Framework for Orienting Engineering Undergraduate Final Year Projects towards New Product Innovation Process

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Abstract

The traditional framework for undergraduate final year project (FYP) has customarily focused on the sharpening of theoretical principles and the honing of fundamental practical skills. This work sees the pressing need for orienting FYPs at the undergraduate level towards new product innovation. Hence, an unconventional framework, incorporating new product development (NPD) processes and practices, is created, aiming to generate more balanced and productive graduates; and enabling them to contribute to the NPD innovation process. For the purpose of comparison, the traditional FYP framework is firstly introduced. Then, each phase in the new framework, which embodies the actual activities carried out in a customer-oriented organization, is presented in detail. In addition to that, a project was developed and the proposed framework was implemented. As a result, a potential was found for the new developed framework.

1. Introduction

In the last few decades, attempts have been made to define the new product development (NPD) process. Many models have also been created to explain the procedures of NPD. A model was described by Booz *et al* (1968) for NPD, which consists of six stages with the following stage-gates: exploration, screening, business analysis, development, testing, and commercialization [1]. The whole NPD process may include many sub-processes, sub-stages, or sub-phases. Wilson et al (1996) have presented a model for the product development process, which is made up of nine distinct phases [2]. The model deals with: product ideas, customer future needs projection, product technology selection and development, process technology selection and development, final product definition and project targets, product marketing and distribution preparation, product design and evaluation, manufacturing system design, and finally product manufacturing, delivery and use. Mcdermott and Handfield (2000) have defined NPD process as a process from new product idea generation (by marketing and/or R&D) to the promotion and sale of the product [3]. In the PDMA Handbook of New Product Development, the product development process is defined as "A disciplined and defined set of tasks, steps and phases that describe the normal means by which a company repetitively converts embryonic ideas into salable products or services." [4]. In fact, a successful new product does more good for an organization than anything else does. A recent study by Cooper (2001) showed that among the successful new products studied, half achieved at least a 33 percent return on investment; half had payback periods of two years of fewer, and half achieved at least 35 percent market shares [5]. This invites a plethora of generic formulations in the field of NPD. For instance, NPD processes have been reengineered to facilitate better planning, formation and organization of cross-functional work teams and groups that may be involved in the product development process [6].

The outsourcing of almost any stage of the NPD process can lead to financial benefits. Basic research and early stage development could be outsourced to universities, government laboratories, and advanced development and product innovation to suppliers. Business processes and new product launches could be outsourced to distributors and wholesalers [7]. A study on Malaysian firms that outsource NPD activities examined the distribution of co-operative partners when a part of the NPD process was outsourced. Percentage of firms, which outsourced their activities to universities or colleges, was notably low [8]. Unfortunately, a similar trend was displayed with universities or research institutes that originated ideas for NPD [9]. Nevertheless, product development partnerships have been established with the industry, as part of a final year undergraduate degree that has been taught at Massey University, New Zealand. The study elaborated on the management of the university-industry partnerships and the selection criteria for projects [10]. In reviewing structured models of innovation and product development, several project works were undertaken by students within the Master program on Industrial Design, at the Faculty of Engineering of the University of Porto. The students were required to develop new product concepts [11].

From the above literature review, the emphasis on enhancements of NPD processes is a paramount concern to many parties. However, the obvious trend is the recognized neglect of the education sector at tertiary level. The objective of this study is to integrate the engineering undergraduate FYP into NPD process and to outline a radical framework to serve this purpose. In addition to that, an automobile innovation project was developed and the proposed framework was implemented. This paper is organized as follows: literature review to define the background of NPD processes, then presentation of frameworks (traditional framework for FYP and a framework for the most common NPD process), after that introducing a generic framework to integrate FYP into NPD process, and finally conclusions and recommendations.

2. Traditional Framework for Engineering Undergraduate Final Year Project (FYP)

In the undergraduate level, the FYP of local university students are involved in solving specific engineering problem using basic applicable theories and techniques, and the implementation of the project design. The student is expected to design a possible solution to the problem, taking into account various aspects such as professionalism, economy, costing and engineering viability. At the end of the project, it is expected that the student submits a proper written report and presents his/her work at a seminar. The aims of necessitating a final year project include exposing students to the techniques and skills involved in project planning, design, implementation and management as well as to enable students to acquire hands-on experience with engineering equipments and in fields related to their major of study so that they are able to relate and reinforce what has been taught in the classroom.

Fig. 1 exhibits a six step traditional FYP framework. It is adapted from the Faculty of Engineering and Technology at the Multimedia University, Malaysia [12]. The framework reflects the standard steps followed in FYP projects in the engineering degrees with a technical approach. Firstly, a topic is proposed by either the supervisor or the student to conduct an in-depth study in a specific field. Subsequently, sufficient literature has to be reviewed to gain a clear insight of the work previously done and an overall picture of current needs. With that, a final idea (concept) of the project is validated, followed by technical work. Purchases are made, ideas are implemented to conduct the required experiments, softwares are learnt, materials are fabricated and tools are machined. After obtaining the results, be it, experimental data, a device invented, a mathematical model or software, proper presentation has to be performed. Findings are discussed in detail and a technical report is written.

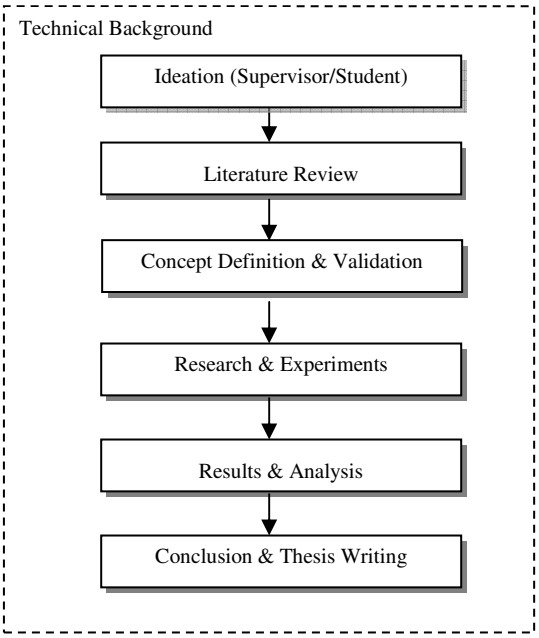


Fig 1. Traditional FYP framework adapted from Multimedia University

3. Industrial New Product Development (NPD) Process Framework

Understanding the processes involved in NPD required the need to study various literatures and referencing to online articles and journals. These provided the platform to summarize a typical NPD process. Fig. 2 exhibits a framework for NPD processes that could be implemented by industries. The framework is adopted from a book authored by Merle Crawford and Anthony Di Benedetto entitled New Products Management. The insights of the book, which provided the management approach and an outlook, focused on marketing [13]. The key focus was developing a product innovation charter (PIC), which encompasses the following components [14]:

1. *Background* where key ideas from a situation are analyzed.
2. *Focus* on a clear technology and market dimensions. The need to concentrate on core-competencies and capitalize on technology and market sources.
3. *Goals and objectives* of the project which determines the accomplishment of the project and develops means of measuring the accomplishment or achievements.

4. *Guidelines*, which sets the strategic path/roadmap. Way in which factors such as cost, quality, and time are greatly dealt with, to develop a competitive new product.

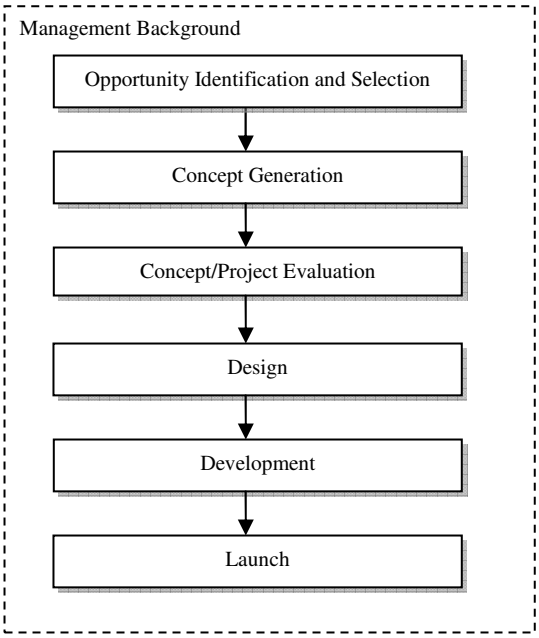


Fig 2. NPD framework adapted from Crawford and Di Benedetto, New Products Management

The framework focuses on five major phases in developing a new product. These categorizations were further elaborated analytically and managerially. Highlighting the need for strategic NPD management with the use of such a framework paves the way for successful NPD.

The first step in embarking on a NPD process would be identifying the opportunities available and selecting it. As mentioned earlier, developing the PIC would be the most important decision made here as the subsequent decisions and steps would be structured and tuned according to the PIC. Referring to the framework (Fig. 2), various channels of opportunity inputs are available such as ongoing marketing plans, special opportunity audits, ongoing corporate planning which opens up a pathway towards exploiting underutilized resources, new resources, responses to external mandate such as quality studies, customer needs, and also to competitive threat. Besides those mentioned, exploring the opportunities within a firm itself such as from owners, top and unit management plans, and gaps within an organization also produce excellent pathways.

Once an opportunity is derived, the subsequent steps for ideation and problem identification are kicked off taking into account the possible means of solving the problem. Concept generation outlines the strategies adopted by firms such as problem-based ideation and solution such as market segmentation analysis, trend areas, Phillips 66 groups and reverse brainstorming [15]. Analytical attribute approaches introduce concepts such as gap analysis, trade-off (or conjoint) analysis and dimensional analysis [16]. Any of these steps would complete the generation of new product concepts. In the next stage, these concepts would be evaluated.

The concept/project evaluation phase is commonly known as screening or pre-technical evaluation. It is a step in which the new product would be quickly screened on its viability in terms of net present values and discounted cash flows. Besides evaluating its financial viability, based on the type of new product, it is also assessed by end-users or technically, or even both. Ozer (1999) discussed thoroughly the new product evaluation techniques and their use at different phases in the new products process [17]. Some firms adopt a complete concept test, which recommends and defines a solution to the problem and analyzes the feedback from potential customers. Analyzing with the risk/payoff matrix or A-T-A-R model (awareness-trial-availability-repeat) provides the overall outcome (success/failure) [18]. Moving on into the development phase, the new product would be fully developed into a complete item or service. Developing product architecture and product platforms provide the flexibility for designers to replace modules easily as concurrent new products could be designed with the improvement of technology, change in market needs, and improvement in manufacturing skills [19]. Firms that embark on prototype development would concentrate on focused prototypes or comprehensive physical prototypes to determine how well all components/services would fit together [20]. Integrating various techniques such as colocation, quality function deployment, and collaboration with vendors help overcome fundamental problems faced such as concurrency and overlapping between steps in development. Introducing computer aided design tools and methods of design for manufacturability are able to point out the major design elements that contribute to slow time or high cost as well as overcome problems on space limitations during design stage. This also significantly reduces design and after-sales problems [21]. Working concurrently in this stage, the marketing team gradually plans a comprehensive strategy and business analysis to ensure that the new product would have a smooth transition into market upon launch [22]. Finally, in the launch stage, the emphasis is on strategic launch planning, implementation of the

strategic plan, market testing, launch management, and issues governing public policy.

4. Generic Framework: Integrating FYP into NPD Process

In this new generic framework, the FYP methodology is innovatively modified to incorporate all the phases involved in an actual NPD process so that the former becomes more product-oriented as well as market-driven. Fig. 3 depicts the systematic approach to this innovation. Primarily, the processes and strategies of new product management are studied in depth. With this knowledge, a detailed plan is established to orient the FYP to the new product innovation process, as shown in the non-intersecting portion of the left circle.

Moving away from the management focus, the student has to first identify where the "greenfield markets" are. Opportunity identification is primarily driven by external customer needs, competitive threat from companies in a similar industry, diversified markets as well as new or underutilized resources. Many techniques can be adopted such as problem-based ideation and analytical attribute approaches. In effect, data is collected through suitable means and analyzed thoroughly. This is illustrated in the region where the left and the right circle intersect each other. Here, a solid foundation in management as well as technical background is essential.

Once a gap in the market is recognized, an ideation team with strong creative capabilities is established to analyze the problem or scenario so that a solid concept may be generated. At this stage, teamwork among students of similar or different academic background is extremely crucial. The elements of product form, technology, and benefit/need can be put together for product innovation with the presence of creative people. A concept in its simplest sense is a technology, which permits the development of a form that provides the benefit. In other words, it is a verbal and/or prototype expression that tells what is going to be changed and how the customer stands to gain (and lose). Active seeking of ready-made new product concepts can be done from inside sources (employees) or outside sources like users or stakeholders. The most difficult, but by far the best, method for creating concepts would be problem-based ideation, which involves finding and solving customers' problems.

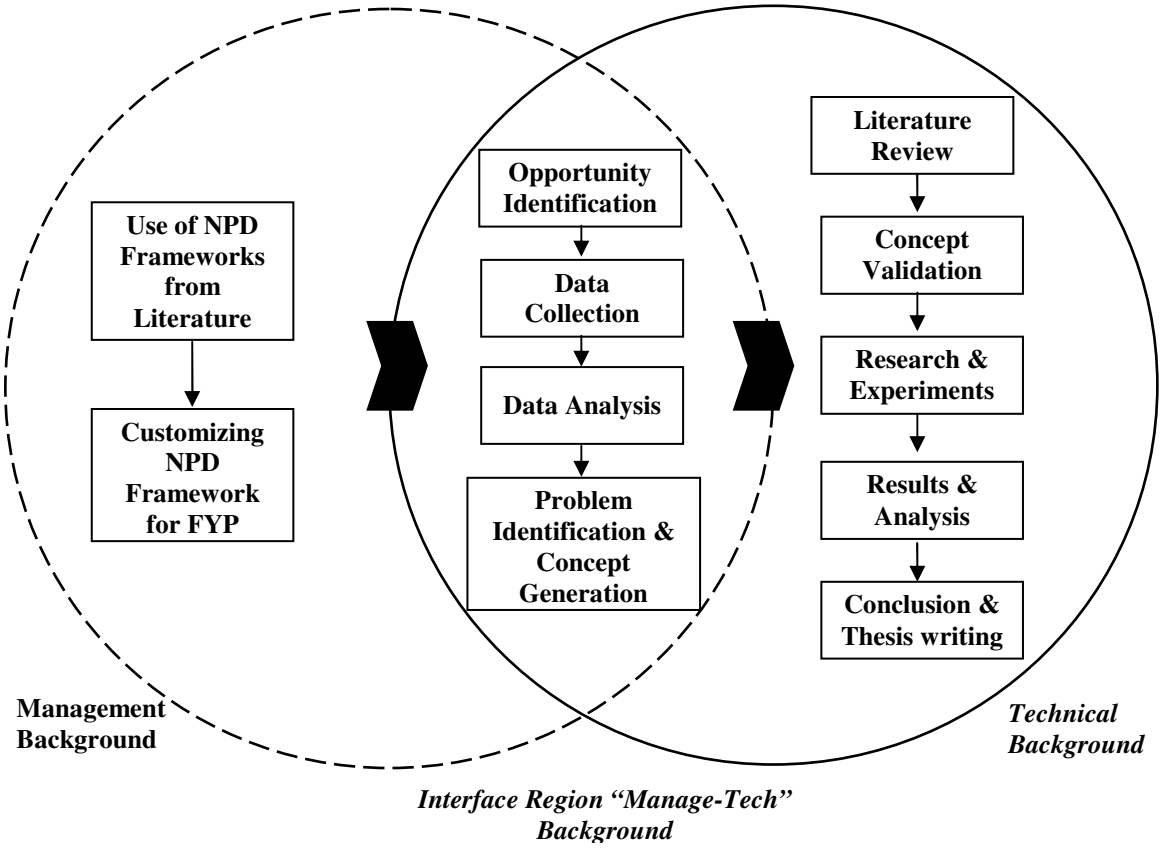


Fig 3. Generic framework: Integration of FYP process into NPD process.

Alternatively, analytical attribute approaches are utilized. Considering the fact that products are essentially groups of attributes (features, functions and benefits), perceptual mapping can be done to analyze and differentiate product attributes and subsequently, determine the "gaps" in a particular market. In trade-off analysis, students must compare and evaluate brands based on their attributes or features whereas in qualitative techniques, relationships between dimensions are analyzed and checklists are made.

The preceding steps define a completely different perspective as compared to the conventional framework presented in the introduction. Since engineers' basic responsibilities are to solve problems, it reveals a practical value of undertaking an FYP.

After a full screen, design kicks in with focus on speed to market, ease of manufacture, meeting customer needs, building or supporting corporate identity and the environment. Besides that, functionality, product architecture and systematic engineering design methods are also delved into. To gain a complete picture of the work already done in this area, literature review is performed. In generating a conceptual design, a function structure is important to break down complex problems into problems that seem manageable. It is, basically, a representation of logical interrelationships. Partial solutions are methodically developed using discursive, heuristic and analogy consideration methods as well as systematic broadening of the solution field.

Working on the validated concept, further research and experiments may have to be carried out as demonstrated in the non-intersecting portion of the right circle in Fig. 3. Findings will later be properly presented and analyzed. To evaluate solutions, evaluation criteria have to be defined for a limited amount of any kind and field and any degree of definition but equal information content. Uniformly acquirable and comparable values are then assigned to each solution and their sums (overall values) are then compared as a ranking in order to find the best solution with the highest rating and the poorest solution with the lowest rating. The development phase takes into full consideration product specifications and design from the previous step. Here, resource preparations come into picture. All members of a team, regardless of his or her role, are working at full swing. Finally, technical plans are launched. Judging from the success of the project, conclusions may be drawn and recommendations are made.

The following section outlines an implementation of this framework in the automobile industry. It further serves to clarify the practical steps involved in customizing the NPD process to the FYP.

5. Case Study: Generic Framework Implementation for FYP

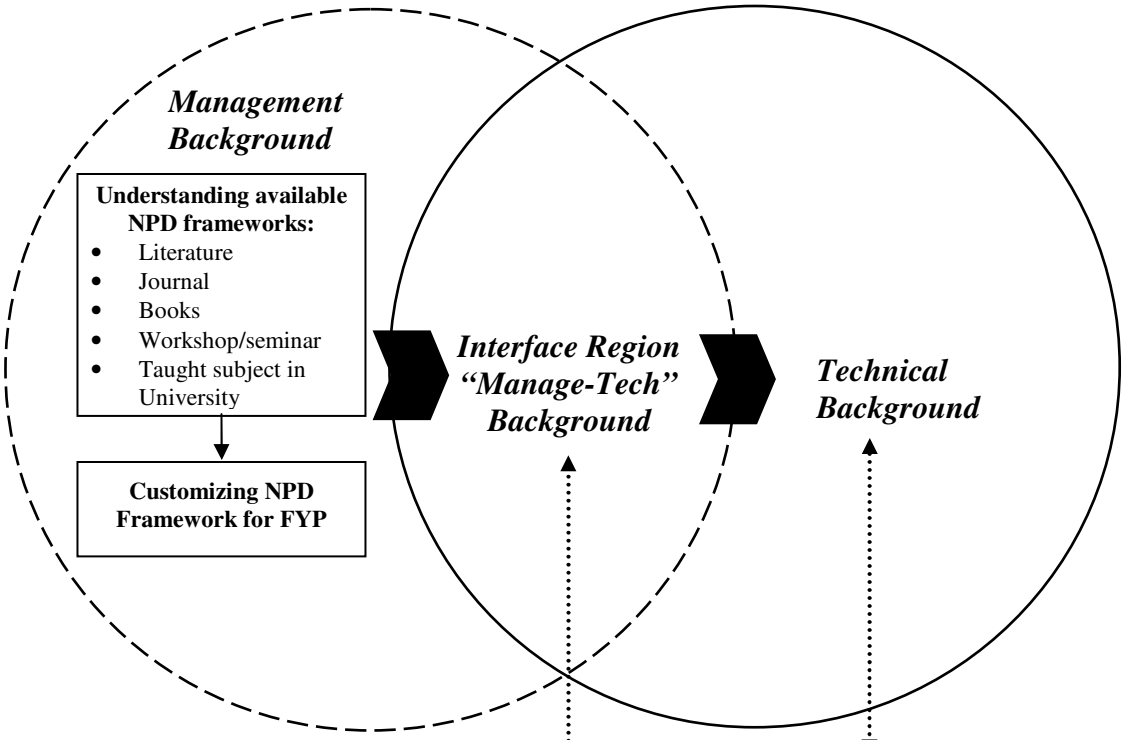
Having examined the customized framework, efforts are made to create one, which is applicable to the local industry. The aim directs towards the modification of an existing product in this area by adhering to a systematic and customized, new product management framework. Fig. 4 provides a bird's eye view of this case study. Choosing a car as the object of study, surveys of local users of cars are carried out to identify the leading problems. The population of 290 users included the mechanics and other working adults as well as university students who have driven or are driving a specific car. This experience is crucial to give an accurate and fair judgment on the questions posed.

Face-to-face and telephone interviews were conducted. The bulk of information obtained, however, was from survey sheets distributed. In addition, an online survey was created to reach outstation people. The first section of the survey was designed to obtain important information about the users such as the age, the gender and the profession. Subsequently, the following data regarding the car itself were gathered: car model, engine capacity, type of transmission, duration of car use, problems occurring and when they started occurring, and criteria in selecting a car.

In the process of interviewing and data collection, comments were also given by the respondents, giving a valuable insight of the possible sources of problems in the local automobile industry. In the process, some skills were acquired on survey development, choosing an appropriate target market, compiling data and presenting them in charts. After close observations, a problem statement was derived for further action.

Automobile power window mechanism

Problems with the power window started occurring in cars within 3 years of its use. Thus, attempts are made to solve it. This led to the investigation of the tribological behavior of power window mechanisms. Beginning with the section where sliding takes place between the wire and the aluminum alloy bracket, the mechanism of interest is that of wire-flat contact. Effects of counterface materials on the tribo-behaviour of a sliding steel wire were discovered.



Interface Region "Manage-Tech" Background

Opportunity Identification:
- Brainstorm on automobile (car) problems

Data Collection:
- Survey: 290 respondents (interviews, online-questionnaires)

Data Analysis:
- Statistical methods (SPSS, MS-Excel)

Problem Identification & Concept Generation:
- Correlation analysis between common problems.
- Addressing automobile problems (power window faulty & dashboard vibration)

Technical Background

Literature Review:
- Books, journals, conference papers
- Consultation with research and technical experts locally and internationally

Concept Validation:
- Faulty power window : Tribological experiments
- Dashboard vibration : Engine mounting validation

Research & Experiments:

Power Window	Engine Mounting: rubber
- Visual inspection - SEM image analysis - Tribology test - Simulation	- Visual inspection - SEM image analysis - Machine fabrication - Fatigue test

Results & Analysis:

Power Window	Engine Mounting: rubber
- Mechanism optimization	- Mechanism optimization

Conclusion & Report writing:
- FYP thesis
- Journal publications [23]
- Result introduction to local industry

Fig 4. Case study incorporating FYP-NPD framework

Block-on-ring (BOR) tribo-tester to simulate the movement of the power window system under fixed test conditions and for a predetermined duration was used. To obtain a better understanding of friction and wear characteristics of this system, relevant literature was read up, particularly regarding adhesive and abrasive wear modes. Based on the experimental results of steel wire sliding against stainless steel, mild steel and aluminum counterfaces, deductions may be made pertaining to the failure of the power window mechanism. Additionally, micrographs were acquired from scanning electron microscopy (SEM). To verify the results from the tribo-tests, stresses acting on specific points and cross sections of the wire were computed in Microsoft Excel. A detailed force analysis was carried out to identify critical points in the wire. Identifying a tribological weakness in the said system, a new material was suggested for the sliding bracket [23].

Vibration of dashboard

Concerning the vibration of dashboards, collaboration and consultation with research institutes from Germany (Institut für Kraftfahrwesen, RWTH Aachen) and from Malaysia (Rubber Research Institute Malaysia, RRIM) was established to strengthen the concepts and experiment methodologies. Conducting mind-mapping sessions on the possible causes of vibration led to the root cause of the problem. A test machine was designed and fabricated to test the various failure modes. Analyzing the data collected from experiments, improvements were recommended with collaborating suppliers and results were revalidated. Hence, a complete solution for the problem was obtained. It provided a great sense of exposure towards solving real technical problems similar to the industry and the management approach towards determining and structuring the entire process of problem definition until solution.

6. Conclusion and Recommendation

Developing a framework for orienting undergraduate FYP to new product innovation process suggests many advantages, some of which are:

- Determining the interaction between product-in-market and users.
- Problem-solving tool for products-in-market for the purpose of modification or improvement.
- Focusing on the innovation aspects of research and development in engineering undergraduate final year projects.
- Increasing the industry's interest in collaborating with universities
- Applicability in industries, service providers, universities.
- Enhances teamwork building at student level.
- Developing a new generation of engineering undergraduates with a sound knowledge in management tools used in the industry.
- Introducing NPD processes and methods to academics and students for further involvement in the NPD innovation process.

Nevertheless, there are some limitations such as unfamiliarity with the management aspect of NPD, which may restrict the usage of the proposed framework. Therefore, it is recommended to carry out another study to address the barriers between the university and industry for integration of FYP into NPD processes. This should focus on the motivation of such partnerships.

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