Paper ID #8362

Multi-purpose Advanced Teaching and Basic Research Analytical and Physical Chemistry Laboratory at Khalifa University's Biomedical Engineering Department

Prof. Abdel F. Isakovic, Khalifa University of Science, Technology and Research

Abdel F. Isakovic graduated with PhD in physics with focus on spintronics (University of Minnesota, 2003), where he was also trained in cooperative teaching method. He worked as postdoctoral research associate in nanotransport, nanofab and X-rays (2003-2006) at Cornel University, where he also served as a lecturer (2006), after which he moved to Brookhaven National Laboratory, NY to work on nanofocusing optics until the end of 2009. He has been employed as Assist. Prof. at Khalifa University (KUSTAR, Abu Dhabi, UAE) since Jan 2010, where he works on research on educational methods in physics and chemistry for engineering majors, and has setup his own research laboratory for nanotransport and nanomagnetism.

Ms. Szu Szu F Ling, Khalifa University of Science, Technology and Research

Szu Szu Ling works as general and biochemistry laboratory instructor at Khalifa University's (KUSTAR) Departments of Applied Sciences and Biomedical Engineering since Oct 2010. She is currently finishing her PhD in Chemistry Education at National University of Malaysia under the supervision of Profs. Lilia Bt. Halim and Abdel F. Isakovic (at KUSTAR). Major focus of her research is game-based learning and setup of novel experiments. She holds MSc degree in Chemistry from University Teknologi Malaysia.

Miss Selwa Mokhtar Boularaoui, Khalifa University of Science, Technology & Research

Selwa Boularaoui, a senior in biomedical engineering at Khalifa University of Science, Technology & Research, anticipating to graduate in December 2013. After graduation I am planning to enroll in graduate school in the US. In summer 2011, I was trained at Imperial College in London, UK to use motion tracking system to analyze human motion. In summer 2012 I did my internship at Siemens Healthcare in Erlangen, Germany where I was introduced to particle therapy and performance analysis of current biological treatment planning approach. After my internship I did an independent study on control of radiation damage to proteins. I was awarded by Sheikh Hamdan bin rashid al maktoum for my educational excellence- distinguished university student award. I tutored science and basic engineering courses at my university and I was a teaching assistant for physics. In 2013 I started my senior design project in which we study the neurocycle enzyme reactions and consequences for Alzheimer and Parkinson diseases.

Miss Sara Bashir Timraz
Mrs. Mualla Kara

Multi-Purpose Advanced Teaching and Basic Research Analytical and Physical Chemistry Laboratory at Khalifa University's Biomedical Engineering Department

Introduction and motivation

Khalifa University (KUSTAR) is a newly founded university in Abu Dhabi, United Arab Emirates (UAE). KUSTAR was administratively established in 2007, and we are expecting the first generation of graduates with the degree of BSc in engineering in May 2013. The mission of KUSTAR is in training engineering, and, in the close future, health and applied sciences graduates who will take leadership roles in transitioning the oil- and gas-based economy of the present day UAE towards an information-driven economy and sustainable energy society by the year 2030, as outlined in the ambitious plan titled "Abu Dhabi 2030"[1].

This report outlines the motivation, standards and initial critical feedback on the start-up efforts to establish a multi-purpose chemistry laboratory to serve the needs of the Biomedical Engineering Department faculty and students. The build-up of such a relatively broad laboratory capability has several aspects that make the effort worthy of a critical look in respect to the global competence of KUSTAR engineering graduates[2,3], such as:

a. The hiring plans for Khalifa University, in general, and for the Biomedical Engineering Department in particular, focus on attracting world class faculty trained as postdoctoral research associates and industry research and development-experienced hires, primarily from leading North American and EU universities, government labs and industrial research and development centers. Maintaining their competitiveness on global scale requires optimization of substantial start-up investment;
b. The desire (and a reasonable standard in the era of globalization) of the KUSTAR faculty and leadership is to enable and provide access of our students and faculty to world class user research facilities (such as nanofabrication foundries, US national laboratories, materials characterization facilities and similar) through exchange and internship programs, and such globally mobile academic workforce requires adequate laboratory skills and experience level;
c. A more specific requirement that resonates with the global competency of KU engineering graduates originates in the undergraduate engineering curriculum requirement dictated by the UAE Ministry of Higher Education, which states that, at the end of the junior year, every student must take an outside-the-university internship position related to her/his major (such as a hospital laboratory intern for biomedical engineering majors, or a software troubleshooting intern position as a computer engineering major, etc.);
d. Lastly, despite the significant local-specific start-up parameters and constraints, the demographics of the UAE (a Gulf nation inhabited by 20% Emirati nationals, and 80% foreign workers employed at all socioeconomic levels) implies the need to train college-age students from the Middle East, North Africa (MENA) region, almost all Arabian peninsula and Persian Gulf nations, and a small number of students from Southeast and Far East Asia, Europe, Sub-Saharan Africa, and North America. Given that only a fraction of foreign college graduates in UAE may count on continuing career locally, the need to establish and maintain college and graduate engineering and science programs that certify globally competent engineers is an existential imperative.

Lab program and intermediate level BME chemistry syllabus outline

In establishing an intermediate and advanced undergraduate training in analytical and physical chemistry for BME majors, we looked at designing lab that contains a set of instruments satisfying the criteria (a) through (d) above, and that could serve as a kernel of future progress as the number of faculty and students increases. It is worth pointing out that the anticipated steady-state graduation rate from the BME program at Khalifa University will be at the level of 20-25 BSc in engineering graduates per year by the year 2020. At the time of the planning and purchasing stage of this laboratory, there were only two permanent and one adjunct faculty member in KUSTAR's BME Department, who worked as a small team on hiring the first two clusters of up to six faculty members.

In KUSTAR's BME Department, opened in 2009 with the first undergraduate class graduating in December 2013, we planned to provide students and faculty with a creative, student-centered, interactive-engagement-friendly teaching and learning environment. From the outset, the BME standards, set by the Department's founding Chairperson, Prof. Stephen DeWeerth, of Georgia Institute of Technology, focused on the practical learning outcomes and training criteria that would satisfy:

a. Local biomedical characterization needs, which would follow the research focii of the BME Department on metabolic disorders and augmentation of human performance
b. The requirements of the ABET accreditation process, which KUSTAR is about to go through in 2014.
c. Entry standards of the leading North American and European graduate schools in engineering and medical field (in terms of desired skill level of beginning BME graduate students in their role as graduate research assistants).

Fig.1 below indicates some of the desired experimental skills and applications themes that led us to propose and develop such a hybrid laboratory.

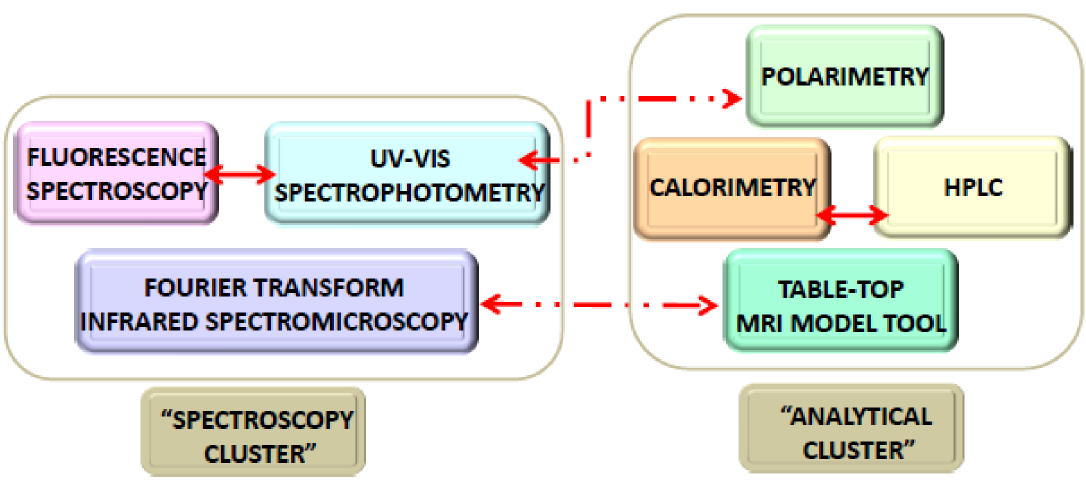

Fig. 1 Two major equipment clusters for the BME Department Chemistry Laboratory

Figure 2 below outlines the lineup of the computer modeling laboratories and the elements of the instruments' rotation. Depending on human resources, the number of instruments, and the prior performance of students, one can execute the syllabus by interchangeably administering one computer modeling lab and one experimental laboratory, or run through all the computer modeling labs first, then use a cyclic rotation of 2- or 3-student groups per instrument for all instruments.

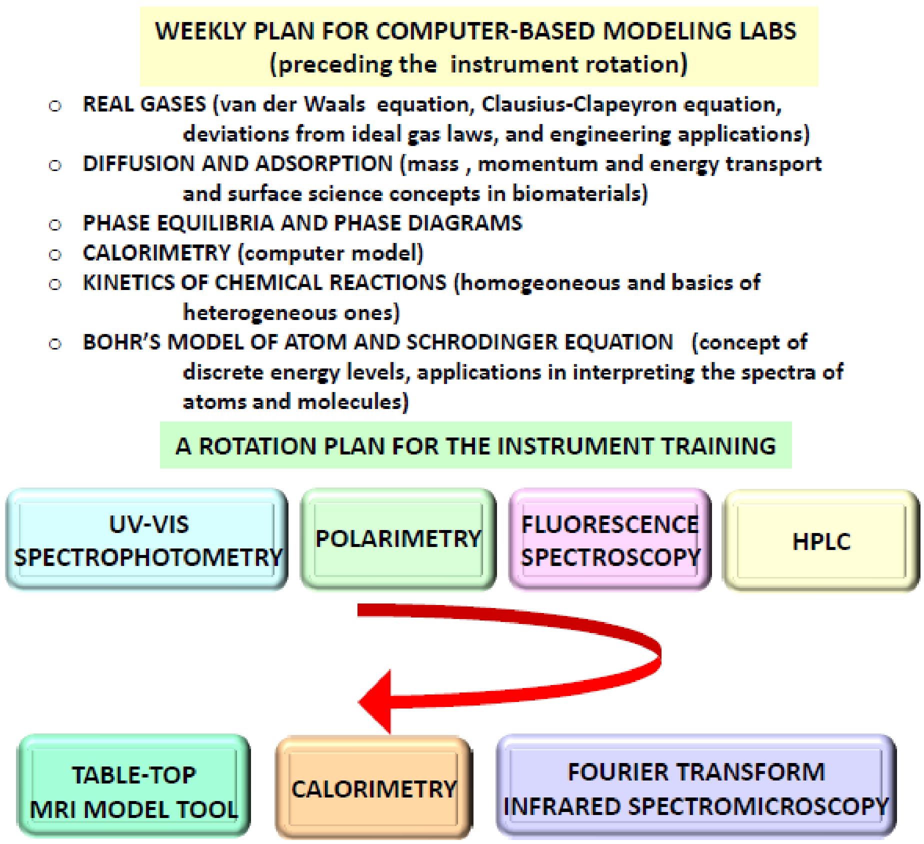

Fig. 2 (TOP) the list of modeling labs realized in the first six weeks of the semester. (BOTTOM) rotation of the three-member student teams through the instrumentation

A hybrid nature of this lab program is dictated by the need to have three chemistry courses for BME majors in our BME curriculum, as this course and its lab are preceded by the General Chemistry for Engineering majors, and followed by the organic chemistry/biochemistry course(s), and by the fact that no modern (20^{th} century-themed) science class existed in KUSTAR's College of Engineering curriculum at the time of building up this lab and the course.

Further, this lab program has been motivated by the need to increase the focus on developing students' competencies and professional skills/soft skills. In recent years, global competency has been introduced as an important "soft" skill[2,3] that engineering graduates should acquire along the training through a standard engineering curriculum. This trend and suggestions for attempting to standardize the "criteria for global competence" of engineering graduates are intuitively attractive. However, we suggest that for developing countries, as well as for the rapidly developing economies (such as the UAE economy), global competency should require somewhat standardized "global lab curriculum" in the discipline-specific laboratory skills, in addition to the requisite "soft skills" suggested by others[2,3]. Furthermore, we suggest that for developing countries, and rapidly developing economies, we need to introduce empirical approach when it comes to estimating the level of global engineering competency. To this end, we find the approach by Y. Li[6] very illuminating and we plan on developing a laboratory-themed assessment tool that would augment the predominantly soft skills criteria outlined in the Li's study[6].

A unique feature of existing KUSTAR engineering curriculum is that, at the end of their junior year, students need to take two-month internship, as dictated by the UAE Ministry of Higher Education. We attempt to collect some descriptive statistical data that represent the beginning of the examination of the differences between three groups of KUSTAR students: (1) those taking internships abroad, (2) those taking internships with global corporations locally in UAE, and (3) with and those who stay at home in UAE, taking an internship with local government or industry.

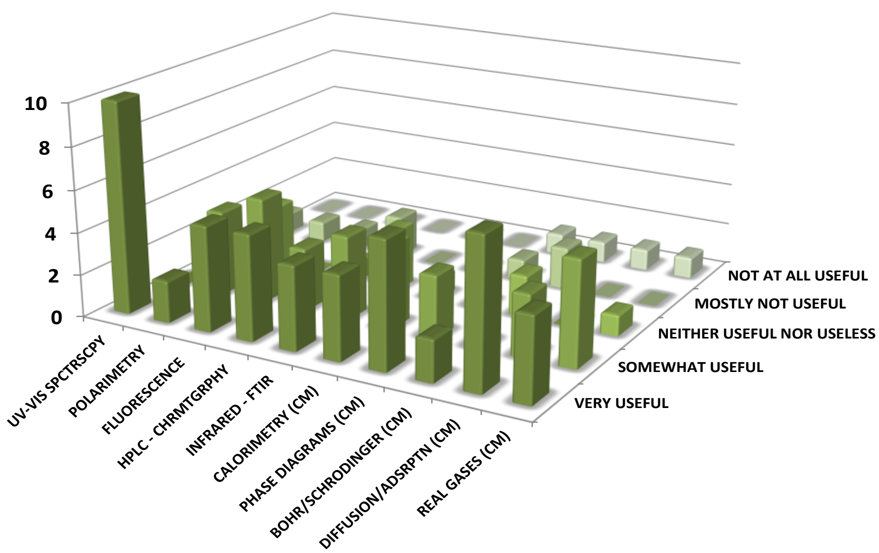

Fig. 3. A survey of the first generation of BME seniors in regard to their views on the usefulness of the Analytical/Physical Chemistry Lab in their internship experience (7 students did international internship, and 4 did local UAE-based internship). "CM" stands for "computer modeling" lab.

We did not attempt to differentiate between different groups of students, mostly because of such small numbers (we only had 12 possible candidates in the senior class that could answer the survey and interview questions), but we intend to follow up with such questions on annual basis as each junior class finishes their internship. As an attempt of triangulating the effects of this multi-purpose lab training, we have also conducted survey of the students' recollection on the overall impression they had of this lab course, now that they are three to four semester past it. Results are shown in Figure 4.

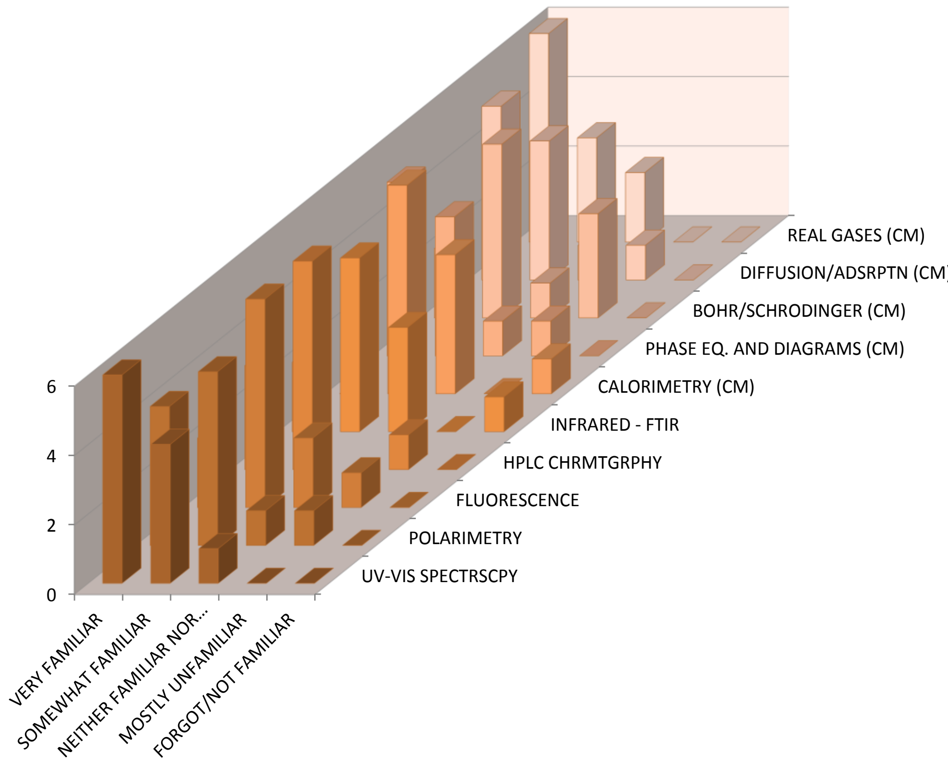

Fig. 4 Students' self-assessed level of recollection of the skills and topics in Analytical and Physical Chemistry Laboratory three to four semesters after taking the course. As before, (CM) stands for "computer modeling" lab. Same group of respondents as in Fig.3.

Some salient features of the survey and interview of the BME seniors in Figures 3. and 4. indicate the following:

i. Computer-based modeling laboratories, which were meant to be a learning and preparation tool in conquering some concepts in modern science (science curriculum beyond General Physics and General Chemistry for Engineers), were not "popular", and interviewed students state that, to quote interviews "the level of abstraction was an obstacle". It should be noted that these modeling laboratories did not include programming tasks, as this instructor has either used codes he prepared, or computer codes from public domain were utilized[4,5].
ii. Those laboratories that were less "hands-on" laboratory exercises are treated with some reservation in the survey; such is the case of the FTIR laboratory, where the instructor is involved in data collection and students assist him/her, as opposed to UV-VIS spectrophotometry, where students can be quickly trained to collect data themselves, and reach a certain level of self-confidence at a much better rate.

In terms of a comparison to similar activities around the world, we find that our approach is similar to the recently published results from R. S. Iyer and M E. Wales, who offered the model for integration of interdisciplinary research-based experiences in biotechnology laboratory[7].

Developing Basic Research Capabilities within this Laboratory as a Core Facility

The second facet of this report covers the buildup of elementary research capabilities, in the form of the "Core User Facility" for Biomedical Engineering faculty with the possibility of serving other departments as well (Applied Science Department, soft matter researchers in Electrical and Computer, Mechanical and Aerospace Engineering Departments, as well as future College of Health Sciences programs).

One of the challenges facing newly appointed science and engineering faculty everywhere is the proper development of their startup research portfolio based on: (1) the combination of the skills and plans that the faculty member arrived with, and (2) local resources in joint facilities and in the labs of other established senior research faculty. The startup package is a hallmark of the faculty support in well developed countries with the long academic and research tradition and strong links between industry and academia. This model, variations of which can be found on a global scale from North American universities all the way to South Korea, Japan and Singapore, has at least indirectly contributed to the stabilization of the expectation about the global competencies (perhaps more so for graduate students in engineering than for undergraduates), despite the apparent difficulties[1,2,3,6] in quantifying what these competencies might entail. At KUSTAR, like elsewhere in the UAE and in the broader MENA and Persian Gulf region, the startup package is not a common practice, and different universities have adopted different models of supporting their research faculty, but, even when some support exists, it is approximately an order of magnitude below the North American investment in junior faculty. Due to the lack of systematic investment, we sought a different mode of laboratory buildup, planning that the lab buildup will lead us to enhancing the global engineering competence of our startup faculty, as well as the students and other engineering trainees (research associates and technical support staff members, for instance). We believe that the facility presented in this report is one possible, however temporary, answer to the lack of the guaranteed individual startup packages.

The path towards maintain global competitiveness of our faculty (and therefore global competence of our engineering graduates) still contains several obstacles:

a. the price tag of many instruments and laboratory supplies increases by approximately 20-30% over the identical instruments obtained from European, North American or Far East vendors,
b. lack of qualified, pre-trained support staff for laboratory maintenance,
c. nearly complete absence of machine shop, glass shop and electronics shop facilities,
d. a very slow pace of recruiting graduate students (on average, UAE nationals do not share the same motivational attitude towards the long term build-up of the career for the research and development sector), and
e. slow pace of recruiting postdoctoral research associates.

Nevertheless, four of our BME, three Applied Sciences and two Aerospace and Mechanical Engineering faculty members have already started using the instrument part of the laboratory program presented earlier in this report. The portion of their activities in this laboratory is presented in an abbreviated, schematic form in the Table I.

Table I Matching of research needs of BME and other KUSTAR faculty with this Lab. Each faculty is labeled as “Dept.#n”, with the abbreviations “AS” for Applied Science, “ASE/ME” for Aerospace and Mechanical engineering, and “BME” for Biomedical Engineering. “**x**” implies that the instrument is already used or declared as essential for the program of that particular faculty member.

FACULTY AND PROJECT OR PROGRAM	FTIR SPECTRO MICROS.	FLUORESC. SPECTRO-SCOPY	HPLC CHROMATO GRAPHY	UV-VIS SPECTROSCOPY	POLARI-METRY	CALORI-METRY
BME#1 PROPERTIES OF CARDIO-VASCULAR CELLS	x		x		x	
BME#2 CELL DYNAMICS		x		x		
BME#3 PROTEIN-BASED DRUG DELIVERY	x		x	x		
AS#1 CELL MEMBRANES	x	x		x	x	
AS#2 NANOPARTICLES				x	x	
AS#3 SOLUTE/SOLVENT OPTIMIZATION	x		x			x
ASE/ME#1 NANO-ENFORCED COMPOSITES	x			x		x
ASE/ME#2 ENGINEERING OF NOVEL OXIDES	x			x		x

Clearly, with these eight faculty members each relying on at least two, and some on as many as four instruments, the laboratory represents a first step in establishing a useful Analytical and Physical Chemistry Core Facility at the BME Dept. of KUSTAR.

Discussion

In terms of global impact and relevance of this development effort at BME-KUSTAR, we find that the many obstacles identified[2,3,6] in the US and abroad could be addressed with our approach. For instance, a *curricular rigidity* could be addressed with such laboratory approach as we clearly address more than one course with such a lab; then a *lack of support for cross-disciplinary activities*, as biomedical engineering (together with environmental engineering) is perhaps one of best examples of cross-disciplinary engineering; *financial restrictions*, as both students and faculty need to remain globally connected, competent and competitive and a multi-purpose laboratory is one way to go about these criteria; *connections to corporate world, industry and government and deep immersion* through mandatory internships connected tangentially or better to the skill set gained in such a laboratory.

Summary

In summary, we present a model of a multipurpose laboratory which combines some standard biomedical engineering and modern science laboratory curriculum with a kernel of a Core/Shared Facility developed at Khalifa University – KUSTAR, Abu Dhabi, UAE. An impact of such multi-purpose laboratory on student global engineering competency is discussed within a survey of the first generation of BME seniors at this start-up university. In the second part of the report, we outline the initial positive impact of this laboratory facility on the start-up effort of the first batch of research-oriented faculty members in the environment where individual start-up packages are still not a norm. In terms of global preparedness of students and faculty, we suggest this model and its variations in other engineering disciplines as a “hard skill set” addition to the currently considered soft skill set needed by current and future engineering graduates.

As discussed in Refs.[2,3,6] one of the major problems in achieving international competence is in the highly sequenced and demanding nature of the current engineering curricula. This manuscript discusses one potential approach to increasing the global competence by focusing on science-driven engineering training as a hard skill, leading to the lab-based internship, in addition to several soft-skill themed efforts, such as international study (study abroad as known in the US), international internships, or more ambitious transnational design projects.

References

[1] http://media.abudhabi.ae/pdfdirectview/en/149360/blaetterkatalog/blaetterkatalog/pdf/complete.pdf, last accessed on March 9th, 2013.

[2] Grandin, John M. and Hirleman, E. Dan (2009) *Online Journal of Global Engineering Education*: vol. 4: Iss 1, Article I.

[3] Jack R. Lohman, Howard A. Rollins and J. Joseph Hoey (2006): *European Journal of Engineering Education*, 31:01, 119-131.

[4] Boris S. Bokstein, Mikhail I. Mendelev, David J. Srolovitz, *Thermodynamics and Kinetics in Materials Science*, Oxford University Press, (2005), ISBN 978-0-19-852804-3;

[5] Burrows *et al*., *Chemistry*^{3} *– Introducing Inorganic, Organic and Physical Chemistry*, Oxford University Press, (2009), ISBN 978-0-19-927789-6.

[6] Yulong Li, (2012), *Decision Sciences Journal of Innovative Education*, vol. 11, No. 1 125 – 143.

[7] Rupa S. Iyer and Melinda E. Wales, *Advances in Engineering Education*, Winter 2012, published by ASEE.

Appendix

Portions of the international and in-country internship survey we developed with the goal of examining the depth of connections between the standard engineering curriculum and the internship experience are available for free online at the following link. We invite the members of engineering education community to use, modify and further develop this survey for their own needs.

https://www.surveymonkey.com/s/MYKJGCY