Selamat Datang di Indonesia: Learning about Chemistry and Chemistry Education in Indonesia

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Indonesia is an extensive archipelago of 17,500 islands located between Australia and the southeast Asian peninsula. According to one of its natural history museums, the country's population of 235 million is a diverse mélange descended from ancient migrations that began on the Indian subcontinent, from the Middle East, and from the southeast Asian peninsula and eastern China. With not even that much background, I spent a little over two weeks in Indonesia in July 2007 as a Fulbright senior specialist *(1).* My project had three parts. First, I gave the opening and closing addresses at the 2007 Indochem Conference, a countrywide gathering of chemistry faculty from its 57 departments of chemistry (at public institutions), commemorating 60 years of higher education in Indonesia. As a part of the conference, which was held from July 9–15, 2007, I also helped conduct two workshops for heads of chemistry departments on the questions of forming international collaborations and on the use of digital resources in instruction. Then, after the conference, I was available for a week to consult with the chemistry departments at public institutions throughout the country.

The Indochem meeting was held at the Institut Teknologi Bandung (ITB, the Bandung Institute of Technology: see Figure 1). Bandung is ~100 miles southeast of Jakarta, which is located on the western edge of Java. According to the Indochem prospectus, higher education in chemistry in Indonesia began in October 1947 when the Faculteit van Exacte Wetenschap, which included a chemistry department, was established in Universiteit van Indonesie (1945–1950), Bandung. Since its establishment, the chemistry department at Universiteit van Indonesie (now the Institut Teknologi Bandung) grew quickly, graduating many chemists participating both in national development and in contributing to the development of science, in general. The ITB department has also influenced the establishment of many chemistry departments at other universities all over Indonesia.

Figure 1. Bandung Institute of Technology campus showing the hall that was the location of the Indochem conference. Photo by the author.

My charge was to introduce the chemistry faculty of Indonesia—who are recently committed to making changes in their undergraduate and graduate curricula—to what is happening today in chemistry education in the West. Without belaboring the point of dealing with an impossible task for an hour's talk, I put together the following outline, which, while necessarily incomplete, gave what I thought was a reasonable starting point for discussion:

I. Generally available resources for faculty (institutional and national)

II. Four critical trends in classroom teaching and learning
   A. The active classroom
   B. Supplemental instruction
   C. Rethinking the laboratory
   D. Student-generated instructional content

III. The role of education research

IV. The need for future faculty preparation

My hosts believed in flexible scheduling. The details for a day's events were fluid, right up to the beginning of session. I started what would be a two-week running joke about the Indonesian custom of "dynamic planning". Although my closing lecture was originally scheduled as a presentation on my laboratory research, the group decided, within 18 hours of the starting time, that a second talk on education was preferable to one on dipolar cycloaddition reactions. One thing was clear: the interest in education, and in making change, is high. PhD chemist, teacher, and researcher Megawati "Mega" Santoso was host, conference chair, and organizer of Indochem; she said that education in Indonesia can be summed up in five words: "We need so much improvement."

I learned a great deal during my two weeks in Indonesia. And while I cannot provide an exhaustive, research-based ethnography, I did spend a great deal of time with the participants at the conference, and with three individual departments during the second week (ITB; Institut Pertanian Bogor, IPB, also called Padjadjaran University; and the University of Indonesia). In this paper, based on my interactions, I would like to introduce chemistry research and education in Indonesia to the readership of this *Journal,* with the hope that others might be more informed about, and perhaps intrigued by, colleagues and chemistry programs in Indonesia.

Indonesia's Education Infrastructure

Megawati Santoso, who received her PhD from the University of Iowa, consults regularly with the Indonesian Ministry of Education. Consequently, she had reasonable estimates of some important and interesting numbers. There are 74 state universities, more than 2600 private universities, and, as in the case of ITB, one of seven state-owned institutions called Badan Hukum

Milik Negara (BHMN), enrolling over 1.2 million students each year. The BHMN universities were originally the best of the state universities. These schools were given a distinctive legal status in order to facilitate greater autonomy for undertaking self-management and pursuing funding beyond government support. Some of conditions (below) are valid only for private and state universities, not BHMN universities.

Across all institutions, the undergraduate tuition ranges from an equivalent of 35–500 U.S. dollars (2007) a term. At the three schools I visited, which were all public and research-active, the tuition was ~\$150–200 a term. Undergraduate students at these schools also pay a one-time admission fee of ~\$500 when they matriculate. The higher end of the tuition range is seen at the private schools, which are almost exclusively undergraduate; not more than 20% of them offer a Master's degree. Through 2006, roughly 14–16% of secondary school graduates seek some form of higher education. Graduate tuition is higher than the undergraduate tuition, between ~\$750–2000 a term, with the lower end for MS and PhD programs and the upper end for medical programs; beginning in 2004, depending on the institution, between 0–50% of graduate students receive a fellowship that covers their tuition. Of the 57 chemistry departments in the country, about 25% of them offer the PhD degree.

At the public universities, the faculty members are civil employees. A base salary is provided to everyone (~\$230–270 a month), and the universities receive budget allocations that are used to supplement these salaries (perhaps doubling them, on average), as well as to provide student fellowships and to cover part of operation and maintenance costs. The typical teaching assignment is 3–4 classes per term, and there is no time release given for directing a research program or carrying out community service. Credit for undertaking research or community services are accumulated by an individual as points for gaining better rank in his or her academic career, on top of credits for teaching assignments.

Research Infrastructure in Indonesia

Carrying out a competitive academic research program in Indonesia is difficult. The funding levels are low; equipment is scarce; supplies are limited; ordering anything can take substantial time; and libraries are understocked, relying on donations and low-cost books and journals, some of which have questionable copyright status.

In addition to the prohibitive cost of equipment, there appears to be some reluctance on the part of the central government to provide or approve funds for major instrumentation because of limited funding or capacity for maintenance. A number of faculty members reported that they had managed a clever end-run: assembling equipment over time by ordering individual components if the instrument had a modular design. Some others try to overcome this problem by undertaking research collaborations with foreign universities.

Consequently, for example, there is only one NMR spectrometer in the country (Indonesian Institute of Sciences, purchased in 2006) and no mass spectrometers at the Indonesian universities. The cost for routine maintenance, such as providing liquid helium, is also a contributing factor to this absence. Experiments requiring long hours of stable electrical current can be a challenge because of unreliable or unstable service. In order to get spectroscopic data, the departments I visited had built relationships with institutions in Singapore and Japan, and send their samples out for analysis. In most cases, such as with the large number of organic chemists doing natural products isolation from the indigenous plants and trees, the agreement is that any discoveries of commercial consequence would be shared (usually 50:50) with the institution providing the instrumental analysis. Because of the large Indonesian oil reserves, there is also a substantial research base in providing materials for oil research and exploration done by the petrochemical companies.

Graduate students follow a "2 + 3 year" MS-then-PhD program. The graduate curriculum is more structured than most programs in the U.S., with a greater emphasis on coursework (see Tables 1 and 2). Faculty members are eligible for modest levels of research funding from the central government, for which they write proposals; the typical stipend for a graduate research assistant is ~\$40–100 a month. Graduate students who provide assistance in the teaching program can receive an additional ~\$10–50 a month for that work.

The departmental structures were a combination of a classical hierarchical model (there are few people who hold the title "professor") with the distinctive North American notion of independent faculty entrepreneurship (the junior faculty members were not "assistants" to the professors). The biggest tension resulting from this seemed to be with the central government's educational administration, which actually grants the promotions in rank based on arguments from the individual universities. I encountered stories of young faculty who, after

Table 1. Representative Chemistry MS Degree Program Requirements by Semester for Indonesian Public Universities

Semester I	Research methodology; Organic chemistry elective; Supramolecular chemistry
Semester II	Research I; Advanced organic synthesis; Chemistry elective
Semester III	Research II; Bioorganic chemistry; Chemistry elective
Semester IV	History of science; Advanced natural products; Writing scientific publications; Seminar and examination

Table 2. Representative Chemistry PhD Degree Program Requirements by Semester for Indonesian Public Universities

Semester I	History of science; Research methodology; Chemistry elective
Semester II	Qualification; Research I (includes proposal)
Semester III	Research II; Special topics
Semester IV	Research III; Special topics
Semester V	Research IV; Chemistry elective
Semester VI	Research V; Examination

having been encouraged into relatively high research productivity, were not completely credited with their work because this would have hopscotched them past a more senior person who had been in the queue for a longer period of time. With their legal status for self-management, the BHMN universities have better human resource management systems that allow for greater flexibility.

The Indonesian Context for Education in Chemistry

Although the undergraduate chemistry curriculum in Indonesia is not fixed by the central administration, there is a strong adherence, across the country, to the sort of technical training model that one associates with many non-U.S. programs. To earn the undergraduate degree, students take six or seven 2–3 hour classes per semester during the first three years, followed by a year that is dominated by a research project (Table 3). At most public universities, the entire first-year class follows a common curriculum. For institutes with a technological focus, such as ITB or IPB, the programs are offered with minimal nonscience courses, while at the more comprehensive universities (such as the University of Indonesia) the number of required courses is the same, but the electives include 4–6 courses from the humanities and social sciences. In general, class schedules follow a one- to two-day schedule: two-credit classes meet once a week (for a two-hour period), while three-credit classes meet twice a week (one, two-hour period followed by a one-hour period on a different day).

Table 3. Representative Chemistry BS Degree Program Requirements by Semester for Indonesian Public Universities

Sequence	Courses
Common first-year program for science and technology students	
Semester I	Calculus I; General physics I; Chemistry I; Scientific writing; Introduction to chemistry; Environmental science; Physical education
Semester II	Calculus II; General physics II; General chemistry II; English; Introduction to bioscience; Concepts of technology; Physical education
Specific program for undergraduate chemistry majors	
Semester III	Mathematics for science; Analytical I: Fundamentals; Organic I: Mono-functional; Physical chemistry I: Thermodynamics; Modern physics; Practical organic chemistry
Semester IV	Biochemistry I: Structure and function; Analytical II: Separation and electroanalytical; Organic II: Poly-functional; Physical chemistry II: Kinetics; Inorganic I: Main group
Semester V	Inorganic II: Transitional metals and catalysis; Analytic III: Spectrometry; Biochemistry II: Metabolics and genetics; Chemistry elective; Religion and ethics
Semester VI	Inorganic III: Structure and reactivity; Organic III: Synthesis; Environmental chemistry; Structure determination; National ideology; Chemistry elective
Semester VII	Final research project I; Seminar; Molecular biotechnology; Chemical thermodynamics; Chemistry elective
Semester VIII	Final research project II; Seminar and examination; Physical organic chemistry; Chemical kinetics; Materials chemistry; Chemistry elective

Note: The elective courses include: Electrochemistry; X-ray diffraction; Stereochemistry; Computational chemistry; Nuclear chemistry; Group theory; Chemometrics; Biochemical research.

Laboratory classes, referred to as "practical courses", are exclusively focused on developing manipulative, experimental laboratory skills. In the three settings I visited, the laboratory rooms accommodated 60–80 students each. In addition to some dedicated teaching staff associated with the laboratories (the equivalent of nontenure track lecturers in the U.S.) there were student assistants, some of whom were paid and others who were upper-level undergraduate volunteers, who worked with students in the laboratory on a roughly 1:8 ratio in order to provide more personal instruction on techniques and procedures.

I spoke with many faculty members about the typical Indonesian classroom and this caricature emerged: a room of 50–70 students who sit quietly and resist efforts to interact with them, including attempts at small-group work. Teaching later in the day is difficult because the students are overwhelmed by so many contact hours of instruction, including densely-packed, Powerpoint-driven presentations; strict adherence to coverage (meaning that if it was not mentioned, it could not be counted as taught;) and a small yet measurable fraction of actual "recitation," where ideas are spoken and then repeated verbatim.

Participation in undergraduate research most closely resembles the German model, in which students are expected to spend their last year with a lighter course load and the requirement to carry out a specific research project. It was graduation week while I was there, and the final posters for the graduating seniors hung in every hallway in the chemistry building. A typical student project reported the synthesis and characterization (by IR) of a series of 5 *N*-acylproline derivatives that, according to the poster, might be used as a chemical additive to help emulsify petroleum/water mixtures during drilling and extraction.

The Indonesian government has a progressive program to encourage undergraduate and graduate students to get educational experiences outside of the country. Through a selection process, students can obtain a grant that pays for their international travel and can provide ~$500–1000 a month in living expenses for up to a six-month period. This is called a "sandwich" program because it happens within the undergraduate or graduate degree program. At present, accepting a student from Indonesia into your department for study requires, effectively, that a tuition waiver be granted and that an inexpensive housing option is available. Currently four countries host Indonesian chemistry students: Germany, Japan, Singapore, and The Netherlands. Students who accept these grants need to return to Indonesia at some point; however, students who studied abroad as undergraduates are not prevented from pursuing further studies (a PhD) in the host country and returning after that. These host countries are definitely using this program for recruitment at the graduate and post-doctoral levels.

Among most of the students I met, there was a great deal of importance placed on rigorous academic preparation as well as strong English language skills. Although this was not required, many students elected to produce their posters, as well as the written theses, in English. As a person who has done oral English language testing in both the U.S. and in China, I would say that the top students that I spoke with would have no problem passing at the level required to be a graduate student instructor. The usual caveats operate, however: a high TOEFL score does not guarantee a confident speaker of oral English.

Themes That Emerged from Visits with Departments

For at least a full day I visited with three different chemistry departments, conversing and consulting on matters of undergraduate and graduate education (see Figure 2). Around the world, a few universal truths appear in conversations about undergraduate chemistry education. These are important departure points for conversations because these ideas are framing the way instruction is designed and implemented. I will briefly indicate some overarching themes that emerged during my visits, as well as some specific projects that the departments have undertaken. Although my descriptions will betray my perspective during these conversations, I do not summarize here the discussions and advice resulting from these consultations; my point is to convey the topics and projects being discussed in these departments.

Tradition Hinders Progress

Also known as the "if it isn't broken, don't fix it" syndrome, this attitude might be even more prevalent in countries such as Indonesia, where the faculty members often hold one of their degrees, usually the BS, from that same institution. The young faculty members I spoke with found it difficult to push for change against one's academic mentors in a system that honors hierarchies so strongly. Regardless of the level of dissatisfaction and intellectual exhaustion with the overloaded curriculum on the part of many students and faculty members, there is a tangible fear that reducing the requirements cannot represent anything other than a reduction of standards.

Students Are Easy To Blame

During my visits with the faculty members, I heard a litany of familiar statements, including these: Students are not motivated; students are not willing to interact during class; students won't work on complex assignments; students only memorize things.

What Is General Chemistry?

I often remind audiences that the first article in the first issue of this *Journal* was titled: "What We Teach Our Freshman in Chemistry" *(2).* At the conference, and then again in the three departmental faculty meetings, there was a single question that came up in every setting: Should the content of the general chemistry course be directed by the needs and interests of the client departments, with separate tracks, or "flavors", for mechanical and civil engineering students, premed students, prenursing students, chemical engineering students, chemistry students, and so on; or, is general chemistry the single course that we, as the chemistry department, decide upon?

Figure 2. Faculty and students from Padjadjaran University (IPB) at the author's presentation there. Photo by Unang Supratman.

High School Teachers Are Also Easy To Blame

This second litany is also familiar: students are not being prepared well enough; the high school teachers don't know enough chemistry; the schools just pass the students through to us.

At the Bandung Institute of Technology (ITB), the faculty members were working on four projects to address teacher preparation, as briefly described below.

MS in Science Teaching Degree for High School Teachers

The proposed program was a set of 12 modified undergraduate classes taught at "a more basic level" than their counterparts in the regular program, which troubled the ITB faculty greatly because these classes needed to be offered for graduate credit. Two classes related to pedagogy—a methods course, and a teaching proposal that was meant to result in a written thesis; however, these were being invented without consulting with colleagues in teacher education, and the nature of these proposals and theses was certainly giving the department anxiety.

New Chemistry Curriculum Proposal

In an effort to provide more flexibility, the department is considering a program where, in reference to Table 3, the following changes would be made: in the common, first-year curriculum, Introduction to Chemistry is replaced by Introduction to Integrated Science, Environmental Science is replaced by Mathematics for Science, Introduction to Bioscience is replaced by a more general Science, Technology, Art, and Environment course, and a full year of English is required. Introduction to Bioscience replaces Modern Physics in the second year. In the third year, Inorganic Chemistry II and III are combined; the Organic Synthesis class moves to the first semester; Introduction to Research moves in from the senior year; and both of the social science classes are eliminated and replaced by a class in business management. There are 10–12 elective classes proposed for the last three semesters (taken from a suite of 18), and a full year devoted to the final research project. Although the number of requirements is not reduced, overall, many of the changes are aligned with the conversations in the U.S. to create a "core plus elective" structure, and to increase the formal requirements for undergraduate research.

Including Honors Courses in the Chemistry Curriculum

The conversation about creating an honors option was intriguing. Our Indonesian colleagues understood that many large U.S. universities offered honors programs, and so had set out to copy these structures. Interestingly enough, the somewhat altruistic, written rationales for investing in these expensive programs (smaller class sizes with better instructors, etc.) did not quite ring true; so I was asked directly: Why do universities really offer these? The idea that large universities create structures to help recruit academically excellent students who might be attracted to the more intimate environments of the four-year liberal arts colleges made perfect sense to the ITB faculty, although I think they might now question whether the investment is meaningful for them.

Modifying General Chemistry

Currently at ITB, the general chemistry program is a perfect storm—a perfectly bad storm. All 3000 students entering ITB take this class, and it is taught in roughly 30–40 sections of 75–100 students. About 30 of the 40 members of the department had a section of this class to teach as a part of their assignment. Although a single, strong-minded individual had been the course coordinator for many years, the department has not moved back to that model for operating since his retirement in the mid-1990s, and during that time, the enrollment at ITB has nearly doubled, adding substantially to the teaching responsibilities in the department. Many of the more important assumptions associated with the problem—class size, having a course coordinator, and staff support—were not being questioned, in favor of only searching for pedagogical methodologies that could (in a sense) rescue them from what was, at least in part, a structural problem.

Padjadjaran University, which was originally located near ITB in Bandung, needed to expand its physical plant about five years ago, and moved some of its operations to an open, rural setting about 45 minutes from the city. Unfortunately, the university administration and the research operations in the institution stayed in the city, and so the undergraduate teaching operation is physically split from the research and administration operations. Although the new rural facility is relatively up-to-date, its teaching laboratories are significantly underequipped because nearly all of the instrumentation is (as they say) located in the city.

On the other hand, in designing a brand-new teaching facility, the Padjadjaran faculty made an interesting choice: because, as at ITB, all 2600 entering students take the same core curriculum in their first year (general chemistry, physics, biology, calculus, and English), they decided to offer these as an Integrated Sciences Program, and to build facilities to specifically house this (see Figure 3). They hired a single coordinator who oversees the first-year Integrated Science Program, and for whom the five individual department coordinators serve as a board of directors. This is the largest integrated first-year program that I have ever heard of *(3).* The Padjadjaran faculty has some compelling evaluation data that begins from before they implemented this program, and I have strongly encouraged them to write up this work and submit it to this *Journal.*

At the University of Indonesia, which is a more comprehensive university than either Padjadjaran or ITB, the university was successful, in 2003, in competing for a $1.5 million, five-year award from the central government to improve teaching on campus. This is a substantial amount of funding, and, as with many such efforts in the U.S., the focus has been split between implementing new methodologies for classroom teaching and collecting educational research data. From my conversations that day, I also had the same impression that I have had in parts of the U.S.: often, new classroom methods are adapted, and mostly adopted, without much regard to the specific content or the institutional context *(4).* Consequently, the same sorts of responses were common from the growing cadre of nay-sayers: we tried that and it did not work, our students are too busy and unmotivated to do this, and we cannot sacrifice so much content in order to add this kind of play time. Research data from some different context is not enough, because changing teaching practices constitutes a change in behavior *(5),* not a mere intellectual change of mind.

Figure 3. One of four buildings housing the Integrated Sciences Program at Padjadjaran University. Photo by the author.

Possible Futures for Chemistry Education in Indonesia

The vexing problems in higher education have a global reach. Concerns and conversations in Indonesia mirror exactly the issues in the rest of the world. Many structural aspects (financial support, instrumentation) still need to be improved, although some have changed, albeit slowly, over the last 10 years. The level of interest in doing things differently, particularly among young faculty, is high; they want to be successful in a way that extends their reach beyond the local environment.

The four actions briefly described below could be undertaken by interested colleges and universities in the United States in partnership with Indonesian colleagues.

Hosting Indonesian Study-Abroad Students

Because the Indonesian government will provide its undergraduate and graduate students with travel support plus a modest stipend, a U.S. institution could, for a small investment, host either undergraduate or graduate students for short-term periods. While covering tuition is a real problem in settings where it was not waived, bringing students in for summer research is likely more easily managed.

Figure 4. A tea *(Camellia sinensis)* plantation outside of the city of Bandung, in southeast Indonesia. Photo by the author.

Sending Study-Abroad Students to Indonesia

The English language skills of students and teachers at the Indonesian universities that I visited were generally very good to excellent, and there is a great deal of interest in increasing the amount of instruction that is carried out in English. The opportunities for nonscience students are probably greater than for science students, and getting good information can be difficult because the departmental Web sites are typically not yet available in English. Although there are many Westerners doing academic work in Indonesia, concerns for both personal safety and health safety are always just below the surface, so a casual or unsophisticated student might not be prepared for living in such a setting.

Collaborations on Teaching

Mechanisms for truly international collaborations about teaching are rare. We consult, we attend meetings, and we hold workshops; however, at the level of department-to-department or even faculty-to-faculty interaction, collaboration on teaching is an area that can be further developed, in my opinion. It might be interesting for the American Chemical Society or the National Science Foundation to convene a meeting—jointly with their southeast Asian counterparts (perhaps in Singapore)—to explore additional mechanisms for fostering more teaching collaborations.

Collaborations on Research

Better communication is perhaps the only hindrance for being able to establish better research ties between Indonesia and the U.S. Other countries have been successful, and they have been rewarded, for example, with first access to new and potentially bioactive natural products. (One product that is the focus of phytochemistry research is shown in Figure 4.) The National Science Foundation already has programs that support U.S. students carrying out research in foreign settings.

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