditional paradigm with those under contemporary constructivist views.

To avoid overlap among the features of constructivist teaching described by the above researchers, and to make the evaluation of lesson more comprehensive, a set of characteristics of constructivist teaching was developed. This list describes a teaching approach that advocates science learning as an active process which focuses on pupils' understanding and use of scientific ideas and inquiry processes. The construction of the set of characteristics that describe constructivist teaching itself can be considered objective in the sense as argued by Galton (1995) that the criteria used to describe classroom life are clearly defined, thus, when the system is used correctly it is unaffected by the personal biases of the observer. The features of constructivist teaching were grouped into six domains with altogether 22 items (in Figure 1) utilized as a guide to evaluating and categorizing classroom teaching. Teachers' teaching performance in their three observed lessons, once a year, were rated according to the 22 features that describe constructivist teaching, with a 4-point rating ranging from strongly agree (3), agree (2), slightly agree (1) to not observed (0).

The teaching of each student teacher was rated towards the end of lesson observation to the extent to which it reflected constructivist teaching. For example, a teacher who started the lesson by involving pupils in talking about the knowledge/content/concept learned in previous lesson/year was considered as exhibiting awareness of pupils' existing ideas. However, the rating of this practice of teaching with either "strongly agree" or "agree" and "slightly agree" depended on the breadth and depth of treatment. Another example was on the rating of the category "pupils explain phenomenon". Sometimes teachers were not found to involve pupils in explaining phenomenon throughout the whole lesson, the rating would then be 0 - "not observed". If this practice of teaching was rarely found, the rating would then be 1 - "slight agree", so on and so forth. The ratings of the teaching were clarified and confirmed by studying the video recordings of lessons and cross-checking with the observational field notes. This was to ensure the ratings were really describing teachers' performance with each particular item.

1. Use pupils' existing knowledge to guide teaching	
	1.1 teacher's awareness of pupils' existing ideas
	1.2 elicit pupils' ideas before presenting teachers' own idea or before studying ideas from textbook or other sources
	1.3 challenge pupils' initial ideas
	1.4 make new ideas accessible to pupils
2. Guide pupils to generate explanations and alternative interpretations	
	2.1 pupils observe phenomenon
	2.2 pupils describe phenomenon
	2.3 pupils generate explanations and interpretations

	2.4 probe pupils' responses for clarification and justification
	2.5 pupils explain contradictions and misconceptions
3. Devise incisive questions	
	3.1 a question-rich learning environment
	3.2 questions based on pupils' responses
	3.3 pupils expand on their questions and justify their responses
	3.4 accept and value pupils' answers and suggestions
4. Choose materials and activities for pupils to test ideas	
	4.1 pupils work with materials and activities
	4.2 pupils engage in scientific inquiry
	4.3 pupils work independently with minimal help from the teacher
	4.4 pupils put their ideas to test (disprove or prove what they think)
	4.5 pupils' suggestion about the direction of the activity/experiment
5. Provide a classroom atmosphere conducive to discussion	
	5.1 pupils put forward and discuss ideas with the teacher
	5.2 pupils put forward and discuss ideas with peers
6. Provide opportunities for pupils to utilise new ideas	
	6.1 relate current teaching points to previous knowledge
	6.2 pupils apply knowledge to new situations or real-life problems

** Teacher's performance in teaching is rated according to the above features, and is accompanied by a four-point rating ranging from "strongly agree" (3), "agree" (2), "slightly agree" (1) to "not observed" (0)*

Figure 1. Components that describe constructivist teaching

Findings

Changes in enactment of constructivist teaching during school teaching experience

This study aimed to find out to what extent constructivist teaching was utilized in primary science lessons. Lesson observations allowed the identification of salient features of student teachers' approaches to teaching in an appropriate setting. The evaluation approach used during the lesson observation pertained to a constructivist view of teaching and learning. Sections of the student teachers' teaching and classroom events were compared and contrasted with reference to researchers' work which advocates learners' active learning. The components listed in Figure 1 were used as a guide for evaluating and categorizing teachings in classrooms by rating teachers' teaching.

Table 1 presents a summary of teachers' teaching during micro-teaching in the early stage of teacher education. It was not common for student teachers to be judged as utilizing constructivist teaching at this stage with a mean rating of 0.83 (1 is considered to be an indicator of a slight use of constructivist teaching). Only a few features of constructivist teaching were observed in the micro-teaching of four student teachers (Teachers K, O, R, and V), who were consequently given ratings below 0.5. Some features of constructivist teaching were found with twenty-one student teachers (with ratings between 0.5 and 1.5). None were observed to have more features of constructivist teaching (i.e. ratings over 1.5).

Table 1. Student teacher's constructivist teaching performance during micro-teaching at Stage 1 of the study. Teaching is rated according to the above features, and is accompanied by a four-point rating, ranging from strongly agree (3), agree (2), slightly agree (1) to not observed.

Lesson features **Student Teacher**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**	**X**	**Y**	**Mean**
1. Use learners' existing knowledge to guide teaching																										1.15
1.1 teacher's awareness of learners' existing ideas	0	1	1	2	1	1	1	2	2	2	0	1	1	1	1	1	2	1	1	2	1	0	2	2	1	1.20
1.2 elicit learners' ideas before presenting teacher's own	0	1	1	1	2	2	1	1	2	2	0	1	1	1	1	2	2	1	1	1	2	0	1	1	1	1.16
1.3 challenge learners' initial ideas	0	0	1	0	1	1	1	1	2	1	0	1	0	1	1	2	1	0	1	0	1	0	0	2	0	0.72
1.4 make new ideas accessible to learners	1	1	2	1	1	2	1	2	2	2	1	2	2	1	1	2	2	1	2	1	1	1	2	3	1	1.52
2. Guide learners to generate explanations and alternative																										0.86
2.1 learners observe phenomenon	2	1	1	1	1	1	1	1	2	2	1	2	2	2	1	2	2	1	2	1	1	1	1	2	2	1.44
2.2 learners describe phenomenon	1	1	1	1	1	1	1	1	2	2	1	2	2	1	0	2	2	1	2	1	1	1	1	2	1	1.28
2.3 learners generate explanations and interpretations	1	0	0	1	1	1	1	1	0	0	0	0	1	0	0	2	2	0	1	1	1	0	0	1	0	0.60
2.4 probe learners' responses for clarification & justification	1	0	2	1	1	1	1	2	2	0	0	0	2	0	0	2	1	0	1	1	1	0	0	1	0	0.80
2.5 learners explain contradictions & misconceptions	0	0	2	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.20
3. Devise incisive questions																										0.97
3.1 a question-rich learning environment	1	0	2	2	1	2	1	2	2	2	0	1	2	1	0	2	1	0	1	2	1	1	1	2	2	1.28
3.2 questions based on learners' responses	1	0	2	2	1	2	1	1	2	1	0	1	2	1	0	2	1	0	1	2	1	0	1	2	1	1.12
3.3 learners expand on their questions & justify their response	0	0	2	1	0	1	0	1	1	0	0	0	1	0	0	2	1	0	1	1	0	0	0	1	0	0.52
3.4 accept and value learners' answers & suggestions	1	1	2	1	1	2	1	1	1	1	0	1	2	0	0	1	1	0	1	1	1	0	1	2	1	0.96
4. Choose materials and activities for learners to test ideas																										0.45
4.1 learners work with materials & activities	1	2	1	2	1	0	0	2	2	2	1	2	2	1	0	1	2	1	1	1	1	1	1	2	2	1.28
4.2 learners engage in scientific inquiry	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	1	0	0	0	0	0.32
4.3 minimal help from the teacher	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0.28
4.4 learners put their ideas to test	0	1	0	2	1	0	0	0	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0.36
4.5 learners' suggestion about the direction of the activities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
5. Provide a classroom atmosphere conducive to discussion																										0.74
5.1 learners put forward and discuss ideas with teacher	1	0	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	0	2	1	1	1	1	2	1	0.80
5.2 learners put forward and discuss ideas with peers	1	0	1	1	1	0	0	0	2	0	1	1	2	0	0	0	0	0	1	2	0	0	1	2	1	0.68
6. Provide opportunities for learners to utilize new ideas																										0.96
6.1 relate current teaching points to previous knowledge	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	0	1	2	1	0	1	2	1	1.04
6.2 learners apply knowledge to new situations or real-life problem	1	1	2	1	0	0	0	2	2	0	1	0	1	1	0	2	2	0	2	0	1	0	1	2	0	0.88
Total	**15**	**12**	**26**	**24**	**20**	**19**	**13**	**23**	**31**	**18**	**7**	**17**	**24**	**13**	**6**	**30**	**27**	**6**	**23**	**20**	**17**	**6**	**16**	**32**	**16**	0.73
Mean	**0.68**	**0.55**	**1.18**	**1.09**	**0.91**	**0.86**	**0.59**	**1.05**	**1.41**	**0.82**	**0.32**	**0.77**	**1.09**	**0.59**	**0.27**	**1.36**	**1.23**	**0.27**	**1.05**	**0.91**	**0.77**	**0.27**	**0.73**	**1.45**	**0.73**	0.83
Rank order	**18**	**21**	**5**	**6**	**10**	**12**	**19**	**8**	**2**	**13**	**22**	**14**	**6**	**19**	**23**	**3**	**4**	**23**	**8**	**10**	**14**	**23**	**16**	**1**	**16**	

The student teachers' performances as judged in six areas of constructivist teaching were as follows:

1. *Using learners' existing knowledge to guide teaching*
   The average rating in this area was 1.15, the highest found among the six areas. Student teachers were more able to make new ideas accessible to their peers acting as learners, they were aware of learners' existing ideas and had tried to elicit learners' ideas before presenting their own, but quite a number of student teachers did not attempt to challenge learners' initial ideas during teaching.

2. *Guiding learners to generate explanations and alternative conceptions*
   The average rating for this category was 0.86. Most of the student teachers were able to guide learners to observe a phenomenon before describing it. However, few student teachers were able to guide learners to give explanations and interpretations and probed learners' responses for clarification. The common reaction to learners' unclear responses was to pass questions to other learners in the class to answer, without going back to that learner who obviously had difficulty in understanding. Only four student teachers (those with ratings 1 and 2) attempted to guide learners to explain misconceptions.

3. *Devising incisive questions*
   The average rating here was 0.97. Many student teachers were able to use questions to guide learners' thinking and their questions were generally based on learners' responses. They were able to accept and value learners' answers. But it was not common for the student teachers to guide learners to expand on their answers and to justify their responses.

4. *Choosing materials and activities for learners to test ideas*
   The average rating here was 0.45. Student teachers were able to choose materials and activities for learners to work with during micro-teaching. Most of the activities did not require learners to engage in scientific inquiry nor to put their ideas to the test. No student teacher asked learners (fellow classmates acted as learners during micro-teaching) to suggest the direction of the activities.

5. *Providing a classroom atmosphere conducive to discussion*

The average rating was 0.74. It was not common to have learners put forward and discuss ideas with their teacher and their peers. In most of the lessons, it was the teacher who put forward questions in class.

6. *Providing opportunities for learners to utilize ideas*
The average rating was 0.96. Some student teachers were able to relate current teaching points to learners' previous knowledge but such instances were not frequent. Only three student teachers (with rating 2) were able to relate current teaching points to previous knowledge. Though seven student teachers (with rating 2) were agreed to have provided opportunities for learners to apply knowledge to reality, ten others were at the another end of the spectrum that they did not even provide any opportunity for learners to apply what they had learned.

The overall performance of the student teachers in each of the features of constructivist teaching provided some insights into student teachers' strengths and weaknesses in performing constructively when using this model of analysis.

Table 2 shows the student teachers' micro-teaching performance. Their performance in each of the items were arranged in a descending order of score. During micro-teaching, student teachers were often observed with constructivist teaching in one item: to make new ideas accessible to learners. They were occasionally observed to show features of teaching in 16 items. And they very infrequently or were not observed at all to show the features of teaching in 5 items.

Table 2. Teaching performance observed during micro-teaching

Feature	**Rating**	**Constructivist Teaching**
Make new ideas accessible to learners	1.52	Often
Guide learners to observe phenomenon	1.44	Occasionally
Learners describe phenomenon	1.28	
A question-rich learning environment	1.28	
learners work with materials and activities	1.28	
To be aware of learners' existing ideas	1.20	

Elicit learners' ideas before presenting teachers' own	1.16	
Questions based on learners' response	1.12	
Relate current teaching points to previous knowledge	1.04	
Accept and value learners answers and suggestion	0.96	
Learners apply knowledge to new situations or real-life	0.88	
Probe learners' responses for clarifications	0.80	
Learners put forward and discuss ideas with teacher	0.80	
Challenge learners' initial ideas	0.72	
Learners put forward and discuss ideas with peers	0.68	
Learners generate explanations and interpretation	0.60	
Learners expand on their questions and justify their responses	0.52	
	0.36	Infrequent
Learners engage in scientific inquiry	0.32	
Minimal help from the teacher	0.28	
Learners explain contradictions and misconceptions	0.20	
Learners' suggestion about the direction of the activity/experiment	0.00	Not observed

A more detailed analysis of student teachers' performance in the six areas (of features of constructivist teaching) showed that the overall performance of student teachers in the six areas of features of constructivist teaching was moderate. Student teachers during their micro-teaching had paid some consideration to learners' prior understanding in their teaching. Comparatively, student teachers were more able to: use pupils' existing knowledge to guide teaching and, devise incisive questions; provide opportunities for pupils to utilize ideas and guide pupils to generate explanations; and, alternative in a micro-teaching setting. They made frequent use of questioning to guide learners to understand new ideas. However, student teachers seemed quite satisfied with the short answers provided by learners and they seldom required learners to further elaborate on their responses.

Only some student teachers provided opportunities for learners to make use of the new ideas learned. Discussion and interaction between learners were occasional: it was always the teacher who led the discussion. Moreover, though it was not difficult to find materials and activities provided by student teachers to involve learners in the lesson, the activities mainly provided opportunities for learners to observe some phenomena or changes, without engaging learners in scientific inquiry, and learners were merely following teachers' instructions without any input on the suggestions and directions of their work. Micro-teaching may be regarded by some as a less intense teaching situation compared to school experience as the learners are the peers of the teacher, it is fully understood that the nature of micro-teaching may have some affect on the performance of some student teachers.

Changes in enactment of constructivist teaching during school teaching experience

Table 3 shows the numerical data of each feature of student teachers' performance in the two stages of the study. A significant increase in performance was found with the features "pupils describe phenomenon", "questions based on pupils responses" and "accept and value pupils' answers". This indicated that during teaching practice, student teachers were more able to have pupils describe phenomena, to ask questions that built on pupils' responses, as well as taking on pupils' responses more seriously. Statistical analysis on the change of teachers' performance was conducted with the 20 student teachers who remained in the second stage of study.

Table 3. Teacher's constructivist teaching in the first two stages of study

		Teaching Performance (Mean)		
		Micro-teaching	School teaching	Changes in
		With 20 teachers		
1.	**Use pupils' existing knowledge to guide**	**1.25**	**1.40**	**-**
1.1	teacher's awareness of pupils' existing	1.35	1.30	-
1.2	elicit pupils' ideas before presenting	1.25	1.50	-
1.3	challenge pupils' initial ideas	0.80	0.95	-

1.3	challenge pupils' initial ideas	0.80	0.95	-
1.4	make new ideas accessible to pupils	1.60	1.85	-
2.	**Guide pupils to generate explanations and alternative**	**0.86**	**1.11**	**-**
2.1	pupils observe phenomenon	1.45	1.70	-
2.2	pupils describe phenomenon	1.30	1.80	↑*
2.3	pupils generate explanations and interpretations	0.55	0.95	-
2.4	probe pupils' responses for clarification and justifications	0.75	0.85	-
2.5	pupils explain contradictions and misconceptions	0.25	0.25	-
3.	**Devise incisive questions**	**1.00**	**1.34**	**-**
3.1	a question-rich learning environment	1.30	1.70	-
3.2	questions based on pupils' responses	1.15	1.65	↑*
3.3	pupils expand on their questions and justify their responses	0.60	0.45	-
3.4	accept and value pupils' answers and suggestions	0.95	1.55	↑*
4.	**Choose materials and activities for pupils to test ideas**	**0.47**	**0.40**	**-**
4.1	pupils work with materials and activities	1.35	0.95	-
4.2	pupils engage in scientific inquiry	0.30	0.55	-
4.3	minimal help from the teacher	0.30	0.25	-
4.4	pupils put their ideas to test	0.40	0.20	-
4.5	pupils' suggestion about the direction of the activities	0.00	0.05	-
5.	**Provide a classroom atmosphere conducive to discussion**	**0.73**	**0.73**	**-**
5.1	pupils put forward and discuss ideas with the teacher	0.80	0.90	-
5.2	pupils put forward and discuss ideas with peers	0.65	0.55	-

6	**Provide opportunities for pupils to utilize new ideas**	**1.03**	**1.08**	**-**
6.1	Relate current teaching points to previous knowledge	1.05	1.30	-
6.2	Pupils apply knowledge to new situations or real-life problem	1.00	0.85	-
Mean		**0.89**	**1.00**	

↑Improved performance with 0.05 level of significance

- Not much change in performance (changes that are not within the 0.05 level of significance)

* P<0.05

Changes in beginning teachers' enactment of constructivist teaching

The beginning teachers were again rated according to the twenty-two features of constructivist teaching. Quite an encouraging performance was found among most of the remaining nine beginning teachers. Though none of them performed at a 'strongly agreed' level of constructivist teaching, six (Teachers I, L, P, S, X and Y) performed closely to an 'agreed level' of constructivist teaching (with a rating between 1.5 and 2.0); two (Teachers B and N) were observed to have slightly agreed constructivist teaching (with a rating between 0.5 and 1.5). Only Teacher F with a rating of 0.41 showed very few signs of constructivist teaching.

There was a statistically significant correlation between performance of constructivist teaching throughout the different stages of the study: Stage 1 with Stage 3 (r = .64*) and Stage 2 with Stage 3 (r = .76*). This indicated that those nine teachers who used constructivist methods more at the early stage of teacher education and school teaching experience were also rated more highly in this respect at their beginning teaching year.

Teachers' performance of constructivist teaching changed from an average rating of 0.84 in micro-teaching, to 1.00 during school teaching experience, and to 1.39 during the first year of teaching. A significant increase in performance was found in Stage 1 and Stage 3 (t = 2.90*, df = 8) which showed an overall shift of teachers' performance from the earliest stage of teacher education to beginning teaching.

Teachers P and Y remained at an 'agreed' constructivist teaching performance at this stage of study from school teaching experience. Teacher N maintained a few signs of constructivist teaching in the three stages of the study. Four other teachers (Teachers I, L, S and X) showed a change in their teaching, from a "slightly agreed" constructivist teaching to "agreed constructivist teaching" in their beginning teaching year. Teacher B, was also changing from "not being observed" to have constructivist teaching in school teaching experience to showing some signs of constructivist teaching in beginning teaching. However, Teacher F, though having a rating of 'slightly observed' constructivist teaching at micro-teaching, was found to have fewer signs of constructivist teaching throughout his teaching in school teaching experience and beginning teaching year. The analysis of Teacher F's teaching in Stage 2 and 3 showed that he had adopted a rather teacher-centered teaching approach with much input from the teacher in his teaching.

The nine beginning teachers' teaching performance in different areas was compared with their performance in the two previous stages (Table 4) in order to offer a meaningful analysis of teachers' change in their enactment of constructivist teaching. Quantitative data analysis with SPSS paired t-tests was conducted with each of the features of the constructivist teaching in school teaching experience and beginning teaching. The results of this analysis are shown below.

Use of pupils' existing knowledge to guide teaching: Minimal change in performance

Though there were apparent changes in every feature of this area, they were not statistically significant. Student teachers were able to make new ideas accessible to pupils, eliciting ideas before presenting the teachers' own and were aware of the pupils' existing ideas. However, student teachers still seldom challenged pupils' initial ideas.

Guiding pupils to generate explanations and alternatives: Minimal change in performance

Change was evident in this area. Student teachers were, however, increasingly guided pupils to describe phenomenon ($t = 2.24^*$, $df = 19$). As in Stage 1, there were occasions for student teachers to guide pupils to observe phenomenon, but there were still limited probing of pupils' responses for clarification. Moreover, it was still very uncommon to have student teachers ask pupils to explain contradictions and misconceptions.

Asking incisive questions: Minimal change in performance

No overall statistically significant change was evident in this area. Nevertheless, student teachers provided more questions based on pupils' responses ($t = 2.45^*$, $df = 19$), as well as to accept and value pupils' answers and suggestions ($t = 2.85^*$, $df = 19$). But most student teachers still did not guide pupils to expand on the questions and justify their responses accordingly.

Choosing materials and activities for pupils to test ideas: Minimal change in performance

No obvious change was evident in this area, and most of the student teachers were still not performing well in this area. There were not many opportunities for pupils to work with materials and activities, even less than that in microteaching. Pupils were seldom engaged in scientific enquiry. Pupils also did not have the chance to put their ideas to the test nor to suggest a direction for their activities. Even when there were activities, they needed help from their teachers.

Providing a classroom atmosphere conducive to discussion: Not much change in performance

No apparent change was observed in this area. Pupils could sometimes put forward and discuss their ideas with the teacher, but it was rare to have pupils discuss ideas among themselves.

Providing opportunities for pupils to utilize new ideas: Not much change in performance

No change was found in this area. Student teachers were not frequently observed to be able to relate current teaching points to previous knowledge. It was not obvious for the student teachers to provide opportunities for pupils to apply knowledge to new situations or real-life. However, a significant correlation ($r = .64^*$) was found in this aspect of teaching performance in the two stages of the study, showing that student teachers were fairly consistent over time.

To summarize, among the twenty student teachers' teaching in their school teaching experience, three of them (B, F and R) had a few signs of constructivist teaching during their school teaching experience (with rating less than 0.5). The majority, fourteen student teachers performed at slightly agreed constructivist teaching (with rating higher than 0.5 but less than 1.5). Three others (Teachers P, U and Y) performed at agreed constructivist teaching (with rating between 1.5 and 2.5). None of the student teachers performed at a strongly agreed constructivist way during school teaching experience at their 2nd year of teacher education. The average rating of the teaching was 1.00 (the 'slightly agree' level), which did not differ significantly to their performance, a rating of 0.89 in the early stage of the study.

During school experience, it was apparent that the major strategies employed by the student teachers that were observed to have constructivist teaching in these two stages of the study mainly rested on: eliciting pupils' prior ideas and understanding of new ideas; engaging pupils in observing and describing phenomenon; questioning pupils' understanding and discussing the relation of current teaching points to pupils' previous knowledge. Detailed analysis found that most student teachers' teaching was only improving in the area of "devise incisive questions". No obvious change was shown in other areas but with individual features like "guide pupils to describe phenomenon", "with questions based on pupils' response" and "accept and value pupils' answers and suggestions".

Changes in beginning teachers' enactment of constructivist teaching

The beginning teachers were again rated according to the twenty-two features of constructivist teaching. Quite an encouraging performance was found among most of the remaining nine beginning teachers. Though none of them performed at a 'strongly agreed' level of constructivist teaching, six (Teachers I, L, P, S, X and Y) performed closely to an 'agreed level' of constructivist teaching (with a rating between 1.5 and 2.0); two (Teachers B and N) were observed to have slightly agreed constructivist teaching (with a rating between 0.5 and 1.5). Only Teacher F with a rating of 0.41 showed very few signs of constructivist teaching.

There was a statistically significant correlation between performance of constructivist teaching throughout the different stages of the study: Stage 1 with Stage 3 (r = .64*) and Stage 2 with Stage 3 (r = .76*). This indicated that those nine teachers who used constructivist methods more at the early stage of teacher education and school teaching experience were also rated more highly in this respect at their beginning teaching year.

Teachers' performance of constructivist teaching changed from an average rating of 0.84 in micro-teaching, to 1.00 during school teaching experience, and to 1.39 during the first year of teaching. A significant increase in performance was found in Stage 1 and Stage 3 (t = 2.90*, df = 8) which showed an overall shift of teachers' performance from the earliest stage of teacher education to beginning teaching.

Teachers P and Y remained at an 'agreed' constructivist teaching performance at this stage of study from school teaching experience. Teacher N maintained a few signs of constructivist teaching in the three stages of the study. Four other teachers (Teachers I, L, S and X) showed a change in their teaching, from a "slightly agreed" constructivist teaching to "agreed constructivist teaching" in their beginning teaching year. Teacher B, was also changing from "not being observed" to have constructivist teaching in school teaching experience to showing some signs of constructivist teaching in beginning teaching. However, Teacher F, though having a rating of 'slightly observed' constructivist teaching at micro-teaching, was found to have fewer signs of constructivist teaching throughout his teaching in school teaching experience and beginning teaching year. The analysis of Teacher F's teaching in Stage 2 and 3 showed that he had adopted a rather teacher-centered teaching approach with much input from the teacher in his teaching.

The nine beginning teachers' teaching performance in different areas was compared with their performance in the two previous stages (Table 4) in order to offer a meaningful analysis of teachers' change in their enactment of constructivist teaching. Quantitative data analysis with SPSS paired t-tests was conducted with each of the features of the constructivist teaching in school teaching experience and beginning teaching. The results of this analysis are shown below.

1. *Using pupils' existing knowledge to guide teaching: change in performance*
   Obvious change was shown in some features of this area, beginning teachers were more aware of pupils' existing ideas (t = 2.45*, df = 8), and were more able to make new ideas accessible to pupils (t = 3.16*, df = 8) in the beginning teaching year. In addition, there was substantial correlation (r = 0.82*) between the performance in Stage 2 and 3 with the feature "making new ideas accessible to pupils". This suggested that teachers who were more able to guide pupils' learning

of new ideas during school teaching experience had the same performance in the beginning teaching year.

2. *Guiding pupils to generate explanations and alternatives: minimal change in performance*
   No great advancement was shown in this area. Only a small change was identified in one item of this area. Beginning teachers were more capable of providing opportunities for pupils to generate explanations and interpretations. It was very uncommon to have pupils explain contradictions and misconceptions.

3. *Devising incisive questions: change in performance*
   Apparent change was shown in this area (t = 2.31*, df = 8). Student teachers were more able to provide a question-rich environment (t = 2.83*, df = 8), and to accept and value pupils' answers and suggestions (t = 2.53*, df = 8). There was also evidence of consistency (r = .69*) in teachers' performance to accept and value pupils' answers and suggestions between Stage 2 and 3 of the study.

4. *Choosing materials and activities for pupils to test ideas: change in performance*
   Though most of the student teachers were still not performing well in most of the features of this area, significant change was found (t = 3.10*, df = 8), especially with the three features "pupils work with materials and activities" (t = 2.83*, df = 8), "Minimal help from the teacher" and "pupils to put their ideas to the test" (t = 2.53*, df = 8).

5. *Providing a classroom atmosphere conducive to discussion: Minimal change in performance*
   No apparent change was observed in this area. Pupils could sometimes put forward and discuss their ideas with the teacher, but it was uncommon to have the pupils discuss ideas among themselves.

6. *Providing opportunities for pupils to utilize new ideas: change in performance*
   Significant progression was found in this area (t = 2.86*, df = 8). Student teachers were more able to relate current teaching points to previous knowledge and to provide opportunities for pupils to apply knowledge to new situations or real-life.

Compared with the teaching performance in micro-teaching and in school teaching experience, though more beginning teachers' (two-thirds) performance was approaching the agreed constructivist teaching level (with ratings higher than 1.5 but less than 2.0), none of them were given teaching performance ratings of 2 or over. This suggested that there was still room for improvement for the beginning teachers towards becoming more constructivist teachers.

Table 4. Teaching performance of the nine teachers in the three stages of study

Features of Constructivist Teaching		Teaching Performance (Mean)			
		Micro-teaching (Stage 1)	School teaching experience (Stage 2)	Beginning teaching (Stage 3)	Changes in Stages 2-3
		9 teachers			
1.	**Use pupils' existing knowledge to guide teaching**	**1.36**	**1.36**	**1.92**	
1.1	teacher's awareness of pupils' existing ideas	1.22	1.11	2.11	↑*
1.2	elicit pupils' ideas before presenting teacher's own	1.33	1.56	1.78	-
1.3	challenge pupils' initial ideas	1.11	0.78	1.22	-
1.4	make new ideas accessible to pupils	1.78	2	2.56	↑*
2.	**Guide pupils to generate explanations and alternative**	**0.98**	**1.16**	**1.47**	**-**
2.1	pupils observe phenomenon	1.78	1.78	2.11	-
2.2	pupils describe phenomenon	1.56	1.89	2.11	-
2.3	pupils generate explanations and interpretations	0.56	1.11	1.56	-
2.4	probe pupils' responses for clarification and justifications	0.78	0.89	1.22	-
2.5	pupils explain contradictions and misconceptions	0.22	0.11	0.33	-
3.	**Devise incisive questions**	**1.14**	**1.39**	**1.75**	**↑***
3.1	a question-rich learning environment	1.44	1.67	2.33	↑*
3.2	questions based on pupils' responses	1.33	1.78	1.78	-

3.3	pupils expand on their questions and justify their responses	0.67	0.56	0.89	-
3.4	accept and value pupils' answers and suggestions	1.11	1.56	2.00	↑*
4.	**Choose materials and activities for pupils to test ideas**	**0.51**	**0.4**	**0.80**	**↑***
4.1	pupils work with materials and activities	1.44	0.78	1.44	*
4.2	pupils engage in scientific inquiry	0.22	0.56	0.89	-
4.3	minimal help from the teacher	0.33	0.33	0.78	↑*
4.4	pupils put their ideas to test	0.56	0.22	0.67	
4.5	pupils' suggestion about the direction of the activity	0.00	0.11	0.22	-
5.	**Provide a classroom atmosphere conducive to discussion**	**0.89**	**0.84**	**0.78**	**-**
5.1	pupils put forward and discuss ideas with the teacher	1.00	0.78	1.00	-
5.2	pupils put forward and discuss ideas with peers	0.78	0.89	0.56	-
6	**Provide opportunities for pupils to utilize new ideas**	**1.11**	**1.00**	**1.56**	**↑***
6.1	Relate current teaching points to previous knowledge	1.11	1.22	1.78	-
6.2	Pupils apply knowledge to new situations or real-life problem	1.11	0.78	1.33	-
Mean		**1.00**	**1.17**	**1.39**	

↑Change in performance with 0.05 level of significance

* P< .05

- Not much change in performance

Conclusion

There have been ongoing calls for constructivist teaching based on the construcivist views of learning during the past decade. The reason of such advocacy is as a result of the search for better ways of teaching and learning because both researchers and teachers have noted persistent shortfalls in learners' understanding and of passive approaches to learning across all ages and grades (Gardner, 1991). There are philosophical and psychological arguments to support constructivist educational practices (Perkins, 1999). Philopsophically, the individual has to construct or reconstruct what things mean because the stimuli we encouter are never logically sufficient to convey the message. Psychologically, research shows that active engagement in learning may lead to better retention, understanding and active use of knowledge.

However, constructivisit teaching practices often require more time than do traditional educational practices and constructivist learning experiences can exert high cognitive demands on learners (Perkins, 1999). Wilson (2000) claimed that "learning is not the goal in many classrooms and the emphasis is on time on task", there is pressure on teachers from the bulky curriculum, tight schedule, expectations of parents and diversity of learners. More direct teaching strategies and text-book bound teaching seem to be an easier way to go.

Recognizing the teaching and learning in Hong Kong primary classrooms portrayed by the Education Department (Education Commission, 1994, p.8) in recent years as "…teachers in general adopted the teacher-demonstration approach in classroom teaching…" and "teacher still assigned class work…. after they had delivered their expository teaching" and "some teachers were too textbound" (Education Commission, 1994, paragraphs 1(2), 2(6), 3(8)), the findings of present study showed that there was a gradual shift of constructivist teaching among teachers throughout the longitudinal study.

From the lesson observations conducted with the student teachers once a year throughout the three years of the study, there was evidence that teachers were developing in their use of constructivist teaching. During microteaching, constructivist teaching among the twenty-five student teachers was uncommon. During the school teaching experience, the twenty teachers' teaching was improving slightly, with 15% performed at agreed constructivist teaching, the majority were still at the slightly agreed constructivist teaching. The other 15% were observed to have only few signs of constructivist teaching in this stage of study. The major strategies employed by the student teachers that were observed to have constructivist teaching were mainly:

eliciting pupils' prior ideas and understanding of new ideas; engaging pupils in observing and describing phenomenon; questioning pupils' understanding and discussing the relation of current teaching points to pupils' previous knowledge. In the beginning teaching year, again a slight increase in teaching performance was observed among the nine beginning teachers remaining in the study. Still none of the beginning teachers performed at a 'strongly agreed' level of constructivist teaching, six teachers (67%) performed closely to an 'agreed level' of constructivist teaching were observed to have slightly agreed constructivist teaching. Only one (11%) beginning teacher who showed very few signs of constructivist teaching. The major observations with teachers' constructivist teaching were mainly their ability to make ideas accessible to pupils, teachers' awareness of pupils' existing ideas, facilitating pupils to observe and describe phenomena, providing a question-rich environment, as well as accepting and valuing pupils' answers and suggestions.

Across the early stage of their teaching, student teachers' seemed to value pupils' own ideas and existing knowledge, and acted as facilitators for pupils to construct knowledge. Besides, student teachers were able to provide a question-rich learning environment and to make new ideas accessible to pupils. Furthermore, teachers were also able to guide pupils to observe and describe phenomena with questions, and they often showed acceptance and valued pupils' answers. There was no problem for teachers to elicit pupils' ideas before presenting their own, to provide opportunities for pupils to utilize new ideas by relating to pupils' previous knowledge and applying to real-life, and to allow pupils to give explanations after the descriptions. But some teachers were more eager than others to give their own explanations, especially when one or two pupils made unclear descriptions or explanations. However, there was not much opportunity provided for pupils by their teachers to work with materials and activities, and teachers seldom challenged pupils' initial ideas and probed pupils' responses for clarification and justification. Besides, it was infrequent for pupils to suggest about direction of the activity, to discuss ideas with peers and to explain contradictions and misconceptions.

A few teachers in the study were found to have difficulty to construct what was regarded as a proper science lesson. They often fell back on using worksheets or workbooks in which the pupils had to do something in class, an activity that they claimed to have involved pupils in learning. Workbooks supplied with published curriculum series tended to emphasize low-level memory tasks and isolated skills practice (Osborne, 1984), which makes it difficult for pupils to achieve meaningful learning. It was stated by Morris (1995) that the textbook, along with its associated workbook, is a major influence on the pedagogy used. The use of a textbook does not provide pupils with the opportunities to work together or to share ideas and information freely with one another (So, Tang & Ng, 2000). Though there has been improvement in the worksheets provided by the textbook publishers, the use of worksheets/workbooks as the only teaching/learning activity reflects that, these few teachers were sometimes managing activities in classroom rather than teaching as a subject expert in subject matter and the associated pedagogy.

Though some student teachers were developing a more constructivist view of teaching and learning, a few of them did not change in the learner-centered direction, but towards a more teacher-centered view. Hence, there is a need for developing more powerful teacher education, with more emphasis on pupil-centered learning and with dissemination of research evidences on effective constructivist teaching, to help teachers develop a more sophisticated understanding of how pupils learn and extend their understanding to teaching practices that support pupils' active learning. And most importantly, to address the influences of textbooks and worksheets on constructivist teaching to prepare teachers to a more proper use of textbook in their teaching.

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