A Model for Teaching, Assessment and Learning in Engineering Education for Working Adults

http://dx.doi.org/10.3991/ijac.v5i4.2249

K.C. Lim[1], Stephen Low[1], S. Attallah[1], P. Cheang[1] and E. LaBoone[2]
[1] School of Science and Technology, SIM University, Singapore
[2] Food and Drug Administration, College Park, Maryland USA

***Abstract*—This paper examines the engineering education programs provided by SIM University (UniSIM) related to teaching, assessment, and learning for working adults. In terms of engineering education, the paper emphasized the changes brought about especially in areas like blended learning, capstone project, continuous assessment, quality control and working with engineering accreditation bodies like ABET. All these helped to ensure that UniSIM is able to offer a quality engineering education that is comparable to other institutions in the region and can serve as a model for working adults to upgrade themselves.**

***Index Terms*—e-learning; engineering education; working adults**

I. INTRODUCTION

The purpose of this paper is to discuss a model for teaching, learning, and assessing an engineering program for working adults at a university in Southeast Asia. The foundation is based upon the Open University model and adult learning theory. The institution initially began offering a few degree programs in 1994 through a partnership and now has evolved into a fully comprehensive self-sustained and governed university with more than 50 academic programs in a variety of different disciplines. The objective in the beginning and today is to provide a university education for the adult working population and specifically as it relates to this paper in Engineering.

Catering to working adults means focusing on teaching and learning principles that specifically cater to the needs of the learners in question [1]. In short, the model used is consistent with the constructivism approaches in learning. This model allows students to experience an environment first-hand through active engagement. Students are exposed to authentic scenarios where they focus on the 'why' and 'how' to solve problems through discussion and rational thought processes, logic, and creativity. The student is then required to act upon the environment to both acquire and test new knowledge [2]. The characteristics of adult learners are 1) the need to know (why); 2) self-direction (responsible for their own learning); 3) problem-centered (real-world tasks); 4) motivation to learn (internal values); and 5) relatable past experiences [3] [4]. Each of these characteristics played a role in the development of a model that guides program practice with the ultimate goal of student satisfaction and a series of quality control measures and continuous improvement processes that facilitate accreditation.

II. BACKGROUND

The building of an institution for working adults began with an organization, Singapore Institute of Management (SIM) that started in 1964 to provide management courses to its members. As demand grew for a wider range of course offerings and recognition of completion, SIM partnered with foreign universities to offer degree courses in several disciplines. In 1992, SIM was officially recognized by the Singapore government's Ministry of Education (MOE) to run a degree program through a partnership established with the Open University of United Kingdom (OUUK) to provide education for the working adult.

The partnership with OUUK provided the catalyst for SIM, and some nine years later SIM achieved institution accreditation through the Open University Validation Services (OUVS) and began developing its own course materials for new undergraduate degree programs. By early 2005, SIM established as a fully sustainable institution and was granted university status from Singapore's MOE. On 14 April 2005 the SIM University (UniSIM) was fully gazetted by the Singapore Government.

UniSIM is Singapore's first and only privately-funded university recognized by the Ministry of Education (MOE) to issue its own degrees and specifically serves the needs of working adults with admission criteria to match. While some specific programs have additional criteria the baseline is that each student has to be at least twenty-one years old and have a minimum of two-year's work experience. This is based upon the institution wanting to attract a certain type of student that most likely has these adult learner characteristics (i.e. - relatable past experiences and self-direction) that the institution's curriculum is built upon.

III. ENGINEERING PROGRAMS IN UNISIM

The intent of the engineering programs at UniSIM is to produce graduates that are ready to meet the challenges of business and industry. The School of Science and Technology (SST) is home to the engineering programs along with 12 other undergraduate programs. The engineering programs consist of BEng Aerospace Systems (BEHAS), BEng Electronics (BEHE) and BSc Biomedical Engineering (BSBE) [5].

As with all of UniSIM programs one of the key factors that can be particularly attractive about the Engineering programs is that it is the only university to offer part-time studies. Students do not have to leave their current jobs in order to pursue their engineering degree. Another reason for the attraction to the engineering programs is that the institutions'' engineering students have been doing well in activities outside the classroom (e.g. – Singapore Amazing Flying Machine Competition 2012 in which Team UniSIM Flyer II students won the Gold award in the Category D, Theory of Flight Award) [6] that have been highlighted nationally through media exposure. Moreover, the Singapore Government has continued to endorse the values set by the institution by providing citizens undertaking an undergraduate program for the first time a 55% subsidy in their tuition fees.

While the specific attraction of UniSIM programs varies, the Engineering programs were development after careful review of local and global business and industry trends. In the years 2001 to 2003, there was a rapid growth and change in the electronics manufacturing, semiconductor foundry production, biomedical instrumentation system maintenance services in health-care organizations, system design work of intelligent automatic control/data logging systems, and IT telecommunication industries in Singapore. The growth in these sectors indicated that a well-trained workforce of engineers would be in demand and the Open University model would be uniquely equipped to handle a certain segment of this demand.

The continued demand for engineering programs at UniSIM is shown in Figures 1 – 3. Since the program began there has been consistent enrollment with a recent climb in 2009 in BEHE and in 2010 in BEHAS and BSBE. This spike in enrollment has been loosely linked to the decision by the Singapore Government to increase the subsidies for students doing their first undergraduate degree program in 2009 at 40% and 2010 at 55%.

The enrollments for the electronics and biomedical engineering program begin in 2004 through SIM Open University Centre even before SIM University was established. The BEHE remains the most popular of the programs followed by the recent addition of the BEHAS in 2008 and then BSBE.

To date the program has graduated 513 students in the three engineering program beginning with their first graduates in 2008. The expectation is that this number will continue to increase as the number of enrollments increase and number of years that students are given to complete their degrees (based upon part-time enrollments).

TABLE I.
ENGINEERING GRADUATION RATES FROM 2008-2011

Program Code	2008	2009	2010	2011	Grand Total
BEHAS	0	0	0	4	4
BEHE	32	121	111	125	389
BSBE	20	24	47	29	120
Grand Total	52	145	158	158	**513**

IV. TEACHING IN THE ENGINEERING PROGRAMS

Each Engineering program is led by a Head of Program (HoP) who is a full-time academic staff member of the institution and an expert in the discipline. The HoP has a staff of part-time associate faculty members that teach the engineering courses. Typically, all part-time associate faculty members must have at least a Master degree in the

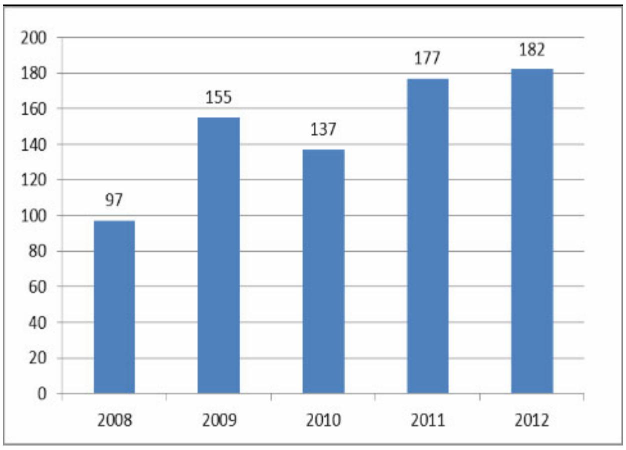

Figure 1. Student enrollment numbers for Aerospace Systems program 2008-2012 (program started in 2008)

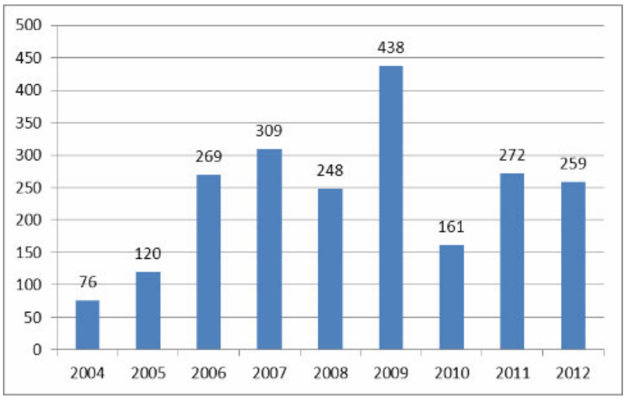

Figure 2. Student enrollment numbers for Electronics program 2004-2012

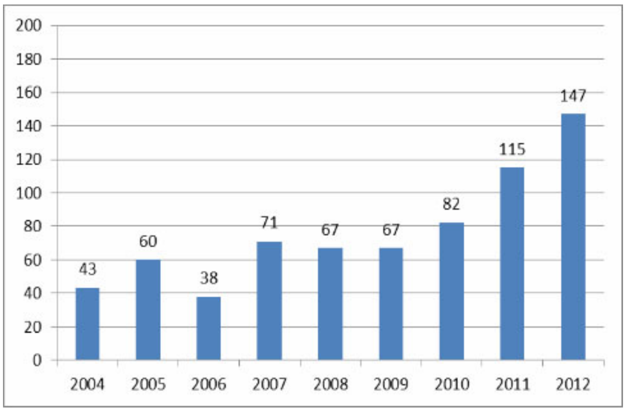

Figure 3. Student enrollment numbers for Biomedical Engineering program 2004-2012

relevant discipline to be appointed as an Associate Faculty member for an initial period of one year. Moreover, the Faculty member must have relevant practical and recent work experience in the discipline, thus to provide the connection between theory and real world practice [1]. The Associate Faculty members would also be required to attend training on "how to teach online" as well as training catered towards "meeting the needs of adult learners"[7]. There is a dedicated Associates Administration department to handle all Associate faculty matters [8].

At the school level, the institution has a School Advisory Committee (SAC) comprising selected prominent members from the academia and industry. Additionally, each program has a Program Advisory Committee (PAC) whose main role is to provide advice to the academic faculty. For example, the PAC would be consulted on changes to the curriculum design for the specific engineering programs.

All Engineering courses are organized in terms of credit units. For example, a 5-cu course would require a student to go through 6 sessions of learning over 6 weeks. Each session will last 3 hours. As students are all working adults, the classes are held in the evenings (7 pm – 10 pm) or on weekends (Saturdays) to give them flexibility.

The Basic degree requires the successful completion of 130 cu of courses. The Honors degree requires the successful completion of 170 cu of courses. Additionally, all students are required to undertake the UCore (University Core) courses (10 cu) which comprise courses on communication, learning skills and the World and I. All students are given 8 years to complete their degree program, however, most students will take less than the full 8 years to complete.

The current teaching approach is blended and mixes a highly didactic style for learners that are autonomous [1][3] and is very much content-oriented with a more traditional classroom based facilitation style[9][10]. One intention of this approach is to make it convenient for students to receive didactic teaching via technology without having to be on campus by 7 pm on weekdays. The institution has started designing and developing a number of e-courses for the engineering curriculum. A number of the engineering e-courses are designed with both asynchronous and synchronous delivery strategies of courses [1]. Many of the developed courses are now available from the Blackboard Learning Management System (which provides both asynchronous and synchronous options), however most of the synchronous delivery is conducted using virtual class sessions through WebEx [19].

In terms of laboratory and other practical work, the institution has physical laboratories for students to use. There is designated times of the day for students who would like to "drop in". The times vary during the afternoon (e.g. from 4 pm – 10 pm on weekdays and 9 am – 6 pm on Saturdays). This is to encourage students to be more independent and take responsibility for their individual learning [1].

In the use of licenses for specialized software like MathCAD, the institution has worked out an arrangement whereby the licensing arrangement allows the students to have the license installed on their own computer instead of on the laboratory computer. Wherever possible, the institution has tried to find an open source version of the software to be used by students, e.g. those for Mathematics and ICT courses.

In addition, the institution prefers to use software simulation rather than the hardware version. Otherwise, the program will work out some arrangement with UniSIM partners like MAJ Aviation [11] on the teaching of certain courses like EAS111 (Flight Discovery) and EAZ211 (Introduction to Flight). Another variation is to have the course conducted by the external body itself, e.g. EAS311 (EAS311 - A Primer on Aerospace and Aviation@Cranfield).

UniSIM students learn much from the practice-oriented curriculum. This is one reason why they are taught by practitioners who come directly from industry [12]. In addition, the program has adopted active learning as a teaching and learning strategy. In this strategy, Associate Faculty members use activities like case studies, discussion, and collaborative learning groups. For example, studying the reasons why some aircrafts crashed or even how wafer fabrication is done in the factories. Other than that, students have their specific laboratory work to complete before they sit for their examinations. Study tours were also conducted to places like the hospitals, the airport and the wafer fabrication plants for UniSIM students to familiarize with the practical realities of the engineer's working life.

In terms of the learning content, there is the course guide, the textbook, the presentation materials (e.g. PowerPoint slides), online learning materials on the Blackboard learning management system, tutorial questions and past examination papers.

V. ASSESSMENT

UniSIM uses a 5–point GPA (Grade Point Average) system to track a student's progress at program level over the semesters of active study, where he/she has registered for courses. For continuation of study in the program, a student must obtain satisfactory progress (i.e. above GPA 2 in every semester) during his/her candidature. The format of the assessment comprises two components: OCAS (Overall Continuous Assessment Scores) + OES (Overall Examination Score). The final program assessment for all students is the capstone project.

A. Examples of Overall Continuous Assessment Scores(OCAS)

Examples include research project preliminary/interim reports, tutor-marked assignments (TMA), case study analyses, essays as well as laboratory reports completed either individually or in groups. Some programs require active student participation in practical hands-on experience training organized as laboratory sessions, mini-project discussion groups or weekend schools. In project-based courses, the continuous assessment component could comprise progress reports or project proposals which will form the basis of the student's final report. This final report forms a part of the examinable component for such courses.

Although many online quizzes are used, these online quizzes are used only for formative learning and never for online testing. This is because of several logistic issues like having to administer about 30 students in one laboratory at a time and then to quarantine these 30 students before another group takes the online test.

When online quizzes are used, these are of the multiple-choice type of questions delivered from the Blackboard online quiz engine.

As far as online tutoring is concerned, the approach is to incorporate simple "computer-based training" type of automated learning. This is good for knowledge recall and comprehension type of engineering courses.

B. Examples of Overall Examination Score (OES)

Most courses typically contain one examinable component, which may be a written examination (e.g. 2-hour examination paper), or an end-of-course assessment report or an oral presentation. Capstone and final year projects have multi-component OES which could include poster and oral presentations as well as a substantially lengthy final project report. In all engineering programs, the ratio of OCAS: OES is 30:70. All students must pass both the OCAS and the OES components.

C. *Capstone Projects*

Capstone projects are culminating projects to be done by students who have completed the 130 cus (credit units) in their engineering programs and who are on the direct Honors track. Capstone projects involve roughly about 600 hours of project work. Having engineering students do capstone projects is one way in which the program makes sure projects stay relevant to the industry. This is done by making sure that both the supervisor and the external examiner are from the industry.

Typically, before the start of the capstone project, the student will select a suitable project from a list of projects put up by their supervisors. Once he or she has selected a suitable project, the student will then submit an interim report. The supervisor will check the interim report and decide whether to allow the student to proceed with the project.

Students doing capstone projects will have a minimum of ten face-to-face meetings with their supervisors. Meetings are recorded and selectively audited by the Head-of-Program (HoP) for quality lapses. The final report is an 8,500-word report in which the students are expected to do some research work. A special Capstone Project day is arranged such that the student will put up his report poster and make an oral presentation to his supervisor and external examiner. The marking of the capstone project is done in the ratio of 55% (supervisor): 45% (external examiner).

D. *Projects with companies*

The capstone projects students work on can be actual projects with companies. In fact, as students are working adults, they do not have any difficulties in getting suitable projects from their companies. Examples of such company projects include those on electronic circuit design and prosthetic limbs for hospital patients.

VI. LEARNING

The institution believes the engineering education has benefitted students in several ways especially with respect to the blended way of learning. Blended learning defined as a mixing of different learning environments. Blended learning combines traditional face-to-face classroom methods with more computer/online-mediated activities [9]. This strategy creates a more integrated approach for both instructors and learners [13].

The first benefit the program provides students is to design courses that are outcomes-based [1]. In fact, through the consistent efforts of an Internal Audit Committee (IAC), there is an alignment of learning outcomes, content and the assessments. Every course is continually being audited. Even the learning objectives of all the courses are carefully scrutinized and changed if they are not stated appropriately.

Secondly, the program encourages students to create their own knowledge and understanding through engaging with the learning tasks, activities and exercises [1][3][4]. Where previously there have been only didactic face-to-face lectures, the institution is making 50% of all engineering courses delivered via e-learning approaches by 2015, either asynchronously (e.g. developed courses with audio recordings using Articulate) or synchronously (e.g. virtual classes using WebEx). Other tools will also be used. Whenever courses have face-to-face sessions between the instructors and the students, the student would engage in active learning activities. With the judicious use of project work, case studies, online quizzes, resource-linked tasks and assignments and more questioning during face-to-face sessions the program is dedicated to helping engineering students to become more independent and self-directed learners [1] [14].

Thirdly, much learning is done through social interaction. The institution believes that engineering students learn better in small groups rather than individually. Students participate in many group activities like providing answers to class quizzes, review of laboratory procedures, discussions of specific project details and participating in discussion forums.

Lastly, students learn in different ways. As much as is possible, the program provides differentiated learning. By providing learning resources in different formats, for example videos / photographs / graphics / text, etc. will cater for different learning styles. The program has even gone to the extent of creating different learning paths by using the SCORM 2004 3rd Edition Specification on Sequencing and Navigation [15]. This has been used in a course on Anatomy and Physiology course for Biomedical Engineering.

VII. ACADEMIC QUALITY CONTROL

There is a shift in academia worldwide towards a learning outcome based system where the emphasis is on

I. The skills the students need to learn and the competencies they need to achieve by the time they graduate.
II. How to measure these skills/competencies before and after graduation and feed that information back into the system in order to improve the existing educational processes.

To be able to set up such a system, the program at the school or institution level needs to define what is to be measured. Hence, there is a need to define clearly the students' attributes and come up with a strategy to achieve them. Following ABET (Accreditation Board for Engineering and Technology, Inc.) [16] terminology, this means that School of Science and Technology (SST) first needs to define the educational objectives (student attributes) for each program based on the mission and vision of the institution with the help of stakeholders and advisory committees. Program educational objectives (PEO) define what graduates are expected to achieve a few years after graduation.

Second, SST needs to define what kind of knowledge, skills and behavior that students need to demonstrate or exhibit before graduation (these are called program outcomes) so that after they graduate hopefully they will achieve the PEOs. Based on this, one can set up a system with feedback to monitor closely the effectiveness of teaching and curriculum content in achieving these goals.

Figure 4. ABET's Continuous Improvement Process

Figure 4 above from ABET illustrates the mechanism that one needs to set up in order to measure the outcomes. Here assessment does not merely mean end-of-course examinations but go further. Indeed, in such a system one needs to collect data regarding student skills and behavior while they are in the system (through focus groups, student portfolio, etc) and also after they graduate (through employer's surveys, alumni surveys, etc) and analyze this data, evaluate it and convert it into actions on what to do next in order to fine tune the system.

The School of Science and Technology, has already started implementing this system and are currently in the phase of collecting data for analysis and evaluation.

VIII. CONCLUSION

UniSIM's engineering programs can be a model for working adults with the following characteristics:

- Flexible curriculum based on credit unit system. Students can take as long as 8 years to complete their undergraduate program.
- Students can still continue working whilst studying for their undergraduate degrees.
- Teaching is done by industry practitioners. UniSIM students learn from these industry practitioners – 'learn today and apply tomorrow" concept.
- Emphasis is placed on continuous assessment of students' work. Capstone projects test out students' capabilities in handling semi-research type of industrial project.
- The system is designed in such a way that students are expected to work collaboratively and in an independent, self-directed manner.
- E-learning plays a big role in making it convenient for students to learn anywhere, any time and at the pace they are comfortable with. By 2015, the institution would have 50% of all courses delivered or presented in e-learning format. This includes both asynchronous and synchronous modes.
- At the same time, the program places much attention on areas like communication skills, project design, group work dynamics, mentorship and solving real-world problems.

As for the future, SST plan to adopt the CDIO Framework [16]. "The CDIO™ initiative is an innovative educational framework to produce the next generation of engineers. The framework provides students with an education which stresses engineering fundamentals. These fundamentals are set in the context of Conceiving — Designing — Implementing — Operating real-world systems and products. Worldwide, CDIO Initiative collaborators have adopted CDIO as the framework of their curricular planning and outcome-based assessment. CDIO collaborators recognize that an engineering education is acquired over a long period and in a variety of institutions. Educators in all parts of this spectrum can learn from practice elsewhere."

Specifically, SST is looking at how to implement the following 12 CDIO standards [18]:

- Program philosophy (Standard 1)
- Curriculum development (Standards 2, 3 and 4)
- Design-implement experiences and workspaces (Standards 5 and 6)
- Methods of teaching and learning (Standards 7 and 8)
- Faculty development (Standards 9 and 10)
- Assessment and evaluation (Standards 11 and 12)

REFERENCES

[1] N. Sthapornnanon, "Social Constructivist Learning Environment in an Online Professional Practice Course," American Journal of Pharmaceutical Education, vol. 73(1), pp. 247-256, 2009. http://dx.doi.org/10.5688/aj730110

[2] S. Ruey, "A case study of constructivist instructional strategies for adult online learning," British Journal of Educational Technology, vol. 41(5), pp. 706-720, 2010. http://dx.doi.org/10.1111/j.1467-8535.2009.00965.x

[3] S. P. Forrest, and T. O. Peterson, "It's called andragogy," Academy of Management Learning & Education, vol. 5 (1), pp. 113-122, 2006. http://dx.doi.org/10.5465/AMLE.2006.20388390

[4] D. Fidishun. (2012 June). Andragogy and technology: Integrating adult learning theory as we teach with technology [Online]. MidSouth Instructional Technology Conference, 2000, Available: http://www.lindenwood.edu/education/andragogy/andragogy/2011/Fidishun_2005.pdf

[5] SIM University (2012 June). Undergraduate programs in the SIM University [Online]. Available: http://www.unisim.edu.sg/programs/Pages/Undergrad-Studies-Overview.aspx

[6] DSO National Laboratories. (2012 June). SAFMC 2012 Award Winners [Online]. Available: http://www.dsoamazingcompetitions.com.sg/safmc/images/gallery/2012/mediaCoverage/SAFMC_2012_Award_Winners_List.pdf

[7] C. J. King, "Restructuring engineering education: Why, how and when?," Journal of Engineering Education, vol. 101(1), pp. 1-5, January 2012.

[8] SIM University (2012 June) Associates Administration Department [Online]. Available: http://www.unisim.edu.sg/about-unisim/Administration/Pages/Office-Academic-Services.aspx

[9] N. Tselios, S. Daskalakis, and M. Papadopoulou, "Assessing the acceptance of a blended learning university course," Educational Technology & Society, vol. 14(2), pp. 224-235, 2011.

[10] A. J. Purvis, L. J. Aspden, P. W. Bannister, and P. A. Helm, "Assessment strategies to support higher level learning in blended delivery," Innovations in Education and Teaching International, vol. 48(1), pp. 91-100, February 2011. http://dx.doi.org/10.1080/14703297.2010.543767

[11] MAJ Aviation Pte Ltd (2012 June) [Online]. Available: http://www.majaviation.com.sg/

[12] J. Chencheng, and N. Othman, "The Effect of Education Condition for the University-Industry Collaboration: A Case

Study of Faculty Mechanical Engineering in UMP," Management Science and Engineering, vol. 5(3), pp. 169-174, 2011.

[13] J. Bourne, D. Harris, and F. Mayadas, "Online engineering education: Learning anywhere, anytime," Journal of Engineering Education, vol. 94(1), pp. 131-146, January 2005.

[14] K. Harries, "What works at work: Six lessons for the classroom," Review of Agricultural Economics, vol. 22(1), pp. 228-236, 2003.

[15] Advanced Distributed Learning. (2012 June). Sharable Content Object Reference Model (SCORM), 3rd Edition [Online]. Available: http://www.adlnet.gov/capabilities/scorm/scorm-2004-3rd

[16] Accreditation Board for Engineering & Technology, Inc (2012 June)[Online]. Available: http://www.abet.org

[17] Conceive-Design-Implement-Operate Framework. (2012 June) [Online]. Available: http://www.cdio.org

[18] E. Crawley, J. Malmqvist, S. Ostlund, and D. Brodeur, "Rethinking Engineering Education: The CDIO Approach," p. 34, Springer, 2007.

[19] CISCO. (2012 June) Web conferencing software from CISCO named "WebEx" [Online]. Available: http://www.webex.com

AUTHORS

K. C. Lim is with the School of Science and Technology of the SIM University, Singapore (e-mail: kclim@unisim.edu.sg).

Stephen Low is with the School of Science and Technology of the SIM University, Singapore (e-mail: stephenlowwk@unisim.edu.sg).

S. Attallah is the Vice-Dean of the School of Science and Technology of the SIM University, Singapore (e-mail: samir@unisim.edu.sg).

Philip Cheang is the Dean of the School of Science and Technology of the SIM University, Singapore (e-mail: kclim@unisim.edu.sg).

Emet LaBoone is with the Food and Drug Administration, College Park, Maryland USA (e-mail: emet.laboone@fda.hhs.gov).

Received 20 October 2012. Published as resubmitted by the authors 14 November 2012.