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Bilateral Collaborative Partnership—Joint Industry/University Perspective*

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This paper describes a framework for synergistic collaboration between National Instruments (ASEAN) and Monash University Malaysia (MUM). This work involves the development of a remote-access web-based engineering laboratory. This paper first stresses the importance and need for collaborative partnership between the industry and university for the enhancement of engineering education. The main goals are to enhance the engineering curriculum and offer a complementary learning experience for students through remote web-based experimentation. Then, it states and discusses the four main enabling factors for developing durable, sustainable alliances formed by this industry-university collaboration. Lastly, this paper reflects the management of this successful collaborative experience and stresses the importance of the proposed critical factors.

Keywords: synergistic collaboration; enhancement; engineering education; remote-access; web-based experimentation

INTRODUCTION

SUCCESSFUL COLLABORATIONS between academia and industry for the purpose of enhancing educational programmes have become important [1]. Such collaboration has also become a significant social experiment in many countries [2]. Most reports have been devoted to case studies [3, 4, 5]. Universities and industries engage in collaborations for a variety of reasons, which have been reported [2, 5, 6, 7, 8].

Two of the most commonly mentioned from industry's perspective, are to gain competitive technological advantages in terms of research and development work and to recruit good university graduates. Industries have engaged the universities for appropriate consultation and manpower needs. Universities collaborate to gain access to external funding from industry for research activities [9] and to expose students and faculty to pragmatic challenges in the real world [10]. Such relationships can founder but mutual benefits can be gained by both parties.

Collaboration for the purpose of enhancing the engineering curriculum is often neglected. Most reports are about joint collaboration for the purpose of engaging in R&D projects. For example, one report focuses on enriching the power electronics industry and drives discipline for a university programme [11].

However, the main goal of the collaborative effort between National Instruments (ASEAN) and Monash University Malaysia (MUM) is to enhance the engineering curriculum at MUM and provide a richer learning experience for engineering undergraduates (EUG). The principle tool was the development of a remote access web-based laboratory utilizing virtual instrumentation, and the target was first year engineering laboratory experiments, covering basic electrostatics and simple electrical circuits.

COLLABORATIVE FRAMEWORK BETWEEN NI (ASEAN) AND MUM

EUG at MUM are required to complete their first year common engineering courses before branching into specific engineering disciplines. It is known that efficient learning requires a good mixture of theoretical and practical exercises with engineering experiments [13, 14, 15, 16].

However, the engineering department at MUM is facing enormous financial pressures brought on by increased enrolments, static budgets and the strong desire to maintain educational quality [14]. This concern was discussed by Ertugrul [17], where he highlighted the need to provide EUG with relevant practical experiences, at the same time facing the reality of finite resources in laboratory environments. A common feedback from our first year EUG is that there is insufficient laboratory equipment. Staff lament that each set of apparatus is usually shared between two to four students working on the same experiment. EUG are required to fulfil the objectives of each experiment and to understand and correlate experimental results with theoretical studies. It is beneficial for

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first year EUG to learn the capabilities of test equipment, for example, oscilloscopes. In present conditions, students are limited in their quest for a good practical learning experience.

Our solution was found in a collaborative framework between NI (ASEAN) and MUM. The challenge was to establish a remote web-based engineering laboratory that would enable EUG to conduct three real experiments over the internet/intranet, a pragmatic arrangement now widely accepted and implemented [17, 18, 19, 20, 21].

Students' access to this e-learning tool was increased substantially. In this collaboration, scheduled meetings and deliverables for this project spanned over one year. They are as follows:

- Two technical review meetings;
- Two technical demonstrations;
- Three deliverables (i.e. three developed remote access experiments);
- One top-level management review meeting about this collaboration.

NI (ASEAN) has provided about US$20,000 worth of virtual instrumentation hardware and software to Monash University Malaysia for this project [22], also some technical support. Manpower resources were derived from the university, mainly one academic staff, one technical staff and two student programmers.

The project entails the transformation of a traditional laboratory into a remote unmanned web-access engineering experiment facility, which is operational around the clock. The aim of the remote access laboratory was to enable students to conduct engineering experiments over the intranet/internet without any time constraint (see Fig. 1).

FLEXIBLE LEARNING PEDAGOGY AND WEB-BASED LABORATORY

The learning approach for engineering undergraduates is changing. Emphasis is being placed on flexibility of learning and technology integration. Monash University is in favour of flexible learning through leveraging information communication technology. In this context, flexible learning aims to provide EUG with increased access to remote experimentation. Existing traditional laboratories are not to be replaced, although a remote web-based laboratory system does have certain advantages:

- It complements an existing laboratory;
- Students on the internet will have access anywhere, anytime;
- It can introduce and expose students to emerging technologies, such as NI's virtual instrumentation tools and remote front panel [16].

The web-based laboratory aims to help remote learners strengthen their fundamental understanding of simple electrical circuits, Kirchhoff's voltage law, also basic electrostatic principles. The only prerequisite is that students must attend lectures and tutorials before the online laboratory classes.

INDUSTRIAL PARTNER'S COMMITMENT TO EDUCATION

National Instruments has always been committed to excellence in science and engineering education and awards corporate grants and product donations to support the implementation of virtual instrumentation in learning environments [23]. From the university's perspective, this is considered one of the most crucial requirements for a successful collaboration.

The company understands that the goal of any academic institution is to educate and prepare its students for rewarding careers. Example: the partnership between NI (ASEAN), LEGO Dacta and Tufts University to create an exciting educational programme called ROBOLAB [12], which gives students hands-on experience with engineering concepts in a fun and innovative way.

NI (ASEAN) works closely with leading educational institutions on research projects in engineering education, control theory, electrical and electronic engineering, biosciences and physics. Currently, it works with National University of Singapore (NUS), Nanyang Technological University (NTU) Singapore, NgeeAnn polytechnic Singapore, Monash University Malaysia, Asian Institute of Technology Thailand and De La Salle University Philippines. It provides training, technical consulting and advice to the research teams as well as substantial educational discounts to facilitate the use of modern technology in universities.

VIRTUAL INSTRUMENTATION FOR REMOTE LEARNING

A survey review by Ertugrul [17], reported the enormous potential in the internet for provision of a high supporting learning environment. Virtual instrumentation has been deployed for classroom learning by [15, 18, 21, 24, 25] as well as by the author [26, 27, 28]. National Instruments has developed tools to provide and support internet-based measurement and automation solutions. These technologies have been used extensively and very successfully to create innovative remote laboratories [16]. A remote laboratory was implemented by using NI LabVIEW remote panels. The LabVIEW program interfaces and controls real-world experiments, demonstrations, signal processing. Three remote experiments were developed in this work. LabVIEW toolkits were utilized for report generation, internet toolkits, etc. There are three first year electrical engineering experiments:

- Resistive-inductive network;
- Resistive-capacitive network;
- Equipotential and electric field lines mapping.

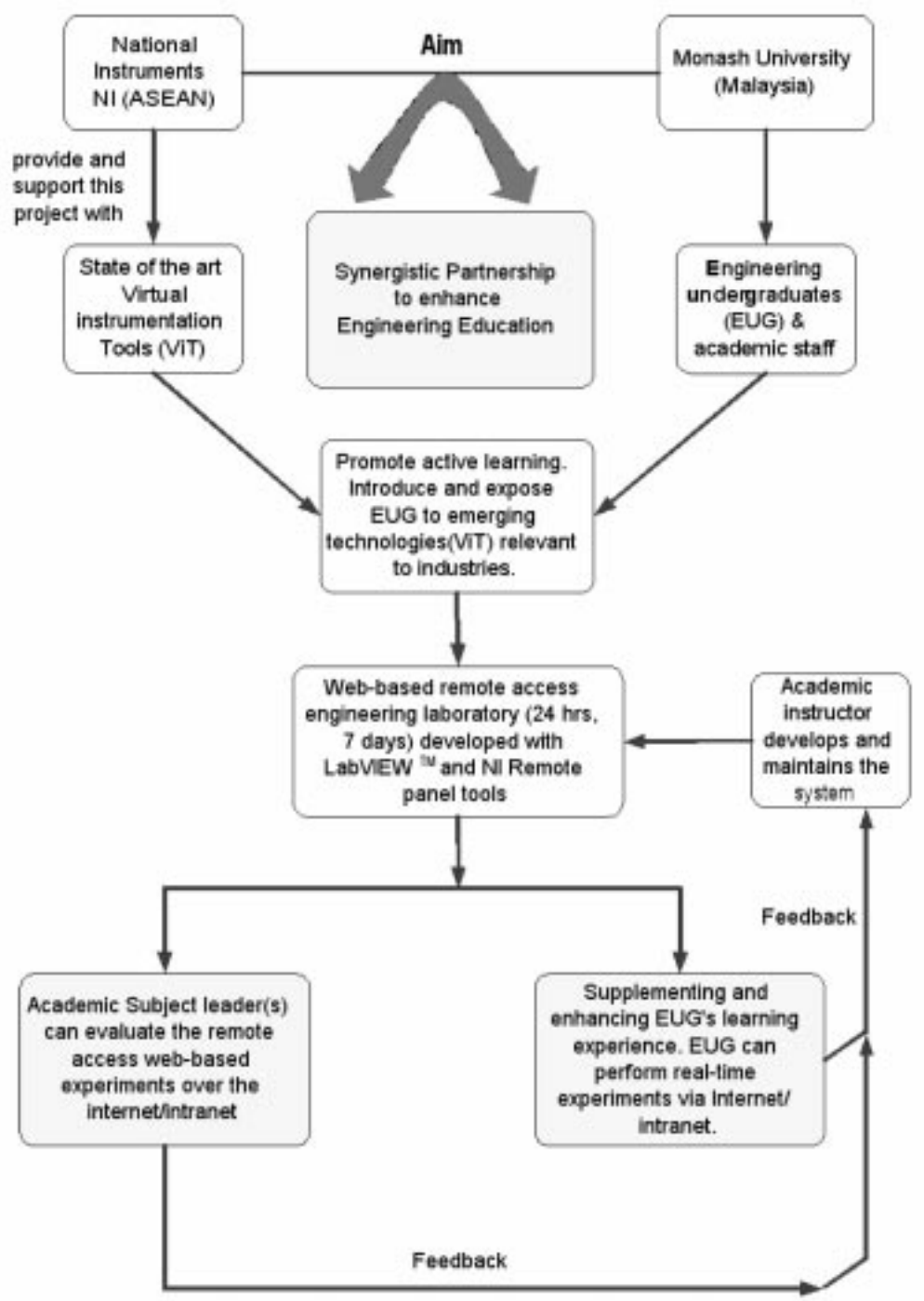

Fig. 1. An overview of the bilateral collaborative partnership between NI (ASEAN) and MUM.

The first generation remote lab was used in a simple circuit and theory course. A remotely controlled PC-based PCI board function generator produces different test signals from the resistive-inductive or resistive-capacitive network of interest. A PCI-based oscilloscope board connected to the network was utilized to detect all phenomena of interest. One of the experiments provided is a test of Kirchoff's voltage law.

Some screenshots of the LabVIEW programs are shown in Figs 2 and 3. Program detail is described elsewhere [29].

Heywood [30] reported that hands-on laboratory experiments in flexible and distance learning is challenging. Only a few evaluations of the effectiveness of remote controlled and in-person operated laboratories have been reported.

SUSTAINABILITY AND FOSTERING STRATEGIC ALLIANCES

Successful collaborations between university and industry are reported [11, 29]. Effective colla-

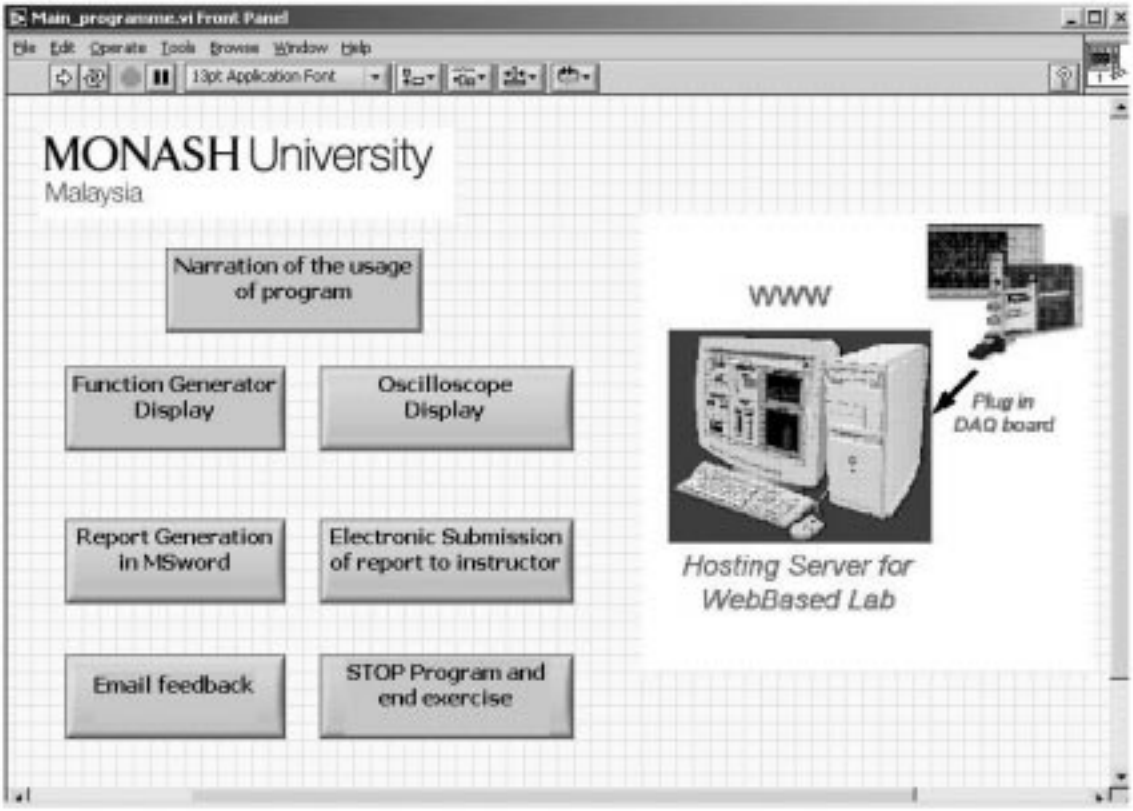

Fig. 2. A LabVIEW program developed for this remote access web-based laboratory. The GUI as shown is meant for interfacing with users. This program was loaded on the host computer with PCI DAQ and FGEN cards, representing Data AcQuisition and Function GENerator.

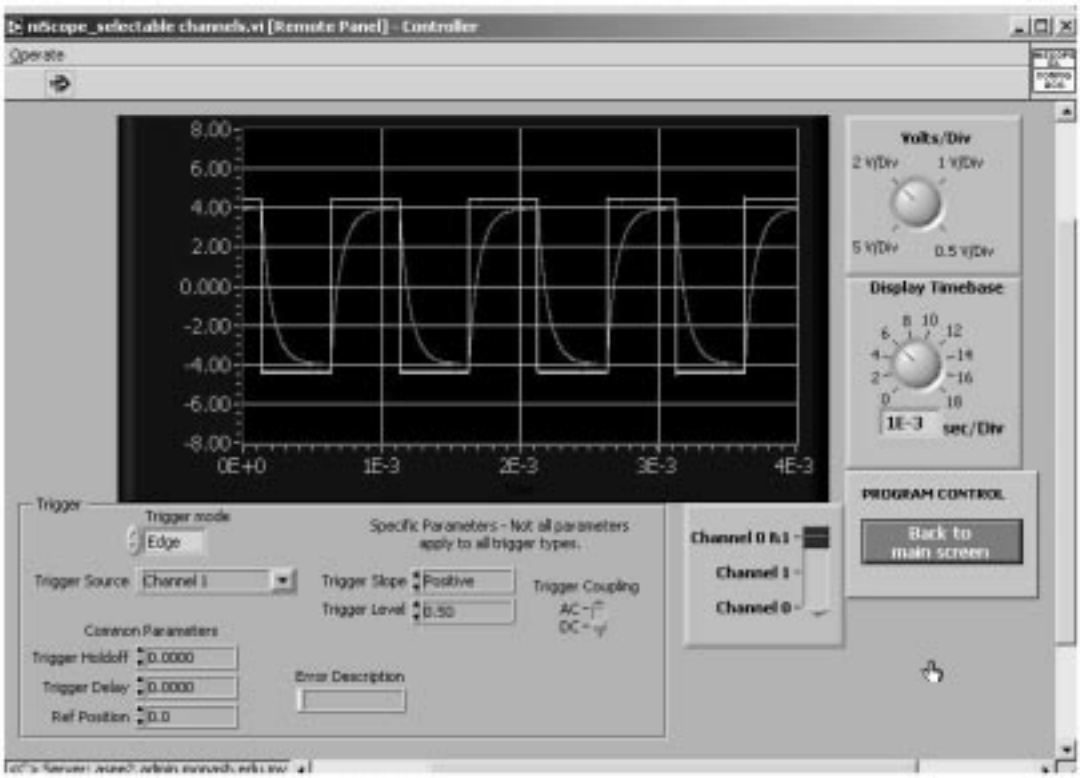

Fig. 3. Screenshot of the digitizer's GUI that was remotely controlled by a user. The simple RC circuit that was connected in series was used. The charging and discharging waveforms can be seen as shown.

borative management factors making industry-university partnerships work are also reported [10, 30, 31, 32]. At the same time, collaboration between university and industry is often difficult to manage and maintain as mentioned by Barnes [1]. For their work, the authors proposed four enabling factors, which are seen to be crucial for the creation of a successful partnership. These factors, which promote sustainability and enhanced cooperation, were based on the current NI (ASEAN) and MUM collaborative experience. An overview of them is in Fig. 4.

Understanding the 3Rs (Risks, Rewards and Resources) through Communication

It is important for the partners to acknowledge that all forms of collaboration involve certain elements of risk and rewards. Partnerships require the commitment of resources on both parties. Risk tolerance and the ability to commit resources are dissimilar for different partners. It is generally acceptable that the partner undertaking higher risk and committing greater resources has the right to expect higher returns/rewards. Open and effective communications are vital to successful inter-organizational collaborative relationships [33]. Constant and open interactions between both NI (ASEAN) and MUM were mainly through the technical review meetings, demonstrations and discussions between the project manager from NI (ASEAN) and lecturer from MUM.

Proper partnership expectations were also communicated and put into writing. Required resources to be committed by both partners were discussed in detail and written as a contract agreement. Risks taken and expected rewards were clearly specified initially to prevent misunderstanding subsequently. Open communication and dealing with issues pertaining to the 3Rs were dealt with up front with integrity and no hidden agendas. It is believed that partnerships that neglect the 3Rs may eventually lead to misunderstanding between partners, dubious sentiment and peril to the relationship.

Mutual Support and Understanding

The work reported by Shamash [29] suggested that it is crucial to recognize that successful collaboration depends on clear understanding by each group of the needs and missions of the other. University faculty must be conscious of the needs of industry and constraints imposed on them by the external community (e.g. government, shareholders, etc). At the same time, industry leaders must have an appreciation of the primary mission of a university and constraints within which an academic unit must operate [29].

NI (ASEAN) and MUM have a clear understanding of such issues and both parties are willing

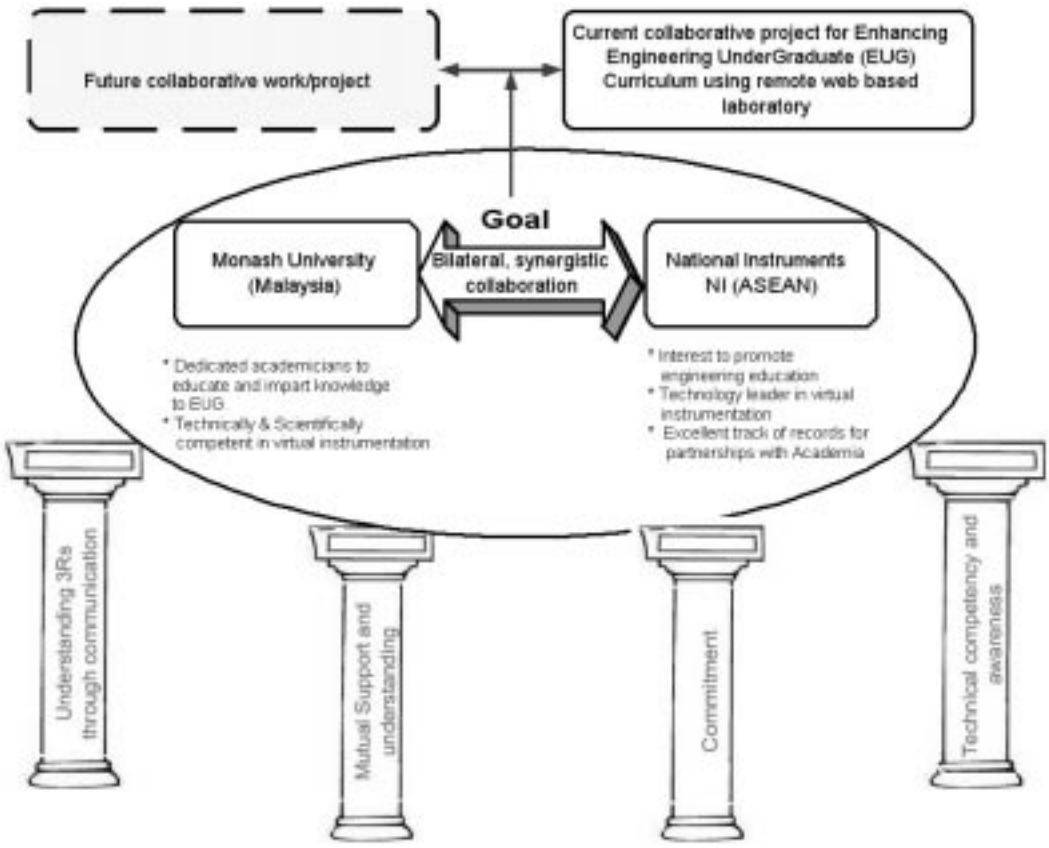

Fig. 4. Four enabling factors proposed to ensure good sustainability and increased cooperation in the NI (ASEAN) and Monash University Malaysia partnership.

to provide mutual support and remain committed to enhancement of the engineering curriculum. In this partnership, support comes in a variety of forms; these included support from the technological partner, loan of equipment, participation in industrial seminars/conferences/workshops, informal/formal technical information exchanges, etc.

Continuing mutual support and understanding in this collaboration has reinforced the commitment by both parties to achieving the goal of enhancement of the engineering curriculum. In the long term, not only have both parties contributed to success in achieving joint goals, but the partnership has brought the two organizations closer together.

COMMITMENT

Commitment is one of the universal success factors for winning partnerships as reviewed by Barnes [1]. This commitment element may be further elaborated to suggest that it must exist from top to bottom of inter-organizations forming the partnership. In our case, initiation of the project was through MUM's faculty staff seeking contact with a NI (ASEAN) field application engineer. This led to further discussion and proposals within the organizations and later to inter-organizational activities. It is important for industry-academia collaborations to be recognized and supported especially at higher management level, as Shamash [5] has pointed out; he particularly stresses that their success depends on commitment from senior management. In establishing a communal goal (i.e. enhanced engineering education), the inter-organizations' commitment has played a significant role; one illustration of 'how?' is to point to the facilitation of certain and speedy release of various resources required for the project.

Commitment on both sides is seen to be one of the most important pillars as it involves the relationship between an external organization and internal collaborators. The achievement is not 'a day and a person effort'. The commitment of NI (ASEAN) and MUM has truly led to the success of this project.

TECHNICAL COMPETENCY AND AWARENESS

Higher education has undergone a fundamental transformation over the past decade with education and technology merging [17]. Implementing technology in today's classroom is not a trivial task. New emphases are in place on experimentation, computation and increased opportunity for distance learning. Technological advancement, especially in internet and computer hardware, research and teaching will unquestionably need to be kept in place to fully take advantage of the benefits presented by these technologies, to present a healthier learning experience for EUG.

In collaborative work, it is important for engineering faculty staff to be kept up to date with latest advances in technology, and also be able to relate them to EUG. The faculty staff from Monash University Malaysia working on this web-based laboratory project is in constant contact with technological partners at NI(ASEAN). Academic staff acquire product knowledge and technical facility in handling web-enabled technology. Various activities were engaged in for technology development updates and new knowledge acquisition. These were mainly through product updates and presentations at seminars such as those offered by the technological partner. Interaction and exchanges of ideas and knowledge between faculty staff and engineers from both partners were deemed to be enriching and a good source of technology transfer. Such interaction and knowledge transfer will subsequently lead to the benefit of the EUG. Faculty staff were invited to speak at annual academic seminars held by NI (ASEAN) to promote knowledge exchange and awareness of technology development.

CONCLUDING REMARKS

NI (ASEAN) and MUM came together with the purpose of enhancing the engineering curriculum for first year EUG at Monash University Malaysia. This synergistic industry-university collaboration was successful with development of three remote web-access experiments. Remote education is evolving, playing a significant role and fast becoming common at higher institutions of learning. This paper documented the need for a web-based laboratory project developed to supplement the shortfall in traditional laboratory facilities for first year EUG. This web-based laboratory, implemented using National Instrument's virtual instrumentation, is a promising technology for engineering education, especially where subjects require experimentation and computation. Remote student learners with proper authentication can easily have access to this web-based laboratory via internet/intranet. Four enabling factors have been mentioned as making an important contribution to the building of a durable and sustainable relationship between NI (ASEAN) and MUM.

Finally, this collaborative work has provided a good opportunity for a joint partnership between NI (ASEAN) and MUM. It has indeed provided insights into industry-university collaboration and invaluable experiences have been gained by the partners.

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REFERENCES

1. T. A. Barnes, I. R. Pashby and A. M. Gibbons, Collaborative R&D projects: A best practice management model, *IEEE Int. Conf. Mgmt. of Innovation and technology* 2000, Vol. 1, pp. 217–223.
2. Yong S. Lee, The sustainability of university-industry research collaboration: An Empirical Assessment, *J. of Technology transfer*, **25**, 2, 2000, pp. 111–133.
3. V. Karri, F. Bullen, Strengthening teaching and research: The use of industry links and case studies, *ASEE Annual Conference Proceedings*, 2004, Session 3557.
4. S. Farrel, R. P Hesketh, C. Stewart and M. J. Savelski, Industry and academia: A synergistic interaction that enhances undergraduate education, *ASEE Annual Conference Proceedings*, 2004, Session 1413.
5. Y. Shamash, R. Massengale, Impact of university/industry collaboration on engineering education—A success story, *Frontiers in Education Conference Proceedings,* 1989, Session 16A4.
6. J. Dinsdale, Industry/university collaboration in mechatronics: the Dundee experience, *IEEE Colloquium on Mechatronics*, 1991, pp. 4/1 to 4/3.
7. K. Strunz, A. Yokoyama and R. P. Behnke, Collaboration is key internationally, *IEEE power energy magazine*, **1**(4), 2003, pp. 50–55.
8. Aitken R., Cheng T., Nigh P., Stewart B., Roy K. and Tollefson G. Industrial and university test research collaboration, *IEEE Design & Test of Computers*, **18**(2), 2001, pp. 98–105.
9. K. J. Nasr and B. A. Nour, An experience on industry-university collaborative research, *Frontiers in Education Conference Proceedings*, 1997, Session T3D, pp. 317–320.
10 M. D. Santoro and S. C. Betts, Making industry-university partnerships work, *Research Technology Management*, **45**(3), 2002, pp. 42–46.
11. F. Blaabjerg, An industry-university collaboration in power electronics and drives, *IEEE Trans. Edu*, **43**(1), 2000, pp. 52–57.
12. National Instruments webpage, http://www.ni.com/company/robolab.htm (Accessed 6 March 2007).
13. D. Magin and S. Kanapathipillai, Engineering students' understanding of the role of experimentation, *European J. Eng. Edu*, **25**(4), 2000, pp. 351–358.
14. Dennis D. Truax, Improving the learning process of laboratory instruction, *ASEE Annual Conference Proceedings,* 2004, Session 2230.
15. Dervis Z. Deniz, A. Bulancak and Gokhan Ozcan, A novel approach to remote laboratories, *33rd ASEE/IEEE Frontiers in Education Conf*. 2003, Session T3E.
16. Distance-Learning Remote Laboratories using LabVIEW, National Instruments, Feb 2002, PN 342238A-01. *(downloadable from www.ni.com)*
17. Nesimi Ertugrul, Towards Virtual Laboratories: a Survey of LabVIEW-based teaching/learning tools and future trends, *Int. J. of Engineering Edu*, **16**(3), 2000, pp. 171–181.
18. K. K. Tan, T. H. Lee and F. M. Leu, Development of a Distant Laboratory using LabVIEW, *Int. J. of Engineering Edu*, **16**(3), 2000, pp. 273–282.
19. Ch. Salzmann, D. Gillet and P. Huguenin, Introduction to real-time control using LabVIEW with an application to distance learning, *Int. J. of Engineering Edu*, **16**(3), 2000, pp. 255–272.
20. D. Gillet, H. A. Latchman, Ch. Salzmann, and O. D. Crisalle, Hands-on laboratory experiments in flexible and distance learning, *Int. J. of Engineering Edu*, **90**(2), 2001, pp. 187–191.
21. Tor A. Fjeldly and Michael S. Shur, *Lab on the Web*, IEEE press, Wiley-Interscience publication (2003). ISBN: 0-471–41375–5.
22. http://www.monash.edu.my/news/Newsline/national_instruments.html (Accessed 6 March 2007).
23. National Instruments webpage, http://www.ni.com/academic/programs.htm (Accessed 6 March 2007).
24. B. Wagner and J. Tuttas, Team learning in online lab, *31st ASEE/IEEE Frontiers in Education Conf.* 2001, Session T1F.
25. R. Lessard, R. Goodrich, J. Beneat and S. Fitzhugh, *ASEE Annual Conference Proceedings*, 2004, Session 2220.
26. Alex See, Utilizing LabVIEW for data acquisition and analysis for a 13 weeks undergraduate course, *ASEE Annual Conference Proceedings*, 2004, Session 2220.
27. Alex See, Hands-on learning and implementing using LabVIEW for undergraduates in 13 weeks, *ASEE Annual Conference Proceedings*, 2004, Session 2756.
28. Alex See, Challenging computer-based projects for a Mechatronics course: Teaching and learning through projects employing Virtual Instrumentation, *J. Computer Applications in Engineering Education,* **14**(3), 2006, pp. 222–242.
29. http://sine.ni.com/csol/cds/item/vw/p/id/611/nid/124400 (Accessed 6 March 2007.
30. John Heywood, Engineering education, Wiley InterScience (2005).
31. Y. Shamash, R. Massengale, University/government/industry program in analog/digital integrated circuits, *IEEE Proceedings of University/government/industry Microelectronics Symp, Ninth Biennial,* 1991, pp. 29–32.
32. T. A. Barnes, I. R. Pashby and A. M. Gibbons, Collaborative R&D projects: A framework for effective management, *IEEE Int. Conf. Mgmt. of Innovation and technology,* 2000, **1**, pp. 210–216.
33. E. Starbuck, Optimizing university research collaborations, *Research Technology Management*, **44**(1), 2001, pp. 40–44.
34. R. V. Bloedon and D. R. Stokes, Making University/industry collaborative research succeed, *Research Technology Management*, **37**(2), 2001, pp. 44–48.
35. M. D. Santoro and P. A. Saparito, The firm's trust in its university partner as a key mediator in advancing knowledge and new technologies, *IEEE Trans. On Engineering Management,* **50**(3), 2003, pp. 362–373.

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