Industrial Technology Program Quality Assurance: Academe Skills Competency on Concurrent Engineering Demands

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Abstract - This paper provides fundamental insights on industrial technology program quality assurance with regards to the latest trends in concurrent engineering and mechatronics in the manufacturing industries. It tackles on the curricular program analysis that attempts to examine existing program relevance to concurrent engineering needs and practices in Region X. The fundamental arguments are anchored on the issue of industry-academe imbalance relative to human resource quality. Issues presented in this paper points to some academic shortcomings and industry's lackluster academic involvement. This imbalance are confirmed and validated through the academic and industry assessment process which attempted to compare industry's actual skills competency needs and the quality of human resources supplied by the academe and or other training institutions. Appropriate complementary curricular program initiatives and industry collaboration were undertaken to address prevailing arguments. The study outcome is perceived to provide sustainable quality assurance in industrial technology program offerings of Mindanao University of Science and Technology in Cagayan de Oro City, Philippines.

Keywords - Quality Assurance, Concurrent Engineering, Mechatronics, Competency-based Curriculum

INTRODUCTION

Since time immemorial, academic and training institutions claim quality education as their name sake. The description may seem hard to measure especially in the third world country like the Philippines. Due to the complexity of measuring quality education, these became the motivation of some accrediting agencies to set up policy standards in the hope of attaining regulatory authority in an established field of discipline.

In the United States (US), the National Association of Industrial Technology (NAIT) was formed to provide direction for the continuing development of an emerging new field that prepares graduates for positions in the industrial settings (Strong, Kassapoglou, Dugger and Rudisill, 1999). Curriculum and accreditation standards established by NAIT provide a framework and structure for the network of industrial technology programs in colleges and universities throughout the US (NAIT, 1997). This is the same field of industrial technology discipline that has been adopted in the Philippines for several decades to usher graduates in the industrial technology programs to that perceived occupational placement. The Bachelor of Science in Industrial Technology (BSIT) was first introduced in the School of Arts and Trades (SAT) in the early 1970s but was later on integrated into the State Universities and Colleges (SUC's) due to the conversion of SATs into state polytechnic colleges (Salvador and Cabahug, 2005). The integration caused the industrial technology program to lose its bearing under the umbrella of the Higher Education Institutions (HEI's) because HEI's are more concern on higher education programs rather than vocational technical courses. The Commission on Higher Education (CHED) does not have existing policy standards on industrial technology programs in the Philippines. In the absence of industrial technology policy standard, the plight of the program in the Philippines may be in jeopardy as its implementation is not guided by concrete direction. However, in the absence of CHED policy on industrial technology, the program under the State Universities and Colleges (SUC's) mandate still try their level best to calibrate industrial technology program offerings into higher educational system through program accreditation via the Accrediting Agency of Chartered Colleges and Universities of the Philippines (AACCUP).

SUC's submission to accreditation process may not achieve real educational quality assurance as the accreditation instrument contains vague requirements which do not address occupational competencies of individual graduates. It is more concentrated to enhancing program quality as perceived by educator's view point and not by the industry which is considered to be the final clientele of the academe. While it has been recognized that program assessment has become an important element of the accreditation process in higher education today (Boser and Stier, 2005), it must be noted that this should be anchored on the essential knowledge, skills, and competencies that the students in the program should learn and be able to do by the time they graduate. In essence, the traditional subject-based curriculum should now be upgraded to competency-based curriculum wherein the skills and competency requirements are set forth by the industry experts and practitioners in a specified discipline.

With globalization and the introduction of modern technologies in the industry, the need for a sustainable quality assurance in education must be in the paramount priority in order to stay in the competitive market. Industry's manufacturing platforms now embrace concurrent engineering concepts. The process of concurrent engineering has been identified by business organizations as simultaneous engineering, life-cycle engineering, parallel engineering, multi-disciplinary team approach or integrated product and process development (Hall, 1991; Ziemke & Spann, 1991 and Prasad, 1996). Concurrent engineering has become a key concept that has enabled companies to attain world-class stature (Tsina, 1995). The concepts of concurrent engineering reveal that all elements of a product's life-cycle, from functionality, production, assembly, testability, maintenance issues, environmental impact, disposal and recycling are considered in the design process and that its preceding design activities should be occurring at the same time, or concurrently (Kusiak, 1992). The nature of concurrent engineering requires interdisciplinary approach to systems engineering wherein its human resources need to comprehend the integration of multiple technologies in the design process. Mechatronics is emerging as a concurrent-engineering thinking framework in the process of designing complex machines (Van Brussel, 1996). Bettersworth (2009) also cited that mechatronics is at the heart of diverse systems applications that enables traditional industries to be more efficient by automating redundant processes, improving quality and increasing productivity. Mechatronics and concurrent engineering has become a significant force in achieving quality assurance in the industry's business framework.

OBJECTIVES OF THE STUDY

The main objective of this study is to explore the enabling technologies and practices applied in concurrent engineering in the Philippines and examine its implications to the quality industrial technology program in the Philippines. Specifically, the study sought to conduct industry-academic assessment on concurrent engineering enabling technologies and or applied technologies utilized in various industries in Region X and establish industry-academic human resource quality assurance initiatives relevant to concurrent engineering.

FRAMEWORK

There is a strong consensus that modern computer technology has been a major driving force behind the increase practice of concurrent engineering (Kelley, 1998). However, there is much more to that idea of managing modern production organization than just advance technologies brought about by the advent of modern computers.

Computerization also paved the way for the integration of multiple technologies popularized by the so-called Mechatronics concept. Mechatronics is the synergistic combination of precision mechanical engineering, electronic control, and systems thinking in the design of products and processes (Bradley, Dawson et al., Chapman and Hall Verlag, 1991). Mechatronics is an enabling approach to technology that is increasingly applied in a number of economic sectors including: automotive, aerospace, medical, xerography, defense systems, consumer products, manufacturing, and materials processing as shown in Figure 1, as presented by Dr. Kevin Craig (2007) of Rensselaer Polytechnic Institute. Mechatronics is at the heart of diverse systems applications that enables traditional industries to be more efficient by automating redundant processes, improving quality and increasing productivity (Brazell, Bettersworth, Vanston and Elliot, 2007).

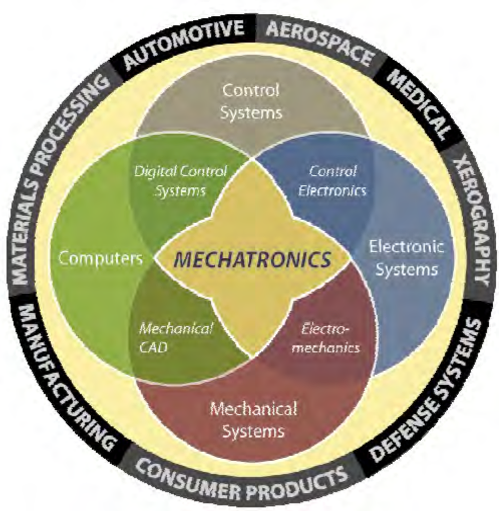

Figure 1- Mechatronics range and application (Source: Rensselaer Polytechnic Institute)

Brazell et al. (2007) in their article on Mechatronics: Integrating Technology, Knowledge and Skills, reveals that mechatronics provides a framework for integrating traditionally disparate mechanical, electronic, control, information technology and other degree programs into a single multi-disciplinary program suited to industry's increasing demand fro multi-craft employees and suggested to integrate existing programs to develop mechatronics degree and certificate programs as appropriate for local industry demands. The study conducted by Texas State Technical College (TSTC) shows recent evidence that U.S. community and technical colleges as well as institutions offering four-year and advanced degrees are adapting their engineering programs to meet a growing demand for skilled workers with integrated skill sets (Brazell et al., 2007).

Cuasito and Namoco (2009) cited some private colleges and universities who embedded applied mechatronics courses in some of their engineering curriculum. De Lasalle University, Mapua Institute of Technology and AMA University are few examples of private academic institutions that offer or embedded applied technologies in mechatronics in their technical and engineering curricula. State Universities and Colleges (SUC) also opted to offer BS in Mechatronics Engineering, Bulacan State University (BULSU), Batangas State University (BATSU) and Mindanao State University- Iligan Institute of Technology (MSU-IIT) offering Bachelor in Industrial Automation and Mechatronics (Cuasito & Namoco, 2009).

MATERIALS AND METHODS

There are two target populations being assessed, the industry and the academe. At these settings, the study sought to explore the concurrent engineering enabling technologies utilized in various industries in Region X by determining the applied technologies and its corresponding skills competency requirements at the same time evaluating the corresponding academic level of relevance and initiatives towards enhanced academic program attuned to concurrent engineering platform.

Industry Assessment

The assessment intends to validate the presence and application of concurrent engineering enabling technologies and or mechatronics core courses in the industrial platform. The assessment also includes studying the skills competency demands of the industry, the range of mechatronics applied and classification of industry's line of business interests. Varied industries served as respondents which are classified into food & beverage, Chemicals, Manufacturing, Cement & Metals and Power industries.

The assessment is conducted using a survey questionnaire designed to analyze the aforementioned variables. The questionnaire used contains a general demographic information and five-point Likert scale that focused on the research questions in four areas: (1) confirmation on mechatronics core courses application, (2) level of application on various applied technologies and automation tools, (3) technical skill level, (4) level of skills training interest. The survey questionnaires were distributed randomly to technical workers serving as technicians, machine operators, and area supervisors.

There were thirty (30) questionnaires floated in each industry classifications and the return rates in the five industry classifications were: (1) 33.3% return rate on manufacturing industry, (2) 86.7% return rate on food & beverage classification, (3) 50% return rate on the power industry, (4) 50% return rate on the chemical industry, and (5) 83.3% return rate on cement & metal industries.

The industry assessment is conducted in the hope of bridging identified skills competency gap in the areas of concurrent engineering by comparing the desired performance level and the status quo. The assessment outcome is perceived instrumental to the quality assurance strategy of continually equipping human resources to its right updated skills and competencies.

Academic Assessment

The academic assessment is also sought to determine the academic relevance to concurrent engineering. Its enabling technologies and mechatronics core courses in the industry were the variables examined.

The survey instrument used the same method of data gathering. The instrument provided queries that determine the presence and degree of implementation of mechatronics core courses into existing academic programs in engineering and technology. The questionnaire is comprehensively designed in a check list form for the academic respondent's appropriate judgment. The questions are presented so as to validate the existence and or congruence of existing programs to the mechatronics range. The survey outcome determines the academic relevance to mechatronics by measuring the frequency of congruence and the interest in keeping pace with mechatronics as provided by the respondents. Validation of responses is further ensured through verbal technical interview to establish consistent information.

The respondents for this survey were the pre-selected academic institutions who belong to the Higher Education Institutions (HEI's) and Vocational Technical Schools (VOCTECH) in Region X. The respondents were categorized into three (3): (a) state university/college, (b) private university/college, and (c) vocational school/training institution. The questionnaires were randomly distributed to area/ program chairpersons and deans of their respective engineering and technology departments using frequency measurement that focuses on the research questions in the following major areas: (1) general demographic information, (2) academic relevance to mechatronics core courses, (3) academic relevance to applied mechatronics.

RESULTS AND DISCUSSIONS

Range of Mechatronics

The Mechatronics transdisciplinary diagram in Figure 2 suggests that core courses and integrated technologies developed in the mechatronics environement are engulfed and inter-related in such a way that each technology is integral to the mechatronics synergy (Wikimedia Commons, 2008; Cuasito & Namoco, 2009). The integration of mechanics, electronics, software and control developed new emerging technologies and mechatronics at its cross-intersection. The emerging technologies in mechatronics are increasingly important in manufacturing systems where it enables traditional industries to be more efficient through automating redundant processes, improving quality and increasing productivity (Brazell et al., 2007).

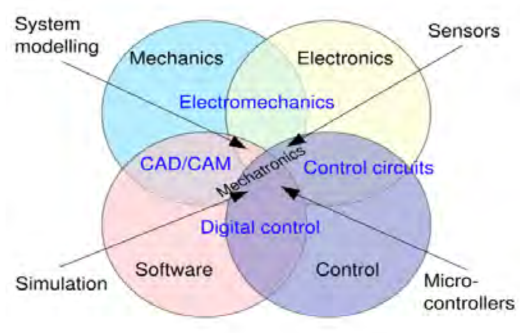

Figure 2 – Mechatronics transdisciplinary approach

Industry survey suggests that the range of mechatronics as presented by foreign experts is present and is actually being utilized in Region X. Table 1 represents the industry-mechatronics relevance. Industries are classified according to the nature of business establishment as indicated by the Legend below the table. The level of mechatronics core courses application in the industry is measured using the Five Point Likert Scale which has the following adjectival rating:

Adjectival Rating	Scale Range
1 – Very Poor	1.4 - below
2 – Poor	1.5 – 2.4
3 – Fair	2.5 – 3.4
4 – High	3.5 – 4.4
5 – Very High	4.5 – above

Table 1. Industry-mechatronics relevance

	Industry Classification/Mean				
Level of application of the following core courses into the industry	1	2	3	4	5
Mechanics	4.5	4.2	4.5	4.5	4.9
Electronics	4.6	4.8	4.8	5.0	4.9

Electromechanics	4.6	4.6	4.8	4.6	4.9
Control Circuits	4.8	4.9	5.0	5.0	5.0
CAD/CAM	4.8	3.8	4.3	3.8	4.8
Digital Control	4.3	4.9	4.7	4.9	4.7
Control	5.0	4.9	5.0	5.0	5.0
Software	5.0	5.0	5.0	5.0	5.0
System Modelling	4.2	4.0	4.9	4.5	4.4
Sensors	4.8	4.9	4.8	5.0	5.0
Micro-controllers	4.8	5.0	4.7	5.0	4.8
Simulation	4.2	3.9	4.9	4.5	4.5

Legend: 1 – Manufacturing, 2 – Food & Beverage, 3 – Chemicals, 4 – Power, 5 – Cement& Metals

Table 1 depicts the mean responses of the industry respondents from different classification when asked to what extent they felt the mechatronics core courses listed are utilized in their industrial activities. Industries classified as manufacturing, food & beverage, chemicals, power and cement & metals all signified their affirmation to the mechatronics core courses application in their respective industrial activities with high range ratings.

The industry also affirmed through the survey response on the application of Mechatronics core courses into applied technology as shown in Table 2. All respondents rated high marks on the mechatronics applied technologies except for distributed control system (DCS) and supervisory control and data acquisition (SCADA) which are identified to be more popular in the power industry. One metal and a chemical industry in the region signified utility in DCS.

Table 2. Mechatronics applied technologies in the industry

Level of Applied Technologies in the Industry	Industry Classification/Mean				
	1	2	3	4	5
Instrumentation & Control Process	4.7	4.8	5.0	5.0	4.9
Electro-Pneumatics	4.4	5.0	4.2	4.7	5.0
Electro-Hydraulics	4.7	4.6	4.8	4.5	4.9
Programmable Logic Controllers	4.9	4.7	4.6	5.0	5.0
Computer Aided Design/Computer Aided Manufacturing (CAD/CAM)	5.0	4.5	2.7	4.5	5.0
Electronic Motor Controls	5.0	4.9	4.8	4.7	5.0
Machine Networking	4.2	3.8	5.0	4.2	3.7
Distributed Control System (DCS)	1.0	1.0	3.3	1.0	3.8
Human Machine Interface (HMI)	3.0	4.5	4.5	4.8	4.3
Supervisory Control and Data Acquisition (SCADA)	1.0	1.0	4.9	4.7	4.1

Legend: 1 – Manufacturing, 2 – Food & Beverage, 3 – Chemicals, 4 – Power, 5 – Cement& Metals

The level of worker's technical skills competency reflected in Table 3 and the level of interest in lifelong learning in Table 4 is measured using the Five Point Likert Scale which has a slightly different adjectival rating, to wit:

Adjectival: Rating		Scale Range:
	1 – No Comment	1.4 - below
	2 – Poor	1.5 – 2.4
	3 – Fair	2.5 – 3.4
	4 – High	3.5 – 4.4
	5 – Very High	4.5 – above

Table 3. Workforce Skills Competency Level

	Industry Classification/Mean				
Workers' Technical Skills Competency Level	1	2	3	4	5
The ability to analyze and apply basic electricall and electronic principles within the various industry environments and applications such as industrial, process controls and other such systems.	2.6	4.0	3.6	4.7	4.4
The ability to analyze and apply basic fluidpower priciples within the various industry applications particularly in pneumatics and hydraulics.	3.0	4.3	3.7	3.9	4.0
The ability to ultilize and program programmable logic controllers (PLC)	2.5	3.5	3.8	3.2	3.7
The ability to analyze and apply basic instrumentation and control process principles. Perform Proportional, Integral and Derivative (PID) tuning and PI&D interpretation.	1.4	2.9	3.5	3.4	2.9
The ability to utilize 2 D and 3D computer-aided design to create drawings and models for products, machines, fixtures and other mechanical devices used in industrial and other business environments.	3.5	2.8	2.9	3.3	3.0
The ability to use and perform human-machine interfacing and utilize SCADA systems within the appropriate control framework	1.0	2.8	2.5	3.7	2.6
The ability to use and perform computer/machine networking within the local area network.	3.4	4.3	4.2	4.5	3.8
The ability to read and interpret manufacturing documentation such as blue prints, technical drawings and diagrams, production plans, tooling plans, quality plans and safety plans.	4.7	4.5	4.6	4.5	4.5

Legend: 1 – Manufacturing, 2 – Food & Beverage, 3 – Chemicals, 4 – Power, 5 – Cement& Metals

The manufacturing industry was identified to have fair ratings in their electronics manipulation abilities, PLC programming with less response on instrumentation and control and SCADA systems. The food and beverage industry also have identified high ratings on the enabling technologies, however, fair ratings were observed on instrumentation and control, SCADA systems, and CAD/CAM. Chemical industry in the region also has high ratings on mechatronics with fair ratings on SCADA. The power sector registered high ratings on instrumentation and control and PLC programming, DCS and SCADA. The cement and metal industries also have high ratings on the enabling technologies, however, it fairly rated instrumentation and control and SCADA systems. The survey outcome is indicative of mechatronics enabling technology application in the industrial settings.

Despite the positive reaction afforded by the respondents, Table 4 depicts the learning interest of the respondents to continuing education and or life long learning. The indication provided by Table 4 justifies the need for continuing professional education even if the aforementioned technologies are already present in the industrial platforms.

Table 4 – Worker's level of interest in life long learning/training

Level of Interest in Life Long Learning relative to the following Applied Technologies in the Industry	Industry Classification/Mean				
	1	2	3	4	5
Instrumentation & Control Process	4.8	4.9	4.8	5.0	4.8
Electro-Pneumatics	4.7	4.5	4.2	3.8	4.4
Electro-Hydraulics	4.3	4.1	4.3	4.1	4.5
Programmable Logic Controllers	5.0	4.9	4.8	5.0	4.9
Computer Aided Design/Computer Aided Manufacturing (CAD/CAM)	4.8	4.6	3.9	3.5	4.1
Electronic Motor Controls	4.3	4.1	4.8	3.8	4.0
Machine Networking	4.7	4.8	4.7	4.8	4.6
Distributed Control System (DCS)	4.8	4.9	4.5	4.8	4.7
Human Machine Interface (HMI)	4.8	4.9	3.7	4.8	4.3

Supervisory Control and Data Acquisition (SCADA)	4.8	4.9	4.9	3.2	3.2

Legend: 1 – Manufacturing, 2 – Food & Beverage, 3 – Chemicals, 4 – Power, 5 – Cement& Metals

Academic Relevance

Figure 3 describes the diversity of mechatronics showing the core courses with some of their corresponding applied technologies. Applied technologies in programmable logic controller, process control instrumentation, hydraulics, pneumatics, human machine interface, supervisory control and data acquisition, distributed control system, networking, motor controls and computer aided design/ computer aided manufacturing are technologies that take center stage in industrial practices. There are more diverse technologies of mechatronics in the advance level, robotics, artificial intelligence and machine vision to name a few that further enhances productivity, quality and systems efficiency in the industry. These applied technologies may be integrated including its corresponding human resources in an industrial process described as concurrent engineering (Cuasito & Namoco, 2009). Concurrent engineering is a philosophy of product development where design issues are integrated as well as its multidisciplinary workforce into the design team (Kusiak, 1992). Mechatronics has significant impact to concurrent engineering practices in the industry.

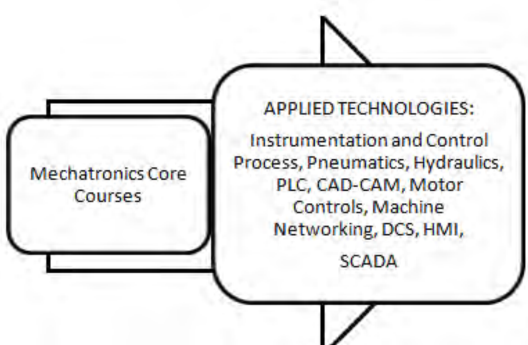

Figure 3 – The Mechatronics Diversity

Table 5 has compelling indications of some HEI's, SUC's and VocTech schools confirmation of mechatronics core courses embedded to existing academic and or training programs. However, there are also indications that some of these courses were compromised due to lack of physical resources and supplementary equipment in instruction delivery. Based on the survey, SUC's are more inclined to embed mechatronics core courses into their curriculum as compared to private HEI's and VocTech institutions. This is an indication that SUC's awareness to latest technology trends and its willingness to be attuned with the industry. Through follow up interview, more SUC's are enhancing their instructional facility to address skills competency demands of the industry while some private HEI's are tied up by the Commission in Higher Education (CHED) policy that they become more subject-based rather than competency-based.

Table 5 – Academic relevance to mechatronics

Confirmation of Embedded Mechatronics Core Courses in the Academic Program	Private HEI's (n= 9)	SUC's (n=6)	VocTech (n=6)
	%	%	%
Mechanics	100.0	100.0	50.0
Electronics	100.0	100.0	100.0
Electromechanics	22.2	83.3	33.3
Control Circuits	100.0	100.0	50.0
CAD/CAM	66.7	100.0	83.3
Digital Control	100.0	100.0	50.0
Control	100.0	100.0	50.0
Software	100.0	100.0	100.0
System Modelling	55.6	66.7	33.3
Sensors	55.6	66.7	33.3
Micro-controllers	66.7	100.0	50.0
Simulation	66.7	66.7	16.7

The academic respondents were also asked to confirm their academic relevance to mechatronics applied technologies utilized in the industry. Table 6 depicts the corresponding ratings made by the categorized respondents. Private HEI's in the region indicated their affirmation to the aforementioned technologies with 66.7% in instrumention and control, pneumatics, PLC, machine networking and SCADA. However, through follow up interviews, some of these technologies were not suitably covered technically due to physical equipment constraints. The courses were limited to theoretical coverage only. SUC's in the region with technology and engineering thrust were found to be more attuned with mechatronics through their supplementary training facilities that facilitate relevant instruction delivery. Voctech institutions on the other hand, registered less relevance to mechatronics. There are applied technologies that are yet to cover in the academic premise namely: DCS, HMI and machine networking.

Table 6 – Academic relevance to applied mechatronics

Academic Relevance to Applied Mechatronics	Private HEI's (n= 9)	SUC's (n=6)	VocTech (n=6)
Instrumentation & Control Process	66.7	33.3	0.0
Electro-Pneumatics	66.7	66.7	66.7
Electro-Hydraulics	33.3	66.7	33.3
Programmable Logic Controllers	66.7	66.7	33.3
Computer Aided Design/Computer Aided Manufacturing (CAD/CAM)	100.0	66.7	33.3
Electronic Motor Controls	33.3	33.3	22.2
Machine Networking	66.7	33.3	0.0
Distributed Control System (DCS)	0.0	0.0	0.0
Human Machine Interface (HMI)	0.0	0.0	0.0
Supervisory Control and Data Acquisition (SCADA)	66.7	33.3	0.0

Quality Education Assurance

The aforementioned Mechatronics core courses presented in Figure 3 requires a curriculum design that suits the range of mechatronics. As validated by the survey floated to the industry, it suggests a growing demand of highly skilled human resources that will handle the mechatronics range.The academe being the prime provider of human resources should be sensitive enough to understand the need to respond to this scenario.

There are compelling reasons to upgrade and align existing engineering and technology curricula to the mechatronics range, the reasons are:

The concurrent engineering practices and human resource requirements demand it.

There is a need to jive curricula to the mechatronics range and core courses.

Mechatronics courses will calibrate technology programs to higher education.

Training regulation and national certification are available and provided by competent authorities.

Professional organization accreditation through Mechatronics and Robotics Society of the Philippines (MRSP).

Employment packaging enhancement.

Furthermore, the existing BS in Mechatronics Engineering offering in some HEI's in the Philippines suggests the need for mechatronics technician/technologist counterparts to run and manage various mechatronics platforms in the industry.

CONCLUSIONS

Concurrent engineering will continue to dictate the tempo of the global economy through its enabling technologies in mechatronics. Its concept not only suggests diverse technology application to various economic sectors but also demands transdisciplinary workforce. The concept of concurrent engineering is a strategy of quality assurance. Quality is assured in all levels in production to market place. The process is cyclical in nature and intends to follow a consistent approach to quality outcome focusing its diversity to customer satisfaction.

Academically, producing quality human resources that is responsive to the will of the industry must be the ultimate goal of every academic institution. The only way to claim quality education is to produce graduates that are inclined, attuned and relevant to the latest trends in the industry. Latest trend means the prevailing technology available for optimal economic adavantage. Academic inclination is not only limited to subject-based but adherence to competency-based education where realistic technical skills specified by industry experts dictate the deciding factor for an occupational placement.

Quality assurance is implied in the industry setting if both the stakeholders (e.i. industry and academe) play their respective roles with utmost commitment to customer satisfaction. This is the essence of this study; concurrent engineering answers the call to optimize economic capabilities while the academe's commitment to supply the right technical skills assures quality human resources for various economic sector concumption.

RECOMMENDATIONS

It is recommended that in order to sustain quality assurance, the economic stakeholders must establish collaborative life long learning endeavor that supports relevant science and technology training concepts. This can be done through massive educational advocacy that promotes technological awareness both in the industry and academic community. Sharing of resources may prove to be cost effective in establishing a cross-training program wherein industry and academic personalities exchange training environments and experience different learning innovations. The ultimate goal is to enhance the occupational competency and qualification of the industry workforce. It is further recommended that a collaborative continuing professional education program should be regularly conducted to provide workers and students with reliable updates on technological breakthroughs.

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