AN APPLICATION OF SOFT SYSTEMS METHODOLOGY (SSM) IN THE LAB: AN ENVIRONMENT TO TRAIN STUDENTS FOR THE INDUSTRY OF FUTURE

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The fourth industrial revolution is bringing new business models and, consequently, is requiring professionals with skills compatible with the new world. It is the role of the university to provide an environment for developing skills and graduate suitable professionals.

Palavras-chave: Soft Systems Methodology; Industry of the Future; Students training; Professional skills.
1. Introduction

The world is passing through a new industrial revolution, characterized by enabling technologies, that change the manufacturing process, provide sophisticated data exchange systems and an efficient automation that influences new business models. (BALASINGHAM, 2016).

Producers and suppliers of products and services have improved their organization by using innovative technologies, taking advantage on the trend of transformation and evolution based on the complete digitalization and the smart production process to ensure high efficiency. To achieve these goals it is necessary to implement new technologies to automate industrial processes, and until that, it is necessary a prepared workforce (PETRILLO et al., 2018).

Looking at this scenario, the role of the university is to prepare professionals for this new industry. In Brazil, the traditional training is based on theory learning without putting into practice, and lack of interaction with companies, which means that it does not meet what the industry of the future demands.

The Open Lab of Brasilia (Laboratório Aberto de Brasília – LAB) is an extension project of University of Brasilia, which aims to prepare professionals for the fourth industrial revolution through digital manufacturing, focusing on multidisciplinary projects which students develop from idea to prototype, using as its primary manufacturing process, the additive manufacturing.

However, this is not trivial, and demands a strong project management process, which ensures the involvement of all stakeholders in appropriate stage to ensure complete development of the student. In addition to ensure the participation of stakeholders, there is a need for internal processes management as well to reinforce the development of professional skills of the industry of the future while the student is in the operation period in the LAB.

Currently the LAB is building its fourth generation of students, the first time when more than ten students are being developed, thus there is a difficulty on managing and monitoring the training of them all. Considering this complex situation, it was identified the opportunity to apply a methodology to understand the problems related to this process of training the student with skills for the industry 4.0’s market, and then understand how the LAB management can be performed to ensure its goal.
The methodology used to understand this complex situation was Soft Systems Methodology (SSM), which allows an examination of the real-world perceptions, defining actions to act in the real situations, reflecting on the possible effects of the actions taken (WANG et al., 2015).

This article describes the application of SSM in the LAB, which the main contribution is to promote this methodology to solve problems related to management and training problems. The structure begins with the review of the SSM literature, a presentation of the LAB concept and the current context of operation, the application of SSM in the presented situation, and conclusion.

2. Soft System Methodology

The real world problems are usually placed in a complex and poorly defined context, so it is necessary to identify the essential characteristics to be considered in the decision making process, which will be based on the analysis, objectives and motivations of the stakeholders involved, and understanding which actions can be carried out.

The Problem Structuring Methods (PSM) are used when a group of stakeholders aims to address a complex an uncertain problem situation, considering all multi perspectives and the common concern through an interactive process (LAMI & TAVELLA, 2019).

The PSM have two main characteristics: Facilitation and Structuring. The facilitation characteristics enable an environment to discuss about the situation and clearly understand about the decision that needs to be taken. The structuring characteristics is related to the process of systematization of the elements presented during the discussion, the purpose is to form a common knowledge about the problem, to improve the quality of the decision making process (ANTUNES et al., 2016).

With this methodology it is possible to identify, analyze and understand the role of each stakeholder involved in the situation, the degree of intervention and power of influencing decisions. It is also possible to identify the relationship between the different stakeholders, identifying their objectives, values and concerns in accordance to the objectives and values of the organization or problem situation (CARDOSO-GRILLO, 2019).

The PSM can be applied by the Soft Systems Methodology (SSM), that is based on a “open world-assumption” which does not simply accept the existing situation but focus on investigating and understanding the complex problem and expressing it in a structured way (WANG et al., 2015).
The SSM is about helping people solving complex organizational problems, that is considered “complex” because of the unknown variables that exist within the problem. For Wang et al. (2015) the “soft” characteristic is related to people and the way they think and relate to one another. The “system” refers to the application of this theory of systems on relationships, human resource’s goals, procedures and resources. The “methodology” refers to the way of thinking, it is about the definition of what the organization currently is, what they might be and what they want to be, and also the actions that should be taken in a given situation to achieve these goals.

The SSM consists on seven steps shown in Figure 1 and described below.

Figure 1: Seven steps of SSM

The first step of the SSM methodology is the complex situation inspection, in which is necessary to find as much information as possible. It is acceptable many different views. It aims to identify the real world situation that is being considered a problem situation, so it can be possible to make a diagnosis of the situation (WANG et al., 2015).

After identifying the real world situation, the second step is to express the messy system through drawing rich pictures explaining the problem and the relationships involved. The problem situation can be expressed by a graphic representation, which the most common strategy in the SSM is the graphic of rich pictures, that represents all the stakeholders and their relationships offering a broad vision of the problem (WANG et al., 2015).
The third step is building the basic definitions for relevant activities system purpose. The root definitions are related to tighten the constructed description of human activity system (WANG et al., 2015). To do so, it is possible to use some techniques like the CATWOE technique.

The CATWOE analysis is used to structure the problem considering customers, actors, transformation, Weltanschauung, owner and environmental, which are described:

a) Customers are the direct recipients of the system’s output, who can be seeing as beneficiaries or victims (WANG et al., 2015);

b) Actors are those who perform the activities of the system (WANG et al., 2015);

c) Transformation is the part of the system were the inputs are converted into outputs and given to the clients (ANTUNES et al., 2016);

d) Weltanschauung is the same as “world view”, and it is about the perspective, point of view or the context (ANTUNES et al., 2016);

e) Owner are those who can create, change or destroy the system and those who supply the system (WANG et al., 2015);

f) The environmental is related to groups who are directly necessary for the system (WANG et al., 2015).

The identification process of the CATWOE can be implemented using the structure defined by Cardoso-Grilo et al. (2019), which follows three steps:

a) Identification of the stakeholders involved into the complex situation, who will be the customers, actors and owners, and the identification of specificities of the process, that is related to the characterization of the transformation process and the environment;

b) Identification of the key objectives and values of each stakeholder involved in the complex situation;

c) The preview results will be analyzed and validated with the main responsible stakeholder of the situation, and then, adjustments will be made based on the defined considerations.

By structuring the problem by defining the root definition, the fourth step is formulating conceptual models, that means that a logical model of key activities and processes will be developed, as simple as possible, to satisfy root definition (ANTUNES et al., 2016).
The fifth step is comparing the conceptual model with reality, and in accordance to Antunes et al. (2016), the model needs to present some elements like a defined mission, performance measurement, decision making process, sub-systems, interaction with the environment, physical and human resources.

The comparison of the models, sixth step, will influence the debate with systematically desirable and cultural feasibility, which aims to identify the possible changes that will be necessary to introduce in the real system process (WANG et al., 2015).

The seventh step is taking actions to improve the system, so the model can be implemented in the real system (WANG et al., 2015).

So, with all these steps it is possible to have a framework to generate ideas to be used in a real problem situation, especially those that represent a messy problem situation, with emphasis on problematic situations and different point of view. The models are developed with the intention to learn about the situation and understand the problem, and not to make a prediction of the situation (WINTER, 2006).

3. The Open Labof Brasilia (Laboratório Aberto de Brasília – LAB)

The LAB is an extension project of the University of Brasilia, implemented in 2017, and approved to provide services for the external community in 2019, which the objectives are enabling entrepreneur education by using the active teaching methodologies to develop the skills required by the professionals of the Industry 4.0 (ZIMMERMAN et al., 2018).

The industry of the future is the fourth industrial revolution, which brings new business models, new factory models, new ways of working and solving problems, and so on, demanding new professionals profiles that are used to the enabling technologies of this new industrial era: autonomous robots, simulation, system integration, internet of things, cybersecurity, cloud computing, additive manufacturing, augmented reality, big data and so on (PETRILLO et al., 2018; MENDONÇA, 2019).

To achieve its objective, the LAB chooses the enabling technology of additive manufacturing, because of its lower cost of implementation. The methodology applied to develop the student in a fourth industrial revolution context are the active teaching methodologies with which the students work in a maker context to solve real problems (MENDONÇA, 2019).

The real problems come from some stakeholders like startups, entrepreneurs, small, medium and large companies, and the university itself. The solution can have three formats: project – a
problem is presented and a solution is proposed to the client; modeling – a solution is presented and the 3D modeling is proposed to the client; prototype – a 3D modeling is presented and the prototype is produced by 3D printing or milling (ZIMMERMAN, 2018).

The organizational structure of the LAB has one coordinating professor, from the department of industrial engineering; one substitute coordinating professor, from the department of mechanical engineering; one industrial engineer and master student from the department of mechatronics, responsible for the operational management; eight graduating students from mechanical engineering, five graduating students from mechatronics engineering and two graduating students from industrial engineering.

The management of the LAB team is not a trivial task since it involves many soft factors such as human activities, conflicts, different objectives, different values, emotions and so on. In this process, it is needed to consider the different stakeholders involved in the preparation of a LAB worker in order to achieve the main objective.

4. Case study: application of SSM in the LAB system

The objective of the SSM application in the LAB is to understand the problematic situation related to the difficulty of implementing a system that provide the employment of a concomitant formation process of the undergraduates. In accordance with the steps presented by Wang et al. (2015), the methodology will be applied until the fifth step, since it covers the objective and the contribution of the article on using the soft system to understand the problem, and not necessarily discovering the problem and present a solution.

4.1 Step 1: Complex situation inspection

The LAB has some problems to employ a system that provide the implementation of a concomitant formation process of the student, usually spending six months to a year in the LAB. During that period, it is necessary to have a solid system that ensures the knowledge transference from already developed students for the new student that are entering in the LAB system. Then it can be ensured that all the students were trained and developed on professional skills of industry of the future and so as to keep the quality of service provided by the LAB.

It is important to highlight that the trained students are those who has been a period in the LAB and developed the industry of the future skills. After this, it is necessary being involved
in the formation process of the new students, those who are not trained and still do not have skills to work in the projects’ demands from the community outside the UnB.

4.2 Step 2: Expressing messy system
To express the messy system a drawing rich pictures was made to explain the problem and relationships related to it. The Figure 2 represents all the stakeholders and their relationships, offering a broad vision of the problem (WANG et al., 2015). Considering the complex situation presented, the LAB appointed problems like capable professionals for the industry of the future and all the main stakeholders involved in this process, which are basically service customers, maker customers, trained students working at the LAB, not trained students working at the LAB, future industries and the regulators organs.

![Figure 2: Rich picture from the LAB system](image)

Source: prepared by the author

4.3 Step 3: Building root definitions
To build the root definitions the CATWOE technique was implemented, using the three steps presented by Cardoso-Grilo et al. (2019). Figure 3 presents the CATOWE analyses to structure the students training problem.
The *Weltanschauung* (ANTUNES at al., 2016) is related to the worldview of the situation for those who are involved, and this is: an adequate implementation of the training process of the students for the industry of the future.

The transformation of the process of training students involved the inputs of students of LAB, the professors and all actors involved, to produce the outputs of the system. This process of formation of the students consider undergraduate students that are in the first, middle or final stage of the graduation. Currently, they are from engineering courses only (currently the actors are from mechanical engineering, mechatronic engineering, and industrial engineering), and are selected considering especially their interest on learning in the LAB.

The selective process of the LAB is composed by three steps. The first one is a LAB introduction, where they are presented to the values and objectives, and then a challenge project, which will depend on the field of knowledge that they are being recruited. Currently there are two types of challenge: i) understand a problem, develop solutions, generate concepts of these ideas, choose the best one and produce the prototype. The duration of the process depends on the difficulty of the challenge launched; ii) work on a piece modeling, by developing 2D or 3D model of a piece, following the premises and restrictions imposed.

After the selection of the new contributors, they attend on an “integration process” which aims introducing the students about the LAB culture, internal rules and internal process, within which is included the process of modeling and operating a 3D printing and a CNC. This process has a duration of two weeks. After this process, it is considered that the student
is prepared to develop the skills in the LAB acting on real world projects, first dealing with internal projects, and then after building up confidence and experience, they can work on requests from startups, entrepreneurs and so on.

A lot of different situations can affect the expected duration and sequence of the students training, so as to guarantee the quality of services that are developed in the LAB, for instance: i) the students may have a job propose before finishing the formation process; ii) the students cannot spend more than eight hours in the LAB; iii) the students that have the role of teaching to the new students need to focus on the Master’s degree, or may fail the program, and then get out; iv) the absence of an structured management; v) the absence of financial resources; vi) the absence of structured forms to transfer the knowledge from the old members to the new ones.

Multiple stakeholders are involved in this process. They are identified as customers, actors and owners from CATWOE:

- **Customers:** not trained students working at LAB, trained student, industry of the future.
- **Actors:** LAB (trained students and partner teachers), partners or possible partners and clients.
- **Owners:** UnB, Finatec.

The training of students is a continuous process that needs to be linked to the stakeholders’ needs to promote a balanced training workforce. All these stakeholders need to be aligned to promote a concise process and allow that all students have developed their abilities to work in the industry of the future.

The environmental that support the training process: financial resources to support the LAB; the number of former members available to train students; the number of enterprises available to invest in LAB (partnership); the limited number of students that the LAB’s physical space can support. These constrains are imposed by the LAB manager.

With the root definition it is possible to build conceptual models, that will show the logical model of key activities, and process will be developed, as simple as possible, to satisfy all stakeholders and areas identified in the CATWOE system (WANG et al., 2015).

**4.4 Step 4 and 5: Build conceptual models and compare with real world**
The conceptual model, presented in Table 1, has twelve activities to propose an adequate plan to form the developing skills of the students in the LAB, from which the first six correspond to the real situation. In this comparison it is possible to see that the conceptual model addresses activities that, in the actual moment, are not performed by the LAB to guarantee the training of its new students, and that, consequently, are not structured in the human resources management model, which affects the objectives of the LAB.

Table 1: conceptual model and comparison with the real model

<table>
<thead>
<tr>
<th>ID</th>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Identify need.</td>
<td>The high turnover of the team is a real challenge to the management of the LAB, in this way, once the need is identified, the selection process must be arranged.</td>
</tr>
<tr>
<td>1</td>
<td>Open recruiting process.</td>
<td>The recruiting process is launched according to the identified need, which can be for a specific course, or a call of students from different courses.</td>
</tr>
<tr>
<td>2</td>
<td>Evaluate performance.</td>
<td>The responsible members evaluate the performance of the candidates on the following requirements: level of knowledge, experience, posture, solution model for the presented problem, performance in presenting the solution.</td>
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<tr>
<td>3</td>
<td>Select students.</td>
<td>Based on assessed requirements students will be selected.</td>
</tr>
<tr>
<td>4</td>
<td>Execute integration process.</td>
<td>The LAB integration process is executed for four days with the new collaborators, where each day corresponds respectively to: presentation of the rules, work processes, organizational structure, mission and culture of LAB; Modeling course; 3D printing course; Milling course.</td>
</tr>
<tr>
<td>5</td>
<td>Verify and record the level of knowledge of the new collaborator.</td>
<td>The student's competencies must be recorded, in order to determine their work plan and to evaluate their evolution during the period of work in LAB.</td>
</tr>
<tr>
<td>6</td>
<td>Set work plan.</td>
<td>The work plan must be defined and validated with the student.</td>
</tr>
<tr>
<td>7</td>
<td>Monitor the development of activities.</td>
<td>The LAB must have an activity monitoring plan to measure the student's performance and identify which skills have been developed, which are being developed and which are to be developed to reach the professional profile with mindset facing the market of the future.</td>
</tr>
<tr>
<td>8</td>
<td>Identify failures in skills development.</td>
<td>Monitoring activities should allow the LAB's master team to identify the skills that are not being developed as well as the cause of the failure.</td>
</tr>
<tr>
<td>9</td>
<td>Develop an action plan to undeveloped skills.</td>
<td>The action plan should involve initiatives such as new training, new activity distribution model, change in mentoring processes, changes in work team structure.</td>
</tr>
<tr>
<td>10</td>
<td>Reassess the evolution of the collaborator.</td>
<td>Should reassess the performance of the student after the implementation of action plan.</td>
</tr>
<tr>
<td>11</td>
<td>Preparation of a new action plan.</td>
<td>If necessary, a new action plan should be developed, implemented and evaluated until the student develops the skills.</td>
</tr>
<tr>
<td>12</td>
<td>Preparation of a general report on student skill building.</td>
<td>Make a general report on the training of each student's skills in LAB as soon as their work period ends.</td>
</tr>
</tbody>
</table>

Source: prepared by the author
5. Conclusion

The new technologies allow industries to improve their processes and make their work more efficient. This is the new industrial revolution that, in addition to social and economic changes, also demands changes in the process of training new professionals.

Cited in this context, this article applies SSM to identify what LAB can do to ensure its goal of training professionals for the industry of the future. The application of the methodology was done with those responsible for the management of LAB and followed five steps: exposing the problematic situation; expression of the situation using the technique of rich figures; description of the system using the CATWOE technique; construction of the conceptual model and comparison of this model with the real context.

In this article it was emphasized the main contribution of the SSM to the situation of LAB, which is the promotion of a systematic self-evaluation, considering the different views on the system, providing an understanding of reality and a conceptual model that can be used to develop alternative improvement of the situation.

Based on the diagnosis made, stands as a suggestion for future work, the application of the conceptual model developed, which encompasses activities of extreme importance for the control and guarantee of the student's education with the appropriate professional profile for the industry of the future.

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