

A case study of Pedagogical Content Knowledge and faculty development in the Philippines¹

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Abstract

The Science Teacher Education Project Southern Philippines (STEPS, 1996-2004) aimed at establishing a science and mathematics education centre and viable teacher education programmes. The most crucial component was faculty development. This involved the selection of faculty and then professional development through on-the-job activities as well as formal degree study. This paper illustrates and to a limited extent evaluates different methods used to stimulate professional development. Professional development and PCK development² is more likely to be successful when there is an opportunity to select the lecturers/teachers most likely to benefit and make it work. Formal studies in science/math education may or may not result in practical and applicable PCK. A well-supervised practical thesis study in their own teaching environment can make all the difference. Intensive team teaching enhances PCK of both partners. A project involving joint development of science service courses with in-classroom coaching had a short term 50% success rate in significantly changing the teaching of those concerned (less lecture, more student activity, PCK based interventions). Long-term success is likely to be lower, particularly in developing countries where workloads are high and educational systems may be demotivating ('swamping') rather than encouraging.

Context

Project: The context for faculty development described in this study was the development of a new teacher education programme for physics and mathematics and for physics and chemistry. Through a scholarship scheme and very active promotion it was possible to attract high ability students but often with deficient backgrounds due to the poor quality of the educational system. For a description of the teacher education programme we refer to a recent book chapter (Berg et al, 2007). The project team was responsible for teaching many of the science and mathematics courses and for developing and teaching eight new science and mathematics education courses.

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2 PCK represents the blending of content and pedagogy into an understanding of how particular aspects of subject matter are organized, adapted, and represented for instruction.

The team also conducted outreach activities to improve the teaching and learning in science/math service courses in the university and to improve teaching in high schools. A key concern in the project was the professional development of the team and of other university lecturers who were likely to be involved in the activities. From 1996 – 2002 the author was seconded to the University of San Carlos, Cebu City, Philippines by the Centre for International Cooperation of the Vrije Universiteit, Amsterdam with funding from the Netherlands Government.

Population: The Philippines is an island archipelago with over 80 million people and a population growth of almost 2.4% per year. There are about 12 million students in elementary schools and 5.8 million students in the 4-year (grade 7-10) high school. The system has not been able to keep up with population growth. Many schools in the Central Visayas region have 70 students per class rather than the 30 – 40 common in other regions of Asia. Problems with educational quality are serious as documented in a 1993 Philippine Congressional Report, TIMSS 1998 results (Balce et al., 2000) where the Philippines ranked 36th out of 38 on both the science and the mathematics sections, and the 2004 High School Readiness Test for elementary school leavers, where 50% of the students scored below 30% and were considered not ready for grade 7 (Olivares, 2004).

Teacher Education: As in other Asian countries, in the 1940s and 1950s many bright students went into teacher education and teaching. However from the 1960s onward they increasingly went into engineering, law, medicine, accounting, and into specializations such as nursing, physiotherapy, and medical technology which have a high chance of leading to employment in the USA and elsewhere. The result has been a steep decline in the quality of students entering teacher education programmes. Simultaneously there has been a proliferation of low quality teacher education institutions (Acedo, 2002). Eighty percent of the chemistry teachers and ninety percent of the physics teachers are considered not qualified in these subjects (Ogena, 1993; Golla & de Guzman, 1998). They majored in other subjects and were then asked or forced to teach physics or chemistry. In mathematics, most teachers (80% or more) are officially qualified, yet student results are poor. Currently more than 500 colleges offer mathematics education (Ibe, 1997). Many institutions put together a mix of math courses intended mainly for other degree programmes. A student training to be a specialist secondary mathematics teacher might be required to take courses such as mathematics for secretaries, algebra for commerce, trigonometry for engineers, etc. The courses often overlap, and key subjects such as calculus are sometimes missing. Teaching methods courses are nearly always of a general character: the mathematics or science teacher education student will probably learn about classroom management, principles of teaching, and methods of assessment, but

is unlikely to be offered courses which address the specific problems of teaching and learning mathematics or science. The PCK component is missing entirely.

Teaching in secondary schools: Somerset et al. (1999a, 1999b) observed over 60 science and mathematics lessons in 15 public and private high schools in the Central Visayas. Most of these visits had been announced. Although they observed some outstanding lessons, most lessons were ineffective due to limited mastery of mathematics and science and specific pedagogy (PCK) for teaching these subjects. Alfafara and Dalman (Berg et al., 1998; Alfafara 2005) spent several weeks in each of two large public high schools. They observed over 60 lessons by 8 teachers. Most observation visits were unannounced thus assessing typical rather than best teaching. Typical lessons consisted of the following:

1. checking attendance,
2. a 5-minute review of the previous lesson,
3. 20-30 minutes of note taking (even when textbooks were available),
4. 20-30 minutes of teacher questions on the notes which usually can be answered by reading a sentence from the notes,
5. a short quiz with peer correction afterwards.

Most of the questions asked in the discussion could be answered by reading a sentence from the dictated notes. Somerset (2002) tested 567 grade 8 and grade 10 students from 15 schools on basic arithmetic and metric estimation. He also observed the teaching and concluded that most math lessons consisted of rules and drills without attention to concepts and contexts. Ravina (2000) observed almost all of the math lessons in 4 selected classes by 4 teachers in two schools during a 2-month period. The lessons were about fractions, proportions and percentages. She did not observe any references to real life problems, such as discounts in stores. She also noted many missed opportunities to involve eager students in actually *doing* mathematics rather than *observing* it on the board. These are typical patterns for teachers who have not had an opportunity to gain a deep understanding of their subject and its pedagogy.

Teaching in university: Please note that university starts after 4 years of secondary education rather than the common six years so students enter university at age 16 or 17. According to recent common observations in Philippine secondary and postsecondary classrooms (Gallos et al, 2005):

- Students are passive with instructors talking 90–100 % of the lesson time.
- Alternatives to lectures such as board work, group work and reporting are often applied but most students are mentally passive while listening to superficial presentations of fellow students.
- The teaching focus is on doing standard problems and not on concepts, conceptual difficulties, and the role of context in applying science concepts.

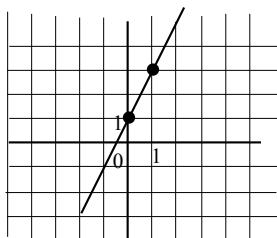
- There is often blind formula work without the conceptual understanding that is needed to realize whether results of computations are sensible.
- Concepts are introduced deductively through abstract definitions without building up an intuitive feel and understanding for the concept through examples and extensive linking with prior knowledge and everyday manifestations of the concept.
- Students have no books and mainly study from notes taken in class in spite of availability of cheap newspaper print editions of US textbooks which sometimes can be rented cheaply from the university book department.
- The taught and assessed curricula are very different from the intended curriculum as described in the syllabus in terms of level and extent of coverage.
- College instructors in physics and chemistry may not be majors in these subjects; even if they are, that is not a guarantee for mastery of the subject matter taught.
- There is no systematic and sustained effort of instructors to stimulate and maintain student work in the course (the instructor may give homework assignments but rarely checks or uses the assignment in class, thus rather than stimulating undermining student dedication).
- Sometimes the classroom atmosphere, especially for engineering students, is so noisy that learning seems impossible. However, this problem is not officially recognized as a factor contributing to low performance. College instructors often feel that keeping discipline to create a good learning atmosphere is the responsibility of students rather than of the instructor. This perception is reinforced by a culture that avoids direct disciplining.
- Many students may enter quite late or have irregular attendance; some students enter the class even without notebooks or ballpoints.

Note that many of these problems occur around the world in both ‘developed’ and ‘developing’ countries and not just in the Philippines.

Some of the problems listed can be countered by enforcing discipline in attendance of teachers and students, in homework, in using books. However, once discipline is there, real improvement in the quality of classroom teaching and learning has to come from a better understanding of the teaching learning process, of the role and importance of science/math concepts, and pedagogy (PCK) to make these concepts work. The following is an example by Haan (2002) of formula based concept teaching, which is typical for college math courses. It comes from a Philippine second year calculus course, which may be equivalent to a grade 12 secondary school course in other countries as the Philippine secondary school only covers grades 7 - 10.

One example of something that struck me:

In deriving the derivatives of all kinds of functions, I started drawing a line on the board like this:



Axes and scale were clear, as were two points of the line, so I asked the class: "What's the slope of this line"? Nobody could answer right away. So I asked if they could see the axes, the scale, the points; they confirmed. But still, they could not tell me the slope of the line, let alone the equation.

This was not the main topic of this lesson, so I briefly explained them how you could use the information from the graph to find the equation of the line, but I was really surprised that these 2nd-year students could not find this themselves, right away.

After the lesson, I asked my co-teacher what the reason could be. She said that this happened because it was never presented to them in this way; if I would have mentioned something like:

"We know two points. We can find the coordinates of these points. Using the coordinates, we can find the slope of the line by using $\frac{y_2 - y_1}{x_2 - x_1}$. Etc.", then the students might have recognized what to do.

Now, I did not mention all these things and they had no clue. So I asked my co-teacher whether they ever learned that you can really see the slope from the graph and that they don't need to write the coordinates of the points. She answered "no" and even admitted that it was not common knowledge for her either.

Similar examples of secondary school teaching of science and mathematics can be found in Somerset et al (1999b) and Somerset (2002). They clearly illustrate the need for PCK.

The University: From 1996-2004 the University of San Carlos (USC) in Cebu City, Philippines was one of 12 universities worldwide to receive large-scale institutional development funding from the Government of the Netherlands. The

support could be used to enlist assistance from Dutch universities. Amongst others USC requested assistance from the Vrije Universiteit in Amsterdam for the development of its science and mathematics education programmes. USC was the only private university in the Dutch scheme and, although affected by many of the typical problems of SE Asian universities, it did have short decision lines making it possible to move quickly and dynamically in implementing the projects.

USC then had an enrolment of about 14,000 students at the college level and 5000 students at the affiliated primary and secondary schools. Students represent a relatively wide section of the population (not an elite university). There is a typical enrolment of about 60 students per lecture section, and typical teaching loads of 24 hours/week with a faculty income of about US\$300 - 400/month. The university budget mainly comes from student tuition and fees. In the Central Philippines region the university is the top institution for science and technology but it is behind the top universities in Manila.

Theoretical Background

Ausubel's (1968, p. vi) famous dictum goes, "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly". The corollary for teachers, schools, and education systems could be formulated as: The most important single factor influencing development of teachers, schools, and educational systems is their current state. Ascertain this and map out a realistic path for development accordingly (Berg, 1996). This dictum led our faculty development efforts in the Philippines at every turn with continuous efforts to assess where the system was, where individual lecturers were, and where students were. It also led us in setting goals that would be just within reach of the system, lecturers, and students.

The lessons concerning educational change (See for example Chapter 16 p286; Fullan, 2001) emphasize the consideration of next steps and the ownership of the main participants in the process. Any change process is iterative. Even if there is a master plan, the next steps in the process have to be logical extensions of previous steps, every time considering again: Where are we? What is the next step considering our current situation and our long term vision? Sometimes even long-term visions have to be adjusted based on learning in the change process. The lessons of both Ausubel and Fullan emphasize the context dependence of education. What is best depends on the context. We named our project STEPS (Science Teacher Education Project Southern Philippines) to emphasize the step-by-step process of educational improvement.

Fullan (1991) states: “Change in teaching needs to be backed up by change in educational systems. Incentive structures may have to be modified to reward the intended behaviour. This works at many levels.” Thus in order to produce lasting educational change, it is not sufficient to try to change curriculum or teaching only. Many other changes have to be made in the organisational and incentive structures. Incentives are not limited to monetary rewards; they could also include more influence on the own work situation, more room for initiative, or professional rewards such as opportunities for professional interaction (conference attendance, etc.). Translated to the reform of a pre-service teacher education programme as in our case, this means that all aspects of the programme needed attention - not only the curriculum, but recruitment and admission, administrative structure and salaries/incentives, links with science departments, lecturers and their working environment, contacts with schools for teaching practice including a means for university instructors to keep up-to-date with the reality of Philippine schools (transport funds for school visits), placement of alumni, and links with the education bureaucracy.

The work of Joyce and Showers (1988) as well as other literature on in-service shows abundantly that teachers can only change their teaching methods through sustained assistance/coaching in the classroom. In-service workshops without support in the classroom do not work.

In our faculty development and our project this had several implications:

- team teaching (a form of peer coaching) became the most important method of training instructors for the teacher education programme;
- a mix of workshops and expert and peer coaching was used to improve the teaching and learning in science/math service courses;
- intense supervision of student teaching practice with many faculty visits; and
- a choice of the project to invest in pre-service teacher education rather than in-service as we did not have financial and staff resources to add quality coaching to in-service training.

Shulman (1987) defined PCK as that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding. PCK includes knowledge about how to transform subject knowledge to forms appropriate to students, knowledge about alternative conceptions and remediation, but also knowledge and skills on using demonstrations and labs effectively, assessing student performance, using content-based motivation strategies, preparing students for the typical exams, etc.

Regarding the importance of PCK a national report to the US secretary of education from a committee for mathematics and science education chaired by astronaut, John Glenn (2000) concluded that the key to long-term improvement [in teaching] is to figure out how to generate, accumulate, and share professional knowledge. The report states that in Japan 99% of the elementary teachers and 50% of the middle school teachers participate 2 – 5 hours a week in collaborative planning/preparing of lessons. That is where PCK is can be generated and shared! In most other countries there are no such opportunities and department meetings are spent on logistics and school-wide affairs rather than on lesson preparation.

Please note that PCK of practising teachers and PCK of science educators can be quite different to the extent that both might blame each other of being ignorant of PCK. For example, many teachers know little about common and exotic alternative conceptions. On the other hand, university science educators often do not know the many little but important details about preparing students for national exams.

From the outset, PCK was used as the leading concept in faculty development. Before the project there were no special teaching methods courses for science and mathematics in the USC pre-service programme. The few science teacher education students took general courses on teaching methods. Since 1996, PCK became the trademark of all science and mathematics education activities at the University of San Carlos. PCK was not only taught in methods courses, but was also developed in faculty research and taught in subject courses permeating all aspects of the science and mathematics teacher education programme as proposed by Berg (1996). A 36-page description of science/math and science/math education courses in the STEPS project is available from the author (Berg, 2002).

Methods

Members of the teacher education team were selected from the science and mathematics departments, based on successful involvement in teaching and development in science and science education. They eventually formed the Science and Mathematics Education Department (SMED) with lecturers holding joint appointments in SMED and one of the Science/Math Departments, a new and unusual structure in the university. Only towards the end of the project the university administration decided to formalize such joint appointments. A wider group of about 30 science and math lecturers redeveloped 25 science/math service courses for engineering, nursing, and for non-science majors and trained and coached others to teach these redeveloped courses. The lecturers

ranged from fresh graduates with local Bachelor of science/math or engineering degrees to senior lecturers with 25 – 30 years of teaching experience with Masters degrees and sometimes foreign PhD degrees.

We used the following methods for professional and PCK development of university lecturers:

For the teacher education team

1. Formal studies: During the project period 4 lecturers obtained Master degrees through full-time study elsewhere, 4 obtained Masters degrees through part-time study at USC itself, and 3 obtained PhD degrees through sandwich programmes with the University of the Philippines and 1 obtained a D.Ed. degree from Curtin University of Technology in Perth. In all cases thesis research aimed at producing PCK and applying it in science/math and science/math education courses, training colleagues in the use of PCK, and evaluating results.
2. Team teaching: A team involved either the expatriate science or math educator with a local lecturer, or local senior and junior lecturers. In our form of team-teaching the lecturers planned the lessons together, divided tasks for the activities in the classroom, both lecturers were present every class session and evaluated briefly afterwards. Team teaching concerned both science/math and science/math education courses and involved 12 lecturers who team taught for at least one whole semester.

Science/math lecturers teaching service courses

3. Joint development of courses: In order to make science/math service courses more effective, many courses were redesigned with emphasis on increasing student activity and involvement in the classroom. The central questions were: a) What should be learned? b) Why? c) How can this be done with optimal student involvement? Which classroom activities can be used to make students active? Course redesign was done by teams of two lecturers per course. Re-design work was scheduled in-between semesters during workshops for 12 – 14 developers who would work for 6 – 10 days in the resource room of Department of Science and Math Education with many textbooks, teacher journals, CDs, and internet. Subsequently developers piloted their course for a semester, revised materials, and then trained and coached colleagues to teach the revised course. During a three-year period about 20 courses were redesigned involving 30 developers. The revised courses had to be “teachable” by most lecturers rather than be state of the art.
4. Coaching: Implementation of redesigned courses by the developers and

a wider group of colleagues was supported by workshops, regular small group discussions, and coaching of lecturers in the classroom.

Evidence of PCK development in lecturers was taken from classroom observations of teaching, course preparation, thesis work, other faculty activities, and participant observation by the author. This evidence is dispersed in course materials, reports of classroom observations, theses, conference contributions, publications, and consultant reports. In the remaining part of the paper I will illustrate rather than proof PCK development of participants in this research.

Examples of Results

1. PCK development through formal degree studies and thesis research

Most learning of PCK through formal degree study probably came from thesis research rather than through coursework, although science/math content coursework may have provided a useful basis. There were three strands of thesis research: a) assessing the status quo of science and mathematics teaching in schools in our region through classroom observation and diagnostic testing (4 Masters theses); b) concept development studies in the classroom (3 Masters theses, 3 PhD theses); and c) a study of the dissemination and implementation of desired teaching methods (1 PhD thesis). I will discuss some examples:

The PhD thesis by Jocelyn (Joy) Locaylocay on teaching and learning chemical equilibrium started with three Masters theses in which young but experienced teachers a) developed and validated a diagnostic instrument, b) studied typical student errors in equilibrium computations, and c) developed activities. Joy tried out remedial methods in her courses for some years before embarking on the actual PhD thesis experiments in which she traced the development of equilibrium concepts through the course by means of tests, interviews and transcripts of discussions of target students during activities. After thesis completion the researcher continued to work with colleagues to implement concept-learning strategies in general chemistry courses for different audiences such as engineers, nurses, science majors, teacher education, and non-science majors. Joy already had 25+ years of teaching experience, had taught many of the courses in the BS chemistry curriculum. She already had an unusual grasp of PCK before starting on her PhD programme. However, she learned much more, generated new PCK in her thesis, and became a source of PCK for all other chemistry lecturers. Details on the research and evidence for PCK development can be found in Locaylocay et al (2005), and Locaylocay (2002, 2006). The lesson sequence developed was demanding in terms of teacher skill and PCK and therefore perhaps only likely to be successful if used by the best lecturers and not by the typical lecturer. In terms of Ausubel, it was taking a

big step from where most lecturers were. But there were many spin-offs which diffused to courses which were taught by typical chemistry lecturers.

A PhD study on optics concerned conceptual change strategies designed by Fred Goldberg. Using a series of activities, students build their concepts from the ground up through small group activities, inventing their own language and reasoning. The scientific terminology is introduced during plenary poster sessions where groups present to each other. The lecturer/PhD student concerned spent a 5-month internship team teaching with Goldberg in San Diego. Then he adapted Goldberg's lesson materials for use in the Philippines (more emphasis on student activities, less computer simulation except as demonstration). Then lessons were run in a 7-week optics unit. Evidence of PCK acquired and developed can be found in Rosaroso (2006) and Rosaroso & Berg (2003). Evidence of applying PCK in good teaching was observed in the lessons during the research (all videotaped) and in subsequent teaching sessions and in-service workshops I observed. Also this thesis used teaching methods which required more skill and time than typically available. The teaching methods could be used to show teacher education students what ideal inquiry and concept development in the classroom could look like, but more realistic versions will have to be developed for typical Philippine classrooms.

PhD research in mathematics education focussed on introduction of real problem solving in an algebra service course. The dominant way of teaching algebra was to teach a technique/algorithm and then practice with standard exercises. This was turned upside down by posing a problem, "mathematizing" it, and then trying to solve it and develop the techniques as part of the problem solving process. This is applying some principles of the realistic mathematics teaching promoted by the late Hans Freudenthal. The lecturer concerned selected and developed materials and practiced applying them. Then she and a colleague spent one month at Curtin University in Perth to develop her materials further with expert input from Dr. John Malone. Subsequently she taught several parallel classes where the teaching learning process was documented through self-reports, visits of observers, assignments of students, and tests.

I observed a teaching session on February 27, 2002 and the 2-page observation report clearly documents the inductive approach starting with a problem and going to different representations, different solutions, and techniques. A rather unusual approach, quite opposite to the deductive and abstract approach I had observed so many times. Students were on task and working, including a student who had entered late and a bit disruptive. He provided an inventive alternative solution. The teaching methods could be used under typical Philippine classroom

conditions, but making a shift from traditional deductive to inductive problem solving methods is difficult for many mathematics lecturers/teachers (Raffiñan, 2004).

An example of development of a more technical type of PCK is the development of micro-scale chemistry which is low cost (only tiny amounts of chemicals are used) and has obvious environmental benefits.

In a Masters project a senior lecturer developed and piloted micro-scale experiments in organic chemistry. This in turn led to implementation of micro-scale experiments in general chemistry labs using low cost South African micro-scale kits and simple reactions in drops. Several colleagues became involved in this and they acquired considerable PCK through these activities from how to make chemical reactions visible in drops to the pedagogy and management of micro-scale workshops for teachers. The micro-scale experiments were right away introduced in the teacher education programme, but it took several years before they were used in the large enrollment chemistry service courses. Somehow the Masters thesis was never completed, but the spin-offs were realized, slowly (1996 – 2004) but steadily.

In summary, development of PCK through formal degree study was successful in producing PCK, programme improvements and professional growth because thesis research was closely linked to development and teaching of existing science/math courses. That way any PCK ideas could be tested and fine-tuned in realistic classroom settings and the researching lecturers experienced deep reflection by their daily criss-crossing of the theory-practice divide.

2. PCK development through team teaching

Subject courses in physics and chemistry and in science education were developed through team teaching. Teaching and developing a course together brings much more depth into the process of course development and provides ideal opportunities for developing PCK in both partners as long as they do not go into 'routine mode'.

A chemistry colleague and I taught a first semester physical science course. My colleague introduced me to lots of chemistry while I did the physics and showed her opportunities for visualization. Together we developed interactive reasoning with our active first semester teacher education students. One time I happened to generate a nice visualization of lattice defects and conduction. Now they must understand, she said afterwards. The next time she asked some clever questions and to her and my disappointment, student answers showed that the visualization had not hit home. Nevertheless, through reading, developing, and

trial and error in the classroom we developed our own PCK.

Publications by Black (1998) and Black and Wiliam (1998) on the importance of formative evaluation led us to the development of fast feedback methods (Berg, 2003) to diagnose conceptual problems in large Philippine classes during the lesson and use the information immediately in the same lesson. This is possible by using diagnostic test items or learning tasks with a graphical response such as sketch, a force diagram, a graph or any other format in which many conceptual problems could be recognized by just one look of the teacher and responded to immediately.

One of the science education courses was one on alternative conceptions and remediation. This was a particularly useful course to team teach as we were continuously diagnosing student conceptions and trying teaching learning strategies to follow-up. One time we let our students draw some ray diagrams with flat mirrors, a topic they had studied the year before. While going around we discovered that about a third of the class drew the image on the mirror rather than behind. Quick interviews during the seatwork indicated different reasons for doing so. During the succeeding plenary the first answer volunteered by a student was a correct one with the proper location of the image and a correct ray diagram. If we had not gone around and looked at student work, we would not have become aware of the alternative answers and the need to deal with them. Obviously now there was a class discussion about 'alternative' diagrams.

In different physics courses colleagues and I experimented with fast feedback methods. It made us much more sensitive to student ideas and ways to assess them during class. Evidence of this PCK learning was joint presentations at national conference workshops and publications (Berg, Capistrano & Sicam, 2000).

In science courses and labs for pre-service teachers much use was made of everyday phenomena, discrepant events, and experiments with everyday objects. Teacher education students organize one small and one big annual science exhibition and theatre in which they demonstrate: concept mastery in their explanations, creativity in demos and show, skill in improvising and handling the experiments and explaining them to high school students, thus displaying a range of PCK skills and attesting to effective PCK of their lecturers. Lecturers were selected and trained through team teaching to support these activities. The tradition of exhibitions and science theatre by students started in 1998 and was still very much alive in 2009.

We involved new physics lecturers in the first and second semester physics course for teacher education students based on Hewitt's (1993) Conceptual Physics which was available in a low cost local newspaper print edition. This course was strongly concept focused as we wanted to discover and remediate the many deficiencies in our students' backgrounds, and at the same time we wanted to establish the conceptual emphasis in our teacher education programme. The course had a large but integrated lab component with many opportunities for lecturer – student interaction. For lecturers who perhaps mastered the math, but not entirely the concepts, this was an ideal course to develop a better understanding of concepts and concept teaching while team-teaching with a more experienced colleague. This was the course where we trained new lecturers through team teaching.

In a national workshop for university lecturers in 2003 a colleague executed the starting lesson of Goldberg's light and shadows material. Many of the participants were mainly teaching mechanics and experienced severe difficulties. The colleague turned the experience into a splendid inquiry lesson with a skilful mix of creating awareness of preconceptions through small group poster presentations, designing experiments to test and challenge ideas, and plenary reporting and debate. He showed that he greatly benefited from his PhD research and from his 4-month internship team-teaching with Fred Goldberg.

Not all team teaching experiences worked out well. Team teaching frequently exposes weaknesses in the science background of one of the partners. Usually this eventually works out positively; sometimes it worked out negatively and led one partner to withdraw from teaching in the science teacher education programme.

Compared to thesis research, PCK development through team teaching focused on wider range of teaching-learning knowledge for a particular course and more restricted to directly practical knowledge. On the other hand, the thesis research usually concerned a narrower range and greater depth through the theory-practice interaction. Furthermore, the team teaching also resulted in a lot of (science) content knowledge. Part of the PCK knowledge developed through team teaching is documented in course manuals, student assignments, activity and laboratory hand-outs. The lecturers who were trained through team-teaching and degree research played an important role as facilitators in joint course development (next section).

3. PCK development through joint course development

As the Philippine high school only has grades 7-10, typical grade 11 and 12

course work still has to be done by all students in university. So there are algebra, trigonometry, physical science, general chemistry, and physics courses, which are taken by 500 – even 2000 (algebra) students per year. Class size was limited to 60 students per class so there were courses with more than 20 parallel classes. Most science lecturers mainly teach these courses rather than courses for majors in their subject. The main purpose of this course development sub-project was to redevelop existing courses to include more student activity during lessons and require more disciplined work from students and faculty. The course development process started with 2 developers per course taking part in 6 – 10 days of full time workshop and course development. Then the two would pilot the new course for one semester in their own classes with regular visits and support from a coach. After the pilot and before the next semester they revise again and then involve more colleagues in implementing the course in parallel sections of students.

Gallos (2002, 2005) piloted a course development process in a general chemistry course. Since then 24 more courses have been redeveloped, reaching thousands of students per semester. But there were both successes and failures.

First a look into the kitchen of course development by one of the coaches. In an internal report Haan (2002) describes how she coached 2 lecturers who were redeveloping a course in statistics.

Both teachers altered their way of teaching, during this semester. They were both very open towards the idea of involving the students more and they both see the value of this way of teaching.

There is a difference between the two teachers however, and that mainly concerns their subject matter mastery.

Noteworthy is that the students are first year students, (comparable to 5th year high school Netherlands), classes are 55 students on average, levels vary very much. One of the groups was a BS nursing group, another one was a BS mathematics.

I will illustrate the difference between the two teachers with an example on the formula of the median of grouped data.

The textbook they use presents the following formula:

$$\text{mdn} = X_{\text{LB}} + \left(\frac{\frac{n}{2} - \text{cf}_p}{f_m} \right) i$$

In this formula, X_{LB} is the lower boundary of the median class, cf_p is the cumulative frequency for the class interval preceding the median class, f_m is the frequency in the median class, i is the interval size and n is the total frequency. There is no explanation for how this formula is derived; the only thing that is explained is how you can find the median class in a cumulative frequency distribution.

I asked the two lecturers how they would deal with this formula. I asked them if they understood the formula. They were planning to present it and to substitute numbers to find the median of grouped data. They did not have the intention to investigate how this formula was constructed.

I gave them a lot of feedback on this formula: about the assumptions that are made in deriving this formula, and what they would think of replacing

$\frac{n}{2}$ by $\frac{n+1}{2}$ in this formula

We had a long discussion in which I said ‘shocking’ things, for instance that I would never use a formula to find the median in this case. During this discussion, I pushed the right button in one of the teachers. In the week following, she presented this topic, without any formula, just by reasoning. From then on, her way of teaching really changed: she started using examples to introduce a new concept, instead of presenting the definition; she let students work on that, instead of lecturing, she showed a good understanding of the subject matter by her way of explaining.

The other teacher however felt very insecure after our discussion. He called me three or four times in the following weekend, checked several books and found the same formula everywhere, and in the end we agreed that I would teach this lesson.

The end of the semester, the first teacher felt so comfortable in her approach to teaching, that she would introduce the binomial distribution just like that (it was not included in the course, that’s why I asked them if it could be done the next semester). She got sick however, so it was not included.

They revised the course in-between the semesters and are both implementing it for the second time this semester and they also found a new implementer, a first year college teacher, who has her BS statistics degree.

My work with this couple was really satisfying; we had open discussions and I am investing a lot in one of these teachers, Mrs. X: the second semester she is involved in the strategies/methods course for B.S. education double-major physics/mathematics and single-major mathematics students, and I foresee a future for her in mathematics education, and therefore in the Science and Mathematics Education Department.

In each of the main disciplines of chemistry, physics, and mathematics there were one or two experts who could ask the kind of questions and pose the kind of suggestions evidenced in Haan's report above. Without them course redevelopment would only result in better documentation and at most rearrangement of existing courses. With them new sequences, articulation, and new teaching methods entered. Evidence of the course development activity is contained in about 24 course manuals with goals, key concepts, lesson plans, student activities and sometimes example tests.

About 30 lecturers participated in course development activities between 1999 and 2003. About half of them visibly grew and developed. A few of them are now teaching abroad but the others still form the core of lecturers who continue to develop their teaching locally. Another 30 – 50% may have succumbed to their teaching overloads and regressed to their former teaching.

4. PCK development through coaching

After a course has been piloted, it is revised, if possible already in consultation with other lecturers who are going to teach it. Then it is tried out again with a wider group of lecturers. These are prepared by workshops. In the abstract of their 2005 IJSE paper Gallos, Berg, and Treagust described the process and the results for the initial pilot course in general chemistry.

It is widely recognized that lectures continue to dominate college chemistry instruction, especially in developing countries, and that lectures limit student intellectual engagement. To address this concern, a general chemistry course in a Philippine university was reconstructed to implement an instructional cycle consisting of three phases: a plenary or mini-lecture, seatwork activity, and a summary or closure. An expert instructor coached the instructors to improve their teaching. Two instructors were involved in pilot implementation and 13 instructors in a large-scale implementation. This article describes the instructors' adoption of the instructional cycle using qualitative and quantitative methods that involved multiple data sources. The instructional cycle and intensive coaching enabled most instructors to change their practices, shift their focus from teaching to learning, and enhance their knowledge of student learning difficulties. Nine instructors were able to significantly change their teaching and apply meaningful student seatwork in their lessons. These nine instructors used student seatwork and activities 30–70% of the time, whereas previously 90% of the time involved lectures. Videotape records showed that more than 70% of the students were continuously on task. Four instructors had considerable difficulties in applying the new approach but also had difficulties with conventional lectures. The project constituted the start of a departmental

reorientation with a focus on effectiveness of teaching and learning. Subsequently the faculty and course development model developed in this study was used to revise other courses.

A major positive outcome of this experimental study was that content and pedagogy became major topics of both formal and informal faculty discussions whereas before discussions in the faculty room were mainly social. Instructors became much more conscious of their teaching, particularly of the subject matter problems and prerequisite skills of the students discovered during the seatwork or activity phase. These changes triggered sharing of ideas on general chemistry concepts and on teaching these concepts. Such discussions resulted in conducting special lectures for instructors on atomic structure, the geometry of orbitals and chemical bonding, and on visualization of atomic models using balloons and computers. I documented the following small group discussion that illustrates the value of sharing teaching ideas when a young lecturer, asked advice from two colleagues about how to introduce the atomic model.

An instructor with over 20 years experience in teaching general chemistry answered confidently and explained how she usually introduced atoms. Then another young instructor in his first year of teaching provided some alternative ideas and others started butting in. We ended up with quite a variety of ideas. The most experienced teacher then said: I have never known that there were so many ways to introduce the atomic model! (Journal, 15 September 2000)

Both experienced and inexperienced lecturers found alternative ways to introduce a topic and they shared this. In the process of sharing experiences, all lecturers learned.

After the pilot described by Gallos (2002), 23 other reconstructed courses were implemented by several dozen lecturers in mathematics, physics, chemistry and biology by several dozen lecturers. In outreach to science/math departments about 50 – 60% of faculty involved can successfully incorporate PCK in their lessons and implement teaching methods which include diagnostics thus generate more PCK. Motivation, age, and subject matter mastery turn out to be the main determinants of success along with support by the department leadership. Motivation and age were correlated. Among the older teachers, the proportion of enthusiastic and successful implementers was smaller. On the other hand, leadership and coaching by successful senior teachers were crucial.

As Fullan (2001) emphasized, changes in teaching/learning need to be institutionalized through changes in departmental/school organisation and

incentives. The role of formal and informal leaders in departments determined whether PCK improvements became self-sustainable (chemistry, mathematics, science/math education) or not (some other departments).

Gallos' study was executed between 1999 – 2001. Meanwhile there is experience with 23 other courses and the fading of projects and time. The science education and chemistry departments have persisted in their course improvement efforts. Recently chemistry adopted and implemented a context-concept approach in general chemistry for nursing. Other redeveloped courses have had their ups and downs, but now course coordinators have been appointed for the large enrolment courses in order to retain the gains. In the mathematics department the core of the original course developers is still active although also burdened with administrative responsibilities. Some others have reverted back to lecturing. In physics course development succeeded very well within the physics courses of the teacher education programme and courses for non-majors, but impact on the physics service courses for engineering was limited to a small group of lecturers due to opposition to change by senior (informal) leaders in the department.

5. PCK Developments through workshops

The most popular method of professional learning is through workshops of one half day, a day or several days. We did have many and a great variety in terms of content, method of working, expected output, and duration. There were workshops by very competent colleagues from abroad that produced wonderful evaluations from participating lecturers. The workshops probably produced some learning, but not in a form that could lead to applications in the classroom in spite of many concrete examples. For example, a workshop on realistic mathematics drew an enthusiastic response but little or no implementation of the many concrete examples in the classroom. Some years later the PhD study of a problem solving approach in algebra (Raffiñan, 2004) and the 2-year everyday presence of a math consultant from the Freudenthal Institute in the Netherlands did result in changes in courses and in classroom teaching. When workshops fitted into a chain of faculty/course development activities with clearly organized follow-up in between and concrete output specified, then there was a chance for workshop content to become visible in the classroom. Such was the case with a workshop on chemistry in drops which fitted well into the micro-scale developments in the chemistry department. This is exactly what literature on in-service has been saying since the early 1980s (Joyce & Showers, 1986), Fullan (2001 and earlier versions of this book), Loucks-Horsley et al. (1998). That is why during the second phase of the project (2000 – 2004) workshops were all integrated in the process of course development described above. In short, even outstanding workshops do not change classroom practice unless the workshop

has been integrated in a long-term professional and course development effort which also has other components such as ‘on-service’ (scheduled implementation in the classroom), coaching and course development activities.

Conclusions

PCK can be a very effective organizer to structure faculty development and make it very concrete and visible to all participants. PCK includes a wide range of knowledge: curriculum knowledge, views on subject goals for different target groups of students, knowledge on how to transform subject knowledge to representations appropriate for particular groups of students, knowledge on which demonstrations are available for certain topics and how to assess particular course goals, and knowledge of alternative conceptions and sophisticated remediation strategies for teaching. Furthermore, there is the skill of using this knowledge productively in the classroom. The different methods in our project to develop PCK of lecturers cover different parts of the spectrum of PCK.

Taking graduate courses in science and science education did result in improved subject matter knowledge (very useful), it did supply theoretical background in science education but for converting this knowledge into useful PCK with different/better teaching it was necessary to get additional experiences such as classroom research closely supervised by a hands-on adviser or team teaching.

PhD and Masters thesis work on concept development strategies in the classroom covered narrow parts of PCK (particular concepts) very deeply and thereby also developed in-depth thinking about conceptual development and teaching in general. The classroom research forced very useful criss-crossing across the theory-practice divide. Working with colleagues to implement concept teaching strategies also increased understanding for what it takes to implement new teaching in classrooms.

Team-teaching covered the whole width of a course curriculum (say thermodynamics or organic chemistry) with less depth but with lots of immediately applicable items such as a particular way of carrying out a demonstration, using an analogy, or student activity. Team-teaching greatly contributed to the ‘bag of tricks’ of both team members and always improved science subject mastery and led to new ways how to present science/math and involve students. Team teaching resulted in PCK with impact on students!

Joint course development paid more attention to course goals, course emphasis and sequence and structure and to student activities but usually lacked the practical team teaching component, although developers would confer often

during piloting and share ideas. Often course development teams need a sparring partner or expert to help them to look at the course material in a new way and to help them see alternatives in sequence and presentation. For chemistry such expertise was available locally through a very competent chemistry educator with solid chemistry knowledge and a large stock of teaching ideas and through the presence of several lecturers with foreign PhD degrees in chemistry and interest in teaching. For math and physics the presence of expat consultants was important. Getting science/math lecturers to develop their own PCK through redeveloping standard science/math service courses is more effective than just teaching PCK through workshops as it is more concrete, more convincing for the hard science types, and immediately implemented.

Coaching to support implementation of redeveloped courses initially had to focus very much on basics such as getting students to come prepared and on time and getting them to work in class. During this initial implementation phase the PCK part was limited to knowledge about how to get students active, which tasks to use, all at a very basic level. Once such basics were running smoothly, implementers got more focussed on teaching and learning concepts with help of the coaching and small discussion groups with colleagues implementing the same course. However, the intensity of the experience was much less than with the other faculty development methods described above.

Workshops can be effective only if they respond to course concerns, result in easily implemented suggestions, are followed through with coaching, and fit in a long term faculty and course development plan.

Please note that for both joint course development and coaching, the support of key departmental leaders is a precondition for sustainability of any improvements. Furthermore, many institutional variables need to be considered for successful redesign of courses. For example, by using existing university structures/rules creatively it was possible to arrange for course development time for lecturers, to arrange textbook lending to several thousand students each semester, and to get a small time allocation for course coordinators for some of the courses. Furthermore there was communication with the major departments of service students about both course content and changed teaching methods.

References

Acedo, C. (2002). *Teachers: Supply and demand in the Philippines*. HDNED, The World Bank. Available at www1.worldbank.org/education/est/resources/case%20studies/phillippines%20-%20tea.doc (accessed August 1, 2008).

- Alfajara, R. M. (2005). *The competence of secondary biology teachers of two science and technology network schools in region VII: Basis for a professional development programme*. Unpublished Masters thesis. Cebu City (Philippines): University of San Carlos.
- Ausubel, D. (1968). *Educational Psychology: A Cognitive View*. New York: Holt, Rinehart and Winston.
- Balce, M., Carale, L., Ferido, M., Guzman, F. de, Mendoza, A., Ogena, E., Savellano, J., & Talisayon, V. (2000). *Third international mathematics and science study—repeat: The Philippine participation (Vol 1&2)*. Manila: Science Education Institute, Department of Science and Technology.
- Berg, E. van den (1996). Science teacher development in developing countries. *ICASE Science Education International*, 7 (3), 3-8.
- Berg, E. van den, R. Alfajara, T. Dalman (1998). *Case studies of science and mathematics teaching in the Philippines and lessons for teacher and school development*. National Association of Research in Science Teaching. San Diego, U.S.A., April 19-22, 1998.
- Berg, E. van den (editor, 2002). *Science/Math and Science/Math Education Courses in the BSEd Physics-Mathematics and Physics-Chemistry Programmes at the University of San Carlos*. Science and Mathematics Education Department, University of San Carlos, Cebu City (available as pdf from the author).
- Berg, E and R van den, N. Capistrano, A. Sicam (2000). Kinematics graphs and instant feedback. *School Science Review*, 82 (299), 104-106.
- Berg, E. van den (2003). Teaching, Learning, and Quick Feedback Methods. *The Australian Science Teaching Journal*, June 2003, 28-34.
- Berg, E. van den, Locaylocay, J.R., Gallos, M.R. (2007). Ten Best Practices in a Science and Mathematics Teacher Education Programme in the Philippines. In M. Nagao, J. Rogan, M. Magno (Eds.): *Mathematics and Science Education in Developing Countries: Issues, Experiences and Cooperation Prospects*. Diliman, Quezon City: The University of the Philippines Press, 231-251.
- Black, P.(1998). Formative Assessment: raising standards inside the classroom. *School Science Review*, 80 (291), 39-46.
- Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education*, 5 (1), 7-74.
- Fullan, M.G. (1991, 2001). *The new meaning of educational change (2nd, resp.3rd edition)*. London: RoutledgeFalmer.

- Gallos, M.R. (2002). *Reconceptualizing a College Chemistry Course to Improve Teaching and Learning*. Ph.D. Thesis. Perth: Curtin University of Technology.
- Gallos, M.R., Berg, E. van den, & Treagust, D.F. (2005). The effect of integrated course and faculty development: experiences of a university chemistry department in the Philippines. *International Journal of Science Education*, 27 (8), 985-1006.
- Glenn, J. et al (2000). *Before it is too late. A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century*. A report submitted to the US Secretary of Education, september 27, 2000 (page 20). URL: <http://www.ed.gov/inits/Math/glenn/report.pdf> (accessed August 6, 2008).
- Goldberg, F. (1997). *The CPU Project: Students in control of inventing physics ideas*. Forum on Education, American Physical Society.
- Golla, E.F., de Guzman, E.S. (1998). Teacher preparation in science and mathematics education: A situational analysis. In: E.B. Ogena & F.G. Brawner (Eds.) *Science education in the Philippines: Challenges for development. (Vol 1)*. Manila, National Academy of Science and Technology.
- Hewitt, P. (1993). *Conceptual Physics, 7th edition*. Menlo Park, CA: Addison-Wesley.
- Haan, D. de (2002). *First Interim Report*. In: STEPS 12th Progress Report. Amsterdam: Centre for International Cooperation, Vrije Universiteit, 36-45.
- Ibe, M.D. (1997). Shortage despite oversupply: the tragedy of teacher education. In: *Higher Education Now or Never*, 85-118. Report, Diliman, Quezon City (Philippines): UP School of Education.
- Joyce, B., & Showers, B. (1988). *Student achievement through faculty development*. London: Longman.
- Locaylocay, J.R. (2002, 2006). *Changes in college students' conceptions of chemical equilibrium*. PhD thesis, University of the Philippines, Diliman, Quezon City 2002. Published as book : Centre for International Cooperation, Vrije Universiteit, Amsterdam, ISBN 90-9019266-2.
- Locaylocay, J., Berg, E. van den, Magno, M. (2005). Changes in College Students' Conceptions of Chemical Equilibrium. In Boersma et al. (Eds.), *Research and the Quality of Science Education*. Dordrecht, Netherlands: Springer Publishers.
- Loucks-Horsley, S., Love, N., Stiles, K.E., Mundry, S.E., Hewson, P.W. (1998). *Designing Professional Development for Teachers of Science and Mathematics*. Corwin Press.

- Ogena, E. (1993). *Science Teacher Education Report*. Bicutan, Metro Manila: Department of Science and Technology.
- Olivares, B. (2004). *Philippine Daily Inquirer*. June 6, 2004.
- Ravina, V. (2000). *Numerical Errors and Misconceptions of First Year High School Students*. Masters thesis, University of the Philippines, Diliman Campus, Quezon City, Philippines.
- Raffiñan, C. (2004). *Non-Traditional Problem Solving for Developing and Assessing Critical Thinking, Affective, and other Cognitive Skills of Students*. Unpublished PhD thesis, University of the Philippines, Diliman Campus, Quezon City, Philippines.
- Rosaroso, N. (2006). *College students' evolution of ideas in geometrical optics using inquiry-based materials*. Unpublished PhD thesis. University of the Philippines, Diliman, Quezon City, Philippines.
- Rosaroso, N., Berg, E. van den (2003). Rosaroso, N., Berg, E. van den (2003). *The evolution of Philippine student conceptions of the formation of shadows and images*. Paper presented at the ESERA conference, Noordwijkerhout (Netherlands), August 2003.
- Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57 (1), 1-21.
- Somerset, A.H., Alfafara, R. & Dalman, T. (1999a). *Science and Mathematics Teachers in Central Visayas Region, Republic of the Philippines: Initial Training, Deployment and Subsequent Professional Development*. Cebu City: SMEI-USC, Talamban Campus.
- Somerset, A.H., Alfafara, R. & Dalman, T. (1999b). *Teaching and Learning Science and Mathematics in the Classroom: Effective and Ineffective Pedagogy Compared*. Cebu City: SMEI-USC, Talamban Campus.
- Somerset, A. (2002). *Basic Number Skills: Why Students Fail*. UP-NISMED, University of the Philippines, Diliman, Quezon City, Philippines.