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Teamwork in Engineering Training: The Case of an Intervention in a Worker Recovered Factory in Brazil*

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This study is the result of a research developed in the course of an intervention in a Brazilian Worker Recovered Factory (WRF) in Brazil performed by a team of fifteen engineers from different areas and levels of training. According to the principles of the Ergonomics of Activity, the intervention sought to analyse and propose solutions to company problems from a participatory process, which also includes workers at all stages of their development. We were able to analyse the intervention through direct participation in the project as a member of the team of engineers (participant research), seeking to draw contributions on engineering training from practice in real situations (action research). The intervention showed the possibility of obtaining a supervised apprenticeship process, reducing complexity without losing touch with reality, creating conditions for students to learn by practice, and making mistakes without causing damage to the host company. This process showed that is possible to overcome the purely theoretical formation of the engineer, allowing developing teamwork skills and the collective construction of emerging and socio-technically responsible solutions.

Keywords: teamwork; participation; industrial assessoring; socio-technical education

1. Introduction

Making the transition from academic training to working as a professional engineer is a difficult, often frustrating, time for many engineering graduates. This is because the reality they are going to act on is much more challenging and requires knowledge and skills that college courses cannot offer today. Part of the difficulties is related to the need to include non-technical variables in the projects. Another part is related to the need to work as a team, to be able to dialogue with different knowledge and value the practical experience of the workers.

Part of the criticism of traditional engineering education focuses on having the curricula concentrate on the technical aspects to the detriment of the social and political aspects. They criticize the pragmatic and "cold" way engineers are trained: "too precise and not human enough" [1]. To overcome this appraisal, they suggest either reinforcing or introducing subjects related to the human areas. However, it is not only a question of including the "humanities" in the engineering curricula, like a colorful trinket used to rouse a technicist soul [2]. The main idea is to provide graduates with opportunities to cultivate other essential skills, and not just the purely technical ones, needed to cope with complex problems, including social dimensions.

The chance to develop teamwork skills at the university level is limited. Opportunities for team experiences are few and far between, and they are not taught by any expert in the subject. When asking for a job (a seminar or report, usually) as a team, the final product is often a confused hodgepodge. Academic practices that most closely approximate relevant teamwork experiences can be found when students get involved in research projects, extension, or join student organizations, such as fraternities, centers, and academic directories. These last ones offer more interesting teamwork involvement, because they bring groups together that need to self-organize to solve their unique set of problems. Yet, few students participate in them. The research case is complicated when it comes to teamwork, because even when a group is involved, it usually leads to a division of labor between those who think and those who carry out the tasks.

In a teaching context, some academic experiences have been tried in an attempt to bring theory and practice together. We can cite Problem Based Learning (PBL) metodology, which creates a learning environment closer to the complexity of the real world. However, there are problems with this method that have not yet been resolved, such as difficulty in implementation, the loss of reality with the necessary simplifications to be effective in an academic environment and its limit in developing students' ability to identify, analyze and formulate their own problems, not just solving predefined problems [3, 4].

Good examples of teamwork can be found in

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extensions programs, such as the Solidary Economy support centers and the cooperative incubators that began to crop up in Brazilian universities in 2001. These are channels through which students who were organized in multidisciplinary teams came into contact with the university's outside environment while looking for support for the development of cooperatives [5]. The experience we will address here is influenced by these experiences.

The case study presented here is an initiative of professors from production engineering courses from three Brazilian public universities, members of the Research Group on Worker-Recovered Enterprises (GPERT – Grupo de Pesquisa em Empresas Recuperadas por Trabalhadores). WRFs are self-managed companies that have recovered from bankruptcy by their own workers as to secure jobs and income. In this quest, they construct alternative ways of organizing work. According to Henriques et al. [7], members of GPERT, Brazil was a pioneer in WRFs, with isolated cases dating back to the 1980s. They spread throughout Latin America amid the advance of neoliberal policies that led to many corporate bankruptcies in the 1990s. Along with the challenge of reversing the bankruptcy process, these companies face formidable difficulties staying in the market. Their demands, however, are typical of small- and medium-sized companies, such as lack of working capital, reinvestment, management tools, and organization. The GPERT found 67 WRFs that were active between 2011 and 2013 [7]. The economic and political crises Brazil has been passing through in recent years have aggravated those difficulties. In a study conducted in 2017, the GPERT estimates that 30% of the WRFs went out of business [8].

The group sought to deepen their understanding about the operating structures of the Brazilian Worker-Recovered Enterprises (WRE), especially the progress and limits of the self-management process the companies have been experimenting with and developing over the years. This interest in knowing more and, at the same time, contributing to their advancement, led researchers to offer to give them technical advice through Ergonomic Work Analysis (EWA), which guides "knowing to transform", according to Guérin's maxim [6]. However, in this article we are interested to explore the dimension of engineering education present in the experience, especially about its potential in the development for collective and team work skills.

The intervention process involved undergraduate, masters and doctoral students in various areas of engineering and levels of training. The team consisted of fifteen members who, according to the theoretical-methodological principles that will be detailed below should elaborate together the entire intervention process, from planning to execution and evaluation. They also had to worry about developing strategies to involve the team and allow the collaboration of the different experiences and for the novices to learn. It required dealing with a heterogeneous group of engineers, instructors, and students at different levels of training in an unconventional context, e.g, recovered companies and the self-management organizational model. Learning to deal with the complexity of the environment and the collective work, which had been extended to include the factory workers' participation, helped in the development of teamwork skills.

In the following lines, we will deal with the methodology used in the research. In the following, the intervention process and its results will be presented in more detail, as well as the internal training devices used in the experience, such as immersion in the company, alternation, academic team meetings and meetings with the pilot group, a group of company workers. Still on the intervention process, we will point out the theoretical and methodological bases that supported the development of the experience and that are common to the formation process that took place in its course. We will try to show in which sense each reference contributes to the whole of what was done. They also provide important elements that become key values for teamwork, such as dialogue based on the appreciation of different knowledge, trust, responsibility, reciprocity, and commitment. Subsequently, the results of the analysis on student learning will be emphasized from two aspects. First, more general, about the practical performance in face of real complex problems, which point to the need for a formation that surpasses the theoretical and positivist view present in the academy. It will also look at the main difficulties that students confronted when faced with a complex and little known reality, having to co-design not only with their engineer peers, but also with the workers. The second aspect focuses specifically on teamwork, where we point out the strategies that allowed students to be involved in a collective problem-solving process. The subdivision of the team into smaller groups, setting up a routine of information-sharing meetings between groups, rotating functions and leadership, acting side by side with de teachers, among other strategies, provided a supportive learning environment for teamwork.

2. Methodology

This paper presents part of a doctoral research on teaching-learning processes in an engineering team, in the context of an intervention in the self-managed

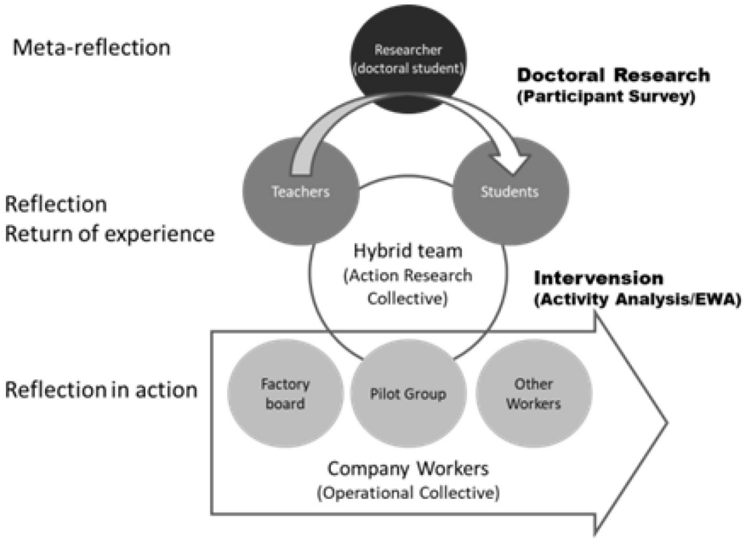

Fig. 1. Methodological scheme of the research and of the intervention.

company. For her analyzes, the researcher conducted a participant research, as she acted as a member of the team that conducted the intervention in the company, following the action research approach. Fig. 1 helps us understand the relationships established between the various actors involved in this process. In this scheme it is possible to observe the actors and the participatory research processes – of the doctorate – and the action research – of the intervention – that occurred in parallel. The researcher is directly involved in both, analyzing the team while developing the intervention process with it.

The results presented here are related to participant research, whose object of study are the formative processes within the team, the action research collective, which was restricted to academics sometimes, but sometimes was expanded with integration of the workers of the company too. The company's workers participated in the action research process through the Pilot Group, formed by their own nomination. We consider that the experience of intervention based on the participation, even with the workers, in its development, is a fertile ground for analysis of teamwork and its formative aspects, the subject of this article.

During and after the intervention process, interviews were conducted with undergraduate and master students and two teachers who proposed the project. Some of the interviews were semi-structured, others occurred freely with subsequent systematization. Among other questions, the interviews also aimed to understand their individual perspective on the collective work and the learning that that experience was providing. However, the results presented here come mainly from observations and analysis of the activity of engineers during the intervention process, who sought there practical evidence about the educational processes.

3. The Intervention Process and Internal Training Devices

3.1 Intervention Process Overview and Main Results

The intervention process analysed took place over a year and a half (between 2015 and 2017), in a WRF that produces plastic drums, which has been under the workers' control for fifteen years. Up to 2015, the company had been able to maintain its activities on a regular basis, but the economic and political crisis that erupted that year had a drastic effect on it, igniting a period of anxiety and uncertainty. The loss of customers, buyer pressure to reduce the price of products, and an increase in energy tariffs triggered a cascade effect on the imbalance of the company's finances. Wage delays, lack of working capital to purchase raw materials, difficulty in equipment maintenance, and trouble paying energy bills were common. The project was not motivated by a specific demand. There was, however, an acute crisis in which the team would intervene, and contributing to its solution through engineering was part of the intervention.

In addition to the GPERT's practical aim, the scientific objective was to study self-management at the level of daily work, since self-management studies are usually featured in sociological, economic, and psychological discussions. The expectation was to help put together recommendations for changing work situations by applying the EWA, based on observation of the activity. The EWA, combined with the workers' participation in the research process through the Pilot Group, has enabled an accurate participatory diagnosis and the development of emerging solutions to the problems encountered.

Over the course of six stages, the team designed and implemented a Production Planning and Control System and a Preventive Maintenance System, tools to help manage the company's production process and address delays in delivery and customer loss. In addition to the co-design of the tools, the intervention also resulted in a greater role for the Pilot Group workers in finding solutions to company problems, strengthening self-management. Despite the efforts of the team and workers, shortly after the intervention, the company was surprised by the power outage by the local subsidiary company. In addition to harming the company, disruption of production also impaired the assessment of project results. The company continues looking for ways to resume your activities.

3.2 Pedagogical Devices and Process of the Team

As already mentioned, this project contained a challenging pedagogical dimension by involving a large and heterogeneous team, made up of undergraduate, masters, and doctoral students. In total that were fifteen members: four instructors, one doctoral student, tree master's degree students and seven undergraduate students. The students were from engineering areas, such as production, mechanical, chemical, food, telecommunications, and environmental engineering. In addition, to coming from different courses and different levels of academic training, there was also a big difference in each person's experience with the context of self-management, the theoretical-methodological foundations of the intervention being proposed, and even teamwork itself.

The research team (teachers, students and even workers sometimes) should collectively plan, execute, and evaluate the actions in the factory. However, in such a large, heterogeneous team, how would these actions be developed? How to make sure that the students followed the project and, more than that, contributed to it? These questions served as a starting point for analyzing this experience from the standpoint of developing teamwork.

3.2.1 Immersion and Alternation

Each of the project's six stages was carried out in four consecutive days of immersion inside the company. These immersions enabled researchers to strengthen ties between themselves and the workers. This is because the research depended on a comprehensive understanding of the workers' reality when performing their duties. Between the immersions there was a period of reflection and systematization of the experience. During this period the team held virtual meetings for alignment, distribution of tasks and socialization of results. The immersion and systematization alternation guaranteed a precious time for reflection on the action that took place during immersion, always quite intense.

3.2.2 Team Meetings

These meetings took place every day during the immersion and were attended by teachers and students. At these meetings the team would collectively plan and evaluate all actions. In addition, there were also theoretical and methodological debates associated with the actions that would be performed.

3.2.3 Pilot Group Meetings

They also took place every day during the immersion, bringing together academics and workers. At these meetings the academics should present their systematizations to be debated with the workers. The continuity of the intervention process depended on the decisions made there. The direct participation of the workers in the research debates allowed the direct dialogue between the knowledge of the practical experience of the workers and the theoretical knowledge of the academics. Thus the educators themselves were also educated.

3.3 The Theoretical and Methodological Bases Common to Intervention and Training

The experience of the intervention analyzed here, as already mentioned, was developed according to the theoretical-methodological framework of Activity Ergonomics, from which the EWA derives. However, it was possible to observe the influence of other references. The two parallel processes that occurred in the case studied, intervention and formation of students, contain a common theoretical-methodological basis that is also the result of the accumulation of studies and previous experiences of GPERT teachers who created the project. Their work together since the student period was carried out through multidisciplinary teams in university extension programs that supported popular production initiatives using models of cooperation. We will point out each of these references here to understand how they can collaborate in building programs, projects and curricula that support engineering training from the perspective of developing teamwork, collective and emerging work skills.

3.3.1 Popular Education

It provides important contributions to the development of skills for collective work because this is a pedagogical principle for Popular Education [9]. More than a methodology, the proposal of the

Brazilian educator Paulo Freire, is a strategy of building popular participation that uses the learner's knowledge as a raw material for teaching, valuing all social subjects in the process. This perspective of valuing the subjects and their knowledge facilitates the establishment of dialogue between the parties and between different knowledge. Thus, it encourages the engagement of students and workers in the project and consequently mutual learning. For Popular Education, dialogue and participation is an assumption of learning.

3.3.2 Action Research

If Popular Education provides the pedagogical principle for intervention and training processes, Action Research (AR) provides the framework in which it has developed in the reported experience. The AR argues that research authors and social actors must be involved: the actors in the research and the authors in action [10]. This requires interactivity, reciprocity, and cooperation to identify problems, and then design and experiment with real-world solutions. From the point of view of training, AR allows that the relationship established with workers support the training of educators themselves. Teachers have, than, the opportunity to learn from workers about the practical effect of their theoretical elaborations so that they are reflected and reworked in the transmission to students.

3.3.3 Science, Technology, and Society

The group's reflections on the relationship between Science, Technology, and Society (STS) and, later, the Ergonomics of Activity (EA), added the perspective of facing the problems associated with the world of work through mediation by developing the technique and the technology. STS studies are presented as a critical analysis of technoscience with respect to the classic triumphalist vision of science and technology, aimed at grasping the general aspects of the scientific-technological phenomenon involving other values than the economics and the scientific knowledge. This comprehension helps adjust the expectations of engineering work by alerting us to the complexity and responsibility involved in technological development. Thus students learn that problem solving is not only based on mathematics, physics and chemistry, but also on social relations.

3.3.4 Ergonomics of Activity

The EA (which has its roots in the Francophone school of ergonomics) starts with the realization that the activity always distinguishes itself from the task. Therefore, in-depth analyses of the activity need to be carried out in real working situations to avoid making deductions from formal models. The analyses derived from it, such as the EWA, strive to understand what is happening in each worker's unique daily work routine through participant observation and ethnographic research. It brings the researcher face-to-face with the challenge of appreciating the workers' practical experience, and looking at the problems through their eyes is neither a spontaneous attitude nor valued in the traditional training of the engineer; it is a "change in perspective" [11]. Intervention should not define the objectives of a business project in this 'new perspective', but rather guide the decision-making process. There are different visions and interests in a business project, so designing is not only solving problems, but, first and foremost, and essentially, its construction [12]. It then becomes necessary to overcome the division of labor and create conditions for confronting the various existing partial elements [13]. Thus, the success of the intervention depends, to a large extent, on the parties' degree of involvement with the proposal. This collaboration needs to be assured as a social construction that supports the intervention and allows a collective commitment between the different positions at stake. From this perspective, it is not enough to have a "scientific" or "ideal" technical solution. Rather, a political solution is called for, which encompasses different values under discussion.

4. Results and Discussion: Dealing with Complex Problems in a Secure Environment

4.1 Complex Problems and the need for a Socio-Technical Education

For some students, this was their first contact with a factory and how it operates. In many situations it was possible to observe the contrast between the real problems they encountered in the company and those that are challenged to solve during the university course. Difficulties began to emerge in the first stage of the intervention, with the demand analysis that would guide the intervention process. As the company was going through a deep crisis phase, various data control and systematization tools, such as spreadsheets, tables, forms, work orders, etc., had stopped working for some time. Thus, obtaining information to analyze the company's problems required the team's effort to perform a primary data collection and systematization. There were no production, inventory, sales and maintenance spreadsheets. There were no numbers that could serve as a basis for analysis, for example. It was necessary to search this information. So the first challenge students experienced was assessing what is important to collect and how to do it. In the academic environment, even in laboratory practices, students are given an experience script, in which the path, the method, is already given and must be strictly followed.

Overcoming the first challenge comes the second: understanding and analyzing the information collected. The causes and effects represented in the "problem tree" constructed generated an intricate web of interrelated problems, which imbedded workers from different sectors and elements inside and outside the company. New connections emerged as the process made it possible to probe deeper into some of the problems.

Thus, a seemingly simple problem, such as understanding the preparation of raw material for production, for example, becomes a complex problem. Because the criterion used to determine the mixing ratio is not a pre-established account and is not related only to laboratory test results. The assessment mixes objective and subjective issues related to the practical experience of workers. It is related to the quantity available in each batch, its color, the quality tested in the laboratory, the daytime temperature, the machines condition at that time and others.

With the lack of systematized data and the apparent disorder of the company, some of students thought, ironically, *"it looks like it has to stop everything and start over"*, because they felt the difficulty in dealing with so many problems and variables at the same time. This is because we have learned to solve structured problems, where variables are controlled and simplified into essential elements that can be modelled. In the meantime, the apprentice engineer will soon discover after graduation what the complexity of day-to-day technical work really means, as revealed in the age-old debates about "ill-structured problems" [14, 15], "wicked problems" [16, 17], "complex problems" [18] or, more recently, technology as a socially-constructed object [19, 20]. As the design work progresses, the engineer discovers an underlying social fabric, a network of actors who are more or less involved in the problem and intervene in its definition and the choice of acceptable solutions [2]. In the real world, variables are not controllable and some of them pop up unexpectedly in the course of the process. The demands are not well-delineated from the outset, obliging the professional to decode reality and take it into consideration when producing effective work.

The elaboration and implementation phase of the Production Planning and Control (PPC) system, in the fourth and fifth stage, provides us with good evidence about the importance of socio-technical understanding in technological development. Filling out work orders in the system seemed like a simple task. The system prototype has been carefully designed to fill in the fields and other information needed to track orders, stock verification, and lead time. Still, it did not work (what is common in any process of developing a new technology)! In this case it didn't work because the researchers had not yet understood that production was not driven by work orders, as they thought. The relationship of the plant manager with the production supervisor, their decision criteria on the prioritization of work orders, what to produce, when, and how much was only revealed during the tool's simulation process. And this understanding was fundamental to adjusting the system and even gaining the trust of the plant manager, who was not previously engaged in the project.

There was an extra element of complexity for the students involved in the project: the company's self-managing organizational model. Self-management is guided by a set of values that can differ dramatically from those observed in conventional companies. This imposed a certain degree of difficulty on the intervention process, since the peculiarities of this system were even stranger to the apprentice engineers. In the company in question, for example, priority was given to keeping jobs and maintaining wages. It was not interested in solutions that were financially efficient at the expense of increasing work, laying off workers, or reducing wages. It wanted to keep the company running and, if there was anything left over beyond maintenance, then to improve wages and hire more workers. Sometimes, the engineering tools we learn to use in the classroom do not account for such cases. An example of this was seen in an attempt by the group of engineers to propose a technical-economic feasibility study early in the intervention process. One of the workers exclaimed, "*Another one?! We've already had three of these things that came with some complex spreadsheets that we got from a capitalist there. I can even send it to you."* The term "capitalist" was a reference to a logic element under which specialists usually prepare the study, meaning it is not in accordance with the principles of self-management. According to the workers, these studies were not "applicable" because they were guided by measures that ran contrary to the company's "mission". And then, the worker further explained: *"Administrators and economists don't know anything about the real world!"* There was, therefore, a criticism of the "capitalist" stance, not just content.

The lack of consideration of the values of the self-management model in the feasibility studies is a problem that can be generalized as they were elaborated exogenously to the context of the company. Regardless of the company's values and mission, what we want to point out here is the need to build emerging proposals, starting from the real conditions in which the problem arises. The kind of positivism that guides most experts' analysis puts them in a position of knowledge holders that gives them a *top-down* perspective. These are laboratory solutions that emerge from the social context in which they will be applied. This way of intervening engenders a viewpoint that overemphasizes the technical aspects (those that engineers deem most relevant to the problem they intend to solve), while disregarding others, such as cultural, social, and organizational aspects, as well as squandering the workers' valuable knowledge and experience. We have to look at the engineering performance critically, which often involves the difficulty in dialoguing with other knowledge areas and workers, difficulty in building collective processes of problem solving or including other variables in the project other than the physical, chemical, physical or mathematical ones.

This view is a strong reflection of a university education. Not that the students involved in the project saw themselves as great holders of knowledge or who consciously underestimated the workers' knowledge, yet the attitude of thinking of a read-made solution rather than co-building one with the workers is almost "second nature", part of the *habitus* the engineers accrued in the course of their training. It seemed impossible not to think of building tools and and making rules in the face of something that, from the outside, looked like complete chaos or incompetence.

Donald Schön [21] associates the "crisis of professional education" with the overvaluation of technical rationality, born of the separation between theory and practice promoted by academia. If we want to contribute with our academic training in engineering, we must broaden our notion of the engineer's real work. In this context, it is convenient to reinsert the engineer's activity within the social context in which he or she works [22], as the experience analysed provided. Then the apprentices will also learn, through experience, that the sociotechnical view becomes less external in relation to technical work. In parallel with the challenge of solving the characteristic problems of the profession, they must deal with the challenge of teamwork, inevitable and essential to cope with this complex reality. Contemporary social demands require future engineers to have a more systemic view of the reality in which they operate, which extrapolates the linear and traditional perspective of technological education as exclusively technical training to a technological education of sociotechnical nature [23].

4.2 The Teamwork

It is clear that the heterogeneity in relation to the knowledge and experience of each member of the team gives them different starting points in the discussion and construction of collective action. The meetings with the PG were important places for learning about the collective concept and teamwork. They sought to engage in "technical democracy," in Callon's term [24]. Technical democracy is different from social or political democracy. In the latter, people are equal and each one has a vote. Not at work. There, people are different because they have different knowledge and skills. Work teams are "hybrid forums" where disagreements are posed regarding problems related to a technical object and negotiation between the different positions takes place [25].

But how to guarantee equivalent conditions of participation and intervention, especially in the formal educational process? Is this possible given the different experiences that put instructors and students in different positions in the possibility of influencing decisions? Strategies need to be crafted to deal not only with the diversity and different perspectives of team engagement, but also with differences in experiences that can subsequently turn into power hierarchies. The following are the strategies observed in this experience.

4.2.1 Performing Tasks in Smaller Teams

The issue of team size was a primary problem, as instructors saw a possible obstacle in the dialogue with workers. Large numbers of students could "scare" or intimidate them in interviews and meetings. Thus, one of the referrals taken was the division of project tasks into smaller teams. The interviews and observations with the workers, data collection, and systematizations were carried out in pairs or trios of researchers who were more or less at the same educational level, professional experience, and gender.

Although it was thought to solve large numbers of questions, this strategy also proved efficient in terms of encouraging student participation in the project. Large groups tend to foster hierarchical relationships, because the differences between individuals stand out more, and the more experienced ones tend to centralize actions or control them. During a meeting, for example, some participants (usually the instructors) monopolize the discussion while others (usually the students) do not speak at all. It is common to reproduce the hierarchical structure and the division of labor in the university classroom, with the senior researcher as laboratory leader, supported by ranks of junior professors and researchers, doctoral , masters, and undergraduate students, the latter being charged with collecting data and the graduate students doing the intellectual work [26]. Reducing staff size reduces the hierarchy and allows each person to have more complete experiences.

Despite the teachers' efforts to establish a great dialogical space, as horizontal as possible, students were still shy when attending general meetings, especially at the beginning of the intervention (over time this was changing). Some of them understood that they had no luggage to contribute to the debate; others simply were ashamed to expose themselves. The division of the group favored participation. On the one hand, smaller groups are less intimidating, so they make it easy to get ideas, doubts and criticism out. On the other hand, each group needed to strive to bring the analyses under its responsibility to the collective, "forcing" participation.

4.2.2 Learn by Doing Together

If work in a large team does not allow adequate conditions for participation, this is also not the case with isolated work. Rarely did anyone carry out a task on their own, because it is desirable that discussions take place during the activity. Even the tasks to be performed in the inter-immersion periods, at a distance, were intended for small groups or pairs of members. And this guaranteed an "instance" of dialogue about the task, allowing its problematization by those involved. Inside the smaller groups their own members defined their role in the task, as the record on preparing for the 3rd immersion interviews shows:

> We could have three people interviewing together:
>
> 1 person: responsible for observing the script and ensuring the collection of necessary information.
>
> 1 person: responsible for recording the interview.
>
> 1 person: responsible for conducting the interview freely, as in a conversation, without being limited by the script.
>
> (Third immersion interview guidance, 2017)

This organization sought to ensure the quality of the interview, which should not be mechanical in the sense of strictly following a pre-determined script, with an interviewer who could talk freely without worrying about the interview record or the script itself, as they would have other people in charge of it. But in addition to serving as a pedagogical guideline on interview technique, organizing the trio was a way to "train" members through collaborative action. The above guidance was followed by the suggestion that roles be changed to broaden learning opportunities.

In collective action it is also possible to take advantage of the differences of the members to learn from each other, especially from novices to experienced ones. Vygotsky had already shown the importance of collaboration between experienced and inexperienced learners in an analysis of child development, called the Zone of Proximal Development. According to the author, learning capacity is enhanced "by solving problems under the guidance or in collaboration with more capable partners" [27].

In the intervention novice and experienced, including counselors and their trainees, were side by side in problem solving. That is, the teachers were not only guiding their students, but were acting together with them in the field. During the intervention process, they held together several theoretical and methodological debates as they emerged, from the practice of the field and the doubts that both faced: Ergonomic Work Analysis, work psychodynamics, Marx, Self-management, interviewing techniques, observation and report writing.

4.2.3 Job Rotation

In defining who would take on a particular task the question posed to the collective was "Who has not yet done and is willing?" As changing roles in previously reported interviews, job rotation occurred at other times as well, including group representation within or outside the company. A certain amount of variation in prominent positions occurs naturally in a group, depending on the moment or requirements of the work, as Schwartz shows through the notion of "Relatively Relevant Collective Entities." Cooperation in carrying out an activity in these entities is different from moment to moment, so they also have a "variable geometry", in time and space, with the people involved [28]. In the PPC System elaboration stage, for example, the undergraduate student who had more experience in programming, assumed this prominent position.

But we also refer to a less natural movement. It is about supplying the conditions and encouraging the students to take a more active role in conducting the process at certain times, as an opportunity for learning. For example, one or two members could represent the team in discussions with the workers during project meetings or participate in factory events or write and present papers related to the experience at academic events. Although the instructors are officially responsible for the project, any member could and should represent the team at some point. Even the most timid students were encouraged to take charge at some of the meetings. It was not forced on them, but as they became more confident, they felt more comfortable taking on this kind of responsibility. As an example, the fifth stage of the intervention was carried out through seven visits of shorter duration and in shorter time intervals. The team executed this step by taking turns in the visits and the instructors were not present in most of them.

4.2.4 Socialization of the Information

The breakdown and distribution of tasks in smaller teams seems to be an advantage when it comes to making project execution more agile and encouraging participation. But there is one important obstacle that needs to be worked out: fragmentation, which contradicts the view of the whole. Here was the problem laid out in the second question at the end of the presentation. Naturally, without this concern, the information would be easily centralized in the instructors and they would be the protagonists in the entire process.

Part of the conditions for participation in a given work team is related to individual issues of each member, such as personality and knowledge about the subject under discussion. It is possible to minimize discrepancies in the latter by standardizing access to information on the subject. Therefore, it was necessary to come up with a strategy for socializing the information being collected and systematized in the smaller teams. The global view would then be shared and this would allow for more effective student participation in discussions and decisions.

A daily routine of team meetings was set up during the immersions. Each sub-team presented its systematized results to the other members at the start of these meetings. That way, the visualization of the whole was being put together collectively, like a jigsaw puzzle. Everyone took part in the discussion because each had one of the pieces and needed to cooperate to assemble a single, global view. The excerpt from the 1st immersion report summarizes how the socialization of interview information was conducted:

> We planned to conduct this research in rounds, that is, the four teams of researchers went out to conduct interviews simultaneously. All research teams gathered after a round to exchange views, briefly summarize what was said, triangulate information, and check correlations. This dynamic allowed the team as a whole to build a common collective understanding of the set of information raised, which helped guide the conduct of subsequent interviews. (First immersion report, 2016)

The meeting took place every day for the purpose of socializing the research data, discussing it, and planning the actions for the following day. They also prepared for a meeting with the Pilot Group for following day, always held in the morning. Lunch breaks and the intervals between activities provided opportunity for informal socialization. The permanent and democratic dialogue (in the sense of technical democracy) between the project team and between the researchers and the workers sustained the trust built between them.

4.2.5 Collective Accountability for Results

This aspect was not explicit and standardized among the team members, but it appeared as an important motivator, especially among the novices. Errors and successes were not personified, but rather assumed by the group. If something went wrong, it was not anybody's fault, but instead an effect of the process. This minimized the "fear of making mistakes", and the members felt more comfortable in acting and making proposals. Petroski notes the importance of error in learning and considers evolution by failure as the essence of engineering [27]. This also corresponds to the way Lave [30] explains the learning process between expert and novice (apprenticeship), where "legitimate peripheral participation" allows learning to take place in situations where it is possible to err in order to learn, but safely. In the company students found these safe conditions. They were encouraged to try and, even insecure, tried, aware that they were learning and that the situation would be circumvented by the most experienced if necessary.

At the end of the first immersion the team distributed the homework. Returning to the second immersion it was found that some of them were executed, but not others. The students tried to justify why they had not done their homework. They expected the teachers called them out and came forward suggesting that they charge more at the next time. But the teachers were less interested in it and more concerned with the solution. According to them *"failing to do the tasks is not the problem; the problem is the expectation of accomplishment."* They explained that in the heat of the moment students are excited to take on the tasks, but do not observe whether the schedule allows. Moreover, they have no dimension of the work that task will require. That is why they recommended: *"It is important to evaluate if the deadline is appropriate, to ask for help when necessary and to assume when it does not give".*

The dialogue about the "homework" was an important learning opportunity for the students, because they came across another work logic, in which they need to take a different position from the usual teacher-student relationship. Undergraduate students, in particular, are accustomed to acting on the most immediate needs of their subjects (studying only when they have tests, for example) and doing only what the teacher requires. In the discussion, it was precisely they who talked about the need for teachers to charge. But in the experience in question they understood that they would have to take responsibility for the project <u>with</u> the teachers.

And gradually, with the practice of the collective process of construction of the intervention, the researchers were increasingly tuning responsibility and engagement with the project. In Dreyfus and Dreyfus's model of expertise development [31], the transition from novice to expert is simultaneous; it depends on the transformation of engagement and implication with one's own activity, which is defined by not strictly obeying rules and creating your own in work activities. This approach is essential in training engineers so that they abandon the pre-formatted school models and adopt a bottom-up approach, focused on the company's real problems.

5. Conclusion

The principles of Popular Education, AR, STS and EWA (participation, democracy, recognizing the value of workers' knowledge, social commitment, and engagement) challenge us to construct a perspective of professional performance that overcomes the obstacle of hegemonic worldviews and positivism present in academic training, supporting the development of skills for the collective construction of emerging and sociotechnically responsible solutions.

The particularity of the relationship with the workers who struggled to recover a bankrupt factory, helped the team to work collectively, because that is the foundation of organization. However, even if this is not true of most companies, the experience is valid for generalizations as it challenges students to seek ways of understanding and acting on real problems that are complex, regardless of whether the company is self or hetero-management. These problems are not always explicit, have no well-defined contours, and have numerous variables, including non-technical variables. In addition, collective work and cooperation is needed even in private companies. Students learned to deal with this in practice by acting alongside the more experienced masters. What was eventually created was a supervised apprenticeship, organizing heterogeneous teams that learned how to deal with real problems on a smaller scale that were reworked and integrated with a larger collective, including workers. It was necessary to deploy formal and informal strategies such as: assigning tasks to smaller teams, pairing novices with more experienced members, establishing socialization routines and systematizing research information, switching roles and representations among team members, and not personifying the team's mistakes and successes. These strategies were instrumental in ensuring a cohesive, harmonious team in which everyone felt comfortable in discussing their ideas, taking on responsibilities and playing prominent roles at the right times, and especially building group trust. Thus, it was possible to reduce the complexity of real problems without losing reality, creating conditions for students to be protagonists, learning by doing and making mistakes without prejudice to the companies that welcome them.

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