CHALLENGES IN DEVELOPING AND MANAGING DESIGN-FOR-X COURSE IN MALAYSIA.

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Abstract *– This paper describes the challenges in developing and managing a Design-For-X course for engineering undergraduates at a premier university in Malaysia. This course is designed, against the more traditional engineering subjects in order to update and enhance the design content of the current Manufacturing and CAD/CAM undergraduates' curriculum respectively. As the nation is gearing up towards becoming a fully industrialized country, there is a new challenge for the current engineering graduates in Malaysia to be able to develop better products at minimum production cost and lead times. Further expansion to this notion has highlighted the need to enable future engineers to be well equipped with knowledge and tools on developing new products. Students are exposed to various DFX tools like Design For Assembly, Design For Environment, Design Failure Mode and Effect Analysis and Quality Function Deployment. It is noted that major accomplishments by students include teamwork awareness, better problem definition skills and innovativeness. The perception that engineers are required to think creatively and critically, is clearly shown by the students. Students' responses on the DFX course are presented. The paper also discusses the strengths and limitations of the current course contents as well as new challenges for future endeavors.*

Index Terms – Curriculum development, design for assembly, engineering education, students' evaluations.

INTRODUCTION

Design-For-X (DFX) consists of many reliable and tested approaches and techniques including Design For Manufacturing (DFM), Design For Assembly (DFA), Design Failure Mode and Effect Analysis (DFMEA), Design For Environment (DfE) and Design for Servicing (DFS). DFX can contribute in many ways to the improvement of productivity, increasing quality and reducing cost of reworks, improving production efficiency and reducing production cycle. In this paper, DFX is defined as 'methodologies, techniques and working practices that cause a product to be designed and manufactured for the optimum manufacturing cost, the optimum quality, and the optimum achievement of life-cycle support (serviceability, reliability and maintainability)'.

Manufacturing sector has turned out to be Malaysia's major incomes generated activities since early 70s. With a contribution of over 28% of the Gross Domestic Product (GDP)[1], the manufacturing sector is spearheading the Malaysian economy notably after the 1998's downturn. Nevertheless Malaysia cannot claim that she is capable to exploit the advancement of manufacturing technologies because in many cases the source and control of these technologies lie primarily in foreign hands.

As the manufacturing sector will continue to be the engine of growth for the future, it is important that skills development measures are undertaken in tandem with the type of skills that are in demand to suit a rapidly changing technological environment. There is a great need to educate and train more engineers and technicians for industries[2]. The output of graduates from universities and technical institutes at present is grossly inadequate. Lack of qualified manufacturing engineers and not enough specialists with industry specific knowledge have been identified as two of the common barriers to implementing advanced manufacturing technologies in Malaysia[1].

This paper is intended to present a manufacturing education course to educate and train young manufacturing engineers at a premier engineering university in Malaysia. The objective of the course is to give the manufacturing engineering students an insight into the expanding role of the manufacturing function by providing a broad based view of the industrial needs and a knowledge of the enabling technologies and techniques, primarily, DFX. A two-year study on the implementation of the DFX course is presented including various feedback statements sent in by the students.

RATIONALE FOR DFX COURSE.

The concepts of Design For Assembly (DFA), the Design Failure Mode and Effect Analysis (DFMEA) technique, Design For Environment (DfE) approaches and Quality Function Deployment (QFD) technique are specifically included within the definition of DFX. On the same footing, educating young manufacturing engineering undergraduates at the university on DFX is a key strategy in which the paper endeavors to draw out two broad aims:-

- DFX relevance to the formation of young professional engineers specializing in total product

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development

- DFX importance within the context of total design and advanced manufacturing technologies in presenting an holistic view of product development.

The holistic view of product development is consistent with Pugh's concept of Total Design[3] which envelopes a much wider spectrum than conventional or traditional engineering. The development of new or improved products will involve design and manufacturing but real business success is achieved if this activity is driven and controlled by the systematic assessment of market need. The design core is that which connects the selling back to the market need. In a product context the appropriate technology dependent methods are necessary and these methods cover the area of traditional engineering which address the suitable use of materials in a product's design and to serve functional needs. Traditional engineering is being complemented with further methods (often team based) to assist with the efficiency and effectiveness of the design core. These include QFD, DFA, DFMEA, DfE, etc. These methods are directed towards the actual process of assessing and serving needs through product design – this includes market needs and manufacturing needs. In the modern manufacturing organization it is axiomatic that serving manufacturing needs will also serve market needs due to the required responsiveness to customers. The danger of the traditional engineering approach centered on product design for function only is that the business organization encourages designers to indulge themselves in engineering design and less in communication and assessing the overall needs to be served.

COURSE DEVELOPMENT AND DELIVERY PROCESS

The DFX course covers a structured methodology in design and manufacture. The planned development and delivery process is shown in Figure 1. This course is offered to the Final Year undergraduate students pursuing the bachelor degrees in Manufacturing Engineering and Computer-Aided Design/Computer-Aided Manufacture (CAD/CAM) respectively as a core subject.

Delivery Process on Design For Assembly

The process begins by understanding the importance of time and cost-savings in developing new products. This is included under the theme Design for Manufacture and Assembly (DFMA). The core component under this theme is the application of Design For Assembly (DFA) method in designing new product. The objectives for teaching DFA are three-fold:

1. To provide the students with a mechanism for simultaneous engineering studies to aid the design team in simplifying the product structure, reduce manufacturing and assembly costs and to quantify the improvements achieved.
2. As a tool to evaluate competitors products and quantify manufacturing and assembly difficulties
3. As a costing-indicator tool to help negotiate suppliers contracts.

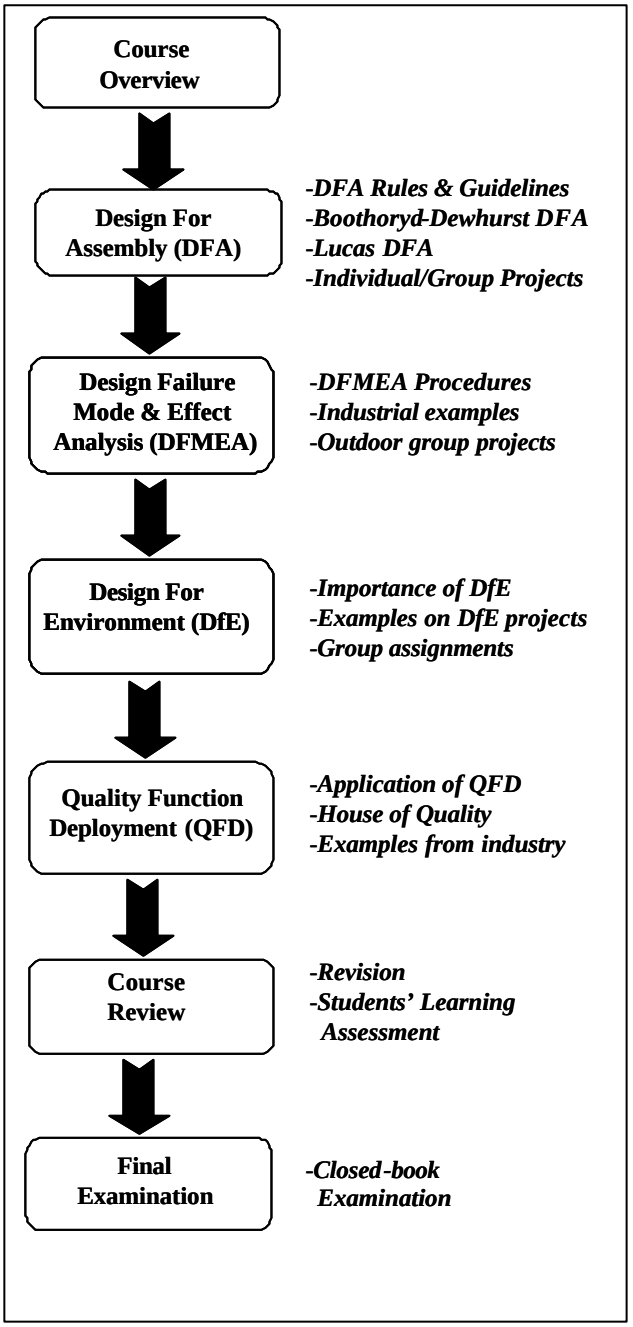

FIGURE 1
DEVELOPMENT AND DELIVERY PROCESS OF THE DFX COURSE.

Within the DFA course, students are given valuable opportunities to learn to simplify product designs and reducing the amount of motion required to assemble a product. The method focuses on designing a product for ease of assembly. Therefore, to accomplish ease of assembly, first and foremost, an assembly has to be rationalized. A rationalization of assembly accomplishes an improvement in the effectiveness of assembly, the quality of the product and the environment surrounding the assembly system. During the sessions, students are told to adhere to the four main goals[4] that must be achieved in designing for ease of assembly:

- Improvement of the effectiveness of an assembly operation,
- Improvement of product quality,
- Improvement of the assembly system usability,
- Improvement of working environment within the assembly system (for the operators).

Two commercially available DFA packages are used in the teaching delivery namely, Boothoryd-Dewhurst Inc. DFA[5] and Lucas Design For Assembly Technique[6]. Students will be given one individual assignment and one group project for learning evaluation purposes. For the individual assignment, the students have to do an investigation on the usefulness of DFA commercial packages, its strengths and weaknesses, the popularity of these packages in related industries and describing several real life applications of DFA. Whilst, on the group project, students will be requested to conduct a DFA analysis on currently available products such as three-pin electric plug, PC mouse, telephone set, PC printer, etc. They have to conduct the study for a given set of time in the classrooms and submit a written report on the project. The students are evaluated on team effort, time, the outcomes of DFA analyses and clarity of the reports.

Delivery Process On Design Failure Mode and Effect Analysis

The topic on Design Failure Mode and Effect Analysis (DFMEA) is taught to the students immediately after completing the DFA exercises. DFMEA is a structured and analytical approach used to identify potential areas of design and process related risks. The ultimate objective in this session is to teach the students on a proven technique to eliminate or reduce the probability of failures associated with the risk in designing new products or at least to minimize the probability of failures occurrence. As appeared in many publications world-wide, DFMEA is used as a tool to assist design teams in addressing problem areas early on in the product development cycle, where changes are far less expensive. A group project is prepared for the students. They are requested to conduct a DFMEA on samples ranging from an automotive engine, car air-conditioning system, braking system, electrical system, suspension system, etc.

Delivery Process On Design For Environment

The topic of Design For Environment (DfE) is relatively new for students in Malaysia. In DFX course, the students are exposed to the importance of considering the impact of product designs on the total environment. DfE considers the potential environmental impacts of a product and the process used to make that product, including components and raw materials. DfE can be considered one facet of life cycle management. The life stages of a product start with the extraction of resources for raw material inputs, move to manufacturing, distribution, use, and end with disposal of the product and packaging at end of life.

DfE principles evaluate facility and local impacts, as well as global impacts and include habitat disturbance, emissions and effluents, chemical releases, inefficient use of water and energy, solid waste, and much more. Application of DfE also considers recovery of the product at the end of its useful life, through Design for Disassembly, Design for Remanufacturing, and Design for Recycling.

Delivery Process On Quality Function Deployment

The fourth DFX component to be taught is Quality Function Deployment (QFD). Quality must be designed into the product, not inspected into it. Quality can be defined as meeting customer needs and providing superior value. This focus on satisfying the customer's needs places an emphasis on techniques such as Quality Function Deployment to help understand those needs and plan a product to provide superior value. Quality Function Deployment (QFD) is a structured approach to defining customer needs or requirements and translating them into specific plans to produce products to meet those needs. The "voice of the customer" is the term to describe these stated and unstated customer needs or requirements. The voice of the customer is captured in a variety of ways: direct discussion or interviews, surveys, focus groups, customer specifications, observation, warranty data, field reports, etc. This understanding of the customer needs is then summarized in a product planning matrix or "house of quality". These matrices are used to translate higher level "what's" or needs into lower level "how's" - product requirements or technical characteristics to satisfy these needs. While the Quality Function Deployment matrices are a good communication tool at each step in the process, the matrices are the means and not the end. The real value is in the process of communicating and decision-making with QFD. QFD is oriented toward involving a team of people representing the various functional departments that have involvement in product development: Marketing, Design Engineering, Quality Assurance, Manufacturing/ Manufacturing Engineering, Test Engineering, Finance, Product Support, etc.

The active involvement of these departments can lead to balanced consideration of the requirements or "what's" at

each stage of this translation process and provide a mechanism to communicate hidden knowledge - knowledge that is known by one individual or department but may not otherwise be communicated through the organization. The structure of this methodology helps development personnel understand essential requirements, internal capabilities, and constraints and design the product so that everything is in place to achieve the desired outcome - a satisfied customer. Quality Function Deployment helps development personnel maintain a correct focus on true requirements and minimizes misinterpreting customer needs. As a result, QFD is an effective communications and a quality planning tool Quality Function Deployment requires that the basic customer needs are identified. Frequently, customers will try to express their needs in terms of "how" the need can be satisfied and not in terms of "what" the need is. This limits consideration of development alternatives. Development and marketing personnel should ask "why" until they truly understand what the root need is. Students are given one group assignment on developing the 'house of quality', which is the first matrix of QFD.

CHALLENGES FACED

It is important to note that, on a wider scale, the survival of manufacturing industries depends largely on faster delivery of better product and high quality and low cost to customers. In the case of Malaysia, the industries and organizations are looking for well-trained graduates to meet the above challenges. With respect to product design and manufacture, the abilities to visualize and predict the outcomes of decision made in developing new products at early design stage are vital for engineers in order to function effectively.

Engineering education has come under heavy criticism because of lack of attention to introducing new skills requirements and the need to better prepare engineering graduates for job demands. A study[7] was conducted on how engineers spent their time and what knowledge was required in their job assignments. This study found a considerable amount of knowledge that the engineers felt was required to perform their job but was not part of their undergraduate education. It was proposed by Troxler[8] that part of the solution to the above challenge involves discovery and identification of integrated activities sets and teaching methods that simultaneously supply students with the basic tools, critical thinking ability and synthesizing experiences with all aspects of modern manufacturing processes, in a way that allows them to be more productive and creative in industry, in a shorter period of time. Engineering students need to learn manufacturing engineering by integrating design, manufacturing processes, customers needs and wishes, cost sensitivity and failure predictions analysis.

Hence, in the DFX course, the challenges to be addressed are identified as follows:

1. Make the engineering students to function on multi-disciplinary teams,
2. Ability to communicate effectively and confidently,
3. Strong action and response in identifying, formulating and solving design and manufacturing problems,
4. Ability to use the techniques (DFA, DFMEA, DfE and QFD) for developing new products and effective processes.
5. Increase knowledge on contemporary issues that are related to new techniques and tools in product development process.

ASSESSMENT OF STUDENTS' LEARNING

The students viewed this DFX course as a totally new subject and it is interestingly different from the 'usual' engineering topics like strength of materials, thermodynamics, fluids mechanics and engineering mathematics. The assessment begins by evaluating the general level of interest on this subject, follows by the study on the usefulness of DFX course, then the interest and participation levels of the students on individual topics covered is covered. In addition, students were also asked to write a critical evaluation of their learning upon completion of the course. This is also presented subsequently.

The assessments were conducted on two students' batches at the university. They were the 2000/2001 Final Year undergraduate students and 2001/2002 Final Year undergraduate students respectively.

Level Of Interest On DFX Course – Before And After

In this survey, students were asked to indicate their respective level of interest on the DFX course prior to the first lecture at the beginning of the semester and at the final lecture before the examination week. The rating format used in the survey is shown in Figure 2.

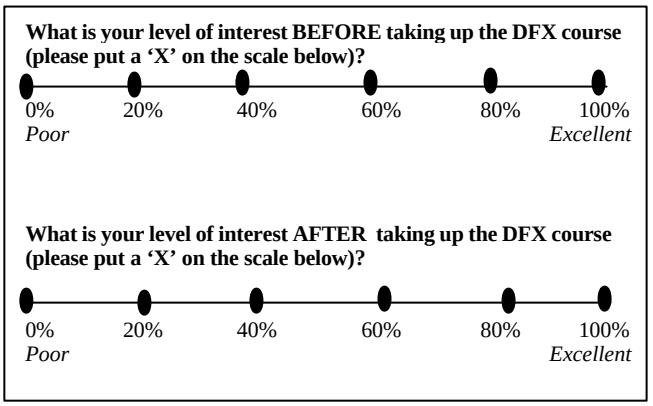

FIGURE 2
LEVEL OF INTEREST ASSESSMENT RANKING.

It is found that for the Year 2001/2002 students' batch, the score for BEFORE is 37% and for AFTER is 69% respectively. It is understood that the nearly half of the class are already well aware of the existence of methods such as DFA and QFD. This is due to the fact that such topics are also covered, although not in detailed, in other courses. Expectedly, nearly two-third of the students did pun a 'X' on the 80% point or higher on the level of interest AFTER taking up the DFX course. Only one student has indicated that the course did not meet the expectation as the scores for BEFORE and AFTER is similar as well as very low indeed.

With this initial assessment, it is believed that the DFX course has managed to increase the interest among the students on the important role of DFX tools and techniques in developing new products.

Usefulness Of DFX Course

The main aim of this particular assessment is to gather an insight among the students on the usefulness of the DFX course for their respective professional career after graduating from the university.

The survey format used in the assessment form is shown in Figure 3.

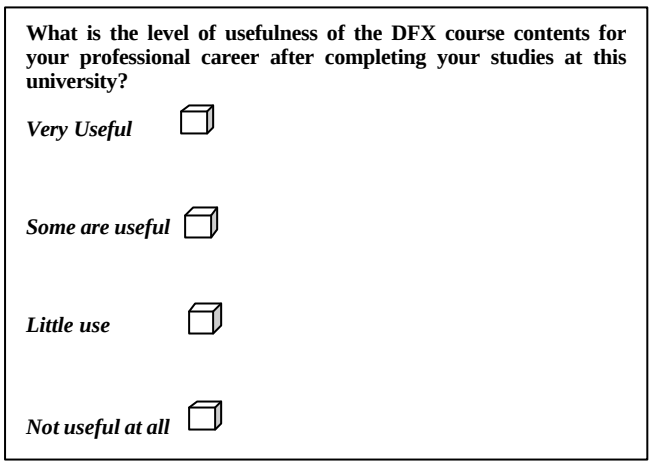

FIGURE 3
ASSESSMENT OF THE LEVEL OF USEFULNESS OF DFX FOR PROFESSIONAL CAREER AFTER GRADUATION.

The responses from students are collected for the Year 2000/2001 batch and Year 2001/2002 batch respectively. These values are shown in Figure 4. The black-colored bar represents the Year 2001/2002 students' batch and grey-colored bar represents the Year 2000/2001 students' batch respectively.

It can be seen that majority of the students ranging 50% to nearly 75% have indicated that the DFX course contents are very useful for their respective professional career after graduation. About 20% to 40% of students have stated that the DFX course contents have some level of usefulness, about 5% to 7% indicated that the DFX course contents have little use and none of the students have stated that the course contents are not useful at all.

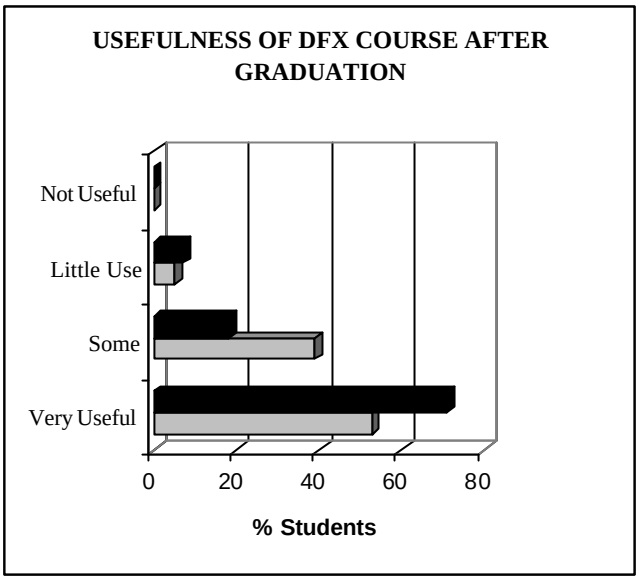

FIGURE 4
STUDENTS' RESPONSE ON THE USEFULNESS OF DFX COURSE CONTENTS AFTER GRADUATION

This assessment provides an indication that the students did value the contents of the DFX course. The high values on the 'Very Useful' category show that the DFX course does provide a value-added knowledge for these undergraduates when they are applying for jobs especially in the manufacturing-related industries.

Students' Interest Level On Individual Topics

There are four topics that are covered substantially in the DFX course, namely, DFA, DFMEA, DfE and QFD. For the DFA topics, there are two major sub-topics that are taught to the students. These are Boothroyd-Dewhurst Inc. DFA Method and Lucas Design For Assembly Method respectively.

The assessment format used in gathering the students' responses is shown in Figure 5. Students were asked to put a 'X' on the appropriate scale for each topics covered in the DFX course. The objective of this assessment is to determine the students' ability to appreciate and apply these tools and techniques in problem-solving environment relating to a product development process. Hence, their appreciations on these tools and techniques are directly proportional to their own interests in learning about these methods. The higher the level of interest would indicate that the students were really well-versed on applying these DFX tools and techniques aptly.

Please indicate your LEVEL of INTEREST in the following topics. Put a 'X' on the appropriate scale.

DFA by Boothroyd-Dewhurst Inc

0% *Not interested at all* — 100% *Very much interested*

DFA by Lucas

0% *Not interested at all* — 100% *Very much interested*

Design Failure Mode and Effect Analysis

0% *Not interested at all* — 100% *Very much interested*

Design For Environment

0% *Not interested at all* — 100% *Very much interested*

Quality Function Deployment

0% *Not interested at all* — 100% *Very much interested*

FIGURE 5
ASSESSMENT FORMAT FOR STUDENTS' INTEREST LEVEL ON INDIVIDUAL TOPICS IN THE DFX COURSE.

Results from the students' assessment on the individual topics covered in the DFX course are depicted in Figure 6. The black-colored bar represents the Year 2001/2002 students' batch and gray-colored bar represents the Year 2000/2001 students' batch respectively.

It can be seen from the bar chart that all the DFX tools and techniques covered in the course have received generously very high level of interest among the students (Rank 100 = Very interested, Rank 0 = Not interested at all). The two-year study has indicated that the DFA Method developed by Boothroyd-Dewhurst Inc. is ranked as the top DFX topic. This DFA technique uses quantitative data like handling time, insertion time and assembly costs whereby students can actually study the impact of their decision-making immediately. Therefore, this would enable the students to visualize the outcomes of analysis in terms of dollars and cents. This is one of the major advantages of Boothroyd-Dewhurst Inc.'s DFA Method.

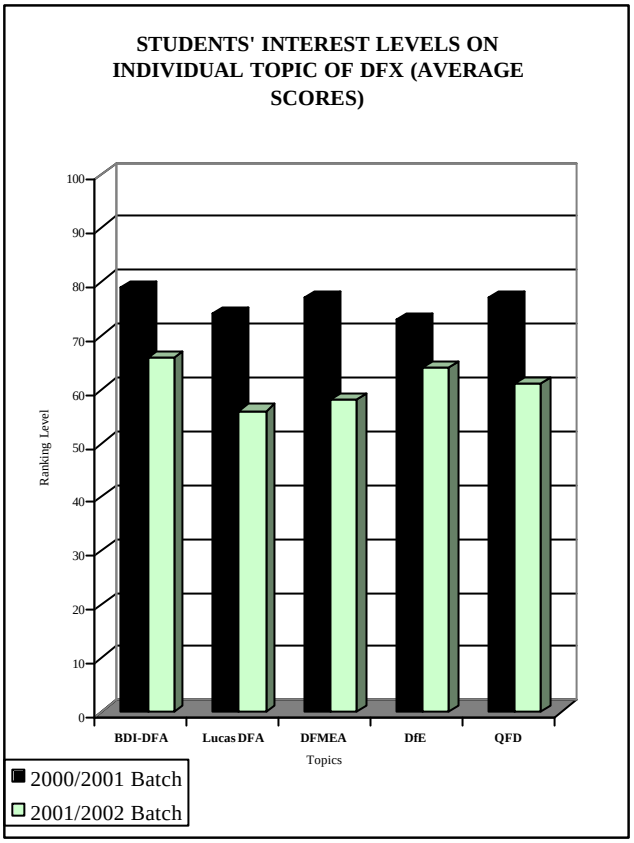

FIGURE 6
STUDENTS' INTEREST LEVEL ON INDIVIDUAL TOPICS OF DFX COURSE

It is interesting to point out that the students regarded these tools as very flexible and easy to implement. This is due to the fact that the techniques involved very little complex mathematical equations that the students are used to in other 'heavy' engineering subjects. The ability to get the results quickly while working in a team environment also provides a significant value-added factor into the delivery process of teaching the DFX course.

Written Critical Evaluation By The Students

In addition to the quantitative assessment above, students were also asked to write a critical evaluation of their learning - throughout the duration of the DFX course – upon completion of the course. Comments from their individual learning statements yielded insight into the students' knowledge development during the course. For instance, the students learned many innovative lessons about the product development process as indicated by comments like these:

> *"This course offers some new innovations and designs into a product development process. It is helpful to create a better and higher quality product."*

"The course has a very wide view (on product development process), can learn many aspects which are related especially the business point of view, how to generate new ideas for a successful business."

"The content of the course, especially (where) I can learn on how to improve a product design through DFA. I learn more about product design."

Many students commented on the 'real world' experiences as offered by the DFX course. Three students made the following statements in the critical evaluation form:

"The real life (examples) and the overall subjects that the lecturer has linked together are very good."

"I gain an experience on developing new products and learn about real life manufacturing problem solving and analysis."

"On hand experience about a real product. That's what I like about this course."

The students also learned how teamwork and communication could strengthen a design team. Three comments are given as follows:

"The group discussion about (re-design) the three-pin plug where we can work as a team."

"Re-design the mobile phone using DFA method with my team is what I really appreciated."

"It (the DFX course) gives me an early experience how to manage the teamwork."

Many students alluded to the importance of DFX course for their career development as they learned how to deal with a product development process scenario as revealed by the following comments:

"Topics (covered in the DFX course) are very important and related for future (career)."

"Very interesting and useful for my career development"

"The course has introduced practical skills that can be applied in industry."

On the constructive criticisms part, students did voice out interesting suggestions for the betterment of future DFX course. The knack to provide these comments demonstrated the students awareness of the importance of value-added contents for the course in future.

"Have more case studies on the practical usage of DFA, DFMEA, etc.,".

"Bring in more real life applications (on DFX techniques) in various industries."

"More outdoor case studies, or real life case studies where we can have a visit to a manufacturing company and evaluate the product development stages."

In fact, nearly 85% of the statements reviewed have indicated the students' desire to have more practical examples regarding actual implementation of DFA, DFMEA, DfE and QFD in industries. This shows that students did value the importance of learning on how these tools and techniques actually used in the manufacturing industry.

There are also comments from the students on the learning approach used by the lecturer in teaching the DFX course. This is expected because the students did have the liberty to compare the teaching approach used in the course with other courses at the university that the students have attended. Among motivating comments are:

"His (the lecturer) ideas and teachings are clear and go directly to the students."

"The lecturer has raised my interest in this subject since the first lecture and my interest has since been very high for this subject."

"The lecturer has managed to address 85% of my early expectations about this course. However, some detailed explanations about QFD are not enough for this course."

"Most of the examples are from automotive industries, but (in) the real world would be better to use examples from other industries."

The statements above do highlight an important point regarding the availability of real life examples from manufacturing companies in Malaysia. Manufacturing companies or organizations are often reluctant to allow access to detailed information, for example, manufacturing times and costs, or often do not know them. It is viewed that in future, better interaction between the related companies and the university could add a bigger impact into getting more examples for the benefits of the students. Undoubtedly, all of the students completed the course with a better understanding of the importance role of DFX tools and techniques and an appreciation for the knowledge gained throughout the course. The value-added responses studied are a clear evident thus far.

DISCUSSION

The students' learning assessment has generated very interesting analysis. Overall, the students' interest level on the DFX course has risen because the course has introduced them to various tools and techniques that are crucial in developing new products. These tools and techniques are never taught in detail in other courses.

Among the topics covered in the course, the Boothoryd-Dewhurst Inc.'s DFA Method has been ranked as the most interesting topic by over 65% of the students from the two batches. Students are given the opportunity to re-design commonly used product such as the 13-amp three-pin plugs using the Boothroyd-Dewhurst Inc.'s DFA Method in a team environment. The three-pin plugs' assignment whereby an evaluation of product design with respect to ease of assembling and, to some extent, ergonomics perspectives respectively, has provided for a highly accessible, error-free learning environment in which all students enrolled in the DFX course have the capacity to participate. The ability for these future young engineers to think creatively along the DFA guidelines[9] has given a valuable exposure into the world of systematic new product development process (PDP).

In reviewing students' project reports, majority of them have indicated that ease of assembly – which is the main aim for DFA - would be easily achieved by removing mechanical fasteners alone. Since elimination of mechanical fasteners like screws, bolts and solders would reduce the total assembly time and total assembly costs. This kind of early exposure on a product development process for them is definitely vital especially when the students are employed by respective manufacturing industries after completing their studies.

The Impact Of Outdoor Assignment and Group Work

The students did enjoy the outdoor assignment on DFMEA. They were asked to perform a DFMEA on one of many systems currently available in a car. Doing an assignment away from the usual classroom environment has created a atmosphere of better communication among themselves. Students were seen to have the freedom to discuss the subject matter rather effectively and confidently when they have a better view of the problems, in this case, identifying possible failures and modes of failure of an automobile's system (braking, electrical, air-conditioning, exhaust, etc.).

Through the DFMEA evaluation by each team member, the students easily identified the anticipated failures and be able to rank these failure according to the three major ranking criteria of DFMEA; 1) Occurrence Ranking, 2) Severity Ranking, and 3) Detection Ranking. In addition, the students would discuss on the possible corrective actions to be taken to overcome or reduced the likely failures of the system.

Students did enjoy doing the group assignments. This is basically the essence of applying the DFX tools and techniques. These tools and techniques are primarily aimed for teamwork and they are quite difficult to be used by a single engineer working on his or her project alone.

Inadequate Practical Examples On DFX

Students have argued that the DFX course lacks practical or real life examples. This view is quite valid. However, to obtain as many real life examples on DFX implementation in Malaysia as possible is seen to be a gigantic task. As indicated at the beginning of this paper, many industries in Malaysia have yet to fully utilized these tools and techniques since most of them are involved only on the so-called downstream activities like final assembly, piece parts manufacturing and product packaging. Whereas the design activity is perform at the parent companies that are located elsewhere in USA, Europe and Japan.

On the positive side, most of the information and references related to DFX course contents gathered by the students were found through the world-wide-web. However, these, according to the students are not adequate. It is found out that nearly 80% of the responses studied did mention on the need to make available study materials including industrial practical examples, case studies materials, industrial projects' reports, related journals and conferences' proceedings to the students. This need would stretch the financial commitments on behalf of the faculty towards a new height. Further work is being done to assess the financial requirements of this need. One suggestion is to request assistance from related industries to play a role in providing the necessary resources.

Teamwork Development

The ability to work as team as mentioned by the students is crucial to overcome the challenges in delivering this course. Arguably, students did appreciate the opportunity to work as a team while completing the projects given to them. The high percentages of students have indicated that the DFX course is very useful for their future career. Hopefully, this scenario could break the 'over the wall' syndrome that have affected many manufacturing companies and organizations throughout the country in particular, and the whole world in general.

Although the time spent and the amount of work being accomplished are not that great to allow the students a much wider exposure into the team work development, but the encouraging comments being mentioned in the students' assessment feedback have indicated the need to allocate more time and resources into finding ways and mechanisms whereby students can perform and be evaluated as a team during the DFX course. The formal student evaluation for this course could be reviewed and better marking scheme

should be created for evaluating each team member role in a group assignment.

New Challenges For Future Endeavors

Overall, the DFX course has managed to address the challenges that are specified early in this paper. The five challenges have been confronted quite successfully. These successes are identified as:

1. The students did function as a team in solving product development related problems and tasks,
2. Students were able to communicate effectively as a team member,
3. Strong action and response in identifying, formulating, and solving design and manufacturing problems using DFX tools and techniques as systematic guidelines,
4. Students were confident in applying DFX tools and techniques, most noticeably, the Boothroyd-Dewhurst Inc.,'s DFA Method and DFMEA.
5. Students' knowledge increases by learning these tools and techniques.

Nevertheless, the study has shown that new challenges are found, and subsequently they require an urgent attention and action must be taken to overcome them. The **new challenges** are:

1. Availability of more real life examples and case studies for the students.
2. Allocation of more time on certain topics including DfE, QFD and DFMEA.
3. Visits to companies that use these DFX tools and techniques should be arranged for the benefits of the students.
4. More outdoor group assignments to be planned for the students.
5. Designing a better formal assessment scheme to evaluate student's performance in the areas of teambuilding and related skills.
6. Encouraging active participations from manufacturing companies in terms of information sharing.

The course administrator and relevant faculty members at the university are studying the new challenges. On-going developments are taking place currently for an improved curriculum of this DFX course. Students' enrolment for this course has been steadily increased.

CONCLUSION

In this paper the challenges in developing and managing a DFX course and the newly found challenges are presented. The teaching delivery process of various DFX tools and techniques and the students' learning assessment are discussed. Allowing students to explore and learn about practical methods in product development process, manufacturing cost savings and reducing human injuries through simple designs remove much of the frustration engendered by attempting to learn without doing[9]. The outdoor group assignments have demonstrated the ability of the students in working as a team in solving design and manufacture problems. Lack of real life examples in DFX related work exposed the limitation in delivering this course. Efforts have been carried out to address this issue.

The paper wishes to conclude by highlighting the following main points:

1. Development of teamwork, creation of better product designs, improvement in visualization skill, and enhancement in problem-solving skill in the DFX course allow the students to see more tangible results from their work and provide an accompanying feeling of satisfaction.
2. DFX course is seen to provide for a range of activities that requires the application of knowledge in a context which relates the market being served, the technology of product design and the applications of advanced manufacturing technologies.
3. Future work on developing competence product design engineers could be based on creating more opportunities for the undergraduate students to learn and apply the knowledge of DFX on a wider scale. This opportunity could be applicable to the Malaysian scenario in order to sustain the rapid growth of manufacturing sector in tandem with the country's pursuit of a fully-industrialized country by the Year 2020.
4. DFX education should be introduced and enlarged in all faculties of engineering at higher learning institutions Students entering the world of professional engineering should be educated and trained in a way that makes them respond to the modern day challenges of industry.

Finally, developing and managing a new course is not a simple job. Just as in the development of a new product, there are many factors that determine the success of the course. The success in overcoming existing challenges has generated new challenges to be confronted as shown in this study. Students' responses and comments were very positive and highly valued. It is anticipated that the course will grow in size. Being a newly-established course, it requires a significant investment of faculty time and effort. The course administrator and the faculty management must develop methods including the delivery process that allow a larger population of students to enroll in this course while keeping faculty commitments at a reasonable level.

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