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Advancing Pupils within the Motivational Zone of Proximal Development: A Case Study in Science Teaching

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Abstract

This case study describes an instructional approach that may be useful in inquiry-based science classes. It involves adopting a particular discourse orientation that aims at helping pupils value their science learning. The contextual descriptions and interpretation presented can help teachers form images of classroom practices that will be conducive to developing pupils' confidence in learning how to do science. The paper reaffirms the value of a synergy between the cognitive and affective domains in optimising pupils' learning of science.

Key Words: affective domain, classroom discourse, inquiry-based science classes, pupils' confidence, zone of proximal development

Most research studies in science education address the cognitive domain and only a few the affective domain. As pointed out by Watts and Alsop (2000), to ignore the affective domain is to exclude consideration of a seminal part of the learning that takes place in science learning. Earlier, Pintrich, Marx, and Boyle (1993) criticised the conceptual change model of science learning as a cold model which ought to be expanded into a hot model that also takes into account learners' motivational factors. It appears that these calls for more emphasis to be placed on affective aspects have not been met adequately. This paper is a response to the above calls. In this paper, we will describe an instructional approach that appears to be useful in inquiry-based science classes. It involves adopting a particular discourse orientation that aims at enhancing not only pupils' cognitive abilities in learning science through inquiry but also empowering them with the motivation and confidence to do so. The significance of this study is apparent since recent reforms in science education stress the importance of inquiry as a key aspect of teaching and learning science (National Research Council, 1996).

Research on Pupils' Learning Motivation

Among the plethora of variables that affect the social and emotional context in which the learning task is located, the relationship between the teacher and pupils is believed to be a major factor (Frymier & Houser, 2000). In terms of expectancy-value theory (e.g., Porter & Lawler, 1968), we can say that a successful learner must value the task, whilst at the same time believing that s/he can succeed at the task. Specifically in the field of science education, Baird and Penna (1996) and Pintrich (1999) have demonstrated that an important aspect of motivation is pupils' beliefs about their capability to accomplish the task. In the context of learning science as an inquiry, it is clear that success will be dependent on learners' skills as well as the confidence they have in using the "research methods" of thinking (hypothesis testing, gathering evidence, considering alternative arguments, etc.) to construct their own scientific knowledge.

Brophy (1999) found that even the best developed lines of theory and research on motivation in education are insufficient for explaining how learners may come to value particular learning domains or activities or how teachers might stimulate the development of such value. Drawing on Vygotsky's (1978) cognitive zone of proximal development (ZPD), Brophy developed the idea of motivational ZPD. ZPD is a central concept in Vygotsky's genetic theory of human development. It is defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). In the context of instruction, ZPD determines the lower and upper bounds of the zone within which instruction should be pitched. According to Vygotsky, instruction is only useful when it moves ahead of a child's development and provides activities that enable the child to rise above himself but are not beyond his capability. On the affective side, Brophy (1999) contends that the features of a learning domain or activity must gear up with the learner's prior knowledge and experiences in such a way as to stimulate interest in pursuing the learning. This would occur when the domain or activity is familiar enough to the learner to be recognisable as a learning opportunity and attractive enough to interest the learner in pursuing it. It would not occur if the activity were overly familiar to the point that the learner had become satiated with it, if it were so unfamiliar that the learner could not understand or appreciate its potential value, or if the learner's prior experiences with it had been unrewarding.

To complement this notion of optimal match, Brophy believes that motivationally effective classroom teachers can help learners begin to see the value in potential learning opportunities that they have not yet come to appreciate on their own. He suggests that teachers can induce and nurture the development in pupils the intrinsic motivation to learn by socialising mechanisms during instruction. Three powerful socialising mechanisms are suggested, namely: (1) modelling, (2) coaching, and (3) scaffolding. Table 1 summarises the main features of Brophy's model of motivationally effective classroom practices.

According to Brophy, from a motivational standpoint, modelling of engagement in a learning activity would communicate not just the strategies used to accomplish a task but also the thoughts and feelings involved in savoring the experience and enjoying the aesthetic satisfaction that it offers. In addition, appreciation-oriented coaching, apart from giving hints and cues to guide pupils' task responses, should convey

Table 1
Brophy's Model of Motivationally Effective Classroom Practices.

	Cognitive domain	Affective domain
Modelling	• Modelling the *cognitive strategies* needed to accomplish a task.	• Communicating *teacher's thoughts and feelings* involved in savoring the experience and enjoying the aesthetic satisfaction that the activity offers.
Coaching	• Giving *hints* and *cues* to help pupils accomplish a task.	• Conveying *teacher's enthusiasm* for the activity. • Helping *pupils to experience* the satisfactions that the activity offers. • Stimulating *pupils' appreciation* of the nature and progress of their learning.
Scaffolding	• Gradually transferring *responsibilities* for managing the *cognitive aspects* of a task to the pupils as they acquire the capacities for doing so.	• Developing *pupils' capacities* for *valuing* and deriving satisfactions from the learning domain or activity as they go along.

enthusiasm for the activity, help pupils to experience the satisfactions that it offers, and stimulate appreciation of the nature and progress of their learning. Likewise, motivational scaffolding should include developing learners' capacities for valuing and deriving satisfactions from the learning domain or activity. This means gradually transferring responsibility for managing these motivational aspects of task engagement to the learners as they acquire the capacities for doing so. This can be achieved by drawing pupils' attention to aspects of the learning experience from which they can take satisfaction, and providing feedback that stimulates pupils not only to recognize but also to appreciate their developing expertise. Such appreciation-oriented feedback provides not just knowledge of results but also commentary on noteworthy qualitative features of the learners' responses or accomplishments, especially features that suggest developing interests or talents that might be pursued further. These and related forms of scaffolding help communicate in subtle or explicit ways the notion that the learner not only is doing something worthwhile but doing it in ways that represent seriousness of purpose, growth in knowledge, aesthetic qualities that reflect the learner's individuality, and so on.

Brophy (1999) contends that even those aspects of the school curriculum that are regarded as well worth learning may not be valued as such by pupils unless their exposure to them is designed to connect with their motivational ZPDs and is mediated in ways that scaffold not only their learning but their appreciation of what they learn. Noticing that many secondary pupils do not feel challenged by the science they learn in schools, Baird and Penna (1996) see also the need of prioritising the affective in science learning (Hodson, 1998). However, it leaves us with the question: How can the motivationally effective practices be enacted in real classroom settings? This paper attempts to report and to analyse a science classroom discourse using the above theoretical lens. This attempt can also be seen as a response to the criticism that studies on pupils' motivation in relation to teachers' practices have long been done in the abstract, separated from the classroom context (e.g., Brophy, 1999; Turner, 2001).

The research reported here looks at how a science teacher helps advancing his pupils within their motivational ZPDs. We have drawn on the interpretive perspective of discourse analysis articulated by Hicks (1996) who also calls for more contextual inquiries. The notion of contextual inquiries in discourse analysis is in line with the call for embedding motivation research in the classroom context. For example, Turner's (2001, p. 89) concept of "motivation-in-context" assumes that motivation is an interactive experience, depending on the influences of pupils and their environments on each other, although different pupils will make different contributions and may also have different interpretations of the context. Environments, broadly defined, will include the teacher, pupils, activities, the content area, and the instructional discourse, as well as the norms and beliefs promoted or accepted by the participants. In brief, in this interpretive approach to discourse analysis, we will have to attend to all the impinging contextual variables that would have shaped the discourse and hence pupils' cognitive and affective learning.

Opportunities exist from time to time in a lesson for teachers to advance the pupils within their ZPDs if the teachers so wish. However, what counts as an effective practice in one situation may not be regarded as such in another. These practices are context-, time-, content- and participant-dependent and need to be observed as multiple occasions that are meaningfully linked over time. This study first attempts to locate instances of these kinds of motivationally oriented practices that were occurring within a lesson, and then to examine if these instances were meaningfully linked to each other during the course of the lesson. Overall, this study focuses on the contribution of the teacher, in terms of the particular scaffolding appreciation that was communicated to the pupils, in helping them to advance within their motivational ZPDs. There is a dearth of such studies in the literature, be it in science education or education in general.

Background and Context of the Study

The study reported here was part of a larger ethnographic study of science teaching in secondary schools in Hong Kong. The data used were taken from a year long observation of Mr L's Secondary 1 (Grade 7) Science class. We have known Mr L for more than 10 years in a professional capacity as supervisors of student teachers placed in his school and have come to learn of his skills and success in building up academically low achieving pupils' confidence to learn science.

In Hong Kong, pupils at the end of Primary 6 are segregated into five bands of ability and allocated into secondary schools on that basis through a complex system that takes into account internal assessment over two years of Mathematics, English and Chinese (plus other subjects with less weightings) which is moderated by an external Academic Aptitude Test to ensure comparability across schools. Consequently, student in-takes in most secondary schools are highly homogeneous with the more established and prestigious schools allocated high band pupils and the less prestigious ones low band pupils. The class observed in this study consisted of 40 pupils (20 boys and 20 girls) many of whom were low achievers of band 4 and 5.

The highly selective system does not stop at the primary level but extends to the entire secondary school. As a result, teaching is generally predominantly examination-oriented with relentless testing. A single inflexible academic curriculum is followed catering, in the main, for the high band pupils. The Chinese values and tradition, still predominant in Hong Kong schools, attribute academic success primarily to effort, rather than to both effort and ability as in the West (Salili, 1996), and low band pupils are blamed for putting in insufficient effort (Watkins & Biggs, 2001). In the classroom, teaching is generally expository and teacher-centred with pupils treated as passive learners, and praise is often withheld and criticism is frequent. Not surprisingly, the sense of failure, despair and boredom with school is prevalent among the low band pupils. This has given rise to many problems such as discipline, truancy, and drop-out (Salili, 2001).

The less established schools have to cope with a high concentration of low band pupils. Many adopt a policy of strict discipline and even more drills and tests to force pupils to work hard but this has not been successful in most cases (Salili, 2001). A few others adopt a more enlightened approach by adapting the curriculum, as far as possible, to the needs of the low band pupils, organising extra-curricular activities to give due recognition of their non-academic abilities, creating a warm classroom atmosphere with more praise and less criticism of pupils' work and various means to build up their confidence to learn, and so forth. Mr L was a science teacher and a deputy principal charged with the responsibility to implement and oversee such an approach in one of these schools. He was so well known for his work in dealing with low band pupils that he had been invited to appear on TV and radio programmes and give talks and seminars to teachers to promote the approach.

There were three science lessons per week for the class observed – two single lessons (45 minutes each) and one double lesson (90 minutes). Apart from the occasional lessons arranged in the computer laboratory where pupils accessed the Internet to search for some science content, the class met either in the classroom or the science laboratory. Inside the classroom, the dominant mode of instruction was by lecture, including extended segments of whole-class discussion. In the science laboratory, pupils were often given problems to solve. They were given opportunities to formulate their own hypotheses and design their own experiments which they then carried out in groups of four. The practical work often ended with a whole class discussion of the experimental results. Mr L's classroom practices were consistent with one of the curricular aims of recent reform in science education that promotes the practice of scientific inquiry by pupils.

Data Sources and Analysis

Over the observation period, all lessons were videotaped, field notes taken, and teacher and pupil artefacts collected. The field notes were used to note relevant interactions, suggest tentative assertions, raise questions for subsequent reflection and discussion within the research team, and identify particular pupils or groups of pupils who might be observed more closely or interviewed. They also became the major reference for narratives which we wrote to summarise our understandings of classroom events. The teacher and 20 pupils were interviewed formally towards the end of the academic year. These interviews were audiotaped. Apart from these, regular informal in-class discussions with Mr L were also noted.

The field notes were studied and videotapes replayed several times before choosing representative lesson segments for transcription and analysis. For the purposes of the present study, one lesson involving a whole class discussion that followed a practical lesson on changes in temperature of water upon heating was used to illustrate the assertions drawn from the interpretive process. This lesson was chosen not only because it featured discourses that were typical of Mr L's classroom but also because of the structural and logical integrity of the lesson itself (see section on the cognitive dimension of the lesson below). No generalisation of the finding(s) of this study to other settings is claimed. Instead, this particular lesson is chosen as a "telling" case (Mitchell, 1984) from the many lessons available for analysis. Mitchell argues for the validity of cases that tell heuristically, as distinct from other case study methodologies which proceed from the premise of typicality.

Instances of the teacher's attempts to cultivate in his pupils confidence and interest in learning how to do science were first analysed. Academic activity was transcribed (and translated) as discursive events to provide a particular inter-textual and inter-contextual representation of the frequency, order, and meaningful relationship among particular academic events. From these representations and meanings, part-whole analyses were made of the particular discourse interactions, that is, the discursive moves of the teacher to inculcate in his pupils the confidence and interest necessary for learning science as an inquiry.

The interpretive method described above guided emergent questions and theorisation. Tentative assertions were generated initially during the fieldwork phase and revised and modified after a more thorough search of the data. Regular debriefing meetings of the researchers provided foci for subsequent lesson observations and interviews, and provided opportunities to confirm or refute their assertions. Member checks (Guba & Lincoln, 1989) also provided the teacher with the opportunity to improve the authenticity of the results by confirming or suggesting alternative interpretations. At different stages of the study, Mr L was asked to confirm the interpretations that the research team had generated. He was also asked to comment on this article when the first draft was prepared. In addition, for the larger study, video of the lesson analysed was used in a lesson study seminar attended by science teachers and teacher educators. Mr L was present at the seminar; he did not disagree with the participants' interpretations which were broadly similar to many of those presented in this article.

In the following, the confidence building strategies that Mr L used at different phases of the lesson, and the progression of the strategies, were identified and analysed using Brophy's model of motivationally effective classroom practices, namely modelling, coaching and scaffolding.

A Lesson with Two Goals: Cognitive and Affective

The lesson described here constituted part of a series of lessons on learning how to do science through inquiry, and was the first time the pupils, fresh from primary school, had experienced hands-on practical work in science. The purposes were to provide them with the opportunity to acquaint themselves with the use of common equipment in the science laboratory as well as to learn various scientific process skills, including identifying the problem, formulating a hypothesis, designing and carrying out an experiment, interpreting the data and drawing conclusions. The lesson was near the end of the series where the teacher was trying to demonstrate to pupils how they could interpret the data collected in order to arrive at a conclusion for the problem under investigation. At the same time, he wanted to continue to inculcate in pupils the confidence of doing science. In other words, the lesson had a dual purpose: cognitive and affective.

The Cognitive Dimension: How to Climb One Step Further?

On the cognitive side, the teacher primarily aimed at developing in pupils the skills necessary for conducting scientific inquiry. In other words, the process of scientific inquiry and the skills involved were the content to be learned and not the scientific explanation of the phenomenon per se. However, the process of inquiry (and its associated skills) cannot be learned in a vacuum. It requires the teacher to interchange the foci of the lesson between the "goals for 'content' (i.e., scientific explanation of the phenomenon at hand)" and 'process' (i.e., understanding of the process of science and acquisition of the necessary skills). The teacher had to bring into the foreground whichever of these he wanted pupils to attend to at a particular time. Below is a brief description of the structure of the lesson.

Introduction

The teacher introduced pupils to the aim of the lesson – learning *how* to arrive at a scientific explanation/conclusion for a certain phenomenon based on observations made. The phenomenon was a question raised by one of the pupils during the last practical – 'Why didn't the temperature of boiling water rise beyond 100 °C?'

Development

The development of the lesson can be divided into the following five phases:

Phase 1: *What are the observations?*

Pupils were asked to report on their observations that were related to the phenomenon. The teacher recorded the observations on the blackboard.

Phase 2: *What are the relevant observations for answering the question?*

The teacher coached the class (by providing verbal cues) on how to assess the relative importance of each of the observations in relation to their contribution to answering the question.

Phase 3: *What inferences can be made of the relevant observations?*

Under the guidance of the teacher, pupils made inference of each of the relevant observations in relation to arriving at a scientific explanation of the phenomenon.

Phase 4: *How the various inferences can be put into a coherent whole to explain the phenomenon?*

Under the guidance of the teacher, pupils re-organised the information into a coherent explanation of the phenomenon.

Phase 5: *How should the explanation for the phenomenon be put down in written form?*

The teacher requested pupils to write down the explanations in their own words and in whatever format they liked.

Summary

The teacher reiterated the importance of knowing how to analyse the collected data in order to solve the problem (i.e., to draw a conclusion).

The structure of this lesson was judged by three independent science teacher educators not involved in this study as a good instructional design with the key questions organised in a logical sequence. Pupils were taken through the lesson step by step, with their attention focused on only one aspect at each step but drawing on their experience from the previous step.

The Affective Dimension: How Much Does the Textbook Cost You?

The affective aim was to inculcate in the pupils the confidence necessary for learning how to do science. Mr L was conscious of this throughout the lesson; as he put it in the post-lesson interview:

> If you observe the young children closely, you will find that they have an innate ability in problem solving. But once they come to the school, their confidence in this area seems to be vanishing rapidly. I think we need to give them more training in this respect in order to restore their confidence in learning science. That's why I'm making use of every opportunity to do so.

Mr L was making the above remark in relation to the nature of his pupils who were mostly academic low achievers. According to him, they were generally unmotivated, had a very short attention span, had low self esteem and lacked confidence in their academic studies. Their general perception that science was one of the most difficult subjects in school added further to the problem. In all, these pupils did not see themselves as capable learners of school science. Mr L was therefore faced with the task of simultaneously motivating the pupils and helping them to complete the task, i.e. to search for a coherent scientific explanation of the phenomenon based on the inferences made from observational data.

We return to the lesson with an affective perspective. In the extracts shown below, T stands for the teacher, S stands for pupil, and S/T stands for teacher and pupil speaking together. [. . .] indicates a brief pause of about one second. A pause of duration longer than two seconds is counted as a separate turn. Three dots . . . indicate omitted utterance. The same italicised headings for the different parts of the lesson are used as in the cognitive dimension.

Introduction

The teacher (T) introduced the lesson in the following way:

14 T: . . . Today, I'm going to teach you something new . . . If you learn this, your ability in (scientific) inquiry will climb a step further. How to climb one step further?

15 T: What have you learned so far? . . . You have learned how to ask questions, right? You have learned how to formulate a hypothesis. You have learned how to design an experiment. Then, you have carried out some experiments, right? Last time, we kept heating up the water. And then, you drew a graph (changes in temperature with time) [. . .] But after doing all these things, at the end, we would like to find out [. . .] the answer of a certain question. Right?

16 T: There's one thing which is very important. In a football match, no matter how well you play in the game, if you can't get the ball into the net, [. . .] not even at the 12-yard spot, then all of what you have done is useless. So, the important thing that I am going to teach you now is what you should do in front of the goal.

17 T: I want to teach you a technique which no one has ever thought that it's so powerful. As long as we calm down ourselves and collect some evidence, even if we don't read the textbooks, we can still find out what is happening. Can you do that?

18 S1: No, we can't do that.

19 T: You can't do that at this moment. But there are techniques for doing it, right? We need to grasp the techniques. What are the techniques?

In line 14, instead of telling the class the objective of the lesson up-front, the teacher told the pupils that he was about to teach them "something new" which would enable them to "climb a step further" in their abilities to carry out scientific inquiry. In so doing, from class observation it appears that he was able to sustain pupils' curiosity to find out what was that further step. In saying that pupils' "ability in inquiry will climb a step further," the teacher was communicating to the class his thoughts and feelings of the kind of satisfactions pupils could possibly derive from the task. In other words, he was practising what Brophy calls appreciation-oriented modelling for the first time in the lesson.

In line 16, the teacher reiterated the satisfaction that could be derived from learning by equating it to scoring a goal in a soccer match. In line 17, he went on to convince the pupils that what he was going to teach them was "a technique which no one has ever thought that it's so powerful." In all these instances, Mr L was trying to communicate to his pupils the importance of present learning to their future learning. All these are examples of appreciation-oriented modelling practices.

After communicating the significance of the learning to the pupils, the teacher then reminded pupils of the question, "Why did temperature of the boiling water stop rising beyond 100 °C despite constant heating?" Instead of telling pupils the answer directly, he invited pupils to find out the answer for themselves by making inferences based on the observations they had made during the practical session.

22 T: First, let's look at the whole thing again and recall what we had done in the last lesson, ok? [. . .] This time, I'll do this with you. Next time, you'll do this on your own . . . This is very important. I'll be very proud of you if you can do this.

In saying "This is very important. I'll be very proud of you if you can do this." (line 22), the teacher was again practicing appreciation-oriented modelling. In addition, he was helping pupils to develop a positive expectation for successful achievement. This was especially important for these pupils who had been labelled as academic low achievers.

Development – Phase 1 (What are the observations?)

The teacher then drew on the blackboard a table with two blank columns headed 'observation' and 'inference' respectively. After that, he continued with the lesson:

25 T: What did you observe?

26 S2: A Bunsen flame.

27 T: You saw that there was a Bunsen flame (the class laughed).

28 T: Don't laugh 'cause each point is very important.

Table 2
A Summary of the Teacher's Responses to Pupils' Reported Observations.

Observation reported by pupil	Teacher's response
A Bunsen flame was used to heat up water.	Don't laugh 'cause each point is very important.
Water temperature rose and then remained stable at 100 °C.	This is starting to test your IQ now. Whether a person has a sophisticated mind or not depends on whether he can make careful observations.
The volume of water became less and less . . .	Hey, this information is very important, no kidding. You'll not be able to answer the question if you did not make such an observation.
There was water vapour rising up.	Wow [. . .] great. Wonderful!
There were air bubbles (coming up).	Wow, really great . . . So incredible!

After confirming with the pupil, the teacher recorded the observation in the table drawn on the blackboard. He then asked the class to report to him other observations they made yesterday during the practical. The lesson moved on in a manner similar to that of the above episode but the remarks he made in response to each reported observation were different. Table 2 gives a summary of the verbatim responses made by the teacher in response to each of the pupils' reported observations.

In each of the above instances, the teacher was once again modelling his appreciation of the observations made by the pupils. Not only did the pupils receive encouragement from the teacher in each case but there was also an observable trend of the teacher escalating his appreciation of the pupils' contribution from "don't laugh 'cause each point is very important" to "so incredible." Mr L's spontaneous expression of admiration of his pupils' observations appears to have encouraged pupil motivation. The class began to volunteer their ideas more frequently. One girl (S3) claimed that she saw "heat coming out from the boiling water" and after being prompted by the teacher, clarified that what she saw was "something like a mirage." The dialogue developed as follows:

78 S3: I saw something like a mirage . . . you see . . .

79 T: Oh, I see. You saw that, through the steam, things were twisted, right?

80 S3: Yes.

81 T: That is, you observed something about the influence of the steam.

82 S3: Not steam. It was from the Bunsen flame.

83 T: That means something from the bottom. Can you draw it out?

84 S3: No, I don't know how to draw it.

85 S4: (A boy chipped in to challenge S3 in a rather rude manner) That means you didn't see it then.

86 T: First, please don't challenge her. She is just stating what she observed. Sometimes, people are very discouraging. Once there was a story. A child saw a chick come out from an egg. He was very happy and went to tell his teacher, 'Teacher, I saw a chick come out from the egg.' The teacher replied, in an uninterested manner, 'Of course, chicks are hatched from eggs.' How snubbing this is ... With the child feeling so excited about his observation, the teacher could have asked if he knew the process of changing from an egg to a chick and asked him to find it out. But instead, the teacher said, 'It's no big deal at all.' So snubbing it is! Therefore when she says something (be it right or wrong), I don't want you to hurt her. Don't pass any judgment so quickly ... ok?

In telling a story to the pupils (line 86), Mr L was making use of this opportunity to model to his pupils the importance of respecting what others say. While he was telling the story, he showed how he wanted the class to work – "Don't pass any judgment so quickly ... ok?" As revealed in the post-lesson interview, Mr L was keen to create a classroom atmosphere where every opinion would be treated in a respectful manner. He considered this to be very important because he wanted to establish a supportive learning community amongst the pupils, as he said in the post-lesson interview:

When we treat one another with greater respect, trust develops. When a trusting and caring relationship develops, a safe learning environment is created. In a safe learning environment, pupils find it much easier to ask stupid questions, to make stupid comments or to ask for feedback and clarification. Often, such questions or comments can make the difference between confusion and enlightenment in pupils. Conversely, when pupils feel threatened, or feel that they are not valued, they will withdraw from participating in the lesson ... For me, 'building up a person' is the most important.

Development – Phase 2 (What are the relevant observations?)

When no more observations were forthcoming, Mr L referred pupils to the blackboard. He re-visited and evaluated each observation that had been jotted on the blackboard. He did this in a very skilful manner by evaluating the observations listed on the blackboard rather than the performance of the pupils who reported those observations. Table 3 gives a summary of the differences in Mr L's responses to the same observations on the two occasions. This is an example of Brophy's (1999) coaching mode (see Table 1) in which pupils were provided with cues on the relative importance of each observation.

It is the shift of emphasis from "child as focus" to "observation as focus" that allows Mr L to objectively evaluate the observations without undermining the confidence he has built up in the pupils. A note of caution needs to be registered here. The use of frequent praise in response to fairly minimal correct responses can be counterproductive (Brophy, 1999), but it is difficult to determine how "frequent" is frequent. The answer depends to some extent on the nature of the pupils. Teachers

Table 3
Teacher Responses to the Same Observations on Different Occasions.

Reported observation	Teacher response	
	1st time (to the pupil)	2nd time (to ideas presented on the board)
A Bunsen flame was used to heat up water.	Don't laugh 'cause each point is very important.	It is not surprising to observe this unless you're blind.
Water temperature rose and then remained stable at 100 °C.	Starting to test your IQ now. Whether a person has a sophisticated mind or not depends on whether he can make careful observations.	It is not surprising to observe this. We all know that.
The volume of water became less and less . . . There was water vapour rising up.	This information is very important, no kidding . . . Wow . . . great. Wonderful.	That's very incredible.
There were air bubbles (coming up).	Wow, really great . . . So incredible.	That's very incredible too. Because an average person can't possibly make such detailed observation.

need to exercise their professional judgement here. It also raises the important question of the extent to which teachers' affective competencies can be trained. It should be noted that in studies on teachers' performance feedback, Salili (2001) found that Hong Kong Chinese secondary school pupils perceived praise or neutral feedback for success as an indication of high ability whereas their counterparts in the West may perceive such as an indication of low ability. In line with the cultural belief, Chinese pupils attribute ability to effort, that is by studying hard and gaining knowledge one's ability can be increased. Thus praise or reward for hard work and good performance can enhance pupils' perception of ability and self-competence and this appears to work well in the Hong Kong situation.

To sum up, in this phase of the lesson, the teacher coached pupils cognitively by providing them with cues on what were the more relevant observations in relation to the problem; simultaneously, on the affective side, he conveyed to pupils his enthusiasm for the activity, helping pupils to experience the satisfactions that the activity offered, and stimulating pupils' appreciation of the nature and progress of their learning (see Table 1).

Development – Phase 3 (What are the inferences?)

Having established the relative importance of each reported observations, the teacher then moved the lesson into its next phase by saying, "It's more important now to ask what's happening to everything we observed. Why was it like that, ok? First of all, why was a Bunsen flame used?" As the lesson moved on, the teacher was coaching the pupils to formulate their own answer to the question at hand. Prompting and probing questions as well as confidence building remarks from the teacher were common features during this phase of the class discussion:

133 T: . . . Try to think carefully . . . To boil the water? What do you mean?

150 T: Ok . . . err . . . you observed the bubbles rushing out. What does this mean?

158 T: But it has a deeper meaning. You said that, not me. Because of what?

170 T: What does evaporation mean? So, let me teach you one thing. You must know what you're talking about. What does evaporation mean? . . . Who is brave enough to tell us the meaning of evaporation? (Identify a pupil) Ok, you.

In this phase of the lesson, the teacher tried to gradually transfer the responsibilities for managing the cognitive aspects of the task to the pupils by urging them to think at greater depth wherever appropriate. At the same time, he was also trying to develop in pupils the capacities for valuing and deriving satisfaction from the learning activity as they went along. Motivational scaffolding remarks (see Table 1) used by the teacher for this purpose include "But it has a deeper meaning. You said that, not me." and "Who is brave enough to tell us . . . ," etc. Under the teacher's scaffolding instruction and encouragement, pupils' cognitive engagement with the task was getting more and more intense. For example, at times, intriguing questions like the following, were raised by pupils:

186 T: Eei, what did you say? You just said something meaningful.

187 S5: Does heat carry the water vapour away or it is the other way round?

188 Ss: (Pupils answered at the same time with mixed answers).

189 T: Wow, you're very thoughtful.

190 S6: Water vapour carries away the heat.

191 T: Really?
(Pupils were still talking about this question).

192 T: I don't want to (. . .) because this question is very meaningful. You remember this, you remember this, ok?

At the post-lesson interview Mr L admitted that, in the above episode, he did not want to deal with the intriguing question raised by the pupil immediately. He expected that the pupils would eventually arrive at the answer by logical reasoning (as indeed they did). Nevertheless, he wanted to acknowledge the pupil in such a way that he endorsed the question as academically meaningful and the pupil as a thoughtful thinker. Indeed, it is argued that only when Mr L had created a safe learning environment, were the pupils encouraged to ask intriguing questions. We argue that the teacher's motivational scaffolding feedback played a crucial part here. In saying words like "you just said something meaningful" and "wow, you're very thoughtful," the teacher was treating pupils as contributing, meaning-constructing members of a learning community rather than passive recipients of information. This is consistent with one of the goals of teaching science using the inquiry approach.

Development – Phase 4 (How to put the information together to form a coherent answer?)

With the encouragement and guidance of the teacher, the class did eventually jointly arrive at the answer to the question at hand (i.e., "Heat gained by water from the Bunsen flame equals that lost through the water vapour leaving the boiling water and hence the temperature does not rise beyond 100 °C"). Mr L then concluded this part of the activity in the following manner:

194 T: Can you now put these bits and pieces of information together to form a whole picture? Why did the temperature of boiling water stop rising beyond 100 °C? Now, we're getting in depth. You have got all the necessary background information (to answer the question). Although you may write a very simple sentence at the end, this sentence isn't simple at all because you don't get it by studying the textbook but by thinking hard. It's obtained through the information gathered from your observations. It's because of your seriousness in getting it. It's due to your very good teacher.

195 S7: Oh, really?

196 T: Is it not?

197 S8: Everything is true, except for the last one.

The humourous remark ("it's due to your very good teacher") made by the teacher (line 194) and the subsequent pupils' responses are reflections of the general warm atmosphere in this classroom. Through this humourous remark, not only did the teacher acknowledge pupils' contribution to the lesson ("because of your seriousness in getting it"), he also affirmed pupils' capabilities in doing science ("this sentence isn't simple at all because you don't get it by studying the textbook but by thinking hard"). Here, the teacher was linking the learning success to pupils' personal effort and ability – yet another kind of motivational scaffolding strategy. In addition, the teacher was also making a difference between learning science (i.e., by studying the textbook) and doing science (i.e., by thinking through the information gathered from observations). In other words, the teacher was practising different strategies that could contribute to advancing the pupils within both their cognitive and motivational ZPDs.

Development – Phase 5 (How to communicate the coherent whole in written form?)

Besides thinking skills, the teacher also emphasised the importance of training pupils' communication skills. This was reflected in how he introduced the next phase of the lesson to his pupils:

208 T: How to re-organise these bits and pieces of information to produce a coherent answer to the question is even more important. Can we put our view into words? How to do it?

209 T: With all the points (on the blackboard), if you have to present this, which point will you put down first? Which one will you put down first as to what has happened? . . . The order and the arrangement of ideas are very important when we write. (. . .) Sit down and think first. Should I do the first one for you first? Ok?

Upon moving into this new phase of the lesson – reorganising the inference into a coherent whole to answer the problem at hand – the teacher tried to maintain pupils' engagement with the task by comparing its importance to that of the previous ones. For example, he said ". . . is even more important" (line 209). In all, he was once again practising appreciation-oriented modelling so as to keep pupils engaged in the next phase of the lesson where a new kind of skill or learning was anticipated. The lesson then moved on with the teacher covering each of the points written on the blackboard by responding to pupils' suggestions as to how the points should be organised in a logical sequence. At appropriate points, the teacher helped cultivating pupils' confidence through his motivational scaffolding feedback. One example was as follows:

253 T: Who said, 'rose up'? I'm sure that my ears heard someone said that . . . something meaningful. What was it?

After the class had jointly arrived at a coherent answer for the question, not only did the teacher show his appreciation to pupils' contribution to the lesson, he also tactfully acknowledged pupils as capable learners through his motivational scaffolding remarks. Examples of this sort include the following remarks he made when he was summarising the whole exercise for the pupils:

272 T: Then, do you find that actually you can clearly tackle some very complicated problems step by step?

273 T: You can refer it (the answer produced by the class as a whole) back to the textbook (to check out if we got the right answer or not).

274 T: How much does the textbook cost you? (It's just not worth buying it 'cause you can learn what is in it even without referring to it.)

At no point during the class discussion did the teacher or the pupils refer to the textbook to see what was already known. It was only after the teacher and the pupils had jointly produced an answer to the question that pupils were asked to refer back to the textbook to check what was in it. We believe that this, in itself, was a powerful way of telling pupils that they have the capabilities of doing science as well as communicating science to the same extent as that of a textbook author. The following excerpts from interviews with pupils held at the end of the academic year provide glimpses of how the pupils looked upon the role of textbook in their learning of science:

We won't just follow the textbooks . . . Mr L allowed us to use our own way to express the ideas. He allowed space for our creativity . . .

I like doing experiments . . . If you really try it out by yourself, and if it turns out to be the case, then I will believe it . . . Sometimes, textbooks are not accurate at all.

Other teachers rarely use activity-based teaching approach. They just follow the textbook and recite things . . . We didn't use the textbook at all. We had hands-on experience on things, not just reading the textbook.

We didn't just follow the textbook. We actually worked it through (by carrying out an experiment to find out the answer).

These comments contrast with the pupil who held a rather different perception regarding the role of the textbook in his science learning at the beginning of the year. This was the pupil (S1) who said "no, we can't do that" (line 18) in response to the teacher's question ". . . even though we don't read the textbook, we can still find out what is happening. Do you think you can do that?" (line 17). We interviewed this pupil at the end of the academic year and asked him if he could still remember why the boiling point of water did not go beyond 100 °C. Not only could he remember, but he was able to explain the phenomenon in terms of the particulate theory and energy content of the three states of matter. What surprised us even more was that he spontaneously suggested to us that the boiling point of water could go beyond 100 °C if steam is not allowed to escape from the system (like the case of boiling things in a pressure cooker) – a concept which the teacher had not taught. This is strong evidence that this particular pupil had advanced considerably within his cognitive ZPD. Evidence of improved motivational ZPD lies in his increased confidence in his capabilities of learning how to do science. He had also come to value science and wanted to purse further studies in the science field as he put it:

I think I would pursue further studies in the science field because I am interested in science . . . Sometimes I don't have to do any revision. I just need my brain to think about the concepts . . . Mr L said we wouldn't need to memorise the materials. He said the materials would be memorised automatically once we understood the concepts. Yes, he can make us understand the ideas without plainly memorising the concepts through his teaching.

This particular pupil further attributed his liking of science to the teacher's mediation via his modeling, coaching and scaffolding instruction. As he put it:

Mr L's lessons are entertaining. He has a sense of humor. He makes you feel warm. He is a forgiving person. He allows room for our creativity. I won't feel bored in the science lessons . . . If you don't understand, he would think of many experiments and stories (analogies) . . . He used many methods, like giving hints to help you understand the concepts. Also, we could draw diagrams if we didn't know how to express in words. Other teachers might not have done the same thing. He never feels fed up with us . . . He rarely scolds us.

Nevertheless, one of the pupils who were interviewed thought that Mr L should be more straightforward in dealing with misbehaviors in class and quickly go back to his teaching as she put it:

I think that he is quite good. I think that if he is really angry (with our misbehaviours), he can just spur it out loudly. Don't just do it at a snail's pace. He stops and thinks between sentences. I think that he is too cautious and too watchful . . . that is, not wanting to hurt others' feeling . . . and very considerate . . . he puts himself into others' shoes.

As pointed out by Op't Eynde, De Corte, and Verschaffel (2001) and Boekaerts (2001), emotions in the classroom are contextualised and unstable since they are based on pupils' unique continuous appraisals and interpretations of events as they unfold. This poses a huge problem for teachers, like Mr L, who have to teach a class of 40 pupils whose temperament, personalities, life histories and ZPDs vary considerably. Nevertheless even the pupil, who preferred Mr L to deal with discipline problems in a more straightforward manner, still appreciated his intention of not wanting to undermine pupils' self esteem.

Summary

In drawing a close to the lesson, the teacher reiterated the importance of what pupils had learned in this lesson – the way of doing science rather than the science concepts per se:

304 T: *We*'ll try this approach again for sure because this is just like an attempt of taking the '12 yards' (the penalty kick in soccer game). If you don't know how to analyse the data collected, then all the things you've done before are meaningless. We don't want this to happen, right? We don't want this to happen, right?

Here, once again, Mr L was making use of the analogy of taking a 12-yard penalty kick in a soccer game to remind pupils of the significance of the learning they just had. In repeating the following saying twice "We don't want this to happen, right? We don't want this to happen, right?" the teacher was reinforcing the importance of learning this process skill. In using the pronoun "we" instead of "you" he was also communicating to the pupils his enthusiasm and determination in helping them to come to grips with this important learning.

To sum up, the teacher had been providing pupils with motivational scaffolding feedback throughout the lesson, trying to develop their capacities for valuing and deriving satisfaction from the activity.

Discussion

Progressive Discourse

The lesson analysis above shows that the teacher seems to have succeeded in empowering his pupils with the confidence necessary for learning how to do science. This he accomplished both through his motivational scaffolding feedback, and by engaging them in a progressive discourse (Bereiter, 1994). The discourse is progressive because besides learning why the temperature of boiling water did not rise beyond 100 °C, the pupils also learned the procedural knowledge of how to analyse the data collected to solve the problem. Yet, the classroom discourse was very much directed and guided, if not dominated, by the teacher, and as such, is not conducive to developing what Lemke (1990) calls a "true dialogue" amongst the pupils themselves. However, it must be remembered that was the pupils' first practical work in school science, and it is understandable that the dialogue was dominated by teacher questions with but few pupil responses. Pupils need scaffolding from the teacher to *do* things that are new to them but accomplishment of which is within both their cognitive and motivational ZPDs. In this case, they need the structure to build confidence in their logical reasoning. As pupils become accustomed to the process and begin to practise logical thinking and mental debate of the ideas; and more importantly to value such intellectual activities, they are then more likely to start asking questions. In fact, there were signs of such optimism when we heard pupils asking intriguing questions like "Does heat carry the water vapour away or it is the other way round?" (line 187).

Confidence Building Strategies

Detailed analyses reveal a close match between the progressive nature of the discourse in the cognitive domain and the kind of confidence building strategies practised by the teacher. These started with simple remarks like: "Wow. Great." and "Incredible." and escalated into powerful, though, subtle remarks like: "How much does the textbook cost you?" Altogether, five confidence building strategies can be identified, namely, the pupils' performance was evaluated in relation to:

1. The task itself: for example, "Wow. Great," "Wonderful," "So incredible."

2. The pupil himself/herself: for example, "You are very smart," "You are starting to get smarter," "You just said something meaningful," "Wow. You are very thoughtful. This question is very meaningful, you remember this, ok?" "But it has a deeper meaning. You said that, not me," "Do you find that actually you can clearly tackle some very complicated problems step by step."

3. The 'average person': for example, "It's very smart of her. She did something which an average person wouldn't have done," "Yesterday, you did something meaningful. Normally people don't question this," "That's very incredible too because an average person can't possibly make such detailed observations," "You have to tell yourself that you aren't an average person."

4. The teacher: for example, "Many pupils raised many good ideas. I've also raised a good point," "You had said something meaningful. I had also said something meaningful," "As people with potential, we should learn this," "Normally people don't question this. Even boyhood Mr L (the teacher addressing himself) didn't question this," "You are better than I am. When I look at you, I know that I wasn't as good as you when I was at your age. I hope you're smarter than I am."

5. The textbook author: for example, "You can refer it back to the textbook now. How much does the textbook cost you?"

It is interesting that these five motivational strategies can be re-categorised according to Brophy's model of motivational effective classroom practices as shown in Table 4.

Table 4
Motivationally Effective Classroom Practices Exhibited in the Lesson.

	Affective domain	Examples observed in the lesson
Modelling	• Communicating *teacher's thoughts and feelings* involved in savoring the experience and enjoying the aesthetic satisfaction *that the activity offers*.	• Remarks that refer to pupils' performance in *the task* assigned, for example, 'Wow. Great', 'Wonderful', 'So incredible.'
Coaching	• Conveying *teacher's enthusiasm* for the activity.	• Remarks with the pattern – '*You* . . . and *I* . . . ,' for example, '*Many pupils* raised many good ideas. *I*'ve also raised a good point.' '*You* had said something meaningful. *I* had also said something meaningful.'
	• Helping *pupils to experience* the satisfactions that the activity offers.	• Remarks with the pattern: *You* . . . , for example, '*You* are starting to get smarter,' '*You* just said something meaningful.' 'Wow. *You* are very thoughtful . . .' 'But it has a deeper meaning. *You* said that, not me.'
	• Stimulating *pupils' appreciation* of the nature and progress of their learning.	• Remarks comparing pupils' performance with that of an average person or the teacher, for example, '*Many pupils* raised many good ideas. *I*'ve also raised a good point.' '*You* had said something meaningful. *I* had also said something meaningful.' 'As *people with potential*, *we* should learn this.' 'Normally people don't question this. Even *boyhood Mr L* (the teacher addressing himself) didn't question this.' '*You* are better than *I* am. When I look at you, I know that I wasn't as good as you when I was at your age. I hope you're smarter than I am.'

Table 4
Continued.

	Affective domain	Examples observed in the lesson
Scaffolding	• Developing *pupils' capacities* for *valuing* and deriving satisfactions from the learning domain or activity as they go along	• Remarks that equate pupils' capability as that of a *textbook author*, for example, 'You can refer it back to the textbook now. How much does the textbook cost you?'

According to Brophy (1999), the meaning of evaluative feedback can be influenced by the attribution that the teacher makes when delivering it. Thus, a teacher who praises pupils' success and tells them that they are smart may teach them to attribute their success to a stable ability factor, but a teacher who praises pupils for working hard enough to succeed will train pupils to attribute their success to unstable effort factors. Mr L appears to belong to the first category. He used discourse as both a medium and a means for constructing and reconstructing pupils' views of their own roles and capabilities in learning to do science. However, it is not sufficient to just praise pupils often and to affirm what they do. This study illustrates that these confidence building strategies and other motivational scaffolding feedback need to be relevantly included and built upon during the lesson such that they are connected to pupils' motivational ZPDs. As a result of such integration, pupils' conceptions of their capability to do science were re-defined and nurtured by the teacher through his various discursive moves. Capability was not attributed to natural ability or academic ranking; rather, it was construed as pupils' understandings, experiences and accomplishments. Interpreted in this way, even the academic low achievers can be shown to be capable of doing science; and even more importantly, of beginning to value their science learning. That science has become valued by this group of pupils, once labelled as low academic achievers, we believe that our study has provided some empirical support to Brophy's (1999) claim.

It has to be said that, since this study did not set out to investigate specifically the effect of the teacher's instruction on developing pupils' confidence in learning how to do science, no pre-instruction data on pupils' confidence was available for comparison. Instead, pupils' gain in confidence was inferred from their behaviour in class and by post-instruction interview data of selected pupils. Nor are we claiming that every pupil in the class had their confidence boosted to the same extent. Pupils can and do adopt different goals and purposes for their school work. In turn, these motivational beliefs can influence their engagement with the learning tasks as they attempt to adapt to the different constraints and demands placed on them by the tasks and activities they confront in classrooms. Thus, there is no intention to generalise the findings of this study to other settings. Nevertheless, despite the above shortcomings, the significance of this paper lies with its power to provide images of classroom practices that seems to be conducive to developing pupils' confidence in learning how to do science by providing detailed contextual descriptions and interpretation.

Conclusion

This study provides us with images of classroom practices that seem to be conducive to developing pupils' confidence in learning how to do science. It also demonstrates the complexity and individuality of each teaching/learning situation, particularly on how the various contextual, personal and interpersonal factors may influence the level of satisfaction for the participants. Notwithstanding this complexity, through highlighting the teacher's role in helping pupils to value their science learning, this study does suggest a way to improve quality of science classroom practices. It is argued that good science teaching needs to prioritise the affective, especially on building up pupils' confidence in exploring science. No matter how good our lesson plans, how cognitively correct our teaching methods, unless the teacher is able to motivate the pupils to value and to feel confident about their learning, the teacher will have given pupils little of lasting importance.

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