Creative teaching of New Product Development to Operations Managers

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Abstract— New Product Development (NPD) has got its roots on an Engineering background. Thus, one might wonder about the interest, opportunity, contents and delivery process, if students from soft sciences were involved. This paper addressed «What to teach?» and «How to do it?», as the preliminary research questions that originated the introduced propositions. The *curriculum*-developer model that was purposefully chosen to adapt the coursebook by pursuing macro/micro strategies was found significant by an exploratory qualitative case study. Moreover, learning was developed and value created by implementing the institutional curriculum through a creative, hands-on, experiencing, problem-solving, problem-based but organized teamwork approach. Product design of an orange squeezer complying with ill-defined requirements, including drafts, sketches, prototypes, CAD simulations and a business plan, plus a website, written reports and presentations were the deliverables that confirmed an innovative contribution towards research and practice of teaching and learning of engineering subjects to non-specialist operations managers candidates.

Keywords: Teaching Engineering to Non-specialists; Operations Managers Education; Teamwork; Product Design and Development; Market- driven NPD; Curriculum development.

I. Introduction

THE Masters in Management of Services and Technology (MMST) is a program that mainly aims at providing competences that enable business students to act as operations managers (Fig. 1).

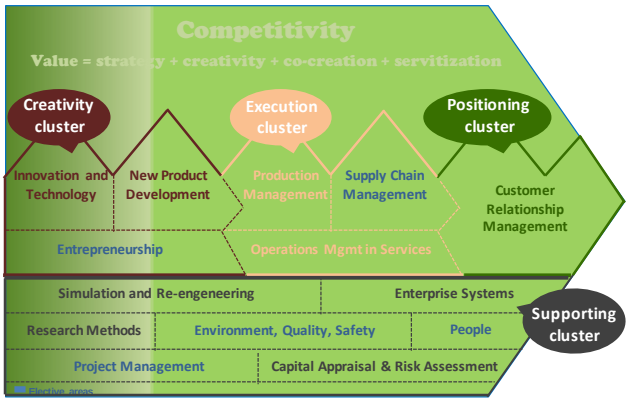

Fig. 1 The MMST layout. Adapted from [1].

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The MMST [1] pursues an interdisciplinary approach and it has been built around three main clusters, as follows: creativity, execution and business positioning.

The course of New Product Development (NPD) has 6 ECTS[1] credits, 30 hours in class and is part of the MMST creativity cluster. Its focus is the integration of the marketing, design, and manufacturing functions of the firm, in creating new products and services, within a structured and interdisciplinary approach. NPD objective is to offer management students the following benefits within the MMST context: (i) confidence in their abilities to create a new product, independently of their backgrounds; (ii) competence with a set of tools and methods for product design and development; (iii) awareness of the role of multiple functions necessary in creating a new product; (iv) ability to coordinate multiple, interdisciplinary tasks in order to achieve a common objective; (v) fostering creativity and formalising its acquisition process; and, (vi) team working skills.

On the other hand, NPD, creative thinking, and exposure to technological innovation have been accepted among the skill-building courses that entrepreneurial-like education must include [2], [3], in Business Schools. Thus, the research objective is to show that it is possible to develop competences in NPD by teaching a team mainly made up of business students, in an appropriate formal, but creative way, in order to get them sensitive to innovation without being engineers. The main research questions that have arisen in the NPD course of MMST concern "What to teach?" (RQ1), "How to teach?" (RQ2) and "How successful is the expected result?" (RQ3). These research questions are aligned with Robinson and Haynes [4] findings that identify as a source of primary concern in education that include entrepreneurship skills, the following: (i) the lack of depth of the programs; (ii) the lack of good solid theoretical bases upon which to build pedagogical models and methods; and, (iii) the lack of formal academic programs. In fact, "ideal *curricula*" that target a professional profile including entrepreneurship skills have failed to be formalized and operationalised in an adequate way. While formalization means defining the contents and the learning activities, operationalisation concerns the approaches to the contents, the activities and the use of resources [5], [6] i.e., the learning process.

This paper reports the exploratory development of both introductory and core competences in product development, as the value thrust of the new business i.e., in close relationship with the expertise that is used to conceive and commercialise a business opportunity [7]. This is approached by setting a

[1] European Credit Transfer and Accumulation System

syllabus, by planning adequate learning activities and by implementing an innovative process to operationalise the *curriculum*, in a lab environment. A "*curriculum*-development strategy" is pursued by following the framework of Shawer [8] (Figure 2). So, this study is of a confirmatory nature, since that the exploratory case study should provide enough information to assess the adequateness of this theory to explain what and how should be taught DNP to modern operations managers.

Students worked in teams of 5-6, coached by the teacher to address the requirement for "Transporting orange juice from the inside of an orange to the inside of a cup", by pursuing an empowered, professional, project-based, hands-on, interdisciplinary, learning approach. Outcomes went beyond product specification (drafts, sketches, prototypes and CAD simulation) to include setting a website, writing up a business plan and delivering presentations.

Next sections of this paper are, as follows: (i) selection of the *curriculum* development theory and setting the propositions for the research; (ii) methodology; (iii) confirmatory case study; and, (iv) discussion and conclusions.

II. Outcomes of the Literature Review

A. *Curriculum-developers strategy*

This research concerns the study of the role performed by the *curricula* development in the process of teaching and learning competences in NPD, which are required by MMST. The theoretical framework of Shawer [8] was purposefully chosen.

Curriculum-developers adopt macro and micro strategies when formalizing *curriculum* [8]. Macro-strategies involve general steps the teachers follow to adjust *curriculum* to their contexts, by transforming the paper *curriculum* into a suitable version (Fig. 2). Micro-strategies are specific steps used to put macro-strategies into action.

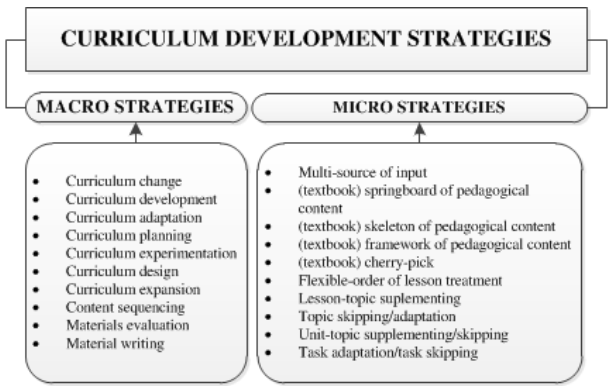

Fig. 2 *Curriculum* development strategies. Source [8].

As concerns macro-strategies, *curriculum* development involves changing the formal or institutional *curriculum* by adapting and supplementing it, in order to promote its adjustment to the context. Moreover, planning the lessons, the activities and the supporting materials are important, despite some degree of experimentation should be allowed. Maintaining some flexibility and expanding or changing the sequences to make the *curriculum* more attractive or even demanding are other possibilities. Finally, designing and writing up the materials will both shape and formalize the *curriculum*. At last, it is important to implement evaluating mechanisms to enable feedback and further reviewing.

Despite micro-strategies mainly concern textbook use, they might also refer to the other sources being used. In fact, course books do have many types of uses, as follows: motivators/pushers to address certain pedagogic content (springboard); generators of ideas; structuring the approach (framework); source of inspiration to pick here and there issues to be discussed (cherry-pick); providing just broad guidance (skeleton); supporters of a dynamic approach (e.g., flexible lesson-order, material-adaptation, topic-adaptation, task-adaptation, material supplementing, and topic-supplementing). *Curriculum* developers also introduce groups of lessons around a topic of the textbook (unit topic) or/and individual lessons around a textbook central idea (lesson topic).

Finally, the chosen operationalisation involves a teaching style that is action-oriented, encourages experiential learning, problem solving, project-based learning, creativity, and is supportive of peer evaluation [7]. Still according to these authors such a process best provides the mix of enterprising skills and behaviours, analogous to those required to create and manage a small business.

B. *Research propositions*

A framework to create competences in NPD was established as the outcome of a literature review by pursuing a hypothetical-deductive approach oriented by the previously established research questions. This model is defined by the following four propositions, concerning conceptual, institutional, operationalisation [5], [6] and assessment levels [9], as follows:

First Proposition (P1) – the conceptual approach

A conceptual approach for NPD should be established by matching the needs of the target professional profile [6], as regards all the competences that support *curricula*, at three educational levels, which should also include the positioning of the professional skills within an operations management context.

While the education levels comprise the introductory, core and advanced levels [10], the competences that support *curricula* are as follows: personal, activity, social & communication and, professional [11].

Second Proposition (P2) – the institutional/formal curriculum

(i) The intended objectives, selected contents and evaluation needs must be formalised into an institutional curriculum that should be adapted, supplemented and adjusted to the context [12];

(ii) The formal curriculum should enable experimentation and maintain some flexibility by expanding or changing the course book sequences or even demanding other possibilities of planning, designing and writing up the materials [8], in order to acquire practical skills in NPD through learning by hands on, experiencing, project-based [13], [14], problem-solving [7], searching and

revealing creativity [15], organized process, orientation to value generation [16].

Third Proposition (P3) – *curriculum* operationalisation

Curriculum operationalisation in NPD should pursue adaptation [8] (*vide* also [17]) which concerns:

i. An active role of teachers that use their knowledge, experience and skills in order to magnify experiences, define activities, allocate resources and affect interactions between students and materials and, also, a teaching style that is action-oriented [7], [18];
ii. An active role of students, in which a flexible and centered in the student [10], [11], encourages experiential learning, problem solving, project-based learning, creativity, and is supportive of peer evaluation [7].

Fourth Proposition (P4) – the assessment/improvement cycle

Curriculum development should be established as a continuous improvement process, which requires the assessment of its implementation [9], that should take place by comparing and discussing the expectations and perceptions of this service (e.g., [19], [20]), by both students and teachers, where exploratory studies might promote a preliminary evaluation of the innovativeness, usefulness, risk and relative interest of the outcomes, in order to confirm the introduced propositions as relevant guidelines to approach the learning and teaching of NPD within an operations management context.

III. Methodology

The scope of this research concerns making a qualitative attempt to figure out the impact of *curriculum* development in the course of NPD, positioned within an operations management context. *Curriculum* development was modeled after (i) definition of the ideal *curriculum* of the NPD course; (ii) formalization of the contents and of the learning activities, by choosing a bestseller course book in NPD [21] and a model to adapt it (macro/micro strategies); (iii) operationalisation by planning a project-based approach to implement the learning activities; (iv) preliminary evaluation of the results, based on the official course questionnaires.

On the other hand, this is not a typical explanatory situation, because neither a clear relationship between performance measures and independent variables was established, nor even these variables were properly defined.

Thus, propositions targeting political-like discussion were defined. Since this is a qualitative exploratory study, one can only discuss and conclude about the relevance of the approach introduced by this research. Being relevant does not and cannot mean that the approach is the best or, even, the only one. Its purpose is also to check the feasibility and the interest of a later explanatory study.

Finally, a case study strategy was chosen i.e., the NPD course, in the context of the MMST. The students of this course developed a project and provided evidence of the level of success of the learning process based on the *curriculum* development model. By discussing the propositions previously set, the research team will assess if the case study provides confirmatory evidence (or not) of the chosen framework as adequate to approach the learning and teaching of NPD within an operations management context.

IV. Developing Skills in NPD: A Confirmatory Case Study

A. A conceptual approach for NPD

The MMST pursues an interdisciplinary and holistic approach to educate Operations Managers (P1) built around three main clusters [1]. The NPD course is part of the MMST creativity cluster and is mainly delivered to students with a background in management. Thus, NPD learning goals must agree with the broad MMST purpose and also, with its specific learning goals (P1); thus, the outcomes of the NPD education & training should have a significant impact at the course itself (NPD) and at the program (MMST) level (P1).

B. Curriculum development

The NPD curriculum was formalised and summarised in a document called the *Ficha de Unidade Curricular* (FUC) [22], the institutional curriculum. In this document, one can find objectives, syllabus, assessment rules, methodology and bibliography of the NPD course of the MMST programme (P2i). Further development of the curriculum will be described together with its implementation.

C. Operationalization with project based approach

For the purpose of delivering a project based and hands-on course, students were given a teamwork project, in the very first day of classes, and they were encouraged to apply knowledge from the first cycle of studies and, also, to integrate knowledge from other courses, by following the process delivered in classes. Students were also encouraged to research in an autonomous way, in order to fill gaps in their knowledge base (P3ii).

A *curriculum*-development approach [8] was pursued by making adjustments to the textbook, namely supplementing and adapting the textbook materials, so that students could use it in the classroom and country context. This macro strategy served as a framework for the implementation of micro strategies [3] (P2ii; P3i). Some of the micro strategies used were, as follows (P2ii; P3ii): (i) team analysis of the case study and discussions, in class; (ii) social networks forums; and (iii) individual assignments involving readings and discussion.

Team analysis of a case study and, individual readings, are classic forms of *curriculum* expansion beyond textbook that were employed, in class (P2ii; P3i). In addition, the social networks have served as a new way of extending the discussion forum to the outside of the classroom (P3ii). The main focus of the external forums was to convey extra information to students about unresolved or lateral issues that arose in discussions in the classroom. These forums enabled the students to discuss matters outside the classroom, therefore, in a more neutral territory (P3ii).

A visit to two companies took place, in order to complement and extend the students learning process. These firms, CEMTIMFE and IBEROMOLDES, develop activities in product development and rapid prototyping (P3i). In addition, special seminars with specialists in intellectual property and standardization were also delivered to the students (P2ii).

Another special class was conducted in the second week of

the course. In this class, a physical benchmarking was performed of orange squeezers, which are currently in the marketplace (see Fig. 3) (P2ii; P3ii). Several orange squeezers and fresh oranges were given to each team. Then, they were asked to «transfer» the juice from the orange to the cup. Before the end of the class, students also performed a functional analysis of each orange squeezer for all the stages of the product lifecycle usage i.e., storage, retrieval, assembly, utilization, disassembly, cleaning, among others. This exercise that was carried out in class, serves two purposes, as follows: firstly, students realized that their task was not an impossible mission due to the existing weaknesses of products already in the market and, secondly, students identified potential improvements or, at least, priorities or hints for improvement concerning their own squeezers.

Fig. 3 Benchmarking class: students, oranges and orange squeezers.

In spite of the list of suggested deliverables, each team decided how to approach the problem and what activities to pursue (P3ii). Data from a variety of sources were collected, synthesized, analysed and compiled into knowledge about the product. The resulting learning was valuable since it was related to the real world and involved skills such as collaboration, reflection and decision-making.

By the end of the semester each team of students presented the following outcomes: (i) a product design of an orange squeezer to satisfy the initial ill-defined requirement; this includes drafts and sketches, physical prototypes and CAD simulation; (ii) a website to introduce, present and promote both the product and the developed work; (iii) a written report, that also concerns the chosen business model, the market research and the investment study in addition to the product development details; (iv) each team also delivered a presentation on its assignment achievements and outcomes.

1) Definition of the project-based approach

Along the semester, students were challenged to develop a new product to solve a market need, by following a structured set of tools from classes (P2i; P2ii). Students should develop market-driven products, from an ill-defined problem and put together in teams of 5 or 6 people. Each student was expected to work about 5.5 hours per week. Such a project demanded from students a decision making ability, within the team, at different points, and also, setting and following a strategy for developing the product (P3ii). These settings emulated a real world situation in the lab. The skills to address it had to be gathered from a NPD course positioned within an operations management context.

The requirements expressed by the teacher concerned "transporting orange juice from the inside of an orange to the inside of a cup". A constraint was that the resulting product should be manually operated. By the end of the term, each team should present the results of its process, the product and a business plan, to a panel of outside experts i.e., other faculty members and invited guests from outside the university (P3ii).

In the mid-term report and presentation, the teams were instructed to prepare and present documents that should include a review of several topics, as follows: mission statement, customer needs analysis, selected concept, and key target specifications (P2ii; P3i). In the final report, besides some corrections to the midterm report, each team should also document the team efforts in concept testing, prototyping, cost modelling and financial modelling. This report was a written description of the intended business strategy and it documented the product development process. Moreover, it should support the business plan commonly used by entrepreneurs to deliver their vision to possible investors.

The suggested list of deliverables was defined, as follows (P2ii; P3i):

- Prepare the agenda of your project.
- Describe the product opportunity in orange squeezing.
- Write down a mission statement for your project team.
- Show sketches and bullet-point descriptions of the different concepts for your product.
- Describe the final concept in as much detail as you can.
- Describe the testing plans for your concept.
- Extract consequences of showing the concept to customers.
- Present a written report of both the main materials and technology that were selected for the part(s).
- Prepare a financial model. Explain the scenario that you are analysing and document the made assumptions.
- Perform a "what if" analysis of the key financial uncertainties that you are facing.

The product development deliverables followed the generic product development process set in the textbook: from planning to production ramp-up [15]. The course book also provides a roadmap of possible methods that can be used at each stage of the structured method for product development (Fig. 4) (P2ii).

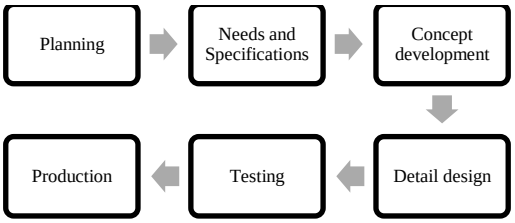

Fig. 4. Generic product development process. Adapted from [21].

2) Discussion of the project outcomes

The existence of such a large group of students enabled the construction of a more extensive workload and the possibility of arising different views on the product to be developed. This confirmed the theory about team project-based learning having

logistics and interpersonal problems inside the team (P1), which could negatively impact the outcome of the project [23]. These incidents contributed to emulate real world problems with group dynamics, in the lab (P1). Teams were built up by mixing students with different skills, personalities and backgrounds. The way each student and each team dealt with these problems and also the way they dealt with workload intensity was reflected in the final product and, so, on the final grade. The concept of extended teams concerning the need to solve issues outside the core team was also applied. For instance, management students had some problems dealing with both industrial design and engineering issues during the development process. In order to solve this, students sought help outside their team, even outside the University (P3ii). At the end of the semester, students had to present the results of their work also as a team.

Students quickly realized that a solid business plan had dynamic interactions with the cost modelling assumptions, the industrial design and what features of the product to develop or use (Fig. 5). Linking business strategy with the product features and with product design helped the students to realize the importance of other disciplines outside their own. In fact, entrepreneurship is often linked with market knowledge, but the other disciplines like design, operations and cost modelling are, many times, forgotten, despite being fundamental for the product design and development process. It is argued that by allowing students to creatively develop a new concept and by preparing all the necessary steps to deliver it to the market, they become more prepared, either to become operations managers, or even entrepreneurs, by participating in similar processes, or by managing them, in the future (P2ii; P3i; P3ii).

Students prepared a final presentation of the developed product taking into consideration the related business strategy for launching the product. Each team was also sensibilised to protect the product with a patent or utility model of its design, despite this study not being compulsory for the grade. Still, the ultimate teachers aspiration is that the teams follow the business plan and establish a firm on their own (P2ii; P3i).

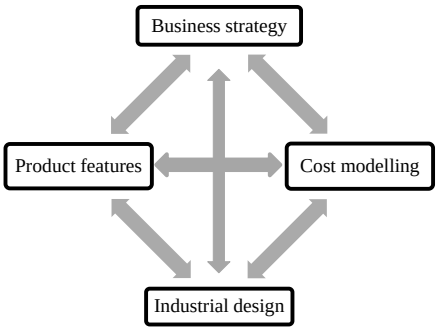

Fig. 5. Dynamics of business plan creation

By following the proposed roadmap (P2ii), students developed several concepts (e.g., the sketch at the left of Fig. 6) and chose the one that better complied with the user needs that they drew out of the surveys applied to the potential end users. The concept was then developed to a prototype, in this case a "looks like" prototype to be tested by the users (vide centre of Fig. 6); the prototype was then transformed into technical drawings that enabled the construction of a bill of materials and allowed for cost determination and estimation (the right side of Fig. 6). From that stage on the establishment of a business plan and a retail strategy for the product were formulated (P3ii).

Fig. 6 From concept, in the left, to a looks like prototype in the centre and to detail design, in the right. Adapted from [24].

D. Assessment of the outcomes

This paper reports a preliminary evaluation of the results, based on the formal course questionnaire that was issued to the students, teachers and panel assessment.

Assessment: teachers evaluation, panel appreciation and students satisfaction (P4)

The designed products were radically different, although the starting point and the initial challenge were the same and, the development process was also similar. In fact, each team focused on some peculiar aspect they wanted to see improved or added to the current orange squeezers in the market.

A preliminary assessment of the reports also showed that some teams better complied with the product development process than others. However, the «quality» of the developed product does not appear to be related to the report. This was expected, since that a process cannot deliver better products by itself. The advantages of having a process concerned more explicit decision making e.g., there are checklists of what to do at which point of the process. It also allowed structuring the documentation concerning the knowledge created in the process. However, this new product was a good indicator of the acquired knowledge along the semester, supporting the learning goals of the DNP course and also, of the MMST.

The students final assessment of the project was based on the presentation they gave to a panel composed of lecturers and outside experts in product development and, also on a formal report where students documented all the product development effort. Beyond the project, students were also evaluated by the

analysis and discussion of individual and group case studies, which took place in class. In general, the several students groups achieved high grades due to the effort employed in the development process, to the results achieved in the final product design and, also, in the related business plan, which is strictly related to an entrepreneurial process of value creation. The marks range assigned by DNP lecturers was between 13 and 18 out of 20. Moreover, the external panel of observers, from an Engineering School, were well impressed and fully agreed with these scores.

Student's assessment

26 out of 28 students answered a survey to evaluate the DNP course at the end of the term, before course grades being issued. The students' scores for the contents and structure of the course were, as follows: 4.3, regarding professional usefulness; 4.4, regarding course adequateness to the MMST program, and 4.4, regarding the level of new knowledge acquisition obtained along the semester (in a scale from 1 to 5). They also rated the course intensity as 2.2 out of 3 (excessive) and found the balance between practice and theory just perfect 2.0 out of 3 (too much practice). As regards work materials, the students rated the program, books and supporting texts with 4.2 and the coverage rate with 4.3. Students found the course somehow demanding as concerns work effort, since the adequateness of the number of work hours related to the ECTS scored 3.2, the number of contact hours adequateness, 4.1 and the number of autonomous work hours 3.1, being all figures out of 5. Finally, the students were happy with their own performance, considering that they regularly went to the lectures (4.5), they participated in class discussions (3.7) and autonomously looked for bibliography (4.0), all the figures out of 5. Finally, students were very happy with the lecturer, since his pedagogic ability scored 4.5, his relationship with themselves, 4.8, and his punctuality, 4.7, all of them out of 5.

V. DISCUSSION AND CONCLUSIONS

The NPD FUC presents a summary of the course information that was organised to provide support to the MMST program, which, in turn, provides the NPD closest pedagogic, scientific and institutional contexts. In fact, the obligation to assure alignment between the course and the programme learning goals was also coming from the AACSB recommendations[2] [25]. According to Leandro [26], the current demand for a «modern Operations Manager» should pursue a broad perspective of operations, which means a holistic, strategic, pluridisciplinary and social sciences view, in addition to the strictly production focused technical approaches, in the Past. These changes to the profile requirements took into consideration two categories of factors, as follows: (i) a new paradigm, briefly characterized by pluridisciplinarity, new technologies, services versus industry and new tools; and, (ii) the Bologna Process, characterized by mobility, transparency, quality, mutual recognition, compatibility and convergence. Thus, the ideal professional profile of a «modern *lato sensu* Operations Manager» should consider all these guidelines. So, NPD appeared to contribute to the core education level of modern operations managers, according to the first proposition, by introducing a holistic pluridisciplinary approach positioned within both the European and International educational contexts [27], [25] (P1). Moreover, the NPD course might also help to build up proactivity and an entrepreneurial attitude, which concern the personal development of the operations manager (P1).

On the other hand, the pursued exploratory research has confirmed that it is possible to develop NPD competences in business students, in a controlled academic environment. Therefore, they were taught in a creative way supported by the institutional curriculum representing the MMST case study. This document resulted from choosing the Ulrich and Eppinger [21] textbook and further adapt it, according to the macro/micro strategies introduced by the Shawer [8] framework (P2).

The process of curriculum operationalisation followed a plan according to the required learning activities. It pursued a hands on, problem solving, project-based approach, which followed the course book procedures, towards the development of a product that properly designed at a fair cost was at the heart of a reasonably attractive business plan. In this way, teams were empowered by an active role of teachers promoting a students centred approach (P3).

The results of the five groups of MMST students confirmed the usefulness and relevance of the Shawer model [8] to teach and learn NPD within an operations management context. Drafts, sketches, prototypes, and CAD simulations of an original orange squeezer were produced and announced in a website, detailed in written reports and exhibited in presentations. Moreover, a business plan was generated to assess the potential value to be created, if entrepreneurial action was taken. Assessment by teachers, experts and students showed that this project was perceived by its stakeholders as successful and so, we argue for an innovative contribution for the research and practice of teaching and learning of NPD within an operations management context (P4). Thus, even engineering subjects might be successfully taught to managers with adequate adaptation and within certain specific contexts.

As further work, it is recommended a more robust assessment procedure, as well as compared tests with students from engineering and/or industrial design backgrounds. Moreover, the motivation of the team members should be detailed, since that the risk of failure is highly dependent on it.

[2] The MMST is part of the school accreditation process with the AACSB.

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