EDUCATING ENGINEERS FOR THE DEVELOPMENT OF PRODUCT SERVICE SYSTEMS (PSS)

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Abstract

Embraer was founded in 1969 to accomplish the vision of the Brazilian government to have the capacity of designing and manufacturing airplanes. The company is organized in three business units: Commercial Aviation, Executive Jets and Defense&Security. In order to have recently graduated engineers prepared to tackle its future challenges, Embraer created in 2001 the PEE – Engineering Specialization Program in partnership with ITA – Aeronautics Institute of Technology. In 2016, more than 6,500 candidates applied for 30 positions. Since 2004, PEE is following the principles of CDIO initiative principles in both the selection of young engineer's process and curriculum design philosophy for the graduate program. As a strategy from Engineering and Technology Department of Embraer, the company needs to adapt its selection process and the curriculum for new engineers to fit to current and future challenges. For instance, from 2008 until now, the number of delivered executive jets dropped from 1315 to 700. Trying to avoid commoditization, the company looks for diversification, searching for new business opportunities. Therefore, offering more services is a natural source of new revenues. More than that, to develop a product and its services simultaneously (Product Service System – PSS from the literature) is a company current objective considering, for instance, the new digital era (Big Data, Industry 4.0 and Internet of Things). To understand how to develop a PSS for the executive jets owners is a major challenge. The other is to present suggestions on how to select and prepare the future engineers of Embraer to be able to conceive, design and implement Product Service Systems for the Executive Aviation Market. For that, a study is being conducted to analyze which competencies and profile are required for that challenge. This paper present as results some guidelines for the selection and education of future engineers of the company in the PSS context.

1 Introduction

1.1 Context

Embraer is a Brazilian airplane manufacturer founded in 1969. It has more than 5,000 engineers (out of 18,500 employees worldwide) working with Research&Technology and Integrated Product Development spread in its three main business units: Commercial Aviation, Executive Jets and Defense&Security.

In order to prepare engineers to work for the company, in 2001, Embraer established a partnership with the Aeronautics Institute of Technology (ITA) to create a Technical Master Program called Engineering Specialization Program (PEE), whose pedagogical approach is connected to the CDIO philosophy.

Until 2017, there were 24 graduated classes that educated more than 1,000 engineers that are currently working at the company. The program is constantly adapting its selection process, as well its curriculum content, in order to prepare the graduated students to face the company's current challenges.

The Executive Jets Business Unit is currently a company focus due to the increase in the market competition and lack of demand in the last five years. A recent challenge of the company is to increase its revenues from other sources than the product (especially services) for the Executive Jets. In January of 2018, Embraer presented its results. According to Embraer Official Website (2018), the total revenue of the company in the period was more than US$ 4 Bi until the third quarter of 2017. Only 0,6% came out of other sources than product selling (including services).

1.2 Objective

This paper has the objective to present some guidelines for the selection process as well as curriculum design for the future engineers of Embraer that are going to work with conceiving, designing and implementing Product Service Systems (PSS) for the Executive Aviation Market.

A literature review was made and specialists were interviewed in order to make suggestions about which competencies and profile are required to tackle this challenge.

1.2 Paper Structure

This paper is structured in four sections. After this introduction, some theoretical aspects about product, service and PSS design are presented. Then an application session presents how the PEE selection process and curriculum design are related to the CDIO philosophy in the context of the Executive Jets design of PSS. The Results section presents a proposal for the process based on specialists' interview and literature research. At the end, final comments and suggestions are included in order to address possible future works.

2 Theoretical Aspects

2.1 Product Design

Ulrich and Eppinger (2008) describe a classical Product Model Design illustrated in Figure 1. This model is a roadmap that can be followed in order to design a product. It is composed by a series of 6 macro phases that start with the customer needs identification that are translated into product specifications (Planning-Phase 0). In the next phase, alternatives of concepts are generated (Phase 1) then selected (Phase 2). Phase 3 consists of the system-level design of the selected concepts. After a screening, those selected concepts are tested, reviewed based on the product specifications (Phase 4) and then the product production starts (Phase 5).

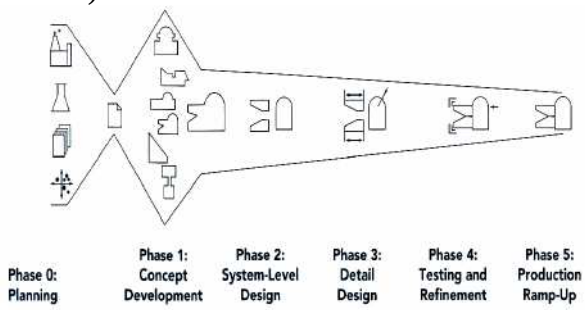

Figure 1: Product Design Model (Adapted from Ulrich and Eppinger, 2008).

2.2 Service Design

In a similar approach of Design Thinking described by Brown (2008) when delivering value to a client by a design process, according to Mazzarella (2015), the Service Design Process can be structured in four macro phases as illustrated in Figure 2.

In the first phase (Discover), the problem is defined as well as the limits of the solution space (considering available resources and capabilities). This is done simultaneously with the gathering process of user knowledge. In the next phase (Define), the findings from the previous phase are analyzed based on the customer needs. Concepts of services and then generated in the Develop phase and these services are submitted to user tests. In the last phase, (Deliver) the service is launched, feedback and insights are captured and shared in order to improve the provided service.

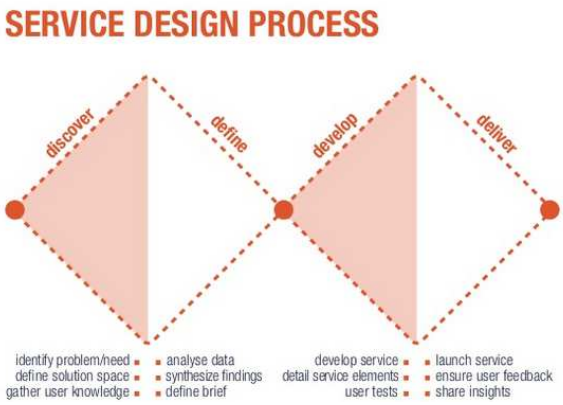

Figure 2: Service Design Process (Adapted from Mazzarella 2015).

2.3 Product Service System (PSS)

According to Clayton et al. (2012), Product Service System is a package formed by a product and service that are delivered to a customer in order to maximize value based on its needs. It is not only the pure product (physical, tangible) nor the pure service, but also both together, in order to maximize the added value for the customer. This concept is illustrated in Figure 3.

Figure 3: Product Service System (Adapted from Clayton et al. 2012).

Rozenfeld (2016), in Figure 4, suggest that there is a great correlation between Product Service System and Servitization. Based on this, Rozenfeld (2016) suggest a model for PSS design as illustrated in Figure 5. This model integrates a business analysis and development simultaneously with the product design in order to let the value proposition of the PSS flow until the delivery to the customer.

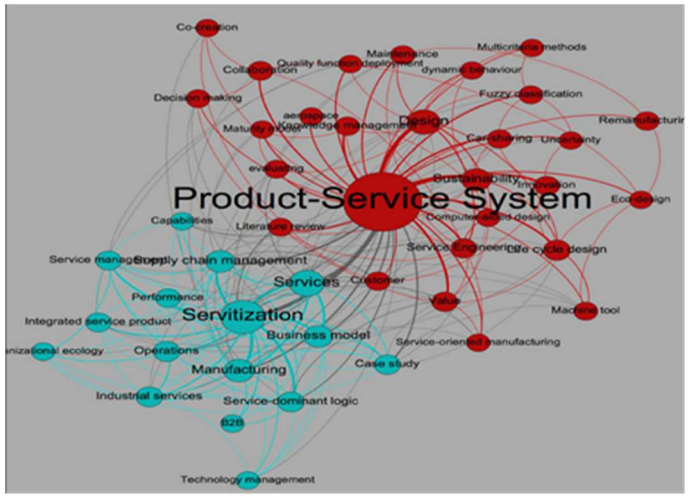

Figure 4: Correlation between PSS and Servitization (Adapted from Rozenfled et al. 2016).

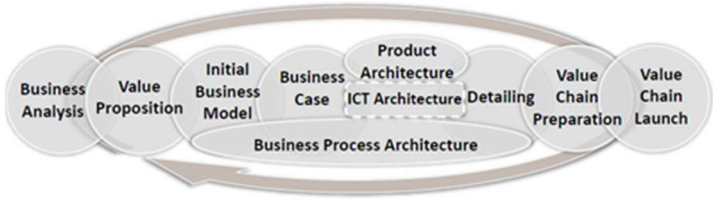

Figure 5: PSS Process Design (Adapted from Rozenfeld 2016).

2.4 CDIO and PSS Design

The CDIO initiative is an educational framework in order to produce the next generation of engineers. PEE and CDIO share the same challenge. PEE has the objective to prepare the next generation of EMBRAER's engineers (in this context, PSS design engineers). According to Lourencao et al. (2015), since 2004 the coordination of PEE uses the CDIO model as reference to conduct the program. This work is related with CDIO Standard 1 particularly when developing competencies in engineers to be PSS developers. The suggestions for a curriculum design and learning experiences in order to face this challenge are related with Standards 3 and 7. In alignment with Standard 9, the staff for the selection process and curriculum content should fit the company's challenge.

The adaptation of PEE focus concerning the development of engineers for PSS

development on the current CDIO Syllabus 2 "Personal and Professional Skill&Attributes" when the adequate profile and competences to be developed for a future engineer are discussed (competences 2.4 Personal skills and attributes & 2.5 Professional skills and attributes). Also, this work is aligned with CDIO Syllabus 4 when preparing engineers with the competences to conceive (4.3), design (4.4) and implement (4.5) PSS in the Executive Jets Business Unit (4.2-Enterprise and Business Context).

3 Application

3.1 EMBRAER Executive Jets

Papers are accepted on the basis that they may be edited for style and language. The author himself is responsible for the correctness of the scientific content.

Abbreviations should be spelt out in full the first time they appear and their abbreviated form included in brackets immediately after. Words used in a special context should appear between single quotation marks the first time they appear. According to Embraer Investors Relationship Website (2018), in the third quarter of 2017, the Embraer Executive Jets Business Unit achieved a revenue of US$ 1,149 million.

As available at Embraer Official Website (2018), the Executive Jets Business Unit was created in 2005 following a strategy of diversification with a portfolio of products consisting in entry-level jets until large airplanes. Today the company has a fleet of more than 1000 airplanes flying worldwide in more than 70 countries. International institutions frequently recognize the company for its innovation and outstanding product design. For instance, Phenom 300, an entry-level airplane, was the most delivered business jet in the world in 2013, 2014 and 2015. It is an airplane for 6-10 passengers that has a range of 1971nm. Its luxury interior shown was developed by BMW and it costs more than US$8 million. The company has an actual portfolio of seven airplanes positioned in entry-level category (i.e. Phenom 100 model cost of more than US$ 3million), mid-size Jets (i.e. Legacy 500 cost of more than US$ 20 million) and large jets such as Lineage 1000 that cost more than US$ 55 million. Figure 6 shows the product portfolio of the business unit.

Figure 6: Executive Jets Product Portfolio. Adapted from http://www.slideshare.net/embraerri/vae-embraer-day2012 accessed in November 15th of 2016.

In this market, there are two main profile of clients: The high-network people and the executive jets company charters. Both aiming for connectivity, rapidness, readiness, exclusivity and luxury. In order to attend its clients, the company has service centers spread in the world for maintenance, parts management, cleaning and catering for instance. A big challenge is how to conceive, design and provide these services and how to design the airplane thinking about adding value services to this exclusive group of clients.

3.2 PEE

The following paragraph highlights the importance of PEE as an EMBRAER strategic resource.

The main objective of PEE is to prepare future engineers to be specialists in several departments of Embraer´s Vice-Presidency of Technology and Engineering. These engineers will be part of multidisciplinary teams, to accomplish the lifecycle design of complex and highly integrated systems, such as airplanes, its systems, manufacturing processes, suppliers, maintenance centers etc. (LOURENCAO et al. 2016, p.1)

The program has the duration of approximate 18 months divided into 3 phases as explained bellow.

> **Phase 1** aims to provide the students with the fundamental knowledge on lifecycle design, covering topics from marketing analysis and research & technology, through product (airframe and aircraft systems) and manufacturing processes,

> up to aspects related to operation, maintenance, and end-of-life disposal. In **Phase 2**, the students select their area of specialization and Master´s thesis topics related to one of the following tracks: a) materials and structures, b) aircraft systems and c) manufacturing d) maintenance. In the last phase, **Phase 3**, multidisciplinary teams, organized by students coming from the three tracks, take part in a Conceive-Design project applied to an aircraft. A group of integration and multidisciplinary mentors from several Embraer technology areas helps the PEE teams. Its results are presented to a team of Embraer technical specialists and managers, and the Final Presentation is done to an audience that includes Embraer high-level technical management. (LOURENCAO et al. 2016, p.6)

Regarding Phase 3, each multidisciplinary group is formed by teams of twenty students, coming from different areas of specialization (previously decided in Phase 2), and receive a marketing challenge as an input to conceive and design a product and or service to attend it. The team is self-managed and the students define their roles, responsibilities and routines for each phase of the process. More than fifteen specialist consultants from Embraer and ITA in half-day weekly meetings support the student groups. The main deliverables and design review phase dates are scheduled by the PEE staff but daily management is done by the students. Each design review phase is presented to a board of specialists that judges the quality of project developed by the students.
As the company aims to develop PSS for the Executive Jets market, the PEE selection process and curriculum design should fit this need to better prepare its future engineers that are going to work in this context.

3.3 Reference Model

The Rozenfeld (2016) PSS reference model, presented in Figure 5, was adopted in order to present to the specialists the context of the interviews. This model was chosen because of its completeness's when exposing the need of developing the business model of the PSS simultaneously with the product design (architecture, concepts and detailing).

3.4 Specialists Selection Criteria

Nine professionals from the industry and from universities were selected to be interviewed. All of them are engineers with post-graduate degree, and have been working with product development for at least 15 years, and are currently working with PSS development and/or research.

4 Results

4.1 Interview

Based on the adopted reference model, semi-structured interviews were conducted based on the case study research methodology described by Yin (1994). Two questions were posed to the specialists with respect to the context of PSS development for the executive aviation.

- How to select engineers for PEE that are going to work with PSS?
- How to prepare engineers for the conception, design and implementation of PSS?

The interviews were conducted between September and December of 2016 and each lasted one hour on average. After presenting the context of the work and the reference model adopted in this work, the questions were presented to the specialists and the answers were collected.

4.2 Specialists

In order to preserve the impartiality in the results analysis, the anonymity of the specialists were preserved and each respondent was classified by a number between 1 to 9, following the criterion of time of experience (1 has more time of experience than the others).

Table 1 shows the interviewee profile in terms of job title, academic background and time of experience.

Table 1: Interviewee Profile.

Respondent	Job Title	Academic Background	Time of Experience
1	Professor	PhD in Engineering	37
2	Professor	PhD in Engineering	32
3	Engineering Manager	Engineer	27
4	Engineering Director	MBA Engineer	22
5	Product Development Engineer	PhD in Engineering	19
6	Product Development Engineer	PhD in Engineering	16
7	Engineering Manager	MSc in Engineer	15
8	Engineering Manager	MSc, MBA, Engineer	15
9	Assistant Professor	PhD in Design	13

5 Compilation and Analysis

All the answers for the two questions of the interviews were registered and a manual content analysis was performed in order to identify common points between them. Semantic themes were identified concerning the selection strategy as well as curriculum content for the company hiring and preparing future PSS developers. All the answers were summarized into two major categories: Selection Strategy and Curriculum for developing competencies and into the following subcategories:

- To select candidates with holistic approach of business and product/service development.
- To select candidates that show characteristics related to customer empathy.
- To develop a strategy that will be unique for the company in order to attend its demand for PSS.
- To select candidates with "return on investment" mindset.
- To develop competencies in order to conceive, design and implement lock-in solutions concerning product/services.
- To develop a holistic view of the PSS life cycle.

5.1 Selection Process

Concerning a selection strategy, all specialists mentioned the importance of selecting candidates that show approaches or characteristics of a “holistic view” of not only the product development process but also of the business model in which it will be developed. Six interviews identified “customer empathy” as a desirable characteristic for the selection process of PSS developers. According to the answers, this is especially important when considering the luxury market of the executive jets, where the customer needs are very specific and require a lot of attention to details. In order to address the development of “customer empathy” competence by the engineers, the PEE strategy has been to put its students in direct contact with the customers both in the marketing analysis phase as well as in conceptual and preliminary design reviews. For example, pilots and flight attendants from a Brazilian Airline were interviewed by the students to understand their requirements and made part of the evaluation board of some design review phases of a commercial aircraft that was under development. Another example include the students that were developing a military cargo airplane that spent one day in a Brazilian Air force Base where they had the opportunity to better understand customer needs, routines and values.

Five of the nine respondents highlighted the importance of a “return on investment” mindset for selecting future PSS developers. These answers can be interpreted as the first ones when the product development must be though simultaneously with how much the return on the investment will be. The challenge regarding these answers is to define how to identify and evaluate these suggested characteristics during a selection process. The importance of recognizing these characteristics is understood but further studies are necessary to establish a strategy to put them in practice.

Six from nine respondents mentioned that before establishing a selection process, the company has to define its own PSS process will be in its context. Without it, according to the interviewees, there is no sense to discuss an adequate profile for PSS developers as each PSS process is unique regarding a company context.

5.2 Curriculum Content

According to six interviewees, it would be important to teach PSS developers how to implement “lock-in” solutions. By that, they mean developing systems where the product and the services form an entire solution to be worth it for a customer, or in other words, to develop products whose services offered by the company are the best option for the clients. Four

respondents mentioned the importance of developing a "holistic view" of the PSS life cycle for future PSS developers. With it, more opportunities in the whole life cycle can be identified by them and also the impact of each decision in the PSS development process can be understood.

Besides the two questions answers, as the interviews were semi-structured allowing more debate around the theme, without losing focus on the objectives, a broad view of PSS was also discussed. As a result of these discussions and literature analysis, four observations about PSS can be highlighted:

a) Observation 1: To design PSS is different from designing either a product or a service only.

b) Observation 2: Although there are PSS models in the literature a PSS solution depends on a company context and so, each company has to elaborate its own PSS model.

c) Observation 3: To concept, develop and implement PSS evolves changes in process, people, technology and in the business model of the companies.

d) Observation 4: The registers of PSS application and PSS developers' adequate competencies are rare.

5.3 Proposed Model

The interviews spontaneously cited desirable characteristics for future PSS developers that are aligned with the CDIO Syllabus described by Crawley et al. (2011).

The building blocks of knowledge, skills and attitudes of CDIO cited during the interviews are highlighted in blue at Figure 7 were put together according to the content analysis. Figure 7 was built based on the four blocks of knowledge described by Crawley et al. (2011).

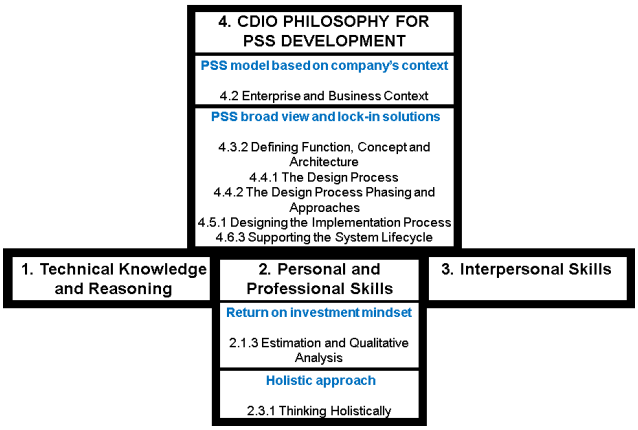

Figure 7: Building blocks of knowledge that were mentioned in the interviews.

Although these competencies were not mentioned by the interviewees, considering the complexity of the business and product development (PSS) for executive jets, the authors also believe that the competencies 2.4.2 Perseverance and Flexibility, 2.4.3. Creative Thinking, 3.1 Teamwork and 4.4.5 Multidisciplinary Design are also important.

Services and products have different natures. According to Corrêa et al. (2007) a service is intangible, is not stored, is consumed at the point of the sale and does not result in ownership. However, the analysis of the results of this work lead the authors to infer that some of the needed competencies for the block of knowledge 4 (conceiving, designing, implementing and operating) product and service development could be different for product development and PSS. Also, that different technical knowledge (block of knowledge 1) could be required for PSS Engineers than for Product Development Engineers considering the challenge of thinking not only about the product and service development but also in terms of the business plan in which it would be inserted. Based on the literature research and in the analysis of the results the authors infer that Personal and Professional Skills (block 2) and Interpersonal Skills (block 3) does not seem to have major changes in the selection process and curriculum design of PSS Engineers and Product Development Engineers. More investigation is

needed to better analyse the impact in each CDIO block of knowledge.

As a proposal, the authors conclude that there could be a possibility to analyse the CDIO process expanded to incorporate also the aspects related with Service Design and consequently PSS development.

6 Final Comments and Suggestions for Future Learning

This paper has the objective of identifying suggestions for the selection and curriculum design for PEE engineers that will work as PSS developers in the executive aviation. The literature review highlighted the gap for defining suggestions for PSS developer's profile and suggestions were made based on the interview of specialists. The analysis of the results suggests that candidates with holistic approach, business vision, customer focus and return on investment mindset could be adequate future PSS developers. This is an important conclusion as it can indicate that only a high-skilled technical profile is not anymore sufficient for a PEE engineer and the PEE selection process and educational strategy should be reviewed.

As opportunities for future learning, there could be a deeper analysis to better explore how to select and develop competencies in PEE students for the PSS development by identifying desirable competencies for them. To define metrics, behaviors and attitudes in order to identify good competencies for PSS developers also remains a challenge. Concerning the staff, a study could be conducted in order to define how the selection team should be composed in order to identify the competencies suggested in the interviews. Finally, there is a need of defining the PSS design, development and implementation process for the executive jets.

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