The Education Advancement Program on Precision Mechatronics in Taiwan

Authors:

Wenlung Li, National Taipei University of Technology, Taipei, Taiwan, wlli@ntut.edu.tw
Jhy-Cherng Tsai, National Chung-Hsing University, Taichung, Taiwan, jctsai@mail.nchu.edu.tw
Cheng-Kuo Sung, National Tsing-Hua University, Hsinchu, Taiwan, cksung@pme.nthu.edu.tw
Wei-Chung Wang, National Tsing-Hua University, Hsinchu, Taiwan, wcwang@pme.nthu.edu.tw
Jennie Y. J. Wu, Ministry of Education, Taiepi, Taiwan, jennie@mail.moe.gov.tw

Abstract — *Anticipating the engineer demands due to the quick development of the hi-tech industries in Taiwan, the Ministry of Education (MOE) has initiated the so-called 'The Education Advancement Project' (TEAP) to assure both quantity and quality of the manpower can meet the needs. Among many capstone programs in TEAP, the precision mechatronics program, started in 1997, is mainly concerned with the most important and fundamental technology for industries. This paper intends to summarize the achievements of this program in the second phase from 2001 to 2004. Major achievements of the program include the expertise laboratories, the educational resource integration and outcome sharing, the e-education, the hands-on project competition and the community service. In addition, the program promoted many academy-industry alliances through communities of expertise that organized by the program office (PO) and MOE. During year 2001 to 2004, ten alliances, guided by the educational resource centers (ERC), were formed in the past four years with more than 78 academic and 25 industrial partners participated. Moreover, about 54 expertise laboratories are established together with accompanying courses and lecture materials. The outcomes and facilities of the each ERC, such as laboratory instruments and course materials, are shared among partners in each expertise alliance. In addition, the program has designed the so-called hands-on competitions to upgrading the practical ability of engineering students. The competition is now an international event and welcome by students. It is worthy to mention that the competition used the real-time video via internet through the carefully designed schedule to avoid the time zone difference. The use of such real-time video has saved lots of expense and made the international competition possible. This event eventually becomes a bi-annual international hands-on video conference. Such model is very successful that the responsible ERC has been invited to organize special sessions at international conferences such as IEEE CDC and ECC 2005. As the conclusions, the outcomes of the program have shown that such a cluster-based expertise community is an efficient approach to integrate and to share the educational resources, especially for hi-tech engineering educations. However, it has been also found that the network of webs can be critical to the program.*

Index Terms — *precision mechatronics, academy-industry alliance, e-education, cluster.*

BACKGROUND

As it is well-known that the engineering manpower today cannot be boosted in a short period, unless it has been carefully depolyed and nurtured at least a few years back. Anticipating the engineer demands due to the quick development of the hi-tech industries in Taiwan, the Ministry of Education (MOE) has initiated the so-called 'The Education Advancement Project' (TEAP) to assure both quantity and quality of the manpower can meet the needs. The main goals of TEAP are to enchance the cuurent science eduction and to assure the quality of the students can meet the needs of year 2020. In the mean time, the project is also intended to play as pilot runs that link the traditional education organizations [1]. In other words, TEAP offers the eduction contents that may be difficult to achieve througth the current institutions. TEAP includes many capstone programs that are flexible and mission-oriented in their contents. One of that is to establish a heuaristic teaching enviroment for science educations. It includes the program similar to STS (Science, Techonolgy and Society) as well. Among those programs in TEAP, the one that focuses on the engeering educaitons is called the advancement programs on strategic industries. The detail missions and action plans have included the program on the precision mechatronics since 1997. The program is called TEAP on Precision Mechatronics (TEAP/PM). For the readers interested in this may refer to [2] for detail. Phase II of the program, from year 2001 to 2004, has been completed and documented. The presented paper is intended to summaize the achievement of the program in this period.

It has been mentioned in [2] that the outcome of the program has conclued that the engineering education on precision mechatronics must be close to industry so that the teaching outcome can be more fruitful. As a consequence, the involved institutions must develop industry-oriented educational curricula in addition to the common engineering fundamental cores. The program at the first stage was thus focus on the integration of academe and industry and to organize the so-called the strategic alliances. One of the many goals of these alliances is to put educational resources together so that they can be shared within the constituents' domain knowledge. The possible resources that may be shared include not only the hardware like teaching facilities, laboratory equipment, faculties, but the software such as the course materials as well. As the matter of fact, these academic-industry alliances are clusters of expertise within the a domain knowledge. The one that plays as the captain is the so-called the educational resource center (ERC) or the center schools. The center schools are supposed to have the richest domain knowledge and more hardware setups in that expertise. In other words, the ERC plays not only a resource divider, but also a resource provider that it acquires from industries. Under the mentioned infra-structure, the students involved in the program obtain their first-hand domain knowledge close to industries. Thus, they can get their jobs with satisfaction. Certainly, on the other hand, the participated industries in the alliance may get the manpower of good quality they need in return.

With the evolvement of the modern technologies, the capable engineers become the hottest issue among the educational institutions. It has no surprises, however, from the viewpoint of the industries. They have found much earlier that the key factor to success is not manpower, but the qualified and sufficient engineers. As a result, engineering education becomes such an important issue in the past two decades. Various technologies have been discussed and tried in order to improve and to facilitate engineering educations [3–5]. Among many other technologies, however, computer-network-based or internet-based education, including e-learning and remote learning, has been proposed and tried. Different programs and/or scheme based on such concept has been widely tried and discussed. Many trials, such as in [6, 7], and in [8], have all been reported that internet-based technologies do facilitate remote learning. This extends the contents of e-learning from computer-aided instruction such as course media to resource sharing such as e-lab. Although it has shown that internet-based technologies can enhance the achievement of e-learning, it is an issue to plan and to design education programs employing internet-based technology to a large scale. Furthermore, it is more difficult to implement such a program in engineering education as it involves technical illustrations as well as hands-on experiments that needs technical expertise to lecture and to develop required course material without lose the contents and spirit of engineering education.

For the completeness of the paper, the organization of the program will be briefly reviewed first in the next section. The reader may be referred to the document [9] for detail.

ORGANIZATION OF TEAP ON PRECISION MECHATRONICS

Based on the strategic plan of the TEAP/PM, a call for proposal, with the given guidelines in which clearly specified the missions and goals of the program, for academic-industry alliances are first open to interested and qualified institutes. The proposals are then reviewed and evaluated. Twelve nation-wide academic-industry alliances on Precision Mechatronics are formed in the first year. The yearly evaluations are performed. Therefore, these alliances are further merged into ten, nine, and finally six alliances in the following years based on their performances. Each alliance consists of an ERC and several partner institutions and industrial companies with focus on the same domain knowledge and technologies. While the ERC is responsible for the steering of the corresponding alliance and provides administrative assistance, the partner institutions focus on the contents and activities of the program, such as setting up the field-oriented feature curricula and laboratory facilities and developing feature course material.

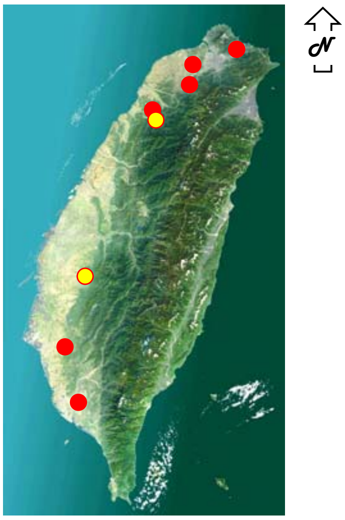

FIGURE 1
LOCATIONS OF ERCS IN TAIWAN ISLAND OF TEAP/PM.

Refer to Figure 1, ERCs of these alliances are located around the island, from northern to southern Taiwan. Each educational resource center is close watched by its steering committee with committee members from both academic and industry. The institutions that are not ERC can freely join the alliance of the same domain knowledge to share the resources with the obligation to open its laboratory facilities and to develop curricula together. The organization of the whole TEAP/PM alliances are briefly described as follows [10] and shown in Figure 2.

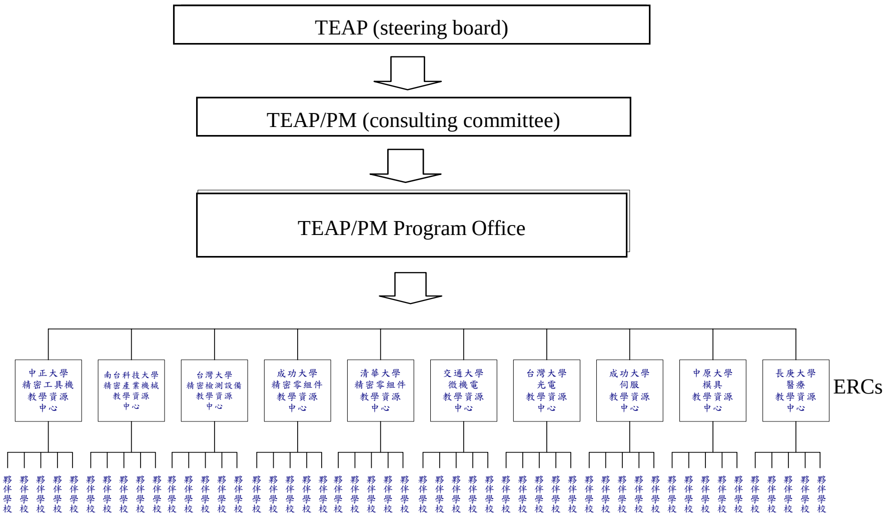

FIGURE 2
THE SCHEMATIC DIAGRAM OF THE ORGANIZATION OF TEAP/PM.

- The Precision Measurement Alliance focused on precision measurement technologies (both contact and non-contact types). The alliance, leaded by the Department of Mechanical Engineering (ME) of National Taiwan University, is formed by ten institutions, five research organizations and three companies. The resource center, combined with the Northern Taiwan MEMS (Micro Electro-Mechanical System) Center sponsored by the National Science Council, also shares educational resources on MEMS.
- The Opto-mechatronics Alliance is intended for the integration of mechanical, electrical and electronic, as well as optical and software/control engineering. The alliance consists of 32 academic institutions, increased from seven in year 2001, and more than twenty research institutes and companies. It is leaded by the Department of Applied Mechanics of the National Taiwan University. The Alliance shared many facilities with the Precision Measurement Alliance as the two educational resource centers located at the same campus.
- The Medical Mechatronics Alliance is a special group aimed on developing programs on medical mechatronics. It consists of eighteen academic institutes and over seventeen industrial organizations, hospitals and companies as partners. The educational resource center allocated at the ME Department of Chang Gung University as there is a need on related technologies at the university-owned medical center and hospitals. The alliance work closely with national-wide rehabilitation assistive technology centers and share resources with them as the alliance provides technologies for these centers while the rehabilitation assistive technology centers supply platforms for the alliance.
- The Micro Electro-Mechanical System Alliance consists of nine institutions leaded by the Department of ME of National Chia-Tong University. The alliance is divided into three groups. The Northern Taiwan group focuses on silicon-based MEMS technology; the Central Taiwan group stresses on non-silicon energy-based fine fabrication technologies; and the Southern Taiwan group emphasizes on bio-MEMS technologies.
- The Mold Automation Alliance is aimed on the process and automation technologies of precision and fine molding. It is formed by 23 institutions, three research institutes and one industrial organization with the educational resource center at the ME department of Chung Yuan Christian University. The alliance also signed strategic contracts with four overseas research institutions in the US, Canada and German.
- The Precision Machine Tools Alliance is formed as machine tool is one of the major industries in central Taiwan. The alliance emphasizes on the technologies for machine tools with the resource center located at the Department of ME at the National Chung-Chen University. Seven institutions, with focus on either machining process or on spindle technologies, joined this alliance as this industry involves processes and key technologies for machine tools.
- The Precision Components Alliance allocates two educational resource centers as it consists of fundamental technologies. The resource centers are located in the National Tsing-Hua University in northern Taiwan and in the National Cheng-Kong University in southern Taiwan. The northern center, consisting of six universities, two research institutes and 14 companies, focuses on the components and integration of media storage systems that. The

southern center, formed by five institutions, stresses on the application of fine fabrication on mechanical and mechatronics of computer systems.

- The Precision Industrial Machinery Alliance focuses on two areas: the semiconductor processing equipments and rapid prototyping equipments. The resource center is located at the ME department of the Southern Taiwan University of Technology with four and five institutions joined in each area as partners.
- The Mechatronic Servo Systems Alliance is leaded by the ME department of the National Chung-Kong University with six institutional members. The Alliance is aimed on the integration of servo and control systems, including pneumatic, hydraulic, and electrical servo systems.

Although each alliance is formed in the way that based on the same interest and industrial technologies among resource centers and partners, the major educational missions include the development of domain-specific programs such as curricula and laboratory practice, and hands-on project competitions. As each alliance forms domain-oriented resources, including university faculties, researchers, industrial engineers, as well as design/fabrication/inspection facilities and creativities from hands-on project competitions, it becomes a cluster of domain-specific expertise and resources naturally. This arrangement adds to the performance and productivity of the alliances as examples shown in CHANG [11]. However, it is also worthy to mention that the web and digitized materials really play critical factor to the organization.

As far as the size of total partners in TEAP/PM is concerned, it consists more than 78 academic and 25 industrial institution partners dedicated to this program in 2004, even though the number varies each year. Note also that the individual ERC is encouraged to obtain its own funds from the industries through all kinds of educational activites, such as traning courses. In addition to these own-generated funds, the program office also allocates certain amount of budget from the government to promote the TEAP/PM program. The total input budgets are listed in Table 1 from all ERCs in the mentioned four-year period [10].

ERC	2004	2003	2002	2001	Expertise Labs
Precision Ind. Machinery	3,000	2,500	4,640	3,819	9
Precision Measurement	4,500	3,750	4,930	3,959	12
MEMS	3,840	3,200	4,814	3,070	8
Opto-Mechatronics	3,000	2,750	800	-	3
Mold Automation	2,080	2,100	-	-	3
Med-Mechatronics	2,520	1,600	-	-	1
Precision Machine Tools	-	2,100	4,350	3,068	8
Precision Components(S)	-	1,500	3,248	1,130	4
Precision Components(N)	-	2,500	4,814	5,068	6
Annul Input Budget	18,940	22,000	27,596	20,114	54

TABLE 1
ERCs BUDGETS ALLOCATED BY THE PROGRAM OFFICE (1,000 NT$).

MAJOR ACHIEVEMENTS OF TEAP/PM

Once the educational alliances get together all possible resources through the corresponding ERC, the whole clusters of expertise become powerful groups that play as key roles in the engineering education program in that particular domain. From the education sides, the expertise laboratories take almost forever to complete 'not-so-good' ones since instruments are often expansive. However, totally 54 expertise labs has been founded or enhanced through the TEAP/PM program, refer to Table 1 for the detail listings. More importantly, the accessibility of these labs is much higher than any other traditional ones. The main reason stems from the program has designed a 'stick' that evaluates ERCs' performances every year in addition to the budget carrots. The outcomes of the former year may seriously affect the ERC budget of the following year. That is, the better ERC performs the more money it gets from PO. In addition, the evaluation outcomes can be easily browsed by all public, no matter he or she is in the program or not. As a result, the competitions among the ERCs are then automatically cultivated.

It may be also worthy to look at the number of the participants or students that directly gain benefit from the program. According to the statistics summed up from the all ERCs, the number of participating students, both from the universities and from the industries, varies ca. 13,000, 17,000, 21,000 and 7,400 from 2001 to 2004, respectively. The statistics of year of 2004 is incomplete when the paper is written and why the number dropped so drastically in that year. The total numbers of these training courses, workshops and seminars are ca. 118, 408 and 328 for year 2001 through 2003. Figure 3 shows a picture that taken from training courses. The pictures and the numbers of participants clearly signify that such domain-oriented courses are highly demanded and appreciated. That is the reason why the program appears on the mass media very often. It appears, directly or indirectly, more than 40 times on TV, newspapers or radios.

FIGURE 3
A SNAPSHOT OF DOMAIN-ORIENTED TRAINING COURSES

Note that SARS attacked the eastern Asian areas during the summer of year 2003. According the program statistics, one can hardly find the decreasing participants. Thanks for the modern technologies, which may be the contributions of the participants from this program, the real time-video systems among the ERCs are set-up so that the geographical barrier is minimized. Totally, forty web-based locations are established in May of 2003. Figure 4 depicts their relative locations of the center stations.

FIGURE 4
THE LOCATIONS OF WEB-BASED VIDEO SYSTEMS AND A TEST MODEL.

Year	No. of ERCs	No. of Teams
2001	6	70
2002	4	50
2003	9	120
2004	6	150

TABLE 2
THE STATISTICS OF HANDS-ON COMPETITIONS IN TEAP/PM

Table 2 shows some statistics of the so-called hands-on competitions to upgrading the practical ability of engineering students. The contents of this competition are somewhat different from those can be commonly found. The ability that an engineering student obtained is not only from the books or classrooms. They may also gain their domain knowledge from competitions or experimental works. Therefore, 'Learning by doing' is also a well-known slogan within TEAP/PM.

To accomplish the idea, the hands-on competition that emphasizes the integration of several domain knowledges in mechatronics is thus initiated. The competition is now an international event and welcome by students. It is worthy to mention that the competition used the real-time video via internet through the carefully designed schedule to avoid the time zone difference. The teams from USA, Japan, Korea, China and Singapore all joined the competition in year 2004. Meanwhile, the evaluators are also selected from different nations. Obviously, the use of such real-time video has saved lots of expense and made the international competition possible. This event eventually becomes a bi-annual international hands-on video conference. Such model is very successful that the responsible ERC has been invited to organize special sessions at international conferences such as IEEE CDC and ECC 2005.

OBSERVATIONS AND CONCLUSIONS

Before the program proposal is included to TEAP, there exist many discussions and doubts for such a domain-oriented and academic-industry strategic alliances. One may refer to the report of Wu [12, 13] for the discussions. However, it has been clearly seen from the outcomes of the last four years that the program (TEAP/PM) is really worthwhile. As far as the authors are concerned, the program has not only advanced the engineering educations in Taiwan, it enhances the related researches as well [14]. Not to mention the hands-on competitions, the domain-oriented courses and workshops do widely disseminate the knowledge to the general public. Nevertheless, the program provides a new possibility that nurtures the hi-tech engineers to fulfill the modern industries' needs in Taiwan.

In addition to the accomplishment the program has attained, several observations may be worthy to mention. Firstly, the capability of webs and the band-width of the communications can be fatal to the program. The main reason is that the activities of this program are mainly inter-institutionwise. Unless the communication is ready at hand, otherwise, there is no way to make the program successful. Secondly, the multimedia course materials which are highlighted in the present program due to their fast transmission through the webs, may be a plus or minus in the program. The plus comes from the colorful pictures and animation that attract the interests of students. However, some experimental experiences may not be replaced by courses like the virtual lab or e-lab. 'Learning by doing' is still a good way that let students get good feeling about the domain knowledge. Finally, the leadership of the individual ERC can be also a key factor to the program. Again, the authors would also recommend the need for further studies.

ACKNOWLEDGEMENT

This advancement program has been sponsored by the Ministry of Education, Taiwan, the Republic of China (TAIWAN). The authors wish to express their gratefulness for the assistance and cooperation from the project leaders of the educational resource centers. It is not possible to form the cluster-based e-education network without their contributions. Advices and suggestions from the MOE advisory board, in particular from Dr. Ying-Chien Tsai and Dr. Chung-Biau Tsay are highly appreciated.

REFERENCES

[1] WU, Jennie Y.J., the Powerpoint materials, MOE, Taiwan, 01.06.2005.

[2] TSAI, J.C., LI, W., SUNG, C.-K., WU, J. Y. J., "Cluster-Based E-Education Network on Precision Mechatronics," In *Proceedings of ICEER2004*., Czech Republic: University of Olomouc, 2004. paper 259.

[3] SOHLENIUS, G., "Engineering Education as a Part of Industrial Society - Product Quality, Process Quality and Quality in Engineering Education," *Robotics and Computer-Integrated Manufacturing*, Vol. 4, No.3-4, 1988, pp.659-667.

[4] BEAUFAIT, F. W., "Engineering Education Needs Surgery," In Proceedings of 21st Frontiers in Education Conference, 1991, pp.519-522.

[5] SIMPSON, I., "Engineering Education in Europe," *IEEE Transactions on Education*, Vol. 37, No. 2, May 1994, pp.167-170.

[6] TUTTAS, J. & WANGER, B., "Distributed Online Laboratories", in AUNG, W. *et. al.*, editor, *Engineering Education and Research –2001: A Chronicle of Worldwide Innovations*, USA: iNEER and Begell House Pub., 2002. pp.117-125.

[7] FJELDLY, T. A., STRANDMAN, J. O., BERNTZEN, R & SHUR, M. S., "Advanced Solutions for Performing Laboratory Experiments over the Internet," In AUNG, W. *et. al.*, editor, *Engineering Education and Research –2001: A Chronicle of Worldwide Innovations*. USA: iNEER and Begell House Pub., 2002, pp.135-145.

[8] DAKU, B. & DIEFES-DUX, H., "An Effective System for Implementing Self-Learning, on-line Instruction for Engineering Students," In AUNG, W. *et. al.*, editor, *Innovations 2003: World Innovations in Engineering Education and Research*. USA: iNEER and Begell House Pub., 2003, pp.307-318.

[9] The Final Report, TEAP on Precision Mechatronics (2001-2004), The Program Office of TEAP/PM, 2005, DVD 1/5.

[10] TSAI, J.-C., LI, W., SUNG, C.-K. & WU, J. Y. J., "Towards A Nationwide Web-Based E-Education Network on Precision Machine and Mechatronic Technologies in Taiwan.," In *Proceedings of ICEE2003*. Spain: University of Valencia, 2003. paper 3956.

[11] CHANG, R.-J., "Problem Solving and Curriculum Development in Precision Engineering," In *Proceedings of 2002 IEEE/ASME International Conference on Advanced Manufacturing Technologies and Education in the 21st Century (AMTE2002)*. Taiwan: National Chung Cheng University, 2002. paper C151.

[12] WU, Y. J. J., "Strategic Planning of Engineering Educational Programs in Ministry of Education, Taiwan," In *Proceedings of ICEE2000*. Taiwan: National Chung-Kung University, 2000. paper TuA4-1.

[13] WU, Y. J. J, "Strategic Alliance of Academy-Industry Cooperation on Aerospace Technology Education, Taiwan, R.O.C.," In *Proceedings of ICEE2001*, 2001. paper 399.

[14] LI, W., TSAI, J. J., TSENG, S.P., and YOUNG, I. F., "Generation of New Ideas for Product Functions and Engineering Innovation Practices: A Hands-on Project Model for Machatronics Education," iCEER-2005, Tainan, Taiwan, 1-5 March 2005.