TEACHING PORTFOLIO

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“It is important that students bring a certain ragamuffin, barefoot irreverence to their studies; they are not here to worship what is known, but to question it.”

Jacob Bronowski (1973)¹

TEACHING PHILOSOPHY

In 1923, the respected biochemist and philosopher of science Haldane stated, “It is the whole business of the university teacher to induce people to think.” ² When I first heard this quotation, I was struck by how it seemed to fully encapsulate in a single statement my own teaching philosophy. It is, I believe, this goal of “inducing students to think” that separates tertiary and secondary education.

However, we also need to consider what we want our students to learn. de Bono wrote, “It must be more important to be skilled in thinking than to be stuffed with facts.” ³ In the context of science education, Biggs stated, “Rote learning scientific formulae may be one of the things scientists do, but it is not the way scientists think.” ⁴ Some students believe that in science there are right answers to everything and that the mastery of a particular body of scientific knowledge allows one to become an expert in the field. My own philosophy of the goal of science education is certainly not original; but in my mind, rather than purely adding to a student’s existing store of knowledge, we should be promoting science education as a way of thinking.⁵

Consequently if we are to help students learn, we need to understand how students learn. We need to predicate our teaching on enabling learning to happen. The literature on how people learn is vast, but perhaps the most influential and accessible theories of learning, and one that certainly strikes a chord with me, is that of constructivism.⁶ Constructivism can be summarised in the phrase: “Knowledge is constructed in the mind of the learner.” ⁷ When we teach, we need to remember that the new facts that we propound do not become directly incorporated


² J. B. S. Haldane. (1923). Daedalus, or Science and the Future. London: Kegan Paul, Trench, Trubner. This paper was read before the Cambridge Heretics, a radical freethinking society established in 1909 and dedicated, inter alia, to the open discussion of religious matters.


into the mind of the student without processing; they have to be fitted into the existing structures and schemata already in the mind of the student. For the learner faced with new information, the only thing that matters is whether the knowledge constructed from this information functions satisfactorily in the context in which it arises.

Thus, individuals may construct different images of reality from the same information, since each is incorporating the new information into a unique set of mental images. This of course explains why students frequently seem to misunderstand completely or fail to remember new concepts that we introduce to them. If we are to enable students to learn, we must accept that we cannot brilliantly transfer into the minds of our students, what we have in our own minds. As a guide to help teachers teach, Ausubel stated that:

“If I had to reduce all of educational psychology to one principle, I would say this: the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.” 8

In applying these ideas to science teaching, it is worthwhile considering that our minds do not contain reality itself, but models of reality that we have constructed. It is important to impress upon students, who can appear to be unaware of the fact, that their concepts of, for instance, atoms and molecules, are only models. Simple models of reality provide a strong framework for a student to incorporate new ideas and so construct a more complex model. It maybe that the final model that we wish our students to understand will require us to help students construct several intermediate models.

Of course the ability of a student to construct a new model of reality is influenced not only by their prior knowledge, but also by the level of intellectual development that the individual has reached. Piaget, the author of constructivism, gave a useful scheme of intellectual development. His research showed that children progress from ‘pre-operational thought’ to ‘concrete operational thought’ and finally through to ‘formal operational thought’. The last two levels are relevant to tertiary education. Concrete operational thinkers argue from concrete examples; typically, they can describe without explaining, and give examples but not general definitions derived from these examples. Formal operational thinkers, in contrast, can follow a formal argument, can set up hypotheses, and are comfortable with hypothetico-deductive reasoning.

However, it is perhaps not the progression of intellectual development that is relevant to higher education, but the fact that students will revert to concrete operational thought whenever they encounter a new area.9 Before one can reason with hypotheses and deductions based on experience, there must be a sound descriptive base that has been put in order. The problem for teachers is that we are frequently expounding to students new topics with which we are very familiar (and consequently operate in formal operational mode) whereas the students are struggling to understand them in concrete operational mode, and necessarily resort to rote learning. If a student remains a concrete operational thinker within a particular topic, it is difficult (although not impossible) for that student to see the inter-connectivity between different topics that a complete understanding of a science demands.

Partly in response to students reverting to concrete operational thought, I have begun to better recognise the importance of peer learning not only as an approach to teaching, but for it to be incorporated into my philosophy of teaching. This realisation has led me away from a largely cognitive constructivist philosophy to a more social constructivist philosophy that the social connections within a peer-learning environment motivate students to learn, and to think. It is also clearly necessary to assess the needs and expectations of students within a given learning context. I have further found it not only useful but necessary to understand both student learning styles and their approaches to learning. Learners need to take an active, participatory approach to their learning and I need to know what teaching style to employ that will best facilitate such learning.

I hope that in the preceding paragraphs I have managed to illustrate my philosophy concerning teaching. In concluding this section, I would like to return to why, how and what we are trying to teach our students. In 1929, the eminent philosopher and mathematician Whitehead turned his thoughts to education and wrote:

“In my own work at universities I have been much struck by the paralysis of thought induced in pupils by the aimless accumulation of precise knowledge, inert and unutilised. It should be the chief aim of the university professor to exhibit himself in his true character—that is as an ignorant man thinking, actively utilising this small share of knowledge. In a sense, knowledge shrinks as wisdom grows: for details are swallowed up in principles. The details of knowledge which are important will be picked up ad hoc in each avocation of life, but the habit of the active utilisation of well-understood principles is the final possession of wisdom.”

Among other things, this statement makes it clear that motivating students to think has been an elusive goal of educators for a very long time. This statement also recognises an additional character of a university graduate, which a tertiary education ought to engender and that is life-long learning.

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TEACHING METHODOLOGY

It is not sufficient to simply inform students of the intended learning outcomes for a module. If I want my students to achieve these outcomes then I have to get the students to engage in learning activities that are likely to result in successful achievement. What a student does is more important in determining what is learnt than what I do as the teacher. Tyler wrote, “Learning takes place through the active behavior of the student: it is what he does that he learns, not what the teacher does.” Furthermore, assessment needs to be aligned with the learning outcomes if I am to know whether the learning outcomes are being achieved. This concept of constructively aligning both practice and assessment with the learning outcomes strongly influences how I put together the learning package for a module. The concept of constructive alignment was first proposed by Biggs, and has become increasingly influential in higher education.

This concept resonates with me as it provides the framework to achieve the move away from a passive, teacher-centred learning model to an active, student-centred learning model. I want my students to focus on the use of knowledge rather than the accumulation of knowledge. In recent years, I have begun to employ the flipped classroom pedagogical approach in my teaching. Flipped classroom or blended learning approaches have the potential to have a significant impact on improving the quality of student learning, and NUS is investing heavily in the infrastructure required for such teaching practice. My implementation provides students with access to online video lectures prior to in-class sessions so that students are prepared to participate in more interactive learning activities that require higher-order cognitive skills. During flipped classroom, students are doing the lower levels of cognitive work (gaining knowledge and comprehension) outside of class, and focusing on the higher forms of cognitive work (application, analysis, synthesis, and/or evaluation) in class, where they have the support of their peers and instructor. Flipped classroom has allowed me to make the much vaunted functional shift in my teaching from ‘sage-on-the-stage’ to ‘guide-on-the-side’. The idea of being a ‘guide-on-the-side’ aligns with Vygotsky’s concept of ‘zone of proximal

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development’.\textsuperscript{23} This concept describes the developmental level between what a student can and cannot do unaided. It describes what a student can do with guidance. This guidance has evolved into the term ‘scaffolding’, which was developed as a metaphor to describe the type of assistance offered by a teacher or more competent peer to support learning.\textsuperscript{24} In the process of scaffolding, the teacher helps the student master a task or concept that the student is initially unable to grasp independently. The teacher offers assistance with only those skills that are beyond the student’s capability. It is important to allow the student to complete as much of the task as possible unassisted. Once a student has shown the ability to complete a task with guidance, this scaffolding needs to be removed and the student’s mastery of the concept needs to be assessed. In a sense, it is this mastered new knowledge that is the wisdom discussed by Whitehead in the previous section. Scaffolding is the methodology that allows the teacher to facilitate the construction of this new knowledge in the mind of the student.

With regard to assessment, the teacher needs to balance summative \textit{versus} formative assessment; that is assessment of learning \textit{versus} assessment for learning. The latter provides valuable feedback to the students on their own learning. Whereas if we want students to take ownership of their learning, to become reflective, independent learners, then assessment as learning is a possible strategy.\textsuperscript{25} Assessment as learning uses self and peer assessment to allow students to reflect on their own learning and identify areas of strength and weakness.

Whether it is in my teaching and learning activities or assessments, I frequently infuse technology into my teaching practice to transform the learning experience of my students. This is not done to simply make the learning experience more engaging or attractive by substituting or augmenting traditional practice, but by truly transforming the learning experience through substantial modification or redefinition of traditional practice. This follows the SAMR framework of technology integration proposed by Puentedura.\textsuperscript{26} For example, the flipped classroom uses technology not as a simple substitute for traditional lectures, but to allow substantial modification to teaching practice, in particular the inclusion of active learning approaches to small class teaching. The peer review and peer grading that takes place during the term paper assessment item would be impracticable without technology. My most recent development in assessment has been a computer-generated individualised homework assignment. Technology is used to generate different assignments for every member of the class. This allows the assignment to be conducted at home without fear of plagiarism. This type of assignment redefines my teaching practice and transforms the students’ learning experience. It would simply not be possible to conduct a similar assignment through traditional means.

\textsuperscript{23} L. S. Vygotsky. (1978). \textit{Mind in Society: Development of Higher Psychological Processes}. Cambridge: Harvard University Press. This text is an English translation of his work published many decades after Vygotsky’s death in 1934. It was published following the growing influence that Vygotsky’s work was having on the educational psychologists of the early 1970s.


To conclude my methodology statement, Figure 1 provides the results from a Teaching Perspectives Inventory survey. The survey suggests that my dominant teaching perspective is Developmental, that my back-up perspectives are Transmission and Apprenticeship, whilst my recessive perspective is Social Reform. The identification of my dominant perspective as Developmental and one of my back-up perspectives as Transmission reflects the change in my teaching practice that has occurred over the last few years as I have implemented the flipped classroom pedagogy. Flipped classroom virtually requires the teaching to be planned and conducted from the learner’s point of view. The active learning components challenge learners to move from relatively simple to more complex forms of thinking. I believe that if I had taken this survey 3 to 4 years ago, then my dominant perspective would have been Transmission. I think that my transition from a Transmission to a Developmental perspective is ongoing; although my beliefs and intentions recognise the transformation of my teaching philosophy, the score for action under Developmental recognises that I have not entirely put my philosophy into practice. As I further develop flipped classroom and introduce the approach to my other students, I expect to see a further shift in my teaching perspectives.

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classes, I anticipate that my actions will better align with my beliefs and intentions as a teacher with a Developmental perspective.

**TEACHING RECORD**

A detailed breakdown of the major lecture modules that I have taught since 2007/2008, together with a summary of student evaluation, is provided in the following tables.

**CM2101 (PHYSICAL CHEMISTRY 2)**

<table>
<thead>
<tr>
<th>Year (Semester)</th>
<th>Activity</th>
<th>No. of Students</th>
<th>Student evaluation (Faculty Average)</th>
<th>Nominations for best teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015/2016 (2)</td>
<td>Lecture</td>
<td>86</td>
<td>4.32 (3.96)</td>
<td>18.8%</td>
</tr>
<tr>
<td></td>
<td>Tutorial</td>
<td></td>
<td>4.41 (4.00)</td>
<td></td>
</tr>
<tr>
<td>2014/2015 (2)</td>
<td>Lecture</td>
<td>112</td>
<td>4.55 (4.07)</td>
<td>37.9%</td>
</tr>
<tr>
<td></td>
<td>Tutorial</td>
<td></td>
<td>4.60 (3.93)</td>
<td></td>
</tr>
<tr>
<td>2013/2014 (2)</td>
<td>Lecture</td>
<td>104</td>
<td>4.49 (4.07)</td>
<td>31.0%</td>
</tr>
<tr>
<td></td>
<td>Tutorial</td>
<td></td>
<td>4.49 (3.99)</td>
<td></td>
</tr>
<tr>
<td>2012/2013 (1)</td>
<td>Lecture</td>
<td>123</td>
<td>4.47 (4.04)</td>
<td>30.0%</td>
</tr>
<tr>
<td></td>
<td>Tutorial</td>
<td></td>
<td>4.51 (3.98)</td>
<td></td>
</tr>
<tr>
<td>2011/2012 (2)</td>
<td>Lecture</td>
<td>97</td>
<td>4.17 (4.00)</td>
<td>12.2%</td>
</tr>
<tr>
<td></td>
<td>Tutorial</td>
<td></td>
<td>4.15 (3.84)</td>
<td></td>
</tr>
<tr>
<td>2009/2010 (1)</td>
<td>Lecture</td>
<td>129</td>
<td>4.15 (4.00)</td>
<td>12.0%</td>
</tr>
<tr>
<td></td>
<td>Tutorial</td>
<td></td>
<td>4.21 (3.86)</td>
<td></td>
</tr>
<tr>
<td>2008/2009 (1)</td>
<td>Lecture</td>
<td>143</td>
<td>3.86 (3.91)</td>
<td>7.3%</td>
</tr>
<tr>
<td></td>
<td>Tutorial</td>
<td></td>
<td>3.93 (3.84)</td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td>113</td>
<td>4.31</td>
<td>—</td>
</tr>
</tbody>
</table>

**GEK1535 (OUR ATMOSPHERE: A CHEMICAL PERSPECTIVE)**

<table>
<thead>
<tr>
<th>Year (Semester)</th>
<th>Activity</th>
<th>No. of Students</th>
<th>Student evaluation (Faculty Average)</th>
<th>Nominations for best teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015/2016 (1)**</td>
<td>Lecture</td>
<td>133</td>
<td>4.44 (4.13)</td>
<td>22.6%</td>
</tr>
<tr>
<td>2014/2015 (1)</td>
<td>Lecture</td>
<td>129</td>
<td>4.40 (4.06)</td>
<td>33.7%</td>
</tr>
<tr>
<td>2013/2014 (1)</td>
<td>Lecture</td>
<td>124</td>
<td>4.32 (4.07)</td>
<td>14.9%</td>
</tr>
<tr>
<td>2012/2013 (1)*</td>
<td>Lecture</td>
<td>197</td>
<td>4.17 (4.07)</td>
<td>20.2%</td>
</tr>
<tr>
<td>2011/2012 (1)*</td>
<td>Lecture</td>
<td>288</td>
<td>4.22 (4.06)</td>
<td>19.7%</td>
</tr>
<tr>
<td>2009/2010 (1)*</td>
<td>Lecture</td>
<td>367</td>
<td>3.90 (4.02)</td>
<td>1.2%</td>
</tr>
<tr>
<td>2008/2009 (1)</td>
<td>Lecture</td>
<td>184</td>
<td>3.98 (4.01)</td>
<td>5.8%</td>
</tr>
<tr>
<td>2007/2008 (1)*</td>
<td>Lecture</td>
<td>353</td>
<td>4.24 (3.98)</td>
<td>8.2%</td>
</tr>
</tbody>
</table>

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28 I have only included modules for which I taught at least half the module.
**CM3231 (Quantum Mechanics and Statistical Thermodynamics)**

<table>
<thead>
<tr>
<th>Year (Semester)</th>
<th>Activity</th>
<th>No. of Students</th>
<th>Student evaluation (Faculty Average)</th>
<th>Nominations for best teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013/2014 (1)</td>
<td>Lecture</td>
<td>45</td>
<td>4.36 (4.09)</td>
<td>13.6%</td>
</tr>
<tr>
<td></td>
<td>Tutorial</td>
<td></td>
<td>4.38 (4.04)</td>
<td></td>
</tr>
<tr>
<td>2009/2010 (2)</td>
<td>Lecture</td>
<td>62</td>
<td>4.05 (4.06)</td>
<td>15.4%</td>
</tr>
<tr>
<td>2008/2009 (2)</td>
<td>Lecture</td>
<td>27</td>
<td>4.18 (4.02)</td>
<td>10.5%</td>
</tr>
<tr>
<td></td>
<td>Lecture</td>
<td></td>
<td>4.25 (4.05)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tutorial</td>
<td>26</td>
<td>4.25 (3.99)</td>
<td>12.5%</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>40</td>
<td>4.25</td>
<td></td>
</tr>
</tbody>
</table>

**SP3175 (The Earth)**

<table>
<thead>
<tr>
<th>Year (Semester)</th>
<th>Activity</th>
<th>No. of Students</th>
<th>Student evaluation (Faculty Average)</th>
<th>Nominations for best teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012/2013 (2)</td>
<td>Lecture</td>
<td>28</td>
<td>4.32 (4.06)</td>
<td>9.1%</td>
</tr>
<tr>
<td></td>
<td>Tutorial</td>
<td></td>
<td>4.32 (4.04)</td>
<td></td>
</tr>
</tbody>
</table>

**CM1131 (Physical Chemistry 1)**

<table>
<thead>
<tr>
<th>Year (Semester)</th>
<th>Activity</th>
<th>No. of Students</th>
<th>Student evaluation (Faculty Average)</th>
<th>Nominations for best teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011/2012 (1)</td>
<td>Tutorial</td>
<td>96</td>
<td>4.41 (3.87)</td>
<td>10.5%</td>
</tr>
</tbody>
</table>

**CM2132 (Physical Chemistry)**

<table>
<thead>
<tr>
<th>Year (Semester)</th>
<th>Activity</th>
<th>No. of Students</th>
<th>Student evaluation (Faculty Average)</th>
<th>Nominations for best teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010/2011 (2)</td>
<td>Lecture</td>
<td>122</td>
<td>4.06 (3.97)</td>
<td>7.4%</td>
</tr>
</tbody>
</table>

**SP1201C (Freshmen Seminar — Idols of the Mind)**

<table>
<thead>
<tr>
<th>Year (Semester)</th>
<th>Activity</th>
<th>No. of Students</th>
<th>Student evaluation (Faculty Average)</th>
<th>Nominations for best teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009/2010 (2)</td>
<td>Sectional</td>
<td>15</td>
<td>4.53 (4.44)</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

* Includes data from the SM2 students not captured in the student feedback online system.
** Includes data from GEH1020. Under the General Education revamp, GEK1535 has been coded GEH1020 for current first-year students.
<table>
<thead>
<tr>
<th></th>
<th>Type</th>
<th>Number</th>
<th>Score (AVG)</th>
<th>% of Faculty Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008/2009 (2)</td>
<td>Sectional</td>
<td>15</td>
<td>4.43 (3.94)</td>
<td>21.4%</td>
</tr>
<tr>
<td>2007/2008 (1)</td>
<td>Sectional</td>
<td>15</td>
<td>4.46 (3.98)</td>
<td>0.0%</td>
</tr>
<tr>
<td>Average</td>
<td>—</td>
<td>15</td>
<td>4.47</td>
<td>—</td>
</tr>
</tbody>
</table>

These modules cover a wide spectrum of module type (from General Education Module to Freshman Seminar to both Core and Elective Modules in Chemistry), teaching activity and class size.

In my time at NUS, I have also lectured or guest lectured for CM3261 (Environmental Chemistry), CM5234 (Chemical Bonding in Materials), GEK1038 (Scientific Methodology), GEK1539 (History of Science), and XD3103 (Planet Earth). I have also been the module coordinator for MW5201 (Topics in Science Communication) and CM5198 (Graduate Seminar Module in Chemistry). In all, I have been involved in the teaching or coordination of 14 different modules in my 11½ years at NUS.

I have not had any student feedback for any module below the faculty average since 2009/2010. Over the last three academic years, my student evaluation scores have average 0.37 over the faculty average. In 2014/2015, my student evaluation scores for all teaching activity averaged 0.50 over the faculty average for module type and level.

**TEACHING DEVELOPMENT**

As a senior member of the Department of Chemistry’s Teaching Committee (formerly the Deputy Chair), I am involved in both curriculum and teaching developments. My most important recent teaching initiative has been the use of the flipped classroom approach in core chemistry teaching. A further major teaching development that I proposed and led was the Interactive Chemistry Laboratory Manual (ICLM). I have also been involved in Faculty curriculum development as the Director of the Special Programme in Science, and in the form of the Environmental Chemistry Minor under the Joint Initiative with the University of Toronto and also with the development of the M. Sc. in Science Communication in a Joint Initiative with the Australian National University. Beyond teaching and curriculum development, I have also taken part in a variety of workshops and educational conferences.

**THE FLIPPED CLASSROOM IN CORE CHEMISTRY**

The educational landscape at all levels is changing. Technology has the opportunity to change education from the current, largely passive, teacher-centred model to an active, learner-centred model. We want to transform the student experience of education from a content-based approach to a context-based approach. Unfortunately, much of the technology that has been introduced into education has reinforced the passive model.

The accumulation of knowledge should no longer be considered a primary goal of education. Knowledge is so readily available to a modern student that knowing something is far less important than using that knowledge. Moreover, the skill of creatively using knowledge will be one of the most important in the post knowledge-driven economy.

Many studies have shown that the thinking required while attending a traditional expository lecture is low-level comprehension of factual knowledge with little evidence of long-term retention of this knowledge. Further, students’ attention to what the lecturer says decreases as
a lecture proceeds. Without the retention of this knowledge there is little hope that students will be able to apply this knowledge.

A traditional learning package, within science at least, includes the small-group tutorial. Within chemistry these classes consist of between 20 to 25 students. The tutor will proceed to go through a number of set problems. The problem being that the tutorial remains teacher-centred and passive. There is little opportunity to investigate student attempts at the set problems. Students see the completion of these set problems as being optional. Providing the solutions reinforces this attitude amongst the weaker students. The tutorials become part of the content of the learning package rather than the opportunity to put the content into context.

The module I taught in this experiment in teaching approach was CM2101. By its nature, it is a subject that relies heavily on fundamental theory and even the stronger students can have problems putting the theory into context. The subject matter should provide a marvellous opportunity to show the connection between fundamental quantum mechanics and its application in spectroscopy.

The solution? Well we need to shift the balance of the learning package from a largely content-based model to a largely context-based model. This is essentially what we achieve with a flipped classroom approach. It should be noted that students entering university are familiar with a context-based education from school, where students are introduced to the context in the form of case studies, involving group work and problem solving. This pedagogy is almost entirely removed and many students do not successfully transition to the tertiary education model. Why does this happen? Primarily it is about class size. A context-based education is easily delivered in the small classes of school, but is much more difficult to deliver in the large classes of an undergraduate lecture theatre.

However, the use of IT to develop a flipped classroom learning package does offer the opportunity to rectify many of these issues. However, the learning experience needs to be monitored. The right learning scaffolds need to be there to help the students put the fundamentals into context.

A major part of this experiment into the flipped classroom model was to develop an active learning strategy that promotes peer learning; one that encourages students to engage in problem solving, sharing ideas, giving feedback, and teaching each other. The active learning approach was integrated into the small-group tutorials. Rather than giving a mainly expository tutorial, I engaged in dialogue and refutation techniques with the students on a problem. This problem was chosen so that we could integrate exposition, dialogue, refutation, experimentation, visualisation, and assessment into the learning session.

I will discuss the details of the implementation of the flipped classroom and the results that can be drawn from the surveys that were conducted in the corresponding Module Folder. This experiment was highly successful and very well received by the students. Importantly, the approach led to a statistically significant ($p < 10^{-16}$) medium learning gain (Cohen’s $d = 0.59$) when compared to traditional teaching (see Figure 2). I strongly believe that the approach taken and implementation employed are directly transferable to other modules mounted not only by the Department of Chemistry, but potentially by other Departments and Faculties throughout the University.
The development of the Integrated Chemistry Laboratory Manual (ICLM) began in February 2008 and went live in August 2008. Its development was a collaboration between the Department of Chemistry and the Centre for Instructional Technology. The courseware website can be found at http://courseware.nus.edu.sg/iclm.

The rationale for this project was to raise the standards in teaching and learning of practical chemistry. Chemical laboratories play a fundamental role in the education of a chemist. As an educational medium they provide an environment that is intrinsically student-centred. It is therefore unfortunate to note that laboratory classes often fail to realize their potential: students see laboratory work as a form of assessment rather than an opportunity to learn. This project aimed to transform the student experience of practical chemistry and to set a new standard for laboratory-based learning, one that integrated laboratory work with new paradigms in e-learning.

In current undergraduate teaching laboratories, students are expected to conduct experiments without necessarily having a thorough understanding of the chemistry and procedures involved before they arrive in the laboratory. In many cases, a cursory glance of the laboratory manual is all that occurs and it is only after the laboratory period, during write-up, that the student gains some idea of what he or she has been doing in the practical.
The ICLM was designed to ensure that the student has a thorough understanding of the reactions, apparatus and chemicals that are being used before the laboratory begins. The online manual integrated a variety of media, including photography, video and animation. Students were expected to familiarise themselves with every component of the experiment, including safety aspects, prior to attending the practical class. Students benefited far more from their time in the laboratory as they were far more likely to understand what it was they were doing during the practical.

Figure 3: Screenshot showing the homepage of an experiment.

Figure 4: Screenshot showing the Experimental Information with embedded video.
Figure 5: Screenshot showing an interactive picture of Distillation Apparatus.

Figure 3 shows the homepage for Experiment 2 of CM1121. The screenshot shows the Laboratory Layout link, the Experimental Flowchart, together with links to Video and Photography resources and Laboratory Safety information. Figure 4 shows the Experimental Information accessed from the homepage of Experiment 1 of CM1121. The screenshot shows an embedded video, which takes the student through the Reflux technique. Figure 5 shows an interactive photograph of Distillation apparatus. Students can mouse over the apparatus labels to identify them on the equipment.

The resources developed for the ICLM have since been incorporated into the Department’s intranet following the curriculum revamp.

THE SPECIAL PROGRAMME IN SCIENCE

In July 2011, I was appointed as the Director of the Special Programme in Science (SPS), the premier academic programme under the auspices of the Dean's Office at the Faculty of Science within NUS. The intention of SPS is to cut across the traditional boundaries between the science disciplines and to teach science as an integrated whole. My first job as Director was to see the implementation of the newly revamped Integrated Science Curriculum (ISC). The ISC developed for SPS consists of four thematic modules (SP2173 — Atoms to Molecules, SP2174 — The Cell, SP3175 — The Earth, SP3176 — The Universe) and two research modules (SP2171 — Discovering Science, SP3172 — Integrated Science Project). Recognising the diverse background of our students, we have also incorporated additional training in sophisticated computation and visualisation software (e.g., Mathematica™) to give students a way to examine concepts that yields an understanding and appreciation of science.
An important feature of the programme is the strong involvement of student mentors (i.e., senior SPS students) who act as role models and guides for the junior SPS students.

The first SPS students to complete the revamped ISC did so in Semester I of 2012/2013. In March 2013, I was awarded a QAFU Quality Improvement Project grant co-funded by the Ministry of Education and NUS through LIF-T. The award was for $450k. The project entitled Active Learning in Integrative Science Education (ALISE) since completed was successful in developing active learning approaches to teach integrated science, and educational technology for use in a studio classroom.

**ENVIRONMENTAL CHEMISTRY MINOR PROGRAMME**

The Faculty of Science at the National University of Singapore and the Faculty of Arts and Science at the University of Toronto in Canada instigated a joint initiative to foster closer ties between the two universities and to give the students from these faculties the exciting opportunity to travel and study in different academic environments. In the first instance, the initiative involved Minor Programmes in Environmental Biology and Environmental Chemistry.

My role was in the development of the Environmental Chemistry Minor. This programme focuses on developing an understanding of the chemical impacts of humankind's activities on the soil, air, and water. Emphasis is given to developing analytical skills and a mechanistic understanding of the subject. Students travel to the University of Toronto in Semester II of their third year in order to complete the necessary modules to qualify for this minor.

The first students under this programme travelled to the University of Toronto in Semester II of 2008/2009.

**M. SC. IN SCIENCE COMMUNICATION**

The Faculty of Science developed a joint M. Sc. Programme in Science Communication with the College of Science at the Australian National University. This was done within the context of the Ministry of Education having launched several professional development packages aimed at increasing the number of teachers with graduate degrees. Most of the existing M. Sc. degrees at both NUS and NTU focused on the needs of future researchers, while most of the M. Sc. degrees at NIE focussed on science pedagogy. This initiative was undertaken to fill the need for a programme that focused on scientific content in an educational context.

My role in this initiative was in putting together a new core module entitled ‘Topics in Science Communication’. This module consists of a series of lectures from across all disciplines of science. These lectures highlights some of the current topics in science which are of major concern to the public. The lectures present the fundamental science behind these topics and show how these topics have been communicated to the public. The bi-directional relationship between science and society is explored and used to illustrate how science communication has evolved in recent history.

Students are expected to develop a deeper understanding of several scientific issues of current concern to society. Students also learn how these issues have been communicated to the public. Students are expected to develop similar methodology in science communication and should be adept at adapting their approach to different audiences. Students also study the current public perception of science and the relationship between science and society. Students develop an understanding for the need of a scientifically literate society.
PUBLICATIONS


INSTITUTIONAL PRESENTATIONS, WORKSHOPS AND EDUCATIONAL CONFERENCES


- A. M. Lee, Why Flipped Classroom?, presented at the 2016 XJTLU Annual Learning and Teaching Colloquium, Xi’an Jiaotong–Liverpool University, 8 April 2016.

- A. M. Lee, How Can We Improve Teaching and Learning with Scholarship, presented at the NUS Teaching Academy Workshop, 22 February 2016.


- A. M. Lee, Promoting Teaching through Teacher Promotion, presented at the University of the Philippines Academic Leadership Conference, Philippines, 10 Mar 2015.
• A. M. Lee, *Why Flipped Classroom?*, presented at the School of Science, Monash University Malaysia, 6 Jun 2014.

**Workshops and Educational Conferences Organised**

- **Chair**, *Partnering Schools and Universities in Chemistry Education*, Inaugural Dialogue on Chemistry Education (organised by NUS, MOE, and NIE), Singapore, 18 Nov 2013.
- **Chair**, *Trends in Chemistry Education*, Chemistry Education Workshop at the Singapore International Chemistry Conference 6 (SICC-6), Singapore, 18 Dec 2009.

**IMPACT ON THE TEACHING COMMUNITY**

My pedagogical research has focused on three main areas: plagiarism, use of IT, and active learning. An on-going initiative has been the effort to highlight the problem of plagiarism and to reduce its practice by students. My interest began in 2003 when I published an article to *CDTL Brief* that noted the problem in laboratory reports. In October 2007, I was asked to join a cross-faculty dialogue on plagiarism at Centre for Development of Teaching and Learning (CDTL). At this time evidence was largely anecdotal, it was clear that hard data was needed to ascertain its prevalence. In Semester II 2007/2008, my colleagues and I used the *Turnitin* system to determine the originality of student laboratory reports for CM3292. This study revealed that plagiarism was ubiquitous. I presented the results from this study at the international conference on *Teaching and Learning in Higher Education* in December 2008. This work was also published in an article in *CDTL Brief*. My work in this area moved away from highlighting the problem to efforts to reduce its practice. This initiative was presented at the Chemistry Education Workshop at the *Singapore International Chemistry Conference 6* (SICC-6) in December 2009. Part of the solution involved training the Teaching Assistants who would be involved in both report grading and teaching in the laboratory itself. To facilitate this, I was asked to lead a workshop on training Teaching Assistants at CDTL in December 2010. Since then, I have also presented a discussion of plagiarism in science education in general at the *Faculty of Science Teaching Workshop* in April 2012. In this presentation, I warned that plagiarism, if left unchecked, is worrying because it leads to the “socialisation of unethical behaviour which has potentially serious repercussions for students’ professional conduct.” This warning was published in an article reporting on the workshop in *CDTL Link* in September 2012.

My most significant development of IT was the Interactive Chemistry Laboratory Manual that was discussed earlier. Before the curriculum revamp, this resource was supporting the laboratory education of approximately 1000 students from the Departments of Chemistry, Biological Sciences and Engineering every year. This project transformed the student experience of practical chemistry and set a new standard for laboratory-based learning, one that integrated laboratory work with new paradigms in e-learning. I presented this work at the CIT

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Audio Visual Awareness Roadshow in October 2008, and later at the 2nd Singapore–Australia Collaborative and Cooperative Chemistry Symposium held at the University of Queensland in December 2008.

My current pedagogical research is centred on using a flipped classroom approach to teaching. This approach integrates the use of IT to deliver module content with active learning strategies in classroom teaching to better facilitate putting module content into context. This approach with reference to the teaching of core chemistry was briefly discussed earlier and will be expanded upon in the Module Folder. This approach is also at the heart of the ALISE project for the SPS programme and is likely to motivate future changes in all my teaching. Within the Faculty of Science, I have advised many of my colleagues on best practice and ways of implementing online delivery of module content, partly in my role as a member of the IT-Enhanced Learning Task Force Committee. I have presented the results from my experiences in delivering a flipped classroom at schools and faculties across the university, for example, at both the CIT BuzzEd 2013 Workshop in January 2013 and at the inaugural Faculty of Engineering TEL Workshop in August 2013. Following NUS’s partnership with Coursera this initiative is receiving a great deal of attention across the university. Outside of NUS, I have also been invited to present my results at the Xi'an Jiaotong–Liverpool University, University of the Philippines, Monash University Malaysia and the University of Bristol.

Following IRB approval, I am leading a small research team from CDTL to investigate faculty members’ approaches to designing blended learning modules. This study is using a phenomenographic research methodology. The focus of the analysis is to identify factors leading to the mode of engagement activities faculty design for blended learning. We are looking at how these modes of engagement have an impact on student learning outcomes with reference to the ICAP framework. A hybrid process of inductive and deductive thematic analysis of the raw data collected from the interview transcripts of 13 early adopters of blended learning in NUS is being performed. The study aims to advance research on effective ways to guide teachers in the design of learning activities for blended learning which focus on generating higher student engagement and better learning outcomes. This has led to the development of a six session blended learning module on blended learning for blended learning practitioners that began on 11 August 2016.

PROFESSIONAL DEVELOPMENT

I successfully completed the University of British Columbia International Faculty Scholarship of Teaching and Learning Leadership Program in January 2015 and was awarded the SOTL Leadership Certificate on Curriculum and Pedagogy in Higher Education.

In recent years, I have attended the following Centre for Development of Teaching and Learning (CDTL) workshops and seminars:

- *Conducting action research in your classroom*, CDTL Seminar Room 1, 16 Apr 2012.

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- *Technology in pedagogy series: Google docs and the lonely craft of writing*, CDTL Seminar Room 1, 9 May 2011.
- *Active learning*, CDTL Seminar Room 2, 17 Sep 2010.

On 1 January 2014, I was appointed as the Deputy Director of CDTL. In terms of professional development, my main responsibility is the coordination of the Professional Development Programme—Teaching for all staff with less than 3 years teaching experience. This programme is undergoing a revamp to ensure that it is on strong evidence-based foundations.

**TEACHING AWARDS AND FELLOWSHIPS**
- Elected to the Executive Committee of the NUS Teaching Academy (August 2014)
- Elected to the Fellowship of the NUS Teaching Academy (July 2012)
- Annual Teaching Excellence Award (2014, 2015, 2016)
- GIST–SNIC Award in Chemistry Education (2012)

**APPROACH TO TEACHING**
To illustrate my approach to teaching and the coherence of my teaching with my philosophy of teaching, I am including Module Folders for CM2101 (Physical Chemistry 2) and GEK1535 (Our Atmosphere: A Chemical Perspective). The choice of modules was predicated on highlighting particular initiatives or issues that have arisen in my teaching. In particular, CM2101 includes the recent initiative in flipped classroom teaching. GEK1535 is the module that I have taught for the longest period. Further because of the general education nature and the diversity of students taking the module different approaches need to be taken. My responses to student feedback will be integrated into the Module Folders.

I hope that it is apparent in the foregoing discussion that my approach to teaching has moved away from a passive, teacher-centred model to an active, student-centred model. What has impressed me with the flipped classroom approach is that it allows the teacher to make far better use of face-to-face contact time. Using technology to deliver the necessary module content enables me to use contact time to improve the quality of learning that takes place. Previously I use to engage students in my traditional lectures with educational technologies, multimedia, and in-class demonstrations. Although engaging, these activities are all passive and are poor substitutes for active learning in which students develop a deep understanding through application and practice. Improvements for large classes included the use of learner response systems, but the move to active learning during tutorial sessions was eye opening.

**COMMUNICATIONS FROM PAST STUDENTS**
The following are a couple of examples of communications I have received from past students who have gone on to further studies.
Lui Sheen Yee took CM3231 (Quantum Chemistry and Molecular Mechanics) with me in 2009/2010. As indicated in her kind note to me above, she came to me for advice with regard to her final year project. Prior to graduation she applied to the prestigious M. Sc. programme in Theoretical Chemistry at the University of Oxford, which she has since successfully completed.

Tan Hui Jia and Hai An Le (Ryo) both took CM3231 (Quantum Chemistry and Molecular Mechanics) with me in 2007/2008 and 2008/2009 respectively. Since then they have both been accepted into Ph. D. programmes in the field of quantum chemistry, Hui Jia with NUS and Ryo with Northwestern University. Hui Jia is currently applying for a position with A*STAR and I can only wish her every success.