Science Teacher Education in Hong Kong

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ABSTRACT

Initial science teacher education in Hong Kong is provided by the Post-graduate Diploma in Education Programme (PGDE) for both pre-service and in-service secondary school teachers. This programme includes a balanced treatment of subject curriculum and teaching in science, general pedagogical knowledge and skills, educational psychology and school administration. The science courses in this programme also have some units that equip science teachers with the knowledge and skills that are essential for teaching a science curriculum that emphasises conceptual change and understanding of the nature and methods of science. This emphasis is illustrated by two studies: (1) Developing a conceptual change model of instruction in Biology teachers, and (2) Constructing understanding of the nature and methods of science.

Key words: Hong Kong, science teacher education, PGDE

In Hong Kong, science teacher education is provided by the Faculty of Education of two local universities, the Chinese University of Hong Kong and the University of Hong Kong. Initial science teacher training is provided by the Postgraduate Diploma in Education Programme (PGDE) for secondary schools (S1-S7 for age 12 to 20) and the Postgraduate Diploma in Primary Education Programme (PGDE Primary) for primary schools (P1 to P6 for age 6 to 12). More advanced education for science teachers is provided by courses such as Advanced Diploma in Education, Master in Education, Master of Philosophy, Doctor of Philosophy (Ph.D.) and Doctor of Education (Ed.D.). Most students enrolling in these programmes are local pre- and in-service teachers, but the higher degree courses such as Ph.D. and Ed.D. also attract a substantial number of science teachers and educators from various regions of the Mainland China.

In this paper, I wish to focus on a description and discussion of the PGDE programme that aims at training and nurturing professional secondary school teachers. This Programme comprises course work and teaching practice. The curriculum is flexible and is reviewed regularly to meet the ever-changing needs arising from social and educational development. There are two modes of study: full-time and part-time. Courses are grouped into the following three domains: (1) Curriculum and Instruction Domain; (2) Organization and Institution Domain; (3) Education Psychology Domain.

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I. THE PGDE PROGRAMME FOR SCIENCE TEACHERS

1. Admission Requirements for the PGDE programme

For the full-time Programme, the applicant shall have graduated from a recognized university and obtained a Bachelor’s degree with a Major/Minor subject in an area of study within the secondary school curriculum. For the part-time Programme, the applicant shall have graduated from a recognized university and obtained a Bachelor’s degree with a Major/Minor subject in an area of study within the secondary school curriculum, and be an in-service full-time secondary school teacher. Once admitted into the part-time programme, students should be full-time secondary school teachers throughout their period of study and should teach at least six class periods per week/teaching cycle in a subject closely related to the major SCT (Subject Curriculum and Teaching) he or she has chosen to study. Integrated Science, a subject taught in the junior secondary school years only, can be considered as an equivalent subject to physics, chemistry or biology. These requirements apply also to applicants holding the post of school principal or vice-principal.

Those who expect to obtain a Bachelor’s degree in the current academic year may also apply for admission. Once granted conditional offer, these applicants should furnish proof of graduation before they can commence their study in the programme. For the full-time Programme, students must complete the prescribed programme requirements in one year, and for the part-time Programme, students must complete the prescribed programme requirements in two years.

2. Study Scheme

PGDE students are required to complete 22 units of courses. The study scheme is as follows:

<table>
<thead>
<tr>
<th>1. Required Courses (8 units)</th>
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<tbody>
<tr>
<td>Curriculum and Instruction Domain (select 1 major SCT)</td>
<td>4 units</td>
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<tr>
<td>Organization and Institution Domain</td>
<td>2 units</td>
</tr>
<tr>
<td>Education Psychology Domain</td>
<td>2 units</td>
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<tr>
<td>2. Core Electives (1 course from each domain)</td>
<td>6 units</td>
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<tr>
<td>3. Electives (4 courses of any domain)</td>
<td>8 units</td>
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<td>4. Teaching Practice</td>
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<td><strong>Total</strong></td>
<td>22 units</td>
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</table>

The courses offered in the PGDE programmes for pre- and in-service science teachers are as follows:
3. Course Description

The course outlines for the Science subjects in the Subject Curriculum and Teaching Domain and the Electives Domain (i.e. Integrated Science) are presented below:
Major: Physics (4 units)
This course is concerned with the knowledge of existing curriculum, teaching methods and
instructional effect. A variety of teaching approach will be used, including lecturing on special
topics, class activities and class discussion. Topics include: (1) Curriculum - the development,
objective content and practical work of physics curriculum in Hong Kong and overseas; (2)
method and effect - feedback from pupils, cognitive development, experiment and
demonstration, lecture and discussion, assessment of learning, special project, individual
counseling; and (3) common misconceptions in Physics and teaching strategies to deal with
misconceptions.

Major: Chemistry (4 units)
This course provides the basic skills and knowledge of teaching Chemistry in secondary
schools. The content includes: (1) aims and purposes; (2) psychology of student behaviour; (3)
curriculum; (4) teaching methods; (5) use of teaching equipment; (6) lesson planning; (7) testing
and evaluation; (8) classroom and laboratory management; and (9) common misconceptions in
Chemistry and teaching strategies for rectifying misconceptions.

Major: Biology (4 units)
This course provides the basic skills and knowledge of teaching Biology in secondary schools.
The content includes:
1. The secondary Biology curriculum in Hong Kong: (a) aims and objectives, (b) recent
   changes;
2. Lesson planning; principles and evaluation of microteaching;
3. Questioning skills; constructivist approach of teaching;
4. Active teaching strategies: group discussion, active reading and active writing activities;
5. Alternative conceptions in Biology; teaching strategies to prevent or rectify alternative
   conceptions;
6. The Science-Technology-Society (STS) approach in Biology teaching;
7. Practical work in Biology; introduction to the AL Biology Teacher Assessment Scheme
   (TAS);
8. The teaching and assessment of AL practical work;
9. Assessment in school Biology; analysis of CE Biology papers; Analysis of Biology subject
   reports;
10. Performing selected investigations; data-logging in Biology practical; and
11. Extra-curricular activities in Biology; course evaluation.

Minor: Integrated Science (2 units)
This is the most popular elective course taken by students who are major in science and
mathematics. In recent years, 3-4 classes of Integrated Science are offered in each year to
accommodate the large number of applicants for this course.

The main themes of this course include:

- Review of the new S1-3 Science Syllabus; nature and methods of science; probing children's understanding of science and implications; strategies for effective teaching of science concepts and investigations.

- Use of games and puzzles; innovative demonstration activities; design and construction of equipment; magnetic card and display board activities; computer assisted learning; organization of projects and field trips; selection of STS videos; retention exercises for videos; use of CD-ROM in teaching.

Other requirements

Micro-teaching is a part of the SCT (major) courses. It is a systematic scale-down training method in teaching, and is usually conducted in groups. The characteristics are: (1) time is short (usually taking about 10 minutes in training selected teaching skills); (2) number of students is small (about 3-5 students as 'simulated pupils'; (3) teaching skills can be trained and practised individually, e.g. set, questioning, reinforcement and body language. Closed-circuit TV is used for training, playing back the recorded tape for analysis, reteaching the same skill until it is mastered by the trainee-teacher. Method of training depends on the instructor's teaching principle.

Teaching practice is an integral part of the PGDE programme. Students should strive to improve their teaching and develop professionally. During the teaching practice period, the Faculty's teaching practice supervisors will pay classroom visits to students for development and assessment purposes. The assessment will take into consideration the student's classroom teaching performance, as well as his/her professional behaviour and attitude.

Teaching practice aims to provide students the opportunity:

1. to practise their teaching skills and hence build up their confidence in teaching;
2. to improve their teaching skills through supervision of SCT instructors and other teaching staff;
3. to acquire teaching effectiveness through the implementation and verification of teaching theories into/with practice; and
4. to understand and experience the school organization and the substance of the teaching profession.

In the full-time Programme, teaching practice will be arranged in both terms and will last for about five weeks each term. Each student will be assigned to a school. If conditions permit, students' preference on school location will be considered. The Faculty will also invite expert teachers to be teaching advisers so as to give more guidance and supervision to students during their practicum period.

In the part-time Programme, students should be full-time teachers and carry out teaching
practice at their working schools throughout the two years of study. In case of special conditions necessitating a temporary quit from the full-time teaching profession, a student must report to the respective programme officer through a written application. The Faculty will, based on individual situation, decide whether such student should be allowed to continue his/her study in the programme. If continuation of study is approved, special arrangement on teaching practice will be provided to the student. If situation allows, the arrangement may be similar to that of the full-time students. As for part-time students not in the teaching profession, they will have two blocks of teaching practices, each of about four weeks when they will teach in an assigned school. The first teaching practice for these students should be conducted in their first year of studies.

II. SPECIAL FEATURES OF THE PGDE PROGRAMME FOR SCIENCE TEACHERS

Some of the courses or topics covered in the PGDE programmes aim at providing novice science teachers the basic pedagogical knowledge and skills for them to be proficient in classroom teaching and management. These include the courses in educational psychology, school administration and classroom management, and topics in the science major courses that are concerned with lesson planning, general teaching skills, assessment skills and practical work. These components can be found in most science teacher education programmes offered in other countries of the world. However, the Hong Kong programme has its special features that are in line with the recent changes of the science curriculum for secondary schools in Hong Kong. In the following sections, I shall highlight and illustrate such features of the Hong Kong PGDE programme for science teachers, referring to two studies on the effects of the Biology and Integrated Science courses on the professional development of science teachers.

1. Developing a conceptual change model of instruction in Biology teachers

In Hong Kong, a central aim of the secondary science curriculum is to promote conceptual understanding and meaningful learning (Curriculum Development Council, 1998). However, science teaching in the classroom has been dominated by teacher-centred, expository instruction. Pupils are trained to be skilful at recalling factual information and the rote application of algorithms in order to gain good grades in public examinations. This tendency is particularly obvious in the study of Biology. Pupils tend to reduce biological principles to a factual level and memorise them by rote. Examiners have pointed out that Certificate level pupils (age 17, equivalent to grade 11), are good at recalling facts from memory, but are weak in applying their knowledge in novel situations and to solve problems (e.g. Hong Kong Examinations Authority, 1999).

A main reason for the prevalence of the didactic mode of science instruction is that most
science teachers in Hong Kong lack a mental model of conceptual development. They do not use a theory of learning based on the constructivist perspective, but believe in a positivist view of science learning. They consider that science knowledge is an accumulation of facts that can be transmitted to pupils through good explanation. Their main task is to present the subject content in science to their pupils in an intelligible way, and understanding will occur spontaneously after pupils have memorized a critical mass of facts (Pomeroy, 1993; Tobin et al., 1997; Yerrick et al., 1997).

This approach of instruction does not lead to effective learning. Knowledge acquired by rote learning is easily forgotten and is not readily transferable to realistic or novel situations. Meaningful learning occurs when the learner actively constructs new knowledge by using existing knowledge to make sense of learning experiences. This constructivist view of learning highlights the impact of learners' preconceptions on the process of constructing new knowledge and the need for an instructional strategy that promotes active conceptual change rather than passive transmission of information.

In order to promote conceptual understanding through Biology teaching, it is necessary to equip science teachers with the knowledge and skills of the constructivist mode of science instruction, and to discourage the traditional mode of teaching for direct transmission of knowledge. To achieve this, the Biology Subject and Curriculum Teaching course of the PGDE programme has introduced teaching methods that are conducive to a conceptual change model of science instruction. The design and effects of this course on Biology teachers' concept and mode of instructional practice have been reported in a previous paper (Yip, 2001a). A synopsis of this study is presented below to highlight the characteristics of the relevant units of the Biology course and the evaluation of the effects on teachers involved in this study.

(Units that promote a conceptual change model of instruction)

This study involved 16 pre-service biology teachers who were university graduates specialised in biological science. They joined the one-year full-time PGDE programme, and they had no previous teaching experience in schools. In their Biology major course, the following units aim at promoting the development of a conceptual change mode of science instruction.

1) Constructivist approach of science teaching

This unit includes an introduction to the notion of learning in the constructivist perspective, illustrated with examples, and a brief description of the teaching strategies trialled in the Children's Learning in Science Project (Scott et al., 1987). It develops the idea that learning for understanding involves the active construction of knowledge by the learner through his or her own experience, rather than the passive transmission of knowledge from the teacher. This constructivist view of learning should provide the prospective teachers with a theoretical model to understand the nature of student learning from a new perspective.
2) Interactive teaching strategies

This unit introduces a variety of teaching strategies that promote teacher-pupil and pupil-pupil interactions. These include small group discussions, cooperative learning activities, role plays, simulation games, active reading skills such as cloze, sequencing and emphasis, and active writing skills such as writing diaries and journalist reports (Centre for Science Education, 1992). The interactive teaching strategies emphasise the active participation of pupils in constructing knowledge, with the teacher acting as a facilitator in the learning process. This unit would equip the teachers with the knowledge of teaching strategies required for the conceptual change model of instruction.

3) Microteaching

This unit presents the principles of microteaching, including questioning skills that probe into pupils' understanding and guide their conceptual construction. The subjects were shown microteaching videos that illustrated good and poor teaching skills, including those concerned with promoting concept understanding and construction.

Each subject was subsequently required to present a microteaching session of about 10 minutes, and the performance was commented by other members of the class. This activity provided an initial opportunity for the prospective teachers to practise certain teaching skills in a more or less controlled environment. The sharing of experience at the end of each microteaching session, guided by the supervisor, provided a good chance for them to consolidate their understanding of good teaching skills. As a requirement of the Biology course, each subject had to submit a written assignment to evaluate his or her own performance in the microteaching session. This provided a further chance for the prospective teachers to review and reflect on their strength and weakness in the deployment of various teaching skills, including those that are related to a conceptual change model of instruction.

4) A study on alternative conceptions in Biology

At the beginning of this unit, the subjects were given a written exercise consisting of 20 statements that incorporated some misconceptions in biology commonly possessed by Certificate level students. The subjects were required to point out the misconceptions contained in each statement, together with their justifications. The subjects' scripts were marked by their supervisor. The results were consistent with the findings of other studies in that the prospective teachers possessed many of the misconceptions held by Biology students (Yip, 1998). This finding was disturbing to the subjects as they realised that, despite university training, they might not possess adequate subject knowledge for teaching Certificate-level biology.

On the other hand, the results helped the subjects to deliberate on the causes of pupils' alternative conceptions and the possible roles of the teacher in propagating such erroneous ideas. This led to a consideration of teaching strategies that might help pupils to rectify their misconceptions and construct a proper understanding of scientific ideas. These included a review
and discussion of the ways to elicit pupils' preconceptions (White and Gunstone, 1992), to challenge these ideas by creating cognitive conflicts and using teaching analogies, and to help pupils to construct scientific conceptions through their existing experience.

As a requirement of the Biology Methods course, each subject had to submit an assignment that described an alternative conception commonly detected in pupils and suggested instructional strategies that could prevent its development in pupils. This exercise provided a chance for the subjects to apply their knowledge of the constructivist approach in designing interactive lessons that promote learning for understanding rather than by rote.

**(Method of assessing the mastery of conceptual change model of instruction)**

At the start of the Biology course, the subjects were asked to complete a questionnaire with open-ended questions exploring their views on the aims of biology teaching and the characteristics of a good biology teacher. The subjects' responses revealed that they all held the belief that their role was concerned with the transmission of biological knowledge to pupils. Biology teaching was concerned with explaining biological concepts and principles accurately and to pupils so that they could acquire and retain the subject matter as demanded by the syllabus.

The subjects were required to participate in two periods of teaching practice in local secondary schools, each lasting for five weeks, one starting in the middle of October 1998 and one starting at the end of April of 1999. During each period, each subject was visited by two supervisors for evaluation of his or her classroom teaching performance. The assessment was made on a Teaching Practice Evaluation Guide (TPEG), which contains 48 items that evaluate performance in different areas of teaching, such as lesson planning, teaching approach, introduction and development of the lesson, questioning skills, treatment of pupils' responses, quality of explanation, communication skills, classroom management, and design of worksheet. Each item was marked on a 5-point scale, with a score of 1-2 as an indication of poor performance, 3 as satisfactory and 4-5 as good.

For each school visit, the supervisor also put down specific comments on the TPEG that elaborated on particular strength and weaknesses of the student teacher. At the end of the lesson, the supervisor, based on the TPEG, discussed with the subject about his or her overall performance as well as particular aspects of teaching. Thus the supervision of teaching practice provided both assessment of performance and feedback to the student teacher for reinforcement and improvement. The two supervisors were experienced teacher educators and they had mutual agreement on the criteria of assessment of the TPEG. By reviewing the performance in classroom teaching in each period of teaching practice, they arrived at a single score for each skill for individual subjects.

For the purpose of this study, only those items in the TPEG that assess the skills related to the constructivist teaching approach are analysed. There are altogether six such items:
1) Lesson plan indicating a constructivist approach. Examination of the lesson plan can reveal whether the teacher intends to use a constructivist teaching approach when planning a lesson and whether the teacher is aware of the importance of determining the existence of pupils’ prerequisite knowledge before learning a new topic.

2) Using questions to help constructing concepts. This is an important skill used in the constructivist approach. Through the use of probing questions, the teacher can guide pupils to build new knowledge by exploring relationships between existing concepts.

3) Using high order questions. This type of question helps pupils explore understanding, think deeply and divergently, and construct new knowledge. Such questions facilitate the active construction of new knowledge by pupils, and are characteristic of a constructivist lesson. A didactic lesson, on the other hand, is normally dominated by low order questions that elicit factual recall.

4) Using probes to explore preconceptions. This skill enables the teacher to find out whether their pupils have mastered prerequisite knowledge and detect the existence of alternative conceptions.

5) Constructive chalkboard layout. The presentation of the keys points of a lesson in a logical sequence on the chalkboard or using transparencies helps pupils develop and consolidate concepts constructively. This practice also builds up a summary of the lesson that would be useful for subsequent revision.

6) Interactive learning activities. These include activities such as small group discussions, role plays, simulation games, text-response exercises and text completion worksheets. They are designed to help pupils actively relate their personal experiences to subject content or to apply biological principles to everyday life or novel contexts. Through the active participation of the pupils, the teacher can probe into their pre-existing knowledge and detect alternative conceptions. The process can also motivate pupils in learning and help them construct new knowledge.

Besides the scores on the above items, the specific comments entered into the TPEG were also taken into consideration when assessing the degree of use of a constructivist approach demonstrated by the subjects.

(Results)

1) Performance in the first teaching practice

The first teaching practice started early in the PGDE programme. At that time, the prospective teachers had only studied the units on ‘constructivist approach of science teaching’ and ‘interactive teaching strategies’ through their Biology Methods course. They had not yet possessed the knowledge of other components that would contribute to the development of a conceptual change model of instruction.

The performance of the subjects is summarized in Table 1. Their scores indicate the extent of
teaching in a constructivist way when most of them still believed in a transmission mode of 
learning. This can be taken as a pretest to be compared with their performance in the second 
teaching practice, when they had acquired a more thorough understanding of the principle of 
constructivist approach of instruction.

Among the six skills related to the constructivist teaching approach, the subjects obtained the 
lowest mean score of 2.31 in the ability to ask high order questions. No subjects demonstrated 
mastery of this skill (score of 4 or 5), and a few (S10 and S13) had the lowest score of 1. Many 
subjects asked a lot of questions during lessons, but most questions were of a low cognitive 
demand. These questions required only simple, recall type answers that failed to reflect 
understanding or stimulate thinking.

The mean score on the ability to probe pupils’ preconceptions is also low, and more than half 
of the subjects got a score of 2. Most subjects asked questions at the start of the lesson as a 
revision. But these questions mainly assessed the pupils’ ability to recall and did not probe their 
understanding or elicit alternative conceptions. When alternative conceptions were apparent, the 
subjects tended to correct them directly by stating the formal scientific ideas, instead of guiding 
the pupils to review and challenge their informal views, or to construct the formal concepts 
through their own reasoning.

In the lesson plans submitted, most subjects were able to list the prerequisite knowledge 
possessed by the pupils and attempted to develop pupils’ ideas step by step. There was, however, 
a lack of key questions that could help the pupils to relate their prior knowledge to the new 
concepts. At most, the lesson plans showed an attempt to promote concept development through 
teaching rather than through the pupils’ active participation and reasoning.

A similar weakness was also demonstrated in the skill of ‘Using questions to help constructing 
concepts’, as the subjects mainly asked questions that require simple, recall-type answers and the 
lesson was focused on the acquisition of knowledge rather than on developing understanding.

The subjects differed considerably in their abilities to present key points constructively on the 
chalkboard or through transparencies. Two subjects (S7 and S15) demonstrated the skill to use 
the board in a constructivist way, presenting the main ideas in a structured manner that helped 
the pupils to see the development of concepts and their relationships during the lesson. Most 
subjects, however, did not demonstrate this skill. They seldom put down the key ideas on the 
chalkboard systematically during instruction. It appears that, with their limited teaching 
experience, they could not cope with talking and writing at the same time.

Although interactive learning methods had been introduced early in the Biology Methods 
course, the subjects showed only a minimal use of this skill in practice. Small group discussion 
was most commonly practised using worksheets.

On the whole, the subjects employed a didactic teaching approach that emphasised the 
three transmission of knowledge. They did not practise the conceptual change teaching approach. 
Although the subjects might have used certain elements of the constructivist model in various 
degrees, there was no evidence of a coherent, well-planned instruction to promote conceptual
Table 1. Performance of the subjects in the 1st and 2nd teaching practices

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<td>Mean score</td>
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Note: 1st TP = 1st Teaching Practice
      2nd TP = 2nd Teaching Practice

change in pupils.

2) Performance in the second teaching practice

The second teaching practice took place after the subjects had completed all the course work of the PGDE programme, including the Biology Methods course. By that time, the subjects should have acquired the basic knowledge of the conceptual change model of instruction and the skills related to this mode of teaching. Analysis of the performance of the subjects in the second teaching practice would show whether they were capable of putting these ideas and skills into practice in the classroom and developing a coherent mode of instruction.

An overall comparison the performance of the subjects in the two teaching practices (Table 1) indicates that the prospective teachers demonstrated an overall improvement in the six selected
elements by the end of the PGDE programme.

The extent of improvement can be evaluated by comparing the mean scores for each skill in the first and second teaching practices using the t-test (Table 2). There is a significant improvement of performance in all skills in the second teaching practice.

Lesson planning with a constructivist approach

The prospective teachers showed an overall improvement in the skill of planning a constructivist lesson through the course of the programme (p<0.001) (Table 2). All lesson plans submitted in the second teaching practice contained a synopsis of the prerequisite knowledge of pupils for the topic to be introduced. This suggests that the subjects were fully aware of the need for determining the existence of prerequisite knowledge before learning a new concept. Some subjects included an activity at the beginning of the lesson to assess whether their pupils had acquired such knowledge. Over half of the subjects, who obtained a score of 4 in this element, were able to apply the constructivist approach in planning a lesson. Their lesson plans incorporated probing questions that aimed at guiding the pupils to build up the key ideas in a coherent way.

Using questions to help constructing concepts

All prospective teachers achieved a score of 3 or more in the ability to use questions to help concept construction in their second teaching practice. A comparison of their performance in the two teaching practices showed an overall improvement in this skill (p<0.001) (Table 3).

While questioning skills were used more frequently in the second teaching practice than in the initial practice, many of the questions asked were, however, concerned with developing factual knowledge rather than with promoting in-depth understanding. For instance, in a lesson on the nervous system, the subject (S7) showed a pig’s brain to the class and successfully got the pupils to observe the presence of foldings, fissures and capillaries in the brain. The teacher, however, did not pursue to guide her pupils to relate these structural features to their functional

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<th>Table 2. Comparison of the mean scores of different skills in the first and second teaching practices</th>
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<td>Skills</td>
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<td>1. Lesson planning</td>
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<td>2. Using questions constructively</td>
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<td>3. Asking high order questions</td>
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<td>4. Probing preconceptions</td>
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<td>5. Constructive chalkboard layout</td>
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<td>6. Interactive learning activities</td>
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</tbody>
</table>
significances. By asking questions such as 'Why are there so many foldings/fissures?' and 'How are the capillaries distributed in the brain?', pupils could be motivated to think actively and develop a more meaningful understanding of the lesson content.

The fact that most of the questions asked by the prospective teachers were concerned with 'What', rather than with 'How' and 'Why', suggests that the subjects had their focus of the lesson on the learning of factual knowledge, though employing a more interactive way of instruction instead of the traditional one-way didactic approach. The failure of the subjects to apply a constructivist approach to help pupils to construct abstract concepts may be related to their inadequate subject knowledge. Some recent studies (e.g. Yip, 1998; Mak et al., 1999) reveal that many biology teachers do not possess an adequate understanding of the topics that they teach, but hold a number of misconceptions that are commonly detected in their pupils. Moreover, they tend to regard biology as a static, disconnected collection of facts (Hewson et al., 1999). Thus they may not be able to appreciate the difficulties encountered by their pupils when attempting to construct new knowledge from existing concepts. Their lack of a deep and coherent understanding of the subject matter may also limit their ability to design and use high order questions for probing student understanding.

The positivist view of knowledge held by the prospective teachers, prior to their entry into the PGDE programme, is in conflict with the conceptual change approach in teaching. The firm belief that a teacher's role is to present scientific knowledge in an intelligible way to the pupils made it difficult for the prospective teachers to appreciate the value of eliciting and exploring pupils' ideas in learning (Lemberger et al., 1999). Even if they were convinced of the merits of the new approach, changing their original belief about teaching and learning needed time and experience.

Using high order questions

In the second teaching practice, many of the lesson plans were well organized with an attempt to apply the constructivist approach of instruction. Key questions were formulated to guide concept development and stimulate pupil participation. However, most of these questions were of the recall type, which at best could only assess prior knowledge and develop factual knowledge.

The prospective teachers seldom asked high order questions that could probe into pupils' understandings and stimulate them to think critically. The teachers seemed to be handicapped by their lack of in-depth understanding of subject matter. In two lessons on the circulatory system, for example, the teachers (S2 and S9) asked the class to point out how the circulation of a mammal was different from that of a fish. After pointing out that mammals had a double circulation and the meaning of this term, the teacher did not relate this to the importance and significance of a double circulatory system. In another instance, after guiding the pupils to point out that the artery had a thicker and muscular wall and the vein had a larger lumen, the teacher (S8) did not ask her pupils to relate these structural differences to the roles of the two types of
blood vessels. Due to the lack of high order questions, pupils could only acquire discrete pockets of factual knowledge without developing a coherent and integrated picture of the biological processes concerned.

Even when high order questions were sometimes asked, the prospective teachers did not make good use of them. When pupils gave a wrong answer, for instance, the teachers usually would not waste time to probe the causes of misunderstanding. Being too anxious to keep pace with the scheduled curriculum, they provided the answers directly as soon as the pupils failed to produce adequate responses. Little time was allowed for the pupils to reflect on the questions and deliberate upon the significance of the answers provided by the teacher. This problem was particularly obvious for two of the subjects (S1 and S3), who had prepared very good and attractive Powerpoint presentations that delivered the lesson content smoothly and automatically. When the pupils showed problems of understanding, the teachers were reluctant to interrupt the lesson to deal with the pupils’ queries.

The subjects in general were incapable of cueing their pupils to answer high order questions. When this weakness was pointed out to the subjects in the post-lesson interview, they offered a number of justifications, such as the pressure to keep to the schedule of the lesson plan, and that dwelling on pupils’ wrong answers would not lead to effective learning. They believed that their primary role as a teacher was to provide accurate explanations to pupils. Although they had the knowledge of the constructivist approach, they only practised this superficially, reverting to the didactic approach after an initial attempt.

A common scene in the classroom was that when high order questions were asked, many pupils did not demonstrate any response but remained silent. They were used to the traditional teacher-dominated approach of teaching and might prefer to play the role of a passive recipient of knowledge in the classroom. Changing this style of learning requires the concerted effort of the teaching staff over a long period of time. It is very unlikely that the isolated effort of an individual student teacher could have any significant impact on the pupils’ learning style during the brief teaching practice period, especially when this novel approach was not compatible with or supported by the established culture of the school. Nevertheless, certain subjects were able to promote the motivation and participation of the class, especially when the pupils found the questions challenging and related to everyday life. The situation could also be improved if the questions and the answers were presented on the chalkboard in a constructivist manner.

Using probes to elicit preconceptions

In the second teaching practice, the prospective teachers showed more attempts to elicit pupils’ pre-existing knowledge. All but one achieved a score of 3 or 4 in this skill, indicating satisfactory to good performance (Table 2). This level of performance marks a significant improvement over that in the first teaching practice (p<0.001).

A common weakness was that the questions asked were sometimes not specific enough so that pupils had to guess at the meaning of the questions. Below are some examples of such questions:
• In order to bring out the importance of photosynthesis, the teacher asked: “What is the significance of the plants to the living world?”
• A pig’s brain was displayed to the class, and the teacher asked: “What special features does the brain show?”
• At the beginning of a lesson on human eyes, the teacher asked: “How can we see things around us?”

This type of vague questions may invite unpredictable and irrelevant answers from pupils, thus defeating the purpose of assessing and consolidating prerequisite knowledge before proceeding to a new topic. Ambiguous questions also made it difficult to detect alternative conceptions held by pupils.

Eliciting pupils’ preconceptions was usually carried out through the use of a set, usually in the form of a newspaper cutting, a short story or a simple activity, at the beginning of the lesson. Based on pupils’ responses, the teacher could assess whether the class had mastered the prerequisite knowledge and consolidate it before starting a related topic. When alternative conceptions were detected, most prospective teachers simply replaced them with formal scientific concepts. They seldom explored the nature and causes of the alternative conceptions, or rectified them through conceptual change strategies.

A good practice of some prospective teachers (e.g. S7 and S15) was to write pupils’ responses on the chalkboard, so that they could be analysed, put into groups or related to other concepts through class discussion. This activity encourages the pupils to play a more active role in science learning.

Constructive chalkboard layout

Comparison of the mean scores of the two teaching practices indicates that, overall, the subjects improved in their skill of presenting chalkboard layout constructively in the course of the programme (Tables 1 and 2). There was however great individual variation in the achievement of this skill as reflected in the wide spread of scores among the subjects in the second teaching practice, which range from a low level of performance (score of 2) to a mastery level (score of 5). Nevertheless, the overall improvement in this skill reached a significant value (p<0.05).

In the second teaching practice, the subjects in general were able to list the main points on the chalkboard, which outlined the development of the lesson and served as notes for student revision after the lesson. A significant number of subjects, however, did not seem to have much planning on the chalkboard layout, as the key points were often presented in an unsystematic manner. Many subjects did not realize the importance of putting down the key questions on the chalkboard, which could help the pupils to understand the questions better. Only a few subjects (e.g. S4 and S11) were able to demonstrate the skill to use the chalkboard layout constructively
to help pupils to follow the development of the lesson and consolidate their learning.

**Interactive learning activities**

In the first teaching practice, the subjects demonstrated a low to satisfactory level of performance in the use of interactive learning activities, with scores of 2-3 (Table 1). The improvement was apparent in the second teaching practice, as all subjects reached a satisfactory to good level of performance in this skill, with scores of 3-4. Comparing the mean scores of this skill in the two teaching practices indicates that the subjects overall achieved a significant improvement in performance (p<0.005) (Table 2).

In the second teaching practice, all subjects were able to use some form of interactive learning activities, such as small group discussions, text-response exercises, simulation games and role plays. These activities were usually accompanied with worksheets, some of which were quite original and contained high order questions that probed into conceptual understanding and stimulated the active construction of new knowledge.

While good attempts were made to incorporate interactive activities into lessons, most subjects lacked the skills to promote the pupils to participate actively in these activities. For example, some teachers did not know how to handle pupils that were passive and non-participating. Not only would these pupils not benefit from the group activities, they might also cause disturbances to other members of the group. This problem was particularly serious when the group size was too large. In order to save time, some teachers discouraged student discussion and interaction. They simply told individual pupils to answer the questions on the worksheet, and made corrections or provided the right answer.

For these activities to be effective in promoting active learning, pupils should be arranged to work in small groups and allowed to present their ideas for class discussion. In this way, the lesson would become more interactive and challenging. In the post-lesson interview, the subjects justified their practice by the concern for time constraint and the passive learning attitude of pupils, which made it difficult for them as a student teacher to effect any change.

**(Conclusions)**

The above analysis of performance of the prospective teachers in the two teaching practices indicates that the subjects achieved significant improvement in the various skills related to a conceptual change model of science instruction through the PGDE programme. The subjects reached a satisfactory to good level of performance in all skills in their second teaching practice. However, only a few subjects demonstrated mastery of most of these skills.

In designing the lesson plans and developing the lessons, the subjects mainly used questions of low cognitive demand that were useful for assessing factual knowledge. High order questions were uncommon, and when these were asked the subjects often failed to use them constructively to explore and develop pupils' conceptual understanding. Being fully aware of the importance of
preconceptions on learning, all subjects attempted to assess pupils' possession of prerequisite knowledge before teaching a new topic. Yet pupils' alternative conceptions were often ignored. Very few subjects could apply conceptual change strategies to guide pupils to explore the limitations of their informal ideas and to construct the scientifically accepted conceptions. Only a few subjects were able to use the chalkboard layout in a constructive way to help pupils to develop and consolidate the ideas covered in the lessons. There were some good attempts to design and use interactive learning activities. However, due to the lack of experience and passive pupil attitude, the learning outcomes of such activities often did not turn out to be as desirable as expected.

A number of factors have been shown to restrict the abilities of prospective teachers to implement the conceptual change approach of instruction. Due to inadequate subject matter knowledge and poor understanding of the nature of science, they may not be able to appreciate the learning problems faced by pupils, or design questions and activities that can probe pupils' understanding (McDiarmid, 1994; Gess-Newsome and Lederman, 1995). The belief that true knowledge exists and that it can be transmitted to the pupils through good explanations, held by the prospective teachers prior to their entry into the PGDE programme, is in conflict with the conceptual change model of learning. With this positivist view of the nature of knowledge in mind, it is not easy to convince the teachers to shift from a didactic practice to a more pupil-oriented approach (Lemberger et al., 1999). Insufficient teaching experience, the lack of pupil motivation, concerns for classroom management, and the pressure to keep pace with a congested curriculum may pose additional constraints to the teachers in putting their plans into action. Furthermore, the Biology course can only provide the knowledge and idea of a novel instructional approach. The acceptance and internalisation of this model of instruction by the prospective teachers may not occur within the limited time of the teacher education programme (Demastes et al., 1996; Hewson et al., 1999).

In the process of applying the constructivist principle into classroom practice, a major resistance comes from the non-supportive condition in schools. In the current system of teaching practice in Hong Kong, placement of student teachers in schools is being viewed as a generous concession on the part of the schools to assist the PGDE programme in training teachers, creating considerable disturbance and inconvenience to their teachers and students. Most of the school teacher advisers are ignorant of the notion of constructivist learning, and they view teaching as an act of transmission. As they rarely model the kind of teaching that our PGDE programme aims to promote, the prospective teachers are placed in the dilemma of how to accommodate competing demands. To address this problem, the Faculty of Education of the Chinese University of Hong Kong plans to organise in-service activities such as seminars and workshops for school principals and teacher advisers in refreshing their knowledge of teaching methodologies and developing their mentoring skills. In collaboration with the university supervisors, they will be able to contribute to a more holistic development and formative assessment of the teaching ability of the prospective teachers. It is hoped that this arrangement
will allow the prospective teachers to establish a closer relationship with the schools and the pupils, thus effectively reducing the stress and pressure in trying out their novel instructional approach.

Given the constraints faced by a student teacher in an alien teaching environment, the apparent improvement achieved by the prospective teachers in using the skills related to a conceptual change approach, as observed in this study, is very encouraging. In anticipation of a more supportive school environment made possible by the new scheme of teaching practice, this initial achievement can be the trigger to a life-long process of professional development, through which the teachers will become more skillful, confident and committed in deploying a constructivist orientation of science instruction.

2. Understanding the nature and methods of science

Textbook science presents science as a prejudiced accounts of the behaviour of the natural world. Scientific knowledge is obtained through a steady and cumulative progression. This improper view of the nature of science is accepted by science teachers and even propagated by science teachers. It is therefore important to provide science teachers with a proper understanding of the nature and process of science, so that they can teach the proper view to their pupils.

In the Integrated Science course of the PGDE, a historical approach is used. A number of historical development of scientific concepts are used as examples to illustrate the process of scientific development and the process of scientific enquiry. The teachers are guided to construct their understanding through a review of the these historical accounts.

(Method)

Outline of the study

This study involved 30 pre-service science teachers who enrolled in the Integrated Science course in the second term of a full-time PGDE programme. In the first lesson of the course, the course teacher distribute to the subjects a worksheet (Fig. 1) which contains a list of questions for discussion in small groups. The subjects were then asked to answer the questions individually and submitted their worksheets to their supervisor. This serves as the pre-test.

In the next lesson, the course teacher presented two examples of historical development of scientific ideas, i.e. the debates on the shape of the Earth in a video, and on the cause of gastric ulcer in Powerpoint slides. For each example, key questions were inserted at appropriate points to help the subjects to identify the key stages in the process of scientific investigation and appreciate how scientific knowledge grows and develops (Fig. 2 and 3). In this way, they were guided to construct an understanding of the methods of science and the nature of science through an interactive process.
Fig. 1. A Pre-test on teachers’ views about science

<table>
<thead>
<tr>
<th>1A</th>
<th>1B</th>
</tr>
</thead>
<tbody>
<tr>
<td>If observations are made carefully enough,</td>
<td>Scientific observations are not always</td>
</tr>
<tr>
<td>different observers should see the same thing.</td>
<td>objective.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2A</th>
<th>2B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific theories are products of the human</td>
<td>Scientific theories emerge from patterns</td>
</tr>
<tr>
<td>imagination.</td>
<td>in data.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3A</th>
<th>3B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A theory such as gravitational theory</td>
<td>Scientific theories are models of how</td>
</tr>
<tr>
<td>describes the world as it really is.</td>
<td>scientists think the world might.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4A</th>
<th>4B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science brings us progressively nearer the</td>
<td>Scientific knowledge is open to change</td>
</tr>
<tr>
<td>truth.</td>
<td>with time.</td>
</tr>
</tbody>
</table>

(Adapted from Johnston et al., 1990)

In these two examples, the subjects were guided by questions to work out the key steps in the process of scientific enquiry and their relationships, such as hypothesis formulation, designing experiments for hypothesis testing, and drawing and evaluating conclusions. Some of the questions also helped them understand the nature of scientific knowledge, such as how scientific ideas are accepted or rejected on the basis of empirical evidence, how scientific controversies can arise from different ways of interpreting such evidence, and how scientific ideas may be affected by the social and historical contexts.

These concepts on the nature of science were reinforced in later topics of the course that are concerned with designing scientific investigations and discussion on specific topics of the science curriculum. For example, when dealing with the traditional textbook experiment on finding the percentage of oxygen in air using a candle burning over water, the subjects were alerted to the fallacy of the conclusion that air contains 20% oxygen (Yip, 2001b). In the topic
Fig. 2. Outline of the video on the scientific study about the shape of the Earth

The triumph of Magellan

Since very early times, people believed that the Earth was a very big piece of flat land. Some people, however, made some observations that could not be explained by this idea:

- The sun does not rise or set at the same time in all places.
- When a ship appears in the distant horizon, we first see the tip of the mast, then the lower part of the mast, and finally the whole ship.

These observations cannot be explained if the Earth is flat.

People began to ask the question: Is the Earth really flat?

*Question: Can you suggest an explanation for the above observations?*

If we imagine that the Earth is a very big sphere, we can explain all the above observations. However, this is just a sensible guess with no direct proof. Such a tentative explanation is called a hypothesis.

*Question: If you believe in this idea, how would you collect evidence to support it?*

To test this hypothesis, some people made a bold prediction: If the Earth is round, a ship travelling in the same direction on the Earth will finally return to its starting point. Many sea explorers had attempted to do this but failed. Finally in 1522, Ferdinand Magellan’s ship Victoria successfully made the first round-the-world voyage and returned to her starting place in Spain.

Even after Magellan’s ship Victoria had completed her round-the-world trip, some people still could not accept the idea that the Earth is round.

*Question: Why were people at that time still skeptical about this idea? But why is this idea accepted by everybody today?*

on force, the subjects were guided to compare critically the explanations given by Aristotle and Galileo on the behaviour of falling bodies.

Near the end of the course, the completed worksheet were given back to the subjects. They discussed the questions in small groups again, and were allowed to make revisions on their original answers on the worksheet individually. This serves as a post-test. The responses of the pre-test and post-test were analysed and compared to show whether there is any significant changes in the subjects’ understanding of the nature of science.

(Results)

The atomic structure

In the pre-test, all subjects could draw the atomic model accurately as made up of a positively charged nucleus surrounded by moving electrons. Most of them, however, could not give the
Fig. 3. Outline of Powerpoint presentation on studying the cause of gastric ulcer

What causes ulcer?

For many years, doctors believed that gastric ulcers are diseases caused by lifestyles. The theory was that stress stimulated the stomach to produce excessive amount of acid. The acid eroded the lining of the stomach and caused ulcers.

Question: Is this a scientific idea? How would you test it?

To cure this disease, doctors usually treated the patients with drugs that reduced the amount of acid produced or neutralized the acid. However, ulcers occurred again once the treatment was stopped.

In the 1980s an Australian, Dr Barry Marshall, observed that the bacterium Helicobacter pylori was always found in the stomachs of all his patients with gastric ulcers. This surprised him because normally all bacteria should have been killed by the strong acid in the stomach.

Question: How would you explain this observation?

This led him to suspect that the bacteria might be the cause of stomach ulcers.

Question: How would you test this hypothesis?

To test his idea, he treated his patients with antibiotics. He found that his patients recovered from ulcers and ulcers did not occur again.

Question: Does this result support Dr. Marshall’s hypothesis? Can you suggest another investigation to test Dr. Marshall’s idea?

He also ingested some H. pylori bacteria, and found himself later developed gastric ulcer. The result gives further support to his theory.

Question: Does this result confirm that Dr. Marshall’s explanation is correct?

When Dr. Marshall first proposed his theory, there was a lot of resistance from doctors and drug companies. Nowadays, however, most doctors accept that H. pylori rather than stress is the major cause of ulcers.

Question: Why did the doctors reluctant to accept Dr. Marshall’s idea?

empirical evidence that supports the atomic model. This indicates that the subjects had learned atomic structure as an established fact, and had little idea that this concept is a theoretical construct invented by scientists through the integration of empirical evidence and imagination. In the guided discussion that followed, the subjects were prompted by their course teacher to relate the various features of the atomic model to the findings of scientists. This activity provided them with a more proper view about the development and nature of scientific knowledge.
Distinction between hypothesis, theory and law

In the second part of the worksheet, most subjects could not distinguish 'hypothesis', 'theory' and 'law' precisely. They showed confusion and poor understanding of the meaning of these terms. The following summarises the most popular views that reveal inaccurate or erroneous understanding on these concepts:

Hypothesis:
- a statement that has not been proved
- an assumption that need to be made before doing an experiment
- an idea not yet confirmed by experiment
- has to be verified by the experiments to test its validity
- it is used to make people easy to study difficult thing of science, e.g. lock-and-key hypothesis

Theory:
- a statement that has evidence to support but is still controversial
- a statement that has been proved by lots of data but may be overturned
- a statement which can or cannot be verified by experiments
- a hypothesis that are confirmed by experiments
- a fact which is obtained by doing observation and some data support

Law:
- a statement that has proven to be true
- a statement that is universally true
- a statement that can be verified by experiments, e.g. Newton's laws
- a scientific theory that is deduced from axioms through deduction
- a law is obtained by doing many experiments

In the post-test, majority of the subjects were able to rectify the misconceptions shown in their pre-test worksheet. They were able to point out that a hypothesis is a tentative explanation for a scientific problem formulated on the basis of scientific knowledge and creative thinking, a theory as a hypothesis well substantiated by empirical evidence, and a law as a generalization or relationship that has been established by experimental data. The subjects, however, showed some discrepancy in their definitions of a scientific law. This discrepancy can be attributed to the fact that historically the term 'law' has been used loosely and inconsistently, and is defined in different ways by different scientists (McComas, 1998). In the law of gravity and Boyle's law, for example, the laws represent a generalization of the relationship between different variables, such as the magnitude of attractive force existing between bodies of different masses, or the relationship between the pressure and volume of a fixed mass of gas. In Mendel's laws of inheritance, however, they include certain hypothetical elements in explaining the observations made from genetic crosses.
Nature of scientific knowledge

For the last part of the worksheet, the pre-test results (Table 3) indicate that a substantial number of the subjects held the following misconceptions on the nature of scientific knowledge:

- Scientists are always objective in making observations (Statement 1A)
- Scientific theories emerge from empirical data (Statement 2B)
- Scientific theories provide accurate description of nature (Statement 3A)
- Scientific knowledge gets progressively closer to the truth (Statement 4A).

Table 3. Responses of the pre-test and post-test on the nature of scientific knowledge

<table>
<thead>
<tr>
<th>Statement</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A: Scientists are always objective in making observations</td>
<td>53%</td>
<td>7%</td>
</tr>
<tr>
<td>2B: Scientific theories emerge from empirical data</td>
<td>70%</td>
<td>0%</td>
</tr>
<tr>
<td>3A: Scientific theories provide accurate description of nature</td>
<td>83%</td>
<td>0%</td>
</tr>
<tr>
<td>4A: Scientific knowledge gets progressively closer to the truth</td>
<td>93%</td>
<td>13%</td>
</tr>
</tbody>
</table>

Note: The differences between the Pre-test and Post-test % are all significant at the 0.001 level.

These views, referred to as 'myths of science' by McComas (1998), are commonly propagated in science textbooks, in classroom discourse and in the minds of laymen. These misconceptions about science are most likely due to the lack of philosophy of science content in teacher education programmes. However, it is encouraging to see that most of the science teachers in this study showed the proper views on the nature of science at the end of the course, as demonstrated by the results of the post-test (Table 3). This means that much improvement in teachers’ conception of the nature of scientific knowledge can be achieved by incorporating appropriate elements into the teacher education programme. A historical approach, together with interactive learning activities such as small group discussion guided by the teacher, appears to be an effective strategy for helping science teachers to construct a proper understanding of the methods and nature of science.

III. FUTURE DEVELOPMENT OF SCIENCE TEACHER EDUCATION IN HONG KONG

Based on the feedback from teaching supervisors of the Faculty, many of the pre-service science teachers are not ready or confident to take up the challenge of classroom teaching in the practicum of the first term. The Faculty is considering various strategies to resolve this problem by providing a more gradual immersion into school life and the full role of a teacher. These include:
- For the first term: enriched school experience with a lighter teaching load in the first school placement, peer observation and support, team teaching with the school teacher adviser or peer student, observation of the teaching of the teacher adviser and other experienced teachers in school; advisory visits from the major course teachers.
- For the second term: an extension of teaching practice to 6 or more weeks, with formal assessments of classroom teaching within this period.

To have a more fruitful teaching practice experience for our students, it is important to promote the quality of "mentorship" and the commitment of teacher advisers. The Faculty suggests the following strategies:

- The Faculty provides courses or workshops for teacher advisers the knowledge and skills of mentorship. An important area for the experienced science teachers who serve as teacher advisers is a course on the philosophy of science, including the historical development of scientific ideas and the nature of scientific knowledge. Teachers completing these courses will gain credits in promotion or in higher degree studies offered by the Faculty.
- The Faculty will produce a handbook on Teaching Practice so as to provide the teacher advisers information on the rationale, principles, skills, strategies and guidelines for mentoring and assessment of student teachers.

According to the feedback from our graduates obtained from focus group surveys and interviews, there is a strong need for increasing the depth or duration of the SCT courses, e.g. increasing the contact hours for SCT courses from 50 hours to 60-70 hours, to be more in line with comparable programmes offered by other local teacher education institutes. One feasible solution to this demand is to recruit experienced school teachers to teach the additional hours of the subject and curriculum courses. By bringing in the experience and tacit knowledge of practising teachers, the relevancy of our PGDE programme will be enhanced and our students can gain a more updated and realistic view of the school environment before they assume the full role of a teacher.

In order to provide a solid training for novice teachers, the Faculty also considers the possibility of providing one year of internship to new teachers after their completion of the PGDE programme. Meanwhile, to ensure the quality of teachers and to reinforce reflection among the teaching profession, some faculty members suggest to launch a "Registration Teacher" scheme in Hong Kong. In this scheme, teachers will be required to re-register 3 years after their initial registration. It is hoped that the scheme will enhance the continuing development of practicing teachers in the teaching profession.
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