

## ***Reformulating General Engineering and Biological Systems Engineering at Virginia Tech***

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### **ABSTRACT**

*Several Virginia Tech investigators including engineering and education faculty have been working together since fall 2004 to reformulate freshman engineering and bioprocess engineering programs using a spiral curriculum theory. They have developed a process to implement the spiral curriculum in the bioprocess program. This IREE award had two major objectives: (1) Provide early researchers, including graduate students, an opportunity to conduct research and have social and cultural experiences at a foreign institution, and (2) Conduct a spiral curriculum workshop for engineering educators and explore international possibilities for future collaboration. National Cheng Kung University (NCKU) offers the largest engineering program in Taiwan and was selected for implementing the objectives of this award. Two graduate students (both women, one African American; 3 months visit each) and five faculty members (one week visit) participated in the program. One of the graduate students investigated the factors that motivate and influence engineering students in Taiwan in selecting their engineering discipline or specialty. She is continuing this study with Virginia Tech students at the time of this writing. Another student explored the similarities and differences in eastern and western philosophies on engineering and environmental ethics. VT faculty investigators conducted a workshop for NCKU participants and shared spiral curriculum experiences and advances in engineering education research in the United States. As a result of this collaboration, NCKU investigators were invited to join a PIRE pre-proposal team of VT investigators. This proposal is currently under review at the NSF.*

## INTRODUCTION

A group of investigators from engineering and education faculty at Virginia Tech received a grant under the Department-level reform (DLR) program of the NSF in 2004. They have since been working on reformulation of freshman engineering and bioprocess engineering programs at Virginia Tech using a spiral theory approach. The twentieth century psychologist, Jerome Bruner, first proposed the concept of the spiral curriculum. Bruner advocates that as a curriculum develops it should revisit essential ideas repeatedly, building upon them until the student has mastered them [1][1a]. In the proposed reformulation, a theme of sustainability has been selected to provide a contextual framework. Figure 1 shows the spiral curriculum process that is being implemented in the bioprocess engineering program [2]. A number of hands-on engineering learning activities have been developed and implemented in the freshman engineering program [3][4]. The investigators have already conducted a number of workshops to share the spiral curriculum work with both national and international audiences [5].

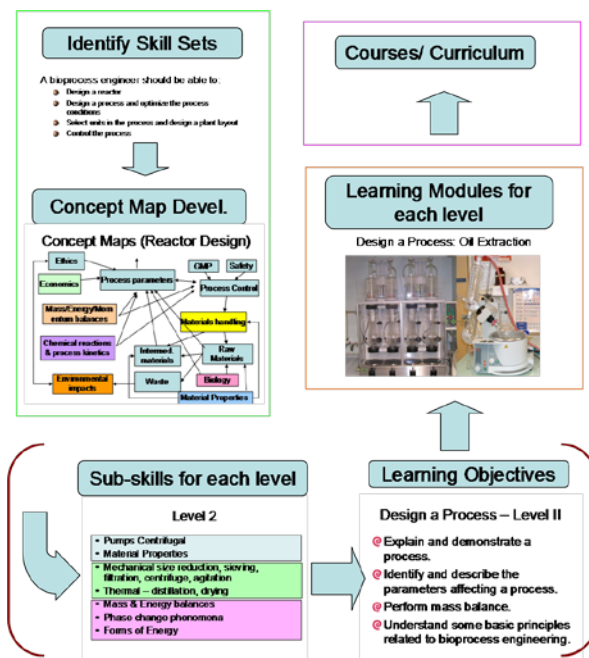


Figure 1: Spiral Curriculum Development Process

This IREE award's two major objectives were to: (1) Provide early researchers, including graduate students, an opportunity to conduct research and have social and cultural experiences at a foreign institution, (2) Conduct a spiral curriculum workshop for engineering educators and explore international possibilities for future collaboration. The National Cheng Kung University (NCKU) in Taiwan was identified as the host institution for this collaboration. The NCKU offers the largest engineering program in Taiwan and its program is comparable to Virginia Tech's. The following persons participated in implementing activities of the IREE award in Taiwan:

Graduate Students (3 months; May 15- Aug. 15, 2008)

Ms. Yolanda Avent, PhD Student, School of Education

Ms. Sara Morris, MS Student, Biological Systems Engineering

Faculty Participants (1 week visit; August 03-10, 2008)

Vinod K Lohani, Associate Professor, Department of Engineering Education

Mary Leigh Wolfe, Professor, Department of Biological Systems Engineering

Terry Wildman, Professor, School of Education

Kumar Mallikarjunan, Associate Professor, Department of Biological Systems Engineering

Jeffrey Connor, Associate Professor, Department of Engineering Education

Prof. J. J. Miao, Professor in the Aeronautics and Astronautics department at the NCKU, acted as the main contact for our group.

## RESEARCH ACTIVITIES AND ACCOMPLISHMENTS OF THE INTERNATIONAL COOPERATION

### A. Summary of Students' work

**Yolanda Avent (PhD Student in School of Education):** Yolanda investigated the factors that motivate and influence engineering students in Taiwan in selecting their engineering discipline or specialty. She worked particularly closely with the Aerospace Engineering department and the Institute of Education at NCKU. The research that drove the inquiry for this study comes from the literature related to the factors that influence students in selecting a major in college. At many universities, engineering students are forced to make specialty choices early in their educational career, often at the time of their admission or shortly thereafter. As with most career-related decisions, these choices come with economic and personal consequences for the decision maker [6]. Thus, educators are coming to recognize the importance of understanding how individuals go about making major/career specialty choices, and how individual differences may impact these decisions. The exploratory study conducted represented an initial attempt to gain a greater perspective into what factors most closely influence engineering students at NCKU in Taiwan in choosing an engineering discipline. This includes ascertaining the major socio-psychological reasons influencing the motivation for choosing engineering as a career, as well as the mechanisms affecting choice and decision-making processes.

The methodology used for this study was presented in the form of an 18-item survey, with additional open-ended questions. Preliminary findings indicate that several factors were deemed highly important to these students, including availability of jobs, high salary potential, social status, passion, college entry scores, and aptitude. Factors that were deemed less important included tuition/cost, years of education required, and work experience. Yolanda is continuing this research at Virginia Tech with engineering students for a comparable analysis of the data. This will be an important contribution to finding out some of the special features involved in the career decision-making process, as well as its connection to social requirements. The results will provide opportunities to design programs through which it would be possible to influence the professional choice of young people in accordance with social needs. They would also help university engineering programs in their international recruitment and retention of engineering students.

**Sara Morris (MS Student in Biological Systems Engineering):** The overall goal of Sara's research was to explore the similarities and differences in eastern and western philosophies on engineering and environmental ethics. The primary objective of the study was to develop strategies for incorporating international engineering ethics into the undergraduate engineering curriculum of the Biological Systems Engineering Department at Virginia Tech. Sara's plan was to develop information that could be used to increase international content and awareness in undergraduate engineering curricula at Virginia Tech, and to develop joint ethics instruction for NCKU and Virginia Tech.

Sara met with engineering faculty members at NCKU to learn how engineering ethics is currently incorporated into the curriculum in Taiwan. She explored the engineering code of ethics in Taiwan and compared it to that of the United States. Sara sought to determine what barriers there might be to incorporating joint ethics instruction into the curricula of NCKU and Virginia Tech. She learned that the engineering criteria for accreditation in both countries specify similar required outcomes, which will help facilitate development of joint ethics instruction for programs at the two institutions. Due to various faculty members travel schedules during the summer, Sara faced some challenges in gathering all of the information she sought about existing ethics instruction. In spite of that, she established a strong foundation for developing joint ethics instruction and also developed ideas for content and delivery of such instruction.

### B. Spiral curriculum workshop

The faculty participants conducted a workshop titled "Advances in Engineering Education: Collaboration between Virginia Tech and NCKU" during Aug. 05-07, 2008 on the campus of NCKU. About 30 participants, including graduate students, attended. The VT investigators discussed and presented a variety of issues including developments in the field of engineering education in the USA, VT's freshman engineering, biological systems engineering programs, tablet PC initiative [7], and School of Education. They met with the Vice President of NCKU and Associate Dean in the College of Engineering and discussed issues of mutual interest and collaboration. The highlight of the workshop was a presentation of the spiral curriculum work that has been done in the bioprocess program at Virginia Tech. After this presentation, the participants were divided into groups including both faculty and graduate students, and were tasked to develop spiral curriculum activities in their discipline of choice. Graduate students and faculty actively participated in this activity and presented their ideas to the entire group. Figure 2 shows some examples of spiral curriculum ideas presented by the participants using Tablet PC technology.

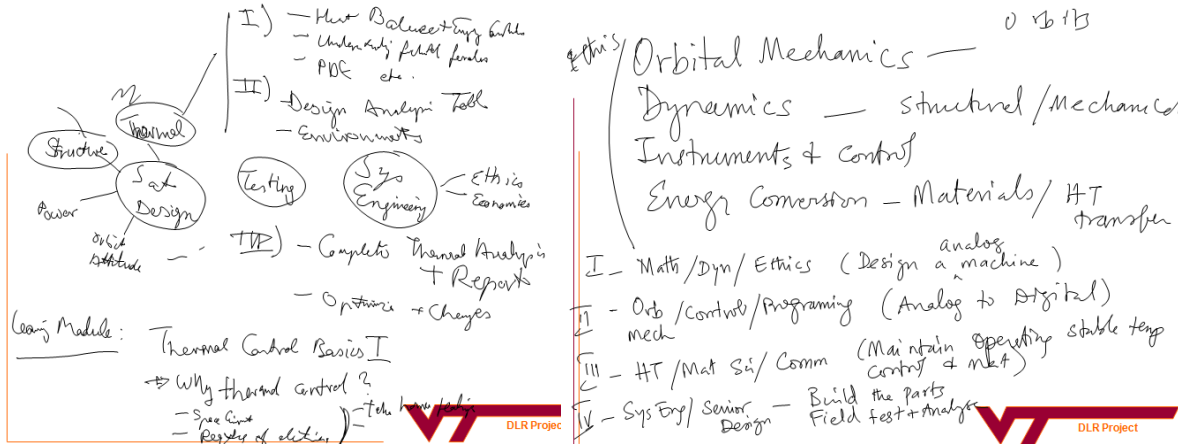


Figure 2: Examples of Spiral Curriculum Design – Space Engineering

The feedback on workshop activities were positive. Some examples are:

*Due to the group activity, I learned a lot of spiral curriculum. Nice Discussion; A wonderful experience; New thinking of engineering education, new approach as well; Spiral Curriculum is very interesting. More explanation of this concept would be more helpful to audiences who have no knowledge if it; Like to learn about the assessment results of the spirial curriculum in Virginia Tech; The spiral curriculum is ideal; It made me know that every country has the same education problem, and also same to try finding solutions, the only difference is the weight of the problem.*

Below pictures show some of the participants in the workshop.



### BROADER IMPACTS OF THE INTERNATIONAL COOPERATION

The supplement award expanded the original scope of the current DLR award in several ways. The dissemination component was expanded to include a workshop for faculty members and graduate students at a non-domestic university. During the workshop, the Virginia Tech team shared our spiral curriculum development work internationally, the NCKU faculty and students participated in a hands-on exercise to develop spiral curriculum elements, and both groups benefited from the different cultural and institutional perspectives offered. The research component was expanded by providing two focused studies by Virginia Tech graduate students in Taiwan for three months. Those studies were not part of the original scope and were made richer yet by the inclusion of another culture and university in the study. As a result, the research begun in Taiwan is being continued at Virginia Tech. Face-to-face interaction is invaluable in fostering future interaction, particularly in a case such as this with language and cultural differences. The 3-month experience of the Virginia Tech graduates on-site in Taiwan provides a framework for future student exchanges. By being immersed for three months in the culture and language of Taiwan, the graduate students gained a significant international perspective. The students engaged in activities to specifically increase their language skills and cultural understanding. The faculty

researchers from Virginia Tech enhanced their international perspective through interaction with Taiwanese faculty and students. One significant activity was a visit to the Business Technology Park at the Southern Taiwan Science Park ([www.stsipa.gov.tw](http://www.stsipa.gov.tw)), and their Small and Medium Enterprise Incubator facility.

#### **A. Social and Cultural Experiences**

Except for the PI (Lohani), all VT participants went to Taiwan for the first time and thoroughly enjoyed their social and cultural experiences. They visited a number of cultural sites of historic importance during this trip. On their way to Tainan from Taipei, the faculty participants took the high speed train (~300 km/hr) that goes through the east coast of Taiwan and on their way back from Tainan to Taipei they went through the west coast, thus completing a full circle around this island nation. One of the students (Sara) engaged actively in learning the language and culture while in Taiwan. She took language classes and interacted with students, staff, and faculty members in a variety of settings. She developed a good working knowledge of Mandarin. Another graduate student (Yolanda) became an Adjunct Professor at the Foreign Language Department English Corner at NCKU during her stay there and conducted a variety of workshops designed to familiarize the students with American history, culture, learning styles, and scholarly pursuits and served as a resource for students interested in seeking educational opportunities in America and regularly taught at the language center of NCKU.

**B. Future Collaboration:** This trip enabled VT investigators to explore opportunities to develop future collaboration with the NCKU investigators. For example, in fall 2008 the PI (Lohani) took advantage of this collaborative relationship in identifying the NCKU as one of the international partners for a pre-proposal, led by Dr. Ishwar Puri of Virginia Tech, that is currently under consideration in the Partnership for International Research and Education (PIRE) of the NSF. This proposal titled “PIRE: Nanotechnology Solutions for Energy Sustainability (nanoSENS)” has identified NCKU as one of two international cultural and technical hubs for providing nanotechnology research and international cultural experiences to the undergraduate and graduate students of the proposed program subject to its approval for final funding. Three investigators, namely, Drs. Fei-Yi Hung, Wang-Long Li, and Jen-Fin Lin from the *Institute of Nanotechnology and Microsystems Engineering (INME)* at NCKU are participating in this effort. Briefly, if funded, this project will employ novel research and educational methodologies to (1) produce solutions to energy challenges in a manner that emphasizes the demand side of energy problems and reflects the social needs of developed and emerging countries, and (2) create professionals who will take a leadership role in forging international partnerships in advancing research frontiers.

### **DISCUSSION AND SUMMARY**

VT investigators (faculty and students) had a wonderful cultural, social, and technical experience as a result of this IREE award. Two graduate students (both women; one African American) were enriched both personally and professionally by their stay at the NCKU. Yolanda is continuing her study, discussed in above section, at the time of this writing. She plans to complete this study in summer 2009. She very proudly includes her experience in Taiwan on her resume. Sara invited her parents to Taiwan while she was there. The investigators engaged in Skype conference calls with Sara and Yolanda while they were there and thus explored the communication technologies in developing remote collaborations. As a result of this trip, NCKU was invited to join another group of VT investigators for developing a pre-proposal to the PIRE program of the NSF. One of faculty members (Wolfe) took advantage of this opportunity to meet her Taiwanese classmate from her days in graduate school in Minnesota and identified potential areas for collaboration with his department. Some recommendations for the IREE program officials are:

- a. Provide additional travel funds for developing future collaborative proposals. International collaborative relationships are developed and cultivated over a period of time, and one time funding may not be very effective. Our Taiwanese counterparts are very interested in internationalizing their graduate programs and welcome opportunities for collaboration.
- b. Develop regular NSF programs that will support international collaborative studies rather than providing funding under supplemental programs.
- c. Long term longitudinal studies should be undertaken to assess the effectiveness of programs like the IREE in career choices of participants, particularly the graduate students.
- d. Expand opportunities to integrate contemporary educational theory and empirical research into ongoing engineering education curriculum development.

## Acknowledgements

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## BIOGRAPHIES

**Vinod K Lohani** is an associate professor in the Engineering Education Department and an adjunct faculty in the Civil and Environmental Engineering at Virginia Tech. He received a PhD in civil engineering from Virginia Tech in 1995. His research interests are in the areas of knowledge modeling, water and energy sustainability, engineering learning modules for freshmen, and international collaboration. He leads the DLR/NSF project (2004-09) at Virginia Tech.

**Mary Leigh Wolfe** is professor of Biological Systems Engineering and Assistant Department Head for Teaching at Virginia Tech. Her research interests are in the areas of nonpoint source pollution control, watershed modeling and management, and engineering education. She is past chair of the Engineering Accreditation Commission (EAC) of ABET, Inc. She is a co-PI for the DLR/NSF project (2004-09) at Virginia Tech.

**Terry Wildman** is a professor of educational psychology in the School of Education at Virginia Tech. He received his PhD in Educational Psychology from Florida State University in 1975. Recently he has served for 13 years as director of Virginia Tech's Center for Excellence in Undergraduate Teaching. His research interests focus on applications of learning research to instruction and curriculum design. He is a co-PI for the DLR/NSF project (2004-09) at Virginia Tech.

**Kumar Mallikarjunan** is an associate professor in Biological Systems Engineering (bioprocess concentration). He is a co-PI for the DLR/NSF project (2004-09) at Virginia Tech.

**Jeffrey Connor** is an associate professor in the Department of Engineering Education at Virginia Tech where he teaches surveying and computer-aided design. He received his M.S. degree in civil engineering from VPI&SU and B.S. degree in civil engineering from the University of Lowell. His research includes water resources modeling, water policy, and engineering education. He is a co-PI for the DLR/NSF project (2004-09) at Virginia Tech.

**Yolanda Avent:** Yolanda is a PhD student in the School of Education and expects to complete her PhD studies in summer 2009.

**Sara Morris:** Sara is an M.S. student in Biological Systems Engineering. Her research interests are in the area of watershed modelling and management.