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Learning Assessment on the Effectiveness of Teaching Delivery in Manufacturing Engineering Education*

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This article presents a two-year study in creating the right environment for teaching delivery in manufacturing engineering education. The core theme in this course is Design-For-X (DFX). A major agenda of this article is the effective teaching delivery designed to enhance the crucial impact of the DFX in developing new and novel products. This course is offered against more traditional engineering subjects in order to update and boost the design content of the current manufacturing and CAD/CAM undergraduates' curricula respectively. Students are exposed to various DFX tools like Design For Assembly, Design For Environment, Design Failure Mode and Effect Analysis, as well as Quality Function Deployment. It is noted that major accomplishments by students include teamwork awareness, better problem definition skills, responsiveness and innovativeness. The perception that engineers are required to think creatively and critically is clearly shown by students. Students' responses to the DFX course are presented and evaluated. The article also discusses the strengths and limitations of the current DFX course contents, as well as new challenges for future endeavours.

INTRODUCTION

The manufacturing sector has turned out to be one of Malaysia's major income-generating activities since the early 1970s. With a contribution of over 28% of the Gross Domestic Product (GDP), the manufacturing sector is spearheading the Malaysian economy, most notably after the 1998 downturn [1]. Nevertheless, Malaysia cannot claim that it is capable of exploiting 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 institutions is presently grossly inadequate. A lack of qualified manufacturing engineers and not enough specialists with industry specific knowledge have been identified as two common barriers to implementing advanced manufacturing technologies in Malaysia [1].

This article has been written in order to discuss an evaluation of innovative teaching delivery of an integrated product design course called Design-For-X (DFX) at a premier engineering university in Malaysia. The objective of this course is to give manufacturing engineering students an insight into the expanding role of the manufacturing function by providing a broad-based view of industrial needs and a knowledge of the enabling technologies and techniques, primarily DFX.

The DFX consists of many reliable and tested approaches and techniques, including Design For Assembly (DFA), Design Failure Mode and Effect Analysis (DFMEA), Design For Environment (DfE), Quality Function Deployment (QFD) and others. The DFX can contribute in many ways to the improvement of productivity, increased quality and reduced reworking costs, improved production efficiency and shortened production cycles.

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In this article, the 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 lifecycle support.*

A two-year study on the implementation of the innovative teaching delivery for the DFX course is presented here.

JUSTIFICATION FOR THE 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) are specifically included within the definition of DFX. At the same time, educating young manufacturing engineering undergraduates at the university level of the DFX is a key strategy that this article endeavours to draw out by addressing two broad aims, namely:

- The DFX's relevance to the formation of young professional engineers specialising in total product development.
- The DFX's importance within the context of total design and advanced manufacturing technologies in presenting a holistic view of product development.

The holistic view of product development is consistent with Pugh's concept of *total design*, which envelops a much wider spectrum than conventional or traditional engineering [3]. 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 needs. The design core is that which connects the selling back to market needs.

In a product context, appropriate technology dependent methods are necessary and these methods cover the area of traditional engineering that address the suitable use of materials for a product's design and to serve functional needs. Traditional engineering is being complemented with further methods (often team-based) in order to assist with the efficiency and effectiveness of the design core, such as 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 organisation, it is axiomatic that serving manufacturing needs will also serve market needs due to the required responsiveness to customers. One danger of the traditional engineering approach, which is centred on product design for function only, is that the business organisation encourages designers to indulge themselves in engineering design and less in communication and assessing the overall needs to be served.

DELIVERY MECHANISMS FOR DFX TEACHING

The DFX course covers a structured methodology in design and manufacture. The planned development and delivery process is shown in Figure 1. This course

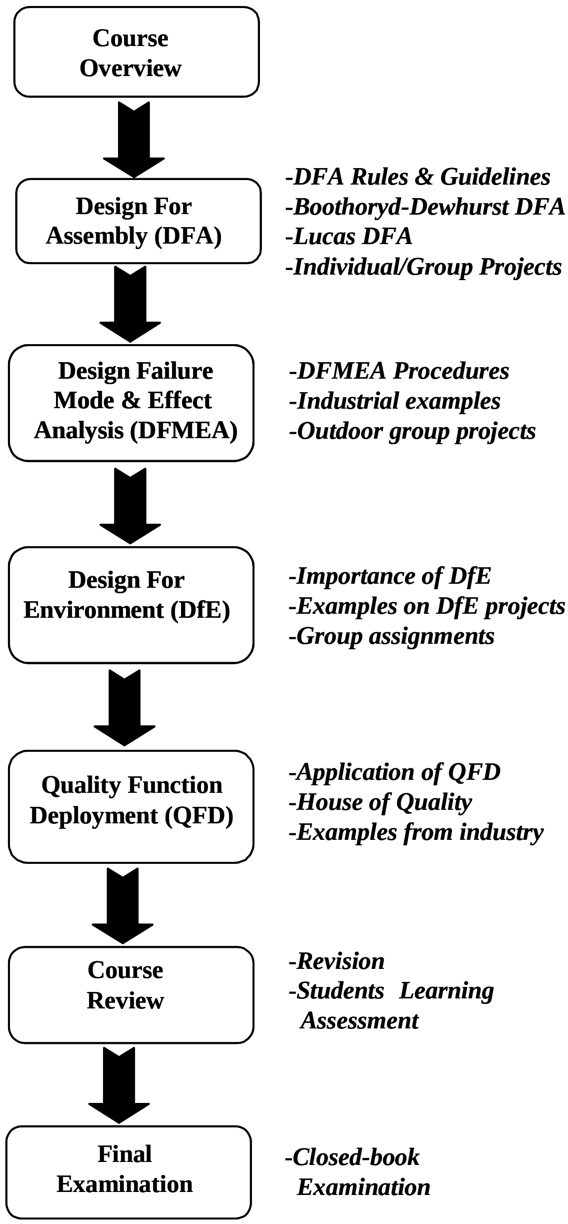

Figure 1: Development and delivery flowchart of the DFX course.

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. The detailed descriptions of each topic can be found elsewhere [4-6].

Within the DFA course, students are given valuable opportunities to learn to simplify product designs and reduce the amount of motion required to assemble a product. The method focuses on designing a product for ease of assembly. Therefore, in order to accomplish ease of assembly, first and foremost, an assembly has to be rationalised. A rationalisation of assembly accomplishes an improvement in the effectiveness of an assembly, the quality of the product and the environment surrounding the assembly system.

During these sessions, students are told to adhere to the four main goals that must be achieved in designing for ease of assembly, namely:

- Goal 1: Improvement of the effectiveness of an assembly operation.
- Goal 2: Improvement of product quality.
- Goal 3: Improvement of the assembly system usability.
- Goal 4: Improvement of the working environment within the assembly system (for the operators).

Two commercially available DFA packages are used in the teaching delivery, namely: Boothroyd Dewhurst DFA [5] and Lucas Design For Assembly Technique [6]. Students will be given one individual assignment and one group project for evaluation purposes.

For the individual assignment, students have to investigate the usefulness of DFA commercial packages, its strengths and weaknesses, the popularity of these packages in related industries and a description of several real-life applications of DFA.

In the group project, students are requested to conduct a DFA analysis on currently available products, such as a three-pin electric plug, a personal computer mouse, a telephone set, PC printer, etc. Students have to conduct the study for a given duration in the classroom and submit a written report on the project. Students are evaluated on team effort, time to complete the given assignments, the ability to defend the outcomes of their DFA analyses and the clarity of their reports.

Delivery Process on Design Failure Mode and Effect Analysis

The topic on Design Failure Mode and Effect Analysis (DFMEA) is taught to students immediately after completing the DFA exercises. DFMEA is a structured and analytical approach that is used to identify potential areas of design and process-related risks. The ultimate objective in this session is to teach students in a proven technique in order to eliminate or reduce the probability of failures associated with the risk in designing new products, or at least to minimise the probability of failures occurring.

As presented in many publications worldwide, DFMEA is used as a tool to assist design teams in addressing problem areas early in the product development cycle, where changes are far less expensive. A group project is prepared for students, who are requested to conduct a DFMEA on samples ranging from an automotive engine, a car’s 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 the DFX course, 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 processes used to make that product, including components and raw materials. DfE can be considered one facet of lifecycle 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 the disposal of the product and packaging at the end.

DfE principles evaluate facilities and local – as well as global – impacts. They also include habitat disturbance, emissions and effluents, chemical releases, inefficient use of water and energy, solid waste, and much more. The 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 of 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. The focus on satisfying a customer’s needs places an emphasis on techniques, such as QFD, in order to help understand those needs and plan a product to provide superior value. QFD is a structured approach to defining customer needs or requirements and translating them into specific plans so as 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, observations, warranty data, field reports, etc.

This understanding of customer needs is then summarised in a product planning matrix or *house of quality*. These matrices are used to translate higher level *whats* or needs into lower level *hows* - product requirements or technical characteristics to satisfy these needs. While the QFD matrices are a good communication tool in each step of 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 towards involving a team of people who represent various functional departments that are involved in product development, including: marketing, design engineering, quality assurance, manufacturing/manufacturing engineering, test engineering, finance, product support, etc.

The active involvement of these departments can lead to a balanced consideration of the requirements, or *whats*, at each stage of this translation process and provide a mechanism to communicate hidden knowledge, which is known by one individual or department but may not otherwise be communicated through the organisation. The structure of this methodology helps development personnel understand essential requirements, internal capabilities and constraints, and thus design the product so that everything is in place in order to achieve the desired outcome - a satisfied customer.

QFD helps development personnel maintain a correct focus on true requirements and minimises misinterpreting customer needs. As a result, QFD is an effective communications and a quality planning tool. QFD requires that 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 the 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 IN ACHIEVING INNOVATIVE TEACHING DELIVERY

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

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

- Engineering students should be able to effectively function in multidisciplinary teams;
- Engineering students should be able to communicate effectively and confidently;
- There should be strong action and response in identifying, formulating and solving design and manufacturing problems;
- Engineering students should have the ability to utilise various techniques (DFA, DFMEA, DfE and QFD) to develop new products and effective processes;
- Knowledge of contemporary issues, which are related to new techniques and tools in the product development process, should be increased.

COLLATING LEARNING ASSESSMENT

Students viewed this DFX course as a totally new subject and interestingly different from the *usual* engineering topics, like strength of materials, thermodynamics, fluids mechanics and engineering mathematics.

Assessment begins by evaluating the general level of interest in this subject, followed by a study on the usefulness of the DFX course, then interest and participation levels of students in individual topics is covered. In addition, students were also asked to write a critical evaluation of their learning upon completion of the course.

The assessments were conducted on two groups of students at the university, namely: the 2000/2001 final year undergraduate students and the 2001/2002 final year undergraduate students.

Students' Interest Level in the 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. It was found that for 2001/2002 group, the score for *before* was 37% and for *after* was 69%.

It is understood that the nearly half of the class were already well aware of the existence of methods such as DFA and QFD, primarily due to the fact that such topics are also covered, although not in detail, in other courses. As expected, nearly two-thirds of the students placed an *X* at the 80% point or higher on the level of interest *after* taking up the DFX course. Only one student indicated that the course did not meet his/her expectations, as the scores for *before* and *after* were similar, as well as being very low indeed.

Usefulness of the DFX Course

The main aim of this particular assessment is to gather insight into students' perception on the usefulness of the DFX course for their respective professional career after graduating from the university. Responses from both groups of students were collected; these values are shown in Figure 2.

The black coloured bar represents the year 2001/2002 group and the grey coloured bar represents the year 2000/2001 group. It can be seen that majority of students, ranging from 50% to nearly 75%, indicated that the DFX course contents were very useful for their respective professional career after graduation.

About 20-40% of students stated that the DFX course contents had some level of usefulness, while about 5-7% indicated that the DFX course contents had little use. No student stated that the course contents were not useful at all.

This assessment provides an indication that students did value the contents of the DFX course.

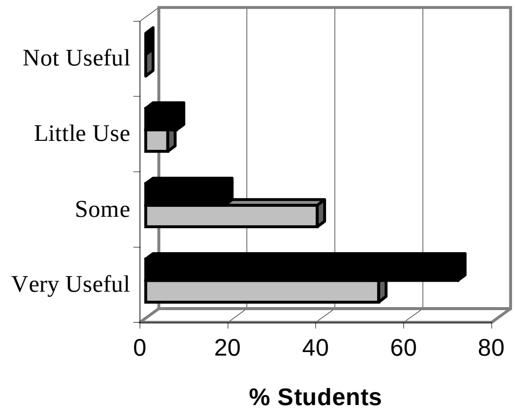

Figure 2: Usefulness of the DFX course.

The high values on the v*ery useful* category show that the DFX course does provide value-added knowledge for these undergraduates when they apply for jobs, especially in manufacturing-related industries.

Students' Level of Interest in Individual Topics

Four topics have been substantially covered in the DFX course, namely: DFA, DFMEA, DfE and QFD. There are two major sub-topics taught to the students with regard to DFA; these are the Boothroyd Dewhurst DFA method and the Lucas Design For Assembly method.

The objective of this assessment is to determine students' ability to appreciate and apply these tools and techniques in a problem-solving environment as it relates to a product development process. Hence, their appreciations of these tools and techniques are directly proportional to their own interests in learning about these methods. The higher the level of interest indicates that students were really well versed in applying these DFX tools and techniques appropriately.

Results from students' assessment on the individual topics covered in the DFX course are shown in Figure 3. The black coloured bar represents the year 2001/2002 group, while the grey coloured bar represents the year 2000/2001 group. It can be seen from this bar chart that all of the DFX tools and techniques covered in the course received generously high levels of interest among students (rank 100 = very interested; rank 0 = not interested at all).

The two-year study indicates that the DFA method developed by Boothroyd Dewhurst is ranked as the top DFX topic. This DFA technique utilises quantitative data like handling time, insertion time and assembly costs, whereby students can actually study the impact of their decision-making immediately. There-

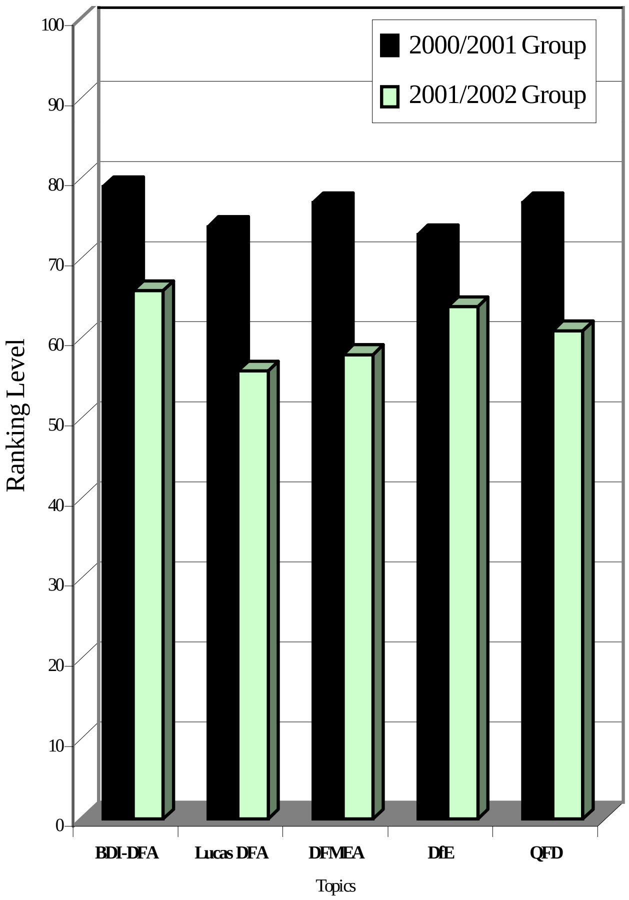

Figure 3: Students' interest levels in individual topics of the DFX course.

fore, this would enable students to visualise the outcomes of analysis in terms of dollars and cents. This is one of the major advantages of Boothroyd Dewhurst's DFA method.

It is interesting to note that 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 of the type that students were used to in other *heavy* engineering subjects. The ability to get results quickly, while also working in a team environment, provided a significant value-added factor into the delivery process of teaching the DFX course.

Students' Written Evaluation

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

- *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 the product development process], *can learn many aspect 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.*
- *Hands-on experience about a real product. That's what I like about this course.*

Students also learned how teamwork and communication could strengthen a design team. Comments on this area included:

- *I liked the group discussion about* [redesigning] *the three-pin plug where we can work as a team.*
- *Re-design the mobile phone using the DFA method with my team is what I really appreciated.*
- *It* [the DFX course] *gives me an early experience on how to manage teamwork.*

Many students alluded to the importance of the DFX course for their career development, as they learned how to deal with a product development process scenario. This was 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.*

With regard to constructive criticism, students did voice some interesting suggestions to improve future DFX courses. By providing these comments, students demonstrated awareness of the importance of value-added contents for the course in the future. Student suggestions included:

- *Have more case studies on the practical usage of DFA, DFMEA, etc.*
- *Bring in more real life applications* [of DFX techniques] *in various industries.*
- *Include 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 indicated 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 how these tools and techniques are actually used in the manufacturing industry within the country.

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

- *His* [the lecturer's] *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.*

These statements do highlight an important point regarding the availability of real life examples from manufacturing companies in Malaysia. Manufacturing companies or organisations 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 the future, better interaction between related companies and the university could add a bigger impact with regard to gaining more relevant examples for the benefit of students.

Undoubtedly, all students completed the course with a better understanding of the importance of DFX tools and techniques and an appreciation of the knowledge gained throughout the course. The value-added responses provide clear evident of this.

DISCUSSION

Students' learning assessments generated a very interesting analysis. Overall, students' interest levels in the DFX course rose because the course 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 Boothroyd Dewhurst DFA method was ranked as the most interesting topic by over 65% of students from both groups. Students were given the opportunity to re-design commonly used products, such as the 13-amp three-pin plugs, using the Boothroyd Dewhurst DFA method in a team environment. The three-pin plugs' assignment, whereby an evaluation of the product design with respect to ease of assembly and, to some extent, ergonomics, provided for a highly accessible, error-free learning environment in which all students enrolled in the DFX course had the opportunity to participate in. For these future young engineers, the ability to think creatively along DFA guidelines gave valuable exposure to the world of systematic new Product Development Processes (PDP) [9].

The majority of students' project reports indicated that ease of assembly, which is the main aim for DFA, would be easily achieved by removing mechanical fasteners alone, since the 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 given that students are to be employed by manufacturing industries after completing their studies.

Outdoor Assignment and Group Work

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

Students easily identified the anticipated failures through the DFMEA evaluation by each team member. They were also able to rank these failures according to the three major ranking criteria of DFMEA, namely:

- Occurrence ranking;
- Severity ranking;
- Detection ranking.

In addition, students would discuss possible corrective actions that needed to be taken in order to overcome or reduce likely failures of a system. Students enjoyed doing the group assignments, which involved applying DFX tools and techniques. These tools and techniques are primarily designed for teamwork and are quite difficult to be used by a single engineer working on a project alone.

Inadequate Practical Examples and Case Studies

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 the DFX implementation in Malaysia as possible is seen to be a gigantic task. As indicated at the beginning of this article, many industries in Malaysia have yet to fully utilise these tools and techniques, since most of them are involved only on so-called downstream activities like final assembly, piece parts manufacturing and product packaging. The design activity is performed by parent companies that are located elsewhere, for instance in the USA, Europe and Japan.

On the positive side, most of the information and references related to DFX course contents gathered by students were found via the World Wide Web (WWW). However, these sources, according to students, are inadequate. It was found that nearly 80% of the responses studied mentioned the need to make available study materials, including industrial practical examples, case studies materials, industrial projects' reports, related journals and conference proceedings, to 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 in order to meet this need. One suggestion is to request assistance from related industries to play a role in providing the necessary resources.

New Challenges Discovered

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

- Students functioned as a team in solving product development related problems and tasks.
- Students were able to communicate effectively as team members.
- Strong action and responses in identifying, formulating, and solving design and manufacturing problems using DFX tools and techniques as systematic guidelines.
- Students were confident in applying DFX tools and techniques, most noticeably the Boothroyd Dewhurst's DFA method and DFMEA.
- Students' knowledge increased by learning these tools and techniques.

Nevertheless, the study has shown that new challenges have been discovered and they subsequently require urgent attention, and action must be taken to overcome them.

These new challenges are as follows:

- The availability of more real life examples and case studies for students.
- The allocation of more time to certain topics, including DfE, QFD and DFMEA.
- Visits to companies that use these DFX tools and techniques should be arranged for the benefit of students.
- More outdoor group assignments to be planned for students.
- Design of a better formal assessment scheme in order to evaluate student performance in the areas of teambuilding and related skills.
- Manufacturing companies should be encouraged to actively participate in terms of information sharing.

The course administrator and relevant faculty members at the university are studying these new challenges. Ongoing developments are currently taking place for an improved curriculum of this DFX course. Student enrolments for this course have steadily increased.

CONCLUSION

In this article, the learning outcomes in developing and managing the innovative teaching delivery of the DFX course and newly found challenges are presented. The teaching delivery process of various DFX tools and techniques, as well as students' learning assessment , have been discussed.

Allowing students to explore and learn about practical methods in the product development process, including 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 demonstrated the ability of students to work in teams to solve design and manufacture problems.

A lack of real life examples in DFX related work exposed one limitation in delivering this course. Efforts have been carried out to address this.

The article concludes by highlighting the following main points:

- The development of teamwork, creation of better product designs, improvement in visualisation skills, and enhancements in problem-solving skills in the DFX course permitted students to see results more tangibly in their work and provided an accompanying feeling of satisfaction.
- The DFX course was seen to provide a range of activities that requires the application of knowledge in a context that relates to the market being served, the technology of product design and applications of advanced manufacturing technologies.
- Future work on developing competent product design engineers could be based on creating a more innovative teaching environment for undergraduate students to learn and apply DFX knowledge on a wider scale. This opportunity could be applicable to the Malaysian scenario in order to sustain rapid growth in the manufacturing sector in tandem with the country's pursuit of a fully industrialised country by 2020.
- 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 modern-day challenges of industry.

Finally, creating and managing an innovative teaching delivery is not a simple task. 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, to allow a larger population of students to enrol in this course, while keeping faculty commitments at a reasonable level.

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BIOGRAPHY

Abdul-Shukor Abdullah, born in 1964, is an associate professor at the Faculty of Engineering Industry, University of Industry, Selangor, Shah Alam, Malaysia. He received his BEng (Mechanical Engineering) from RMIT in Melbourne and MSc in Computer Integrated Manufacture from Loughborough University of Technology in England. He has written and published numerous articles and refereed papers on product design strategies and techniques. Abdul-Shukor is regarded as a pioneer in introducing new product design learning delivery in Malaysia. He serves as an advisor-cum-external assessor for the Malaysian Technology Development Corporation (MTDC), a government agency for the distribution of technology acquisition funds.

His research interests include engineering curriculum design, product design for manufacture and assembly, quality management techniques, computer-aided design and design for the environment.

In 2003, he has been nominated for the Malaysia Toray Science Foundation's *Science and Technology Award* in recognotion of his impressive contributions in the field of technology and engineering education development.