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The New Product Development Process: a discussion on the teaching proposal

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Abstract: The new product development process is of crucial importance for many organizations' survival. Many graduate programs in Brazil teach the subject in a non-applied. This article describes the experience in teaching the subject of new product development (NPD) through empirical research and, as a result, presents a proposal for teaching NPD integrated with other subjects.

Keywords: teaching, new product development, problem-based learning.

1. Introduction

Several organizations depend on new products development (NPD) to remain competitive. There are many factors to be considered in the new products development, such as cycle time, cost, quality, among others. This environment requires that several multifactorial knowledge to be interconnected so that good results to be achieved.

Knowledge in the NPD can be a barrier or a source of innovation and the opportunity to learn through practice enhances knowledge as a source of innovation (CARLILE, 2002). The qualified engineers and specialized training is essential to the modern economy (GRANT et al., 2010).

The NPD subject contains a set of subjects and skills this requires integration work that goes beyond the teaching of concepts within the chambered subjects. It requires that NPD subject needs to be addressed within a practical context surrounded by problems that must move beyond the theoretical knowledge, capabilities involving project management, economic management, leadership, teamwork and deadlines.

There is a gap between theory and practice and the problem-solving learning can help in closing such a gap as it forces students to apply tools and concepts to current business situations rather than just memorize theories the most examinations (BAMFORD; KARJALAINEN; JENAVS, 2012).

The current study was developed in the production engineering course of the Federal University of São Carlos (UFSCar), Brazil. As presented, several challenges are associated with the teaching of the concepts involved in the new product developing process to students. In this context this article describes a discussion on the teaching proposal through an empirical approach.

2. Literature review

The following is a brief review of the literature and it brings two main teaching proposal central in NPD: new product development and active learning styles.

2.1. Reference model for NPD

The proposal of the use of a reference model is to unify the vision of the product development process between all involved.

From a reference model of product development process you can manage each product launch as a project and this brings advantages such as understanding the limits of the various stages of development as well as of the costs and time associated with each one.

The reference model used in the subject of design and product development of UFSCar of Sorocaba is proposed by Rozenfeld et al. (2006), being shown in Figure 1. The model is divided into three macro-phases classified as predevelopment, development and post-development.

The pre-development phase is characterized by promoting the alignment of the product to be developed with the strategy of the Organization and the availability of their resources and competencies. This macro-phase is decomposed in two phases of strategic planning and project planning.

The development comes to the materialization of the productive aspects and product marketing. This macro-phase is deployed in stages of informational design, conceptual design, detailed design, preparation of production and product launch.

The post-development aims to monitor the performance of the product on the market with focus on improving. It also aims to facilitate the withdrawal of the product on the market. This macro-phase is deployed in stages of product and process Monitor and Discontinue the product.

The various stages in the three following macro-phases use the approach of stage-gates in that after each phase, according to Cooper (1990), the gates are used to evaluate the activities for each so that decisions about the continuation, revision, freezing or cancellation of the project or phase are taken.

Recent research in companies that adopt the approach of stage-gates in the new products development show that decisions on the gates are prioritizing more financial criteria than those related to customers and the market. And this hinders the successful application of the approach of the stage-gates (JESPERSEN, 2012).

2.2. Active learning styles

There are a few approaches that aim to replace or complement the expositive native higher education classes, among them, Postholm (2008) highlighted the work on projects, group work and problem-based learning.

> The work in projects enables the student to produce knowledge own research so that brings together "[...] the actions reflect, talk, argue and create the possibility of taking the issue to develop a complex and contextualized vision of reality." (BEHRENS, 2006, p. 173). Grant et al. (2010) complement stating that the project-based work assists in the development of important skills for the student's insertion in the market.

Group work is an important part of this strategy in that sharing and learning assessment form an essential element in the development of solutions (BENJAMIN; KEENAN, 2006).

Problem-based learning allows the development of activities involving the participation of individual, collective, critical and reflective discussions. She understands the teaching with a complex vision that causes students to live together with the diversity of opinions, converting the methodological activities in rich and meaningful situations for the production of knowledge and learning (BEHRENS, 2006).

In problem-based learning, students start from a real-world scenario without a single correct answer. From the analysis of a problem, they search for an alternative and the recommended solution. This experience plays the kind of situation that the students will find when they leave to the market (HSIEH; KNIGHT, 2008).

Carvalho, Porto and Belhot (2001) there are different learning cycles that, when applied properly, generate significant learning that occurs when a new information if the relevant concepts in cognitive structure of pre-existing who learns. Those authors highlight that the learning cycle under the constructivist logic is best suited for engineering education, constituting the following steps:

- Background and rationale: are presented, to the individual, the concepts to be studied, why study them, putting them in the environment in which the individual lives. The problems that are associated with them are presented and the relevance in resolving them as well;
- Conceptualization: in this stage are passed all the concepts related to the subject, and the stage at which values the logic, deductions and ideas. The individual comes into contact with new concepts, but they are related to other concepts previously purchased;
- Resolution and test: in this step the concepts presented above are consolidated through practical exercises, applications of related problems. Are stimulated the development of the skills and creativity of the individual; and
- New situations: in this stage the individual applies the concepts consolidated in real situations, developing decision making, safety experience, giving the individual conditions to check if the application of the concepts acquired in the first step.

The problem-based assessment provides a better learning experience for the, although more expensive than a traditional exam (BAMFORD; KARJALAINEN; JENAVS, 2012).

Finally, the work on projects, group work and problem-based learning combined with the idea of interdisciplinarity, are present in discussions involving current practices of teaching and learning. According to Richter and Paretti (2009), interdisciplinarity occurs when participants identify and integrate different perspectives to work together to solve a problem, so that all learn and can reshape their behaviors and practices.

3. Teaching of NPD

The educational proposal of NPD developed in this article is based on the experience gained in the period from 2008 to 2011 by two professors who teach the subject of NPD and related production engineering Sorocaba campus of the Federal University of São Carlos, São Paulo, Brazil. NPD subjects as well as other subjects of production engineering course are characterized by presenting 15 weeks in duration, independent of the load time.

3.1. Integration of subjects

The teaching of NPD involved the direct integration of three subjects: design and development of Sustainable products and processes (PDPPS), methods and tools for control and Quality Improvement (MFCMQ) and practical production engineering 2 (PEP2).

The integration of subjects, according to the pedagogical project of the production engineering course is a mechanism to develop in the student the ability to identify, understand, apply and synthesize knowledge from various areas of production engineering knowledge. The integration of the three subjects was driven by the following questions:

- What part? The subjects chosen for integration were: PDPPS, called "Guiding Subject", due to its potential to indicate from which the academic period given knowledge can be developed with students; MFCMQ classified as "Subject", as it provides support for the subject of NPD in diffusing new knowledge of methods and tools for the control and process improvement; and PEP2, classified as "Integrative Subject", because it determines that transdisciplinary knowledge are applied in its development;
- How to integrate? The integration of knowledge of PDPPS and MFCMQ was stimulated by the application of problem-based learning. Developed in a laboratory a real production line and from there, problems were created by controlled the intervention of two teachers in the process of production of that line. This dynamic has been developed in the subject of PEP2, classified as "Integrative Subject", because it determines that transdisciplinary knowledge to be applied in its development; and
- When integrating? What time given knowledge must be recovered, or anticipated delivered to students? The subject of PDPPS was used to direct the content of the PEP2 and MFCMQ subjects, which happen in the same semester that PDPPS, because it has as main content reference model of product development, which has well defined steps and allows the supply of these other subjects be established concomitant way in integrated projects.

The answers to previous questions have provided guidelines for the integration of the three subjects, however, there are external content to these subjects that also need to be integrated in order to meet the demand of NPD.

3.2. Content integration

The format of the NPD to meet the goal of practical education demanded a proposal for integrating content with subjects already studied, being taken and to be taken. On this basis, was an elaborate array of integration of the contents of these subjects (Table 1).

Table 2 shows the abbreviated terms of the contents of Table 1 and Figure 1.

That Table 1 was discussed among the teachers involved with the subjects identified in interactions with the subject of PDPPS, so that content and works were chronologically aligned to the needs demanded by the subject of PDPPS. Table 1 and Figure 1 show the when, how and what will be integrated:

- In week 2 of the classroom, it will be necessary to convey to students the basic concepts of Economic Engineering and Industrial Costs, because this content will be used in week 3 in the subject of PDPPS, when will broadcast the content of strategic planning of the product;
- At the same time, will be taught methods and tools to control and improve the quality of classes A1 to A8 according to demand in the PDPPS subject. For example, up to 4 week students should be taught the QFD (Quality Function Deployment), because in week 5 it is vital for the smooth running of the PDPPS and PEP 2;
- From week 2 to week 8, the PEP 2 subject will serve to transmit knowledge of other subjects, before and after the current term and will also serve to consolidate the knowledge of PDPPS and MFMCQ given throughout this period;
- In week 9, for example, will be the first batch of products produced in the laboratory. This batch will be used to collect data and information from various fields of knowledge production engineering

Table 1. Knowledge Integration.

Day	**Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
	Subject	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	*RT10*	*ReT10*	*RT12*	*ReT12*	*RT14*
TU	**PEP2**	ApG	EE/ Costs	Abou	GProj	MKT	Sketchup	ACAD	Simu	(F)	Fm	Fm	(F)	Fm	-	TF
TH	**MFCMQ**	A1	A2	A3	A4	A5	A6	A7	A8	M	THE	THE	M	THE	-	TF
FR	**PDPPS**	MG	AG	PEPr	THE/ PP	THE/ PI	THE/ LCA	THE/ PC	THE/ PD	PD	AS/ PPR	THE/ LP	AS/ AD	-	-	LP
										RP1	*ReP1*			*RP2*	*ReP2*	

Source: Own Elaboration.

Table 2. Content Label for Table 1 and Figure 1.

PEP 2-2 Production Engineering Practices		**PDPPS-design and development of Sustainable products and processes**	
ApG	General presentation of the subject	MG	Generic Model
EE/Costs	Economic/Engineering Costs	AG	Generic Activities
Abou	Production strategies	PEPr	Product Strategic Planning
GProj	Project management	PP	Project planning
MKT	Marketing	PI	Informational Design
Sketchup	Sketchup-graphics program	LCA	*Life Cycle Assessment* or analysis of the product life Cycle
ACAD	AutoCAD	PC	Conceptual Design
Simu	Simulation	PD	Detailed Design
(F)	"Crop" – production in batch product laboratory for assessment.	PPR	Manufacturing Preparations
Fm	"Crop of Improvement" – production in batch production laboratory to support the improvement of quality, not being used for assessment score.	LP	Product Release
TF	Final Work	AD	Monitoring and Discontinuity
MFMCQ-methods and tools for control and Quality Improvement RP		THE	Presentation of the seminar
		Partial Report	
M	Application of methods for Improvement	ReP	Return of the RP (vacant)
A(Week#)	Class of Week #		

Source: Own Elaboration.

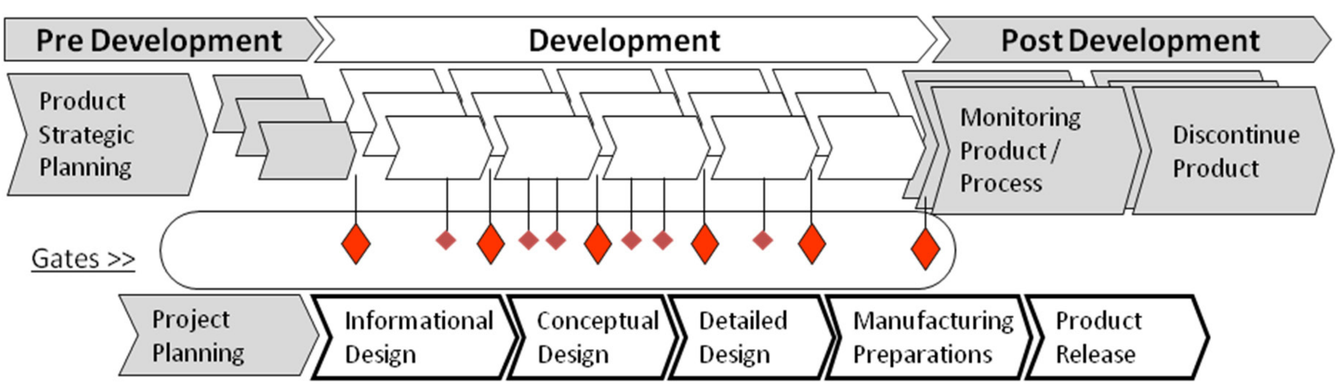

Figure 1. Product Development Reference Model. Source: Rozenfeld et al. (2006).

(Production and Market management, products and quality). From this information, a first assessment will be made of PEP 2 with delivery of partial report 1 (RP1), whose feedback will be given by teachers in week 10 (ReP1);

- Week 10 will be produced lot of improvement (Fm) in PEP 2. These lots are not intended to assess the progress of the subject, but allow students to apply engineering knowledge for improvement of products and processes, without that worry whether they are or are not being evaluated;
- Two days after, the students will present seminars in MFMCQ to demonstrate to teachers as they applied their knowledge as described in item 5 above; and
- In weeks 1 to 8 of MFMCQ are delivered weekly reports about the practice in class of methods and tools learned in class, being applied not in same problem 2 PEP but in other simpler and that includes, at the end of the semester, diversity of cases to provide broader learning of students.

Anyway, by the Figure 1 notice that the PDPPS subject acts as demand expertise in guiding production engineering necessary for students to develop their activities in the subject of PEP2. These expertises are show in Table 3.

4. Experience report

Below are highlighted some elements in the conduct of PDPPS during the period from 2007 to 2011.

Table 3. Input of production Engineering Knowledge throughout the Semester.

Knowledge	Week of Entry	Week knowledge assessment (suggestion)
Economic/Cost Engineering (EE/Costs)	1 or 2	13 (technical report)
Production strategies (Est)	3	13 (technical report)
Project management (GP)	4	13 (technical report)
Marketing (MKT)	5	13 (technical report)
Computer Graphic Techniques (TCGráficas)	6 and 7	13 (technical report)
Simulation (SIM)	8	13 (technical report)
Operations Research (PO)	7	13 (technical report)
Production planning and control (PCP)	7	13 (technical report)
Mechanical Technology (TMC)	7	11 (technical report)
Automation (AUT)	7	11 (technical report)

Source: Own Elaboration.

4.1. Work environment planning

The choice of problems developed in the subject of PDPPS took into account factors such as the complexity of the product as well as the estimated cost of the components of the product. The products chosen for development in subject of low complexity and low cost could be executed within a horizon of 15 weeks to a budget affordable to students.

Some restrictions related to facilities were imposed to make the application environment of the product development project the closest to a real situation.

In this way, the prototypes were developed exclusively in the Management Laboratory of the Department of Production Engineering-LAGESP located at the Federal University of São Carlos - Campus Sorocaba. The layout of the production process was restricted to installations of this laboratory. Equipment already provided were restricted to available in the laboratory and were shared between the teams.

Each team was treated as a company that needed to identify customer needs, develop the product and still make your release within a period of four months, for the academic period.

The students became involved with decisions related to the company›s strategy, deadlines, product characteristics and production process, sale price and marketing.

4.2. Development of subject

Initially the students received a lecture of awareness about the importance of teaching PDPPS be on a real project and also about the integration of the subjects of the semester.

Groups were set up with about seven members and to try to replicate a real environment, the students were randomly allocated in the teams.

The development of the subject was executed according to the model of product development process proposed by Rozenfeld et al. (2006) plus the analysis of cleaner production (P + L) that permeated all phases. Then for each phase are presented the highlights identified in interaction with the students throughout the development of the subject.

4.2.1 Strategic product planning

At this stage, the teams realized they would pressure on the time constraint and also with the competition between the teams.

As part of the strategic planning phase, the lifting of the skills of the team promoted students ‹ awareness on the need to master knowledge, current and even future on the subjects of the course. Among these are concepts knowledge on production systems, business strategy, new product development, organization and assessment of work, quality management, project management, cost management, work design, production planning and control, application of quality tools, knowledge of technical standards and tools.

4.2.2 Project planning

The definition of roles and those responsible came from the team members themselves. However, a critical factor in this activity was identified in relation to the distribution of responsibilities within each group due to some members of the groups are off in terms of technical knowledge and also with restrictions for extra-curricular meetings because of Deprecations in previous years.

The teams also felt insecure in the establishment of the resources to be used, time and financial expenses required for this phase. This insecurity has been attributed, in part, to the lack of students ‹ experience in product problems and also to the lack of theoretical knowledge of all phases of the product development process. This made the students go forth in relation to the content of the subject of process and product development.

4.2.3 Informational project

The focus of this phase was working on the development of QFD, which required a lot of students in terms of time.

Several dynamics in the classroom with all groups of students involving the application of quality tools such as brainstorm, diagram of affinities, laminating, correlation Mudge Diagram were developed for the construction of QFD.

Alongside this, the students had to seek in-place market information about customer needs, as well as evaluate competing products through market research, which were made using competing products for sensory analysis.

During the application of QFD students presented several reports showing to be satisfied with the practice to the extent that they realized the direct relationship between theory and practice. This has left the dedication of the students.

4.2.4 Conceptual design

In this step the focus was on the functional modeling and definition of systems and subsystems. After this students sought by modeling solution principles that meet the demand of the functions.

Several other subjects such as knowledge of strength of materials, chemistry, polymeric and metallic materials are needed.

The choice of solution alternatives students encountered with the task of identifying criteria aligned with leading customers to choose the best alternative solution.

4.2.5 Detailed design

At that stage, some activities such as the decision between make and buy components, manufacturing process planning and Assembly and product optimization and processes were that demanded greater commitment.

At this stage it is worth mentioning the case of a specific project, the cookie, in which additional information such as the labeling of the packaging following the government health and safety regulations were raised by students, who by this time were more involved and ripe for product design.

In the optimization of products and processes, students realized the usefulness of various quality tools in improving the product and manufacturing processes. The four production cycles made that possible causes were identified and improvement hypothesis were tested. This practical experimentation brought credibility to the theory as they sought to delve in the use of quality tools with the teachers. The use of approaches such as Failure Mode and Effect Analysis (FMEA) was also highlighted by the students as useful in preventing failures. This made the production cycles had significant improvement advances. Another point highlighted by the students was training together with all students involved in the production process, providing greater knowledge and discussion of the factors at stake.

4.2.6 Manufacturing preparations

This phase was marked by extensive use of quality improvement tools. Data were collected during the production cycles for further analysis and during the period when new content of PDPPS and other subjects were passed, the improvement analysis and improvements were carried out to be implemented in the next production cycle.

It might realize that over the production cycles, the students have become more systematic in the conduct of the improvements on behalf of greater knowledge of the methods and tools taught at the same time to carry out the improvements. Hypotheses were formulated and tested.

4.2.7 Product release, product monitoring, product discontinuance

At the product release, the teams present their products to potential consumers and competing teams.

The stages of monitoring and discontinuity, due to temporal constraints of subject could not be evaluated.

In the end of the subjects were made meetings with groups to capture the perception of them in relation to the main challenges encountered by during subject. The challenges were lack of time and excess of assessments.

4.3. Assessment

During the assessment, the focus was on learning of integrated concepts in the subjects by students and not on the results of the products.

The assessment of integrated subjects is based on student achievement and the team at various times, such as: partial reports, on-the-spot reviews of production cycles, called oral, and final report.

The partial reports allowed, according to the teams that have developed, a reflection on what had been done and the feedback given by the teachers, what could be improved. These changes should be included in the final report so that trends can be observed.

On-the-spot assessments of production cycles allowed evaluate planned and carried out by students, as well as highlighted elements related to organization and integration between the members of the groups. In addition, the feedback was given on the fly.

The oral test allowed teachers capture perceptions of each Member of the Group about his role, his colleagues, his relationship with the other members and their knowledge of the broadcast content through integration of subjects.

The final report was a combination of partial reports duly modified with the feedback data during assessments of those partial reports, in order to show the work as a whole.

By and large, the assessment process with partial and general feedbacks under individual and group contributed to stimulate student learning.

5. Final remarks

This article has presented a proposal for teaching NPD integrated with other subjects through problem-based learning approach.

The NPD teaching proposal presented important steps in the process of building an integrated subject, highlight the integration form between related subjects along with the need for integration between content ever seen, being seen and to be seen as a result of the NPD breadth subject.

In the *Planning of the work environment* is that the complexity and cost factors as fundamental for operationalization of the development of education in the subject. Other conditions that have helped bring the learning environment a real working environment were the restrictions of facilities and the allocation of the members to the groups at random.

In the *Development of the subject* using a model of product development provided a clear vision of the deliveries of the various steps involved in the development of a product. This helped in the control of deadlines and in the process of assessment of students.

Learning encouraged in NPD: Strategic planning; Teamwork; Customer focus; Project management; Market research; Financial management; Time management; Improved communication; And so it stands out that the focus of the desired degree of learning about these topics can vary according to the intended purpose.

The discussion of different approaches related to the NPD process made it possible for students to place on the use of different methods and tools taught that could, by different paths, lead to similar results.

Another gain is in the vision and understanding of the product development process instead of just product development project, being the first involves a lot more factors than the second.

Although the low product complexity, it was possible to observe different performances between the teams. Some teams quickly become familiar with the problems of developing product, while others had greater difficulty in understanding the needs of customers and other stages of the project. Therefore, the products had different results, with some being economically viable and others do not. Nevertheless, the concepts on the product development process, the tools and methods used in the development and dissemination of concepts of other subjects was facilitated by the problem developed in the subject and its integration with other.

The limitations of this study is the fact that product development can take years and the NPD subject discussed the process in just a few months, this made some steps as the experiments were simplified. It is necessary that these dynamics evolve to more complex products and thus incorporate new learnings.

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