SUI LING WONG

11. LEARNING ABOUT NATURE OF SCIENCE THROUGH LISTENING TO SCIENTISTS' STORIES OF SCIENTIFIC ENQUIRY

INTRODUCTION

This chapter first reviews a series of curricular reforms of science education in Hong Kong that started at the turn of the 21st Century. It moves on to share the decade of efforts in promoting teachers' learning and their subsequent teaching of the nature of science (NOS). Among these efforts, two teacher professional development programmes received overwhelmingly positive views from teachers in terms of developing their understanding about NOS and scientists. Both programmes provided teachers with special encounters with world-renowned local scientists. The first encounter was an in-depth case study of the authentic scientific enquiry in the Severe Acute Respiratory Syndrome (SARS) epidemic in which Hong Kong scientists played a crucial role in many important research findings about SARS. This included the identification of the SARS-coronavirus as the causative agent, and the subsequent sequencing of the virus. Video clips of interviews of the scientists involved in the fight against the deadly disease provided information about the various key events that happened during the SARS crisis. The second encounter was a personal sharing of the research journey of a local scientist, Professor Dennis Lo, who recently achieved a breakthrough in deciphering the fetal genome through analysing trace amounts of fetal DNA in the mother's blood.

Elaboration of each programme with the embedded NOS features is then given followed by the views of Ivy and Henry who experienced the training of both programmes. Their views on their general learning experience and the impact of both programmes on their teaching of science were solicited. Specifically they were invited to reflect on the following questions:

1. What did you learn most from the SARS case study related to NOS and beyond NOS?
2. What did you learn most from Professor Lo's story of discovery related to NOS and beyond NOS?

Upon receipt of their written responses, a follow-up interview for clarification and further elaboration was conducted with Ivy and Henry individually over an Internet

B.J. France and V.J. Compton (eds.), Bringing Communities Together: Connecting learners with scientists or technologists, 147–160.

video conference. Ivy's interview lasted for about 60 minutes whereas Henry's lasted for about 30 minutes.

Their sharing reveals some common and unique advantages of teaching NOS through an in-depth case study of a complex socioscientific issue such as the SARS epidemic, and a detailed personal account centred on the scientific pursuit of a scientist with his interaction within and beyond the scientific community. The chapter ends with a final note with some recommendations on how sophisticated understanding of NOS and excitement in learning NOS could be achieved.

SCHOOL SCIENCE CURRICULUM REFORM IN HONG KONG

Understanding NOS as a curriculum goal

Science education in Hong Kong has undergone considerable change in the last decade since the implementation of the revised junior secondary science curriculum (Curriculum Development Council [CDC], 1998). The curriculum advocates scientific investigation as a desired means of learning scientific knowledge, and highlights the development of enquiry practices and generic skills. It was the first local science curriculum that emphasized understanding of some features of nature of science, for example, "the evolutionary nature of scientific knowledge" (CDC, 1998, p. 3). In the first topic, "What is science?" teachers are expected to discuss with students some features about science such as its scope and limitations, some typical features about scientific investigations, fair testing, control of variables, predictions, hypotheses, inferences, and conclusions.

Such an emphasis on NOS was further supported in the revised secondary 4 and 5 (grade 10 and 11) physics, chemistry, and biology curricula (CDC, 2002). Scientific investigation continued to be an important component while the scope of NOS was slightly extended to include recognition of the usefulness and limitations of science as well as the interactions between science, technology, and society (STS). In preparation for the implementation of the recent curriculum structure (from a 7-year secondary education system to a 6-year one) in September 2009, a new set of Curriculum and Assessment Guides was devised for senior secondary level science subjects (CDC-HKEAA, 2007). I note a further leap forward along the direction of earlier curriculum reforms in the curriculum and assessment guides. Here the importance of promoting students' understanding of NOS is more explicitly spelt out.

To put greater emphasis on environmental issues, students' appreciation of STS is extended to STSE, where "E" stands for environment. For example, in the physics curriculum, students are expected to "appreciate and understand the nature of science in physics-related contexts," "develop skills for making scientific inquiries," "be aware of the social, ethical, economic, environmental and technological implications of physics, and develop an attitude of responsible citizenship," and "make informed decisions and judgments on physics-related issues" (CDC-HKEAA, 2007, p. 4). There is a clear intention to develop students' awareness and understanding of issues associated with the interconnections among science, technology, society and the environment.

In sum, development of local science curricula in the last decade has seen a shift from predominantly content-focused goals to a wider goal of promotion of scientific literacy. This shift is a result of a considerable influence from western countries where understanding of NOS has long been regarded as a major component of scientific literacy and important learning outcomes of science curricula (American Association for the Advancement of Science, 1993; Council of Ministers of Education, 1997; Millar & Osborne, 1998). In other words, local curriculum developers have subscribed to the important goals of learning NOS commonly advanced by advocates in the field of science education, for example, the utilitarian, democratic, cultural, moral, and science learning arguments put forward by Driver, Leach, Miller, and Scott (1996).

PROMOTING THE ABIILITY OF HONG KONG TEACHERS TO TEACH NOS

Challenges and problems

Based on the literature and our local context, we identified a host of problems and challenges to tackle in encouraging and training teachers to teach NOS. In particular, we have been cognizant of the disappointing conclusions that were consistently reached by various studies. That is, both students and science teachers have inadequate understanding of NOS (Lederman, 1992) and STSE (Rubba & Harkness, 1993). There is, however, emerging empirical evidence that can inform efforts to improve NOS and STSE understandings. Explicit and reflective approaches in teaching NOS can support learner development of sophisticated NOS ideas (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002). Teachers with good understanding in NOS still face many constraints including concerns for student abilities and motivation (Abd-El-Khalick, Bell, & Lederman, 1998; Brickhouse & Bodner, 1992), lack of pedagogical skills in teaching NOS (Schwartz & Lederman, 2002), and lack of teaching resources particularly those in local contexts and language (Tsai, 2001). Effective NOS teaching also depends on teachers' belief in the importance of teaching NOS (Lederman, 1999; Tobin & McRobbie, 1997) and their conception of appropriate learning goals and teaching roles (Bartholomew, Osborne, & Ratcliffe, 2004). On top of the problems identified above, Hong Kong teachers very rarely have experienced learning of NOS during their own schooling. Noting teachers' inadequate NOS understanding and hence their lack of appreciation and less than effective use of the NOS instructional materials, science educators at the University of Hong Kong then restructured our teacher training programmes to allow more time on these aspects. In the early 2000's, we attempted to use science stories, such as the discovery of penicillin, the development of cowpox, Newton's proposition of the Law of Universal Gravitation, and the treatment of stomach ulcers (Tao, 2002), as a medium through which NOS could be introduced to students. However, due to the lack of both understanding of NOS, and experience in learning and teaching NOS, many teachers made use of them only for arousing the students' interest. Hence, the availability of teaching resources would not by itself result in teachers' learning of NOS and an effective teaching of NOS. Unless teachers had the ability to understand and appreciate the rationale behind the design of the instructional materials, it was likely that they would overlook or miss the targeted learning objectives (learning NOS features) and gravitate toward the parts which were more appealing to them (dramatic stories which promote student's interest). Such a situation was reflected in the comment made by a junior science teacher who had been telling interesting science stories to his students. He came to realise his oversight of not having made good use of the stories for teaching NOS after he attended our NOS training workshop:

> I found the story on stomach ulcers very interesting....Marshall tested his hypothesis by trialling out himself...students all enjoyed the story...I only realise now that there are deeper meanings behind the story and other important learning outcomes to be achieved through it and other stories.

We also reckoned that there were inadequacies in some of these relatively "old" stories. Teachers and students expressed that though these stories aroused their interests, they happened quite a while ago. Those who did not have the historical and cultural backgrounds of the scientific discoveries and inventions would fail to develop an in-depth understanding of, and hence appreciate, the thought processes of the scientists related to what they encountered at their time.

A contemporary story of scientific enquiry to promote NOS understanding

In the summer of 2003, when the crisis due to SARS in Hong Kong was coming to an end, we saw a golden opportunity to turn the crisis into a set of meaningful instructional resources that might help address the issues raised above. The SARS incident was a unique experience that everyone in Hong Kong had lived through and the memories of which would stay for years to come. At the beginning of the outbreak, the causative agent was not known, the pattern of spread was not identified, mortality and morbidity soared, yet an effective treatment was uncertain. It attracted the attention of the whole world as scientists worked indefatigably to understand the biology of the disease, develop new diagnostic tests, and design new treatments. Extensive media coverage kept people up to date on the latest development of scientific knowledge generated from the scientific enquiry about the disease. We believed that the incident could be used to reveal many interesting aspects about NOS. Such aspects could be based on: the interviews with key scientists who played an active role in SARS research, analysis of media reports, documentaries, and other literature published during and after the SARS epidemic. The SARS incident illustrated vividly some NOS features advocated in the school science curriculum. These included the tentative nature of scientific knowledge, theory-laden observation and interpretation, multiplicity of approaches adopted in scientific enquiry, the inter-relationship between science and technology, and the nexus of science, politics, social, and cultural practices. The incident also provided insights into a number of NOS features less emphasized in the school curriculum. These features included the need to combine and coordinate expertise in a number of scientific fields, the intense competition between research groups (suspended during the SARS crisis), the significance of affective issues relating to intellectual honesty, the courage to challenge authority, and the pressure of funding issues on the conduct of research.

Full details on how we made use of the news reports and documentaries on SARS, together with episodes from the scientists' interviews to explicitly teach the prominent features of NOS, have been published in an earlier paper (Wong, Hodson, Kwan, and Yung, 2009). Since January 2005, we have been using the SARS story[i] in the training of hundreds of pre-service and in-service science teachers about NOS. The feedback has been very encouraging. The SARS story was particularly successful in promoting teachers' understanding of NOS in terms of (i) the realization of inseparable links between science and the social, cultural and political environment, (ii) deeper understanding of how science and technology impact on each other, and (iii) a richer appreciation of the processes of authentic scientific enquiry and the humanistic character of scientists. The effectiveness was mainly attributed to immediacy, relevance and familiarity of the SARS story, which made the abstract tangible. Teachers' personal experience of this unique piece of 'history' of science and the powerful affective impact of the interviews with scientists also contributed to the favourable learning outcomes (Wong, Kwan, Hodson, & Yung, 2008).

Further efforts in promoting teachers' ability in teaching NOS

Ivy and Henry were among those earlier groups of teachers who experienced the training on NOS understanding through the story of SARS in 2005. Ivy and Henry also subsequently participated in further professional development projects[ii] conducted by a team of science educators from the University of Hong Kong to further develop their pedagogical content knowledge and confidence in teaching NOS from 2005 to 2010. Some of the outcomes of the projects have been presented in Wong, Wan, and Cheng (2011). These teachers have been making very good progress on this front.

Recently, in the beginning of 2011, Ivy and Henry were invited by the Education Bureau (EDB) to share their classroom practice of integrating teaching NOS in biology and physics lessons respectively in a seminar which aimed at enhancing science teacher's awareness, ability and confidence in teaching of NOS. The last session of the seminar was a 75-minute talk by Professor Dennis Lo followed by a 15-minute open dialogue session between Professor Lo and the floor.

Professor Lo is a Hong Kong medical scientist who is internationally renowned for his contribution in the research area of prenatal diagnosis. It was just about a month before this seminar that his breakthrough in deciphering the fetal genome through analysing trace amounts of fetal DNA in the mother's blood was widely reported both locally and internationally in the news media. The seminar coordinator of the EDB invited Professor Lo to talk about his personal story of scientific enquiry in prenatal diagnosis and beyond during the past two decades with the intention that the audience could appreciate the NOS exhibited in his research pursuit. Having noted the goal of the seminar, Professor Lo deliberately embedded some NOS features prominent in his story with some explicitly spelt out while some were implicitly covered.

PROFESSOR LO'S STORY OF HIS SCIENTIFIC ENDEAVOUR

This section is devoted to elaborate on the key events occurring in the two decades of the odyssey of Lo's scientific enquiry together with the NOS features that were covered in his stimulating talk.

Fascinated by the stories of science and scientists – doing science is a way of life

Lo got interested in science when he was studying secondary school in Hong Kong. He was most fascinated by Biology, in particular, the DNA molecule that 'plays a determining role in our lives' as he put it. He recalled he was attracted to the many interesting photos of scientists and the description about them in a biology textbook. He was most attracted to the photo of Watson and Crick standing in front of the King's College Chapel in Cambridge which made him determined to pursue further study in Cambridge. He was later admitted to Cambridge to study medical sciences after his completion of secondary education in Hong Kong.

In Cambridge, he studied at Emmanuel College where Thomas Young was an alumnus. Lo shared the legend that Young who probably got inspiration for the double-slit experiment when he was relaxing near the pond in the College and noting the interference patterns of water produced by two ducks. Lo said that to him, doing science is a way of life, rather than a job. The inspiration of research ideas often comes from daily experience in life.

"Doctor, I can't find it in the books" – a student could contribute to science

After he graduated from Cambridge, Lo became a clinical medical student at Oxford University where he came across a patient with a rare type of rectal cancer. He searched through his medical textbooks for more information about the cancer but was in vain. He then spent a further three weeks in the library searching through all relevant medical journals but was still futile. He later found that the type of cancer was so rare that there were only four cases ever reported. He then wrote up a case report of this '5th case' to a medical journal and got published. This story taught him a lesson that even if someone is just a student, he/she can still make contribution to science. The experience boosted his interest and confidence in research and paved him the way to do scientific research. He wished very much to be able to find something new next time.

In a later instance, when Lo was a medical student receiving training in obstetrics and gynaecology at Oxford, he felt that the process of amniocentesis was rather threatening to the mother and also risky to the fetus, with about a 1% chance of miscarriage. He then thought if there could be safer ways, e.g. by testing the pregnant mother's blood to deduce if the baby was carrying any serious genetic disease. The traditional view then was that the blood circulations of the mother and the baby were separated. Lo thought 'would this 'separation' be incomplete and that one could use the small number of fetal cells that have 'leaked' into the mother's circulation to do prenatal diagnosis?'

Lo spent the next six months coming up with an idea for testing the presence of the baby's cells in the mother's blood. He proposed to detect if DNA from the Y chromosome was present in the mother's blood when she carried a boy. Since there was no Y chromosome in her own blood cells, the presence of Y chromosome in her blood would support his hypothesis that the circulations of the mother and the baby were not entirely separated. He was so excited with the ideas but was frustrated that most professors he approached to allow him to try out this investigation in their laboratories were skeptical of his hypothesis. One even commented, 'if that phenomenon does exist, why would the discovery be left for you to find out?' Lo shared that, "it's like a discouraging teacher who could drive a student full of fascination about science away from it." However, he was fortunate enough to have a professor who was open-minded enough to let him carry out the investigation in his laboratory. Lo eventually showed that his hypothesis was correct and published his findings in the *Lancet*, a top medical journal, in 1989.

Embedded NOS aspects and characteristics of scientists as reflected in this episode include:

- Scientists need perseverance in their pursuit of science.
- Atypical observations are worthy of reporting as these may serve to provide better understanding by having more information to the existing limited knowledge about a phenomenon (in this case, a rare type of cancer).
- Posing a meaningful research question is just a beginning. The design of a logical and feasible investigation is most crucial and often takes a long time to incubate.
- Scientists not only need the courage but also a logical and feasible plan to challenge the established scientific knowledge.
- Publishing papers is a core business in the scientific community for communicating findings that are important for the collective construction and enrichment of scientific knowledge.

Needle in a Haystack – A long journey from discovery to practical application

Hoping to turn the finding into a safer and routine way to do prenatal diagnosis, Lo decided to pursue a Doctor of Philosophy degree along this direction. Although he did more than adequate in the area of research for graduation with numerous publications, his goal had not yet been achieved. The tiny amount of the fetal cells (of the order of 1 fetal cell per million maternal cells) in the maternal blood did not allow him to arrive at a simple and robust method for routine non-invasive prenatal diagnosis through taking the mother's blood.

Lo continued to work on the same area of research in the Oxford Medical School as academic staff. In late 1996, Lo received a job offer from the medical school at The Chinese University of Hong Kong. While getting himself prepared for the move back home to Hong Kong, he was reflecting on his work in between the 1989 demonstration of the presence of fetal cells in maternal blood using a modern molecular method, and the various approaches he had tried in the past years in improving the detection of the fetal cells. He asked himself, "what have I been doing wrong for not solving the problem?" During this time of reflection, he came across two papers published in *Nature Medicine* in 1996, reporting that the DNA of tumours could be found in the plasma of cancer patients. He realised the parallel between a tumour and a fetus in the mother's womb and thought, "A fetus is similar to a tumour living inside a mother's body. Furthermore, a fetus in the later stages of pregnancy can be some 8 pounds and is much larger than any tumour that I have seen. Would the fetus release fetal DNA into the plasma of the mother?"

Lo therefore attempted to see if he could find Y chromosomes in the plasma of pregnant mothers who carried male fetuses. To his pleasant surprise, he found about 5% of fetal DNA swimming in the mother's plasma – an amount which would make routine diagnosis possible! This discovery was published in the *Lancet* in 1997.

With such a finding, a number of applications in the diagnosis of different sex-linked and blood-group linked diseases carried by the baby could be done. Lo demonstrated that the accuracy of detection was about 96% in 1998. Similar results were reproduced by other laboratories in the decade after the year 2000 for a number of genetic diseases. With such a high degree of accuracy, many countries including Britain, USA, and Holland are currently using this non-invasive prenatal diagnosis as a routine test for some of these conditions, e.g. for testing the blood group of the fetus.

Embedded NOS aspects and characteristics of scientists as reflected in this episode include:

– When new scientific knowledge becomes available and there is a need from the society, there may be proposals for its technological application, e.g. safer means of medical diagnosis.
– Creativity and innovation of science. Many new ideas in science come from drawing analogies between different areas.
– Exposure to other research areas helps scientists to gain insights into their own expertise.
– A fundamental assumption in science is that if one follows the same procedures, the data obtained should be replicable within a reasonable error margin.

Research is very competitive - Scientists are racing with each other every moment

Lo's next target then was to attempt the detection of Down Syndrome, a chromosomal disease most parents-to-be are concerned with. Unlike detecting sex-linked diseases which rely on a differentiation of the presence or absence of certain sex-linked DNA, this time it was the challenge of detecting an extra copy of the chromosome 21 in a baby with Down Syndrome. In 2007, Lo calculated that according to the ratio of 95% maternal DNA versus 5% fetal DNA in the maternal plasma, one would have to develop a DNA test that can tell a 2.5% difference in the amounts of chromosome 21. At that time, such a precision was thought by many scientists to be very difficult to achieve, if at all. Lo proposed that one way to solve this problem was to use methods that would allow one to count DNA molecules, one by one. By 2008, the development of a new generation of DNA sequencers allowed millions of DNA molecules to be counted rapidly. In late 2008, Lo's research group and a group in Stanford University independently demonstrated and published that the use of such sequencers could indeed allow the robust non-invasive prenatal detection of Down Syndrome.

Lo then asked more ambitious questions, "How far can we push forward this technology? Is the entire fetal genome present? If yes, can we obtain the entire fetal genome from maternal blood?" He shared in a light-hearted manner with the audience the inspiration he finally got after months of pondering from watching the 3D opening of the movie, *Harry Potter and the Half-blood Prince*. He recalled the Eureka moment as follows:

> When the 3D letter 'H' of Harry flying out from the screen, I suddenly saw the two sides of the 'H' as the strands of the father's and the mother's genomes... The baby's genome is a combination of the mom's and dad's. So we could first focus on those fragments of DNA sequences inherited from the dad, i.e. sequences that are only present in the father's genome but absent in the mother's. For the mother bit, it's more challenging as they will be mixing with that of the mother's fragmented sequences in her plasma. For those mom's sequences which are inherited by the baby, it will have a slightly greater quantity than those not passing to the baby, and we now have technology to differentiate such a small difference in quantity!

In his explanation of the complex idea, he used a jigsaw puzzle representing the genome of the baby with some pieces with distinctive features of sharp colour which are easily noticed to represent the sequences from the father's genome. For the mother's, he used x repeated pieces to represent those sequences not having passed to the baby while (x + 1) repeated pieces to represent those sequences having passed to the baby.

Lo further shared how the once unexpected presence of DNA found in the plasma has been applied to some other areas including cancer diagnosis and rejection of transplantation by his research group and other research groups using on similar principles.

He closed his talk by briefly revisiting some lessons and thoughts accumulated through his experience as a scientist:

– Don't over-rely on established wisdom (e.g. fetal-maternal circulations are separate);
– Look in non-obvious places and take unconventional approaches (e.g. DNA outside cells);
– Be confident (e.g. a student can contribute);
– Science is competitive (e.g. research groups across the world are racing against each other at every moment);
– Doing science is fun (e.g. inspiration from watching movies) and meaningful (e.g. can help patients);
– Scientific advancement is achieved through teamwork (showing the last slide of his talk with his research team of over 30 members!)

Embedded NOS aspects and characteristics of scientists as reflected in this episode include:

– Advances in technology allow theoretical scientific prediction to be realized in practice.
– Science at the frontier is highly competitive and many research groups are racing to be the first.
– Another instance of scientists gaining inspiration while they are not formally doing research.
– In scientists' presentations to their peers or laymen (such as science news reporters), analogies are often used to communicate thought processes and ideas for ease of appreciation and understanding by the audience.
– Large-scale collaboration is common in modern science.

As in the case of the SARS story, Lo's story about his scientific endeavour also vividly illustrated a number of NOS aspects. Though not as extensive and intensive as the case of SARS involving a number of complex socioscientific issues, his story revealed in greater details the subtle thinking and reasoning in problem solving during scientific enquiry.

VIEWS BY IVY AND HENRY ON SARS CASE STUDY AND PROFESSOR LO'S STORY

Steep curve in learning NOS through a contextualized approach

Ivy recalled that she was carried away when she first experienced the NOS training through the SARS story. Her excitement was still noticeable when she described the experience as an 'eye-opening' one and said, "…it's like a sudden realization that I had been blindfolded for years…the SARS lessons came to remove the bandage over my eyes…". Such feelings was resonated by Henry.

Ivy and Henry could appreciate numerous NOS features in both the SARS case study and Professor Lo's story of scientific enquiry. They could identify almost all NOS features in Professor Lo's talk, including those features that were not obviously reflected in the SARS case, e.g. creativity and innovation in science. Ivy commented that the focus in SARS was about the incident whereas the focus in the sharing of Professor Lo was about scientists. Henry elaborated a key difference between SARS and Lo's story. He said:

> SARS as a very serious unknown disease then, urgently required many scientists to address the problem, he saw more about the *interactions* among scientists, for example, peer review of research findings, establishment of science knowledge through consensus among science community. The SARS story was embedded with a rich list of the NOS aspects in the social dimension.

Professor Lo's sharing focused on the development of his research covering more the thinking processes of scientists reflecting vividly scientists' creativity and innovation. Factors that affected his research development, such as funding, technological advances, society needs, and stimulation by findings in other areas of research were also more obvious. Henry further elaborated another difference between the SARS and Professor Lo's research journey.

> In SARS there was little agreement about the disease at the initial stage of the outbreak. For example, different scientists had different opinions about the pathogen of SARS. On the contrary, there was already some well-established scientific knowledge for Professor Lo's study.
>
> I found Professor Lo did not submit to authority. Such courage of daring to challenge authority was extraordinary and impressed me a lot.

Both Ivy and Henry consider the SARS case study has had a larger impact on their learning of NOS. One major reason is related to the steep learning curve when they first began formal learning about NOS through the SARS case. Another reason was the familiarity of the context as many of us have experienced the battle against SARS in 2003. It is a context so familiar to every citizen in Hong Kong. On the other hand, although Professor Lo had adjusted his sharing so that it was of appropriate level for the audience, some ideas might still not be easily understood, especially for non-specialists in the field. The combined goals of telling the story of scientific enquiry, highlighting NOS and attempting to explain the science at the frontier may be too ambitious to be achieved in the limited time available. It would be interesting to see how a more comprehensive story of Lo is expanded to a six-hour training workshop on the SARS case to see if the current inadequacy due to limited available time might be addressed.

Impacts on teacher's general teaching of scientific practice

Ivy found it very encouraging to hear the successful story of Professor Lo, a local Hong Kong scientist who received his primary and secondary education in Hong

Kong. She felt that it was the strong dedication, commitment and attitude towards science that enabled his success.

> I now see…science as a career, a life-style, and a way to perceive the world… How he thinks and reasons, how he lives his life, and how he perceives about the events in his life. Scientific knowledge is a result of scientist's life and living.

She attributed Professor Lo's success to such an attitude. It had dawned on her that she might not have done enough in her teaching of science in promoting such committed attitude as she said, "Attitude is important. Without a positive attitude, it's impossible to overcome difficulties".

Henry also found Professor Lo's talk very inspiring. During my follow-up interview with him, I recalled his exclamation, 'I was carried away…", on our way out of the seminar room after Professor Lo's talk. I asked what he meant exactly. He said, 'Let me show you an item… you will then know better what I meant…" He then showed me a biology book with the title "The Human Body Book". We carried on our conversation:

> Henry: This is what I bought after the seminar. In the past, I hated Biology very much. I disliked a science subject that requires students to memorize so many things. Yet after the seminar, I realised Biology could be very interesting and made me feel wanting to do some reading in Biology again.
>
> Alice: Interesting. I must tell him [Professor Lo] about it…he would be very pleased…Will such a revived interest impact on your future teaching?

Henry: Yes, yes…probably not on my physics teaching but on my general teaching to my class. Under the New Senior Secondary Curriculum structure, the class can only choose two elective subjects. They have chosen chemistry and physics and biology is out. Now, I grasp every opportunity in encouraging them to read some biology on their own. In fact, when I bought this book, I planned to put it in their classroom for their interest reading. I wish them to have an opportunity to also appreciate biology…not like me in the past…and broaden their vision.

The above responses from Ivy and Henry demonstrated a strong affective impact on their general teaching in science from listening to the life story of a local scientist.

IMPLICATIONS IN TEACHING NOS AND BEYOND

Our earlier effort in the use of the SARS story and the recent effort in the use of the personal story of scientific endeavour of a local scientist have given support to the effectiveness of the approach in enhancing teacher understanding of NOS and confidence in teaching NOS through listening to scientist's authentic scientific enquiries. Contextualising the learning of NOS in real authentic scientific enquiries should further enhance sophisticated and holistic understanding of NOS and address the issue of some apparently contradicting NOS features (eg. objectivity versus subjectivity of science, replicability of science versus theory-laden observation and interpretation) when these are situated in the appropriate contexts.

Teachers who have fundamental understanding of NOS could easily identify from further stories of science the embedded NOS features even when they are introduced in an implicit manner. The use of more science stories with familiarity to the learners or personal accounts from scientists who are well known to the learners are features that could be of considerable impact on the affective dimension. Inclusion of captivating stories of scientists in textbooks and lessons may also promote student interest towards science and inspire some to become scientists just as Professor Lo who was inspired by the biographies of scientists and their fascinating discoveries in science in his Biology textbook.

Students should be provided with more opportunities to carry out more open-ended investigations or involvement in creative activities. Such activities could develop students' investigative and problem solving skills, which would be helpful to solving life and work problems. Teachers should also be open to the possibility that a student could also make innovative contributions in science and technology. Appreciation and encouragement on original input, however small, could boost student confidence.

The ability of seeing linkages between apparently unrelated areas appear to be the sources of idea generation in many scientific breakthroughs as reflected in the thinking processes of Professor Lo in solving some puzzling problems in science. Highlighting the analogical similarities of some related topics in science, e.g. the analogical similarities of electric, magnetic, and gravitational fields, may not only enhance better appreciation of the beauty and neatness of the nature, but also encourage more creative thoughts.

Finally teachers could draw on the social norms practiced in the scientific community to help build good attitudes and habits among students, e.g. accurate and honest reporting with all necessary details of the scientific investigation so that the report can be used if someone wants to repeat the study and reproduce the results

REFERENCES

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, *82*, 417–437.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of the nature of science: A critical review of the literature. *International Journal of Science Education*, *22*, 665–701.

American Association for the Advancement of Science. (1993). *Benchmarks for scientific literacy*. New York: Oxford University Press.

Bartholomew, H., Osborne, J., & Ratcliffe, M. (2004). Teaching students "ideas-about-science": Five dimensions of effective practice. *Science Education*, *88*, 655–682.

Brickhouse, N. W., & Bodner, G. M. (1992). The beginning science teacher: Classroom narratives of convictions and constraints. *Journal of Research in Science Teaching*, *29*, 471–485.

CDC [Curriculum Development Council]. (1998). *Science syllabus for secondary 1-3*. Hong Kong: Curriculum Development Council.

CDC. (2002). *Physics/Chemistry/Biology curriculum guide (Secondary 4-5)*. Hong Kong: Curriculum Development Council.

CDC-HKEAA. (2007). *Physics/Chemistry/Biology/Integrated science curriculum guide and assessment guide (Secondary 4-6)*. Hong Kong: Curriculum Development Council and Hong Kong Examinations and Assessment Authority.

Council of Ministers of Education. (1997) *Common framework of science learning outcomes*. Toronto: CMEC Secretariat.
Driver, R., Leach, J., Miller, A., & Scott, P. (1996). *Young people's images of science*. Buckingham: Open University Press.
Khishfe, R., & Abd-El-Khalick, F. (2002). The influence of explicit/reflective versus implicit enquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching*, *39*, 551–578.
Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, *29*(4), 331–359.
Lederman, N. G., Abd-El-Khalick, F., Bell, R.L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*, 497–521.
Millar, R., & Osborne, J. (Eds.). (1998). *Beyond 2000: Science education for the future*. London: King's College.
Rubba, P. A,. & Harkness, W. L. (1993). Examination of preservice and inservice secondary science teachers' beliefs about science-technology-society interactions. *Science Education*, *77*, 407–431.
Schwartz, R. S., & Lederman, N. G. (2002). "It's the nature of the beast": The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching*, *39*, 205–236.
Tao, P. K. (2002). A study of students' focal awareness when studying science stories designed for fostering understanding of the nature of science. *Research in Science Education*, *32*, 97–120
Tsai, C. C. (2001) A science teacher's reflections and knowledge growth about STS instruction after actual implementation, *Science Education*, *86*, 23–41.
Tobin, K., & McRobbie, C. J. (1997). Beliefs about the nature of science and the enacted science curriculum. *Science & Education*, *6*, 355–371.
Wong, S. L., Hodson, D., Kwan, J., & Yung, B. H. W. (2008) Turning crisis into opportunity: Enhancing student teachers' understanding of the nature of science and scientific enquiry through a case study of the scientific research in Severe Acute Respiratory Syndrome. *International Journal of Science Education*, *30*, 1417–1439.
Wong, S. L., Kwan, J., Hodson, D., & Yung, B. H. W. (2009). Turning crisis into opportunity: Nature of science and scientific enquiry as illustrated in the scientific research on Severe Acute Respiratory Syndrome. *Science & Education*, *18*, 95–118.
Wong, S. L., Wan, Z., & Cheng, M. M.W. (2011). Learning nature of science through socio-scientific issues. In T. D. Sadler (Ed.), *Socio-scientific issues in the classroom contemporary trends and issues in science education*. 39, 245-269.
Wong, S. L., Yung, B. H. W., & Cheng, M. W. (2010). A blow to a decade of effort on promoting teaching of nature of science. In Y.-J. Lee (Ed.), *The world of science education: Handbook of research in Asia* (pp. 259-276). Rotterdam: Sense Publishers.

Siu Ling Wong
Faculty of Education,
The University of Hong Kong

NOTES

[i] An update version of the NOS training materials using the SARS story could be accessed at http://learningscience.edu.hku.hk/

[ii] Details of the two projects could be found in http://learningscience.edu.hku.hk/ and http://web.edu.hku.hk/knowledge/projects/science/qef_2010/