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TECHNOLOGY TRANSFER WITH AN OPERATIONAL FOCUS ON ERGONOMIC DEMAND: TRAINING OF THE RIACHUELO CLASS CREW OF THE BRAZILIAN NAVY

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Abstract

This article deals with technology transfer with a focus on knowledge retention for the crew of the Riachuelo Class Submarines (SCR[4]) of the Brazilian Navy (MB). The process is part of the Brazil-France military agreement (2008). The study deals with the evolution of knowledge necessary for the crew's operational training process. The training is modeled on Ergonomics, more precisely from the perspective of Anthropotechnology (WISNER, 1985). Its methodology was made possible by the contributions of Grounded Theory, enabling the evaluation to instrument the training of submariners, within the concept of simulators such as Computer Based Training (CBT). To this end, the generation of categories and concepts, based on the observed elements, is carried out throughout the development of an explicit theory, which contributes to the determination of the applied demands necessary for the aforementioned training.

Keywords: Ergonomics; training; technology transfer; simulation; Grounded Theory, underwater work.

1. INTRODUCTION

The origin of the word technology goes back to the Greek language, as it combines the roots tecknikós (art, craft) with logos (treatise, study). In common sense, the concept involves: capacity for creation, development of knowledge and application in the production and operation of material goods. From a commercial perspective, its meaning has relevant consequences for decisions for the economic development of a country.

In Brazil, the search for external independence, added to the desire to strengthen national defense, justifies the fact that the Brazilian Navy (MB) invests in technology transfer plans that aim to promote the trinomial security, defense, and development (BRASIL, 2018). The maritime space is a heritage of Brazil, since it is home to 80% of the commercial volume of exports and imports, and is also a source of natural and mineral wealth, scientific, fishing and

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tourist activities. MB's role in providing protection for this natural heritage called the Blue Amazon is closely related to the power of the oceans in international relations and the constitutional mission resulting from it.

In this sense, according to Fonseca Júnior (2015), investments in defense with the development of technologies for patrolling and monitoring should be a reality, as such investments will return as a benefit to society, contributing to innovation in science and technology of the Naval Force. At this juncture, MB launched the Submarine Development Program (PROSUB) in 2009, the largest Brazilian industrial and technological training program in the national defense and scientific-technological infrastructure sectors. In this vision, MB adopts sustainable actions for the development of defense technologies, such as: partnership with universities and research centers; encouragement of the participation of companies in nationalization; training and maintenance of professionals; and technology transfer.

It is also noteworthy that the main technologies involved in PROSUB have repercussions in other areas of the industry, such as the modernization of shipbuilding infrastructures and techniques (BRASIL, 2018). In this context, the problem to be investigated is the provision of adequate conditions for the good retention of operational knowledge by the crews, during the transfer of technology in PROSUB. The justification of this study is the need to bring out relevant benefits for the operational training of the SCR crews, taken as a characteristic situation. Thus, the general objective of this article is to present a framework that models the ability to identify elements that impact the performance of the SCR crew, based on the perception of the focus groups pertinent to such an effort.

In parallel, it follows the specific objectives:

a) Inventory available technical resources in the defined context;

b) Explain knowledge gaps throughout the initial training phase; and

c) Deepen learning about innovation at the specific stage.

It is expected to establish, in the content of this study, the consolidation of an ergonomic model that serves as a basis for the diagnostic and consolidated construction, according to the methodical, orderly and systematic itinerary recommended by Vidal (2003). To achieve these objectives, ergonomic science will be used, with a focus on the Anthropotechnology tool.

2. METHODOLOGY

The methodology applied during the work was the Grounded Theory (TFD) with instrumentation of an anthropotechnological appreciation.

GT has three main methodological perspectives: Classical, Straussian, and Constructivist. Although they have common characteristics, such as theoretical sampling, comparative data analysis and the elaboration of memoranda, there are differences in the data analysis system. In view of this, it is worth saying that here we adopt the Straussian approach, in which the theory evolves during the research process itself, and is a product of the continuous interaction between analysis and data collection (GLASER AND STRAUSS, 1967).

Thus, the main premise of Straussian GT in this research is that the theory should be developed inductively based on the interactive and constant analysis of the collected data to develop an in-depth understanding of the phenomenon studied, moving through various levels for the construction of the theory, going through description, abstraction to a conceptual categorization, in order to investigate the conditions, consequences and underlying actions (GLASER and STRAUSS, 1967).

As for the type of theory, they can be classified as: explicit theory, implicit theory, syntagmatic or process-oriented theory, paradigmatic theory (GOULDING, 2002). In this study, the explicit theory approach was used, which is defined as a set of concepts that describe a hierarchy or a network of propositions, such as an innovation scenario (GOULDING, 2002). In short, GT corresponds to a set of distinct procedures or stages, presented and described in sequence, with the final intention of aiming at an explicit theorizing.

A) **Application of Grounded Theory:** the data systematically collected and analyzed supported the application of Straussian GT. To apply this methodology, interviews were conducted with the purpose of the interlocutor immersing himself in the interviewee's perspective.

B) **Selection of Participants or Sampling:** according to Wegbrayt (2020), regarding the approach to GT, the selection of participants in a research is according to the phenomenon to be studied. In order to meet the process of absorbing knowledge from technology transfer, it was decided to interview the submarine military personnel of the Átilla Monteiro Ache Instruction Center (CIAMA - Submarine School) and the Humaitá Submarine. To compose the target audience, instructors from CIAMA and military personnel from the

submarine's Operations department were selected. The following steps were applied in the selection of the sampling:

B.1 Definition of eligibility criteria**:** for Duarte (2002), the eligibility criteria of individuals are essential, since they provide the data that will serve as support and object of study for the investigation, therefore, their quality is decisive for the result.

Taking into account the importance of correctly identifying the sample to be studied, the following eligibility criteria were adopted:

- Be an Officer or Private, with the Alpha phase (theoretical and simulation phase) of the SCR course completed;
- Be an Officer or Private with the Alpha and Bravo phase (embarked phase) of the SCR completed; and
- Be an Officer or Instructor Private.

The criteria adopted were intended to ensure that the participants had technical knowledge of the submarine both in the port and at sea, therefore having an understanding of the scenarios that preceded the training, as well as the framework established at the end of it, thus being able to properly answer the questions of the technology transfer. And to ensure the multiple managerial views of the tasks assigned and exercised by the military, coverage was made at different levels of hierarchy.

B.2 Negotiation and Authorization: to carry out the interviews, contact was established through electronic channels with the CIAMA Submarine School. Subsequently, through a face-to-face meeting, the process prepared for their execution was presented, and the scheduling was at my discretion and responsibility.

B.3 Approach to the invitation: the initial contact was made by formal email to the qualified military personnel, with a brief description of the objective of the work, and, at the end, they were invited to semi-structured interviews by videoconference, with the meetings scheduled according to free availability.

C) Data collection: at this stage of the research, the relevance of the data collected is of paramount importance, as they need to capture the essence of the revelations collected from the respondents related to the theme addressed in the study, showing in detail information, data, ideas, technical and professional concepts

(ARAÚJO JÚNIOR, 2021). The data collected needs to be of quality and have credibility, and for that, it is necessary to put down roots in your analyses. Data collection management makes it possible to detect process variation, helping to improve it and make the analysis more comprehensive, until it reaches the data saturation point. Saturation, that is, theoretical sufficiency, marks the moment when data collection no longer instigates the researcher to acquire new theoretical perspectives from the data, nor does it reveal additional properties of the main theoretical categories (ARAÚJO JÚNIOR, 2021). The following are the data collection steps carried out:

C.1 Script: according to Wegbrayt (2022, p.39) the script constructed aimed to: "not direct the interviewee in their answers, being made up of open questions". Thus, the first interviews conducted were conducted through two open questions, to obtain opinions. From the sixth interviewee onwards, there was an important report related to the theme of the study, which made him return to the beginning of the interviews and ratify this relevant information. In this way, greater security was provided to maintain the script of questions until the last interviewee.

C.2 Interviews: as already mentioned, the method chosen to conduct the interview is semi-structured, using a script with previously defined questions and faithful to the imposed delimitations, which makes it a possible scenario for an adjustable and meaningful study (WEGBRAYT, 2020). With an established guideline, without predetermined answer options, as would occur in a multiple-choice approach, a balance is provided between the structure offered by the planned questions and the flexibility for the interviewee to express his answers in a broad way. The interview period ranged from 20 (twenty) to 40 (forty) minutes in duration. In the end, of the 10 (ten) invited participants, 9 (nine) participated in the process.

C.3 Transcription: the transcription of the recorded audios collected occurred through the recordings followed by the transcriptions of the submariners' answers using the "Voice Typing" tool of Google Docs, with the review and finally the validation with the interviewee, that is, sent to the military for his final approval.

D) Coding: at this stage, the organization of the data already collected took place through a Google spreadsheet, updated after each interview. Coding is the

process of analyzing data, and at this point, the researcher can identify hundreds of codes that may have potential meaning and relevance. As a result of constant comparison, the data found are reduced and grouped into significant categories. Codes are the building blocks of theory. By codifying, in all possible ways, it will allow you to give direction to categorization (GOULDING, 2002). This process is divided into stages: the initial, the focused and the theoretical. The initial coding is broad and generic, as all the collected speeches will serve as data, which makes it possible to navigate through various theoretical directions. Focused coding, on the other hand, can be understood as a moment in which the researcher uses the codes already mapped in the initial stage, making a rigorous evaluation to select the most significant and/or frequent initial codes, which enable a better analytical understanding to categorize the data in an incisive and complete way. Finally, theoretical coding helps to tell an analytical story coherently by specifying the relationships between the data categories of the focused coding. This classification instigates comparing the categories at a complex level that allows for more refined organization and analysis in search of a central or main category.

E) Theory construction: this stage requires the ability to select the important information for the development of the theoretical model that will represent the studied problem. For this theory to be valid, there is a need to compare the theoretical concepts studied and their relationships with the data collected (BAGGIO AND ERDMANN, 2011). It was observed that the influence of the data categories in the construction of the main category led to the emergence of "Simulator Training" as the central category, which was closest to the purpose of the research, and which is interrelated with the other 3 emerging categories (Figure 1), for training in the approach to the results at the end of this article.

3. TECHNOLOGY TRANSFER

Building a technological chain requires investment, organization, and allocation of human and material resources, as well as effort, continuity, and constancy for its maintenance. Studies like this are essential to create, develop, produce, approve, operate, and maintain a technological system or process (FREITAS, 2022).

With the advent of telecommunications and the increase in foreign trade, according to Freitas (2014), this technological chain had a high growth in the eagerness to obtain solutions more quickly in favor of development. In this context, technology transfer emerges as a very attractive commercial possibility and accelerates this process.

Freitas (2014) also points out that, for there to be technology transfer, it is essential that the foreign contractor has a great commercial interest in allowing the absorption of technology, as well as the capacity, convenience and willingness of the national contractor to absorb it.

For the preservation and maintenance of the knowledge absorbed in the technology transfer processes, there must be one's own effort and constancy through technical-scientific-industrial stimulation of the teams and people involved. LONGO and MOREIRA (2012) conclude that, taking into account that, normally, defense projects have long deadlines, it would be essential to have appropriate knowledge management to avoid discontinuity and losses caused, such as with the retirement or departure of professionals, who originally received the knowledge. And they cite brain drain as a possibility and a threat.

As for the transfer of technology, signed through a Strategic Political Agreement between Brazil and France to enable Brazilians to design and build submarines in the PROSUB project, the final production of four new conventional SCR submarines was made possible in addition to the submarine armed with nuclear propulsion. Currently, the first is in operation (Riachuelo Submarine), the second in final tests (Humaitá Submarine) and the other two under construction, as well as the manufacture of the prototype of the first Brazilian submarine armed with nuclear propulsion scheduled for 2029.

It should be noted, however, that for the development of this complex nuclear propulsion project there is no exchange of knowledge, corroborating the content of Freitas (2022, p. 72): "as technology is power, it is unlikely that the holder of a new technology will allow its absorption". All nuclear technology for PROSUB is being developed in Brazil, through the Navy's Nuclear Program (PNM), at the facilities of the Navy's Technological Center in São Paulo (CTMSP).

Operational training, which is the object of study in this article, and the knowledge of submariners became pillars for the beginning of the technology transfer of the agreement signed between Brazil and France, which is carried out through the SCR Crew Training Course, conducted at the Almirante Áttila Monteiro Aché Instruction and Training Center (CIAMA), located at the MB Naval Complex in Itaguaí, Rio de Janeiro. The course is divided into two

phases: a theoretical phase, called Phase A, which covers basic, specific training and simulations (this being the main stage), and a practical phase known, as Phase B.

By constantly training staff and improving our own skills, especially in internal systems, we can achieve greater technological independence and drive innovation and technological growth. An example of this is the computer-based training tool, called *Computer Based Training* (CBT), in use in the SCR course.

In short, in this context, LONGO and MOREIRA (2009, p. 12) conclude that "the following are stages of effective technology transfer: absorption, adaptation, improvement, innovation and diffusion".

As every technological process involves commitment, people, circumstances, organization and absorptive capacity, it is of great relevance to address some of these topics with the help of the science of Ergonomics through the Anthropotechnology tool.

3.1. Ergonomics and Technology Transfer

Ergonomics plays a role in adapting work processes to human needs and capabilities, seeking to optimize the efficiency, safety, and well-being of employees. By involving Ergonomics in the technology transfer process, it is possible to ensure that the implemented technologies are designed taking into account the characteristics and requirements of the end users (MÁSCULO and VIDAL, 2011).

Másculo and Vidal (2011) highlight Ergonomics as a fundamental factor, from the initial phases of planning and development of technology transfer, to the implementation and evaluation of results. Their active and early inclusion in these stages will ensure the mitigation of potential problems and the maximization of the organization's benefits.

Based on the introductory concept of the scientific-technological binomial adopted by MB as part of the strengthening of the infrastructure and sustainability of the PROSUB project, Ergonomics can be recognized as a science that plays a role in multidisciplinary articulation and integration, aiming to promote positive transformations.

By adopting Ergonomics as a multidisciplinary basis along with the technology transfer process, you can ensure that interactions between team members, technologies and organizational processes are optimized. Thus, a participatory device is created that allows better objectivity and consensus within the organization, contributing to an effective management of changes (MÁSCULO and VIDAL, 2011).

Wisner (1979) shows through studies in Anthropotechnology some origins of the failures, partial or total, of many technology transfer experiences, highlighting for example: geographical conditions of high temperatures that affect the quality of products and means of transport; insufficient training of personnel; inadequate maintenance policies; difficulty in the form of conversation and understandings. (MÁSCULO and VIDAL, 2011).

In this study, with regard to the technology transfer agreement between Brazil and France up to the present moment, some original conditions similar to those pointed out by Wisner (1979) were listed, such as: difficulty in communication and understanding due to different languages; absence of teaching material, especially in the initial period of the contract; cultural differences related to professional training, while the French is departmentalized, that of Brazilian submariner officers is generalized.

In this context, regarding the mastery of transferred technologies, the organization will be closer to success the greater the capacity for organizational adaptation, adjustment and repair, corroborating Másculo and Vidal (2011, p. 46): "the mastery of transferred technology is only possible when technical devices, work organization and worker training undergo a global process of reconception".

With this is the future suggestion in the adoption of Ergonomic science as a facilitating instrument in the process of technology transfer, since Másculo and Vidal (2011, p.52) conclude: "The best hiring of an external group is the one that helps the company to define the paths of Ergonomics, in a planned, methodical and consistent way".

3.2. Training in Technology Transfer

Education plays a key role in technology transfer, from basic education to vocational training. The quality of the receiver of information and content is strongly impacted by education, as it provides the skills and knowledge necessary to receive and properly use the transferred technologies (FREITAS, 2014).

Investing in education is essential to develop a skilled and skilled workforce, stimulating innovation and ensuring the success of technology transfer.

In the scenario of indispensable continuity to the Technology Transfer process, Freitas (2014) highlights that the ability to absorb technology results from a technical managerial capital accumulated over years and from several processes, not undone by disaggregation of teams or loss of technical memory.

Also according to Freitas (2014), the loss of capabilities in the technology transfer programs in obtaining submarines under an agreement signed between Brazil and Germany in the 80s and 90s, constituted a good reference of experience in the need to have a permanent submarine construction project.

In this research, the purpose is to invest in the search for suggestions for the maintenance of this knowledge acquired with the process of technological absorption in the course of the SCR crew, especially regarding the training related to practical training related to the exploration of simulators. One of the practical training already existing in the course, and throughout the submariner's career, is based on simulators called *Computer Based Training* (CBT), a type of *E-learning* that uses computers to provide instructional content, and which will deserve full attention in the completion of this research, since CBT is an effective way to retain knowledge and provide training for updating and improvement.

The information above corroborates the content presented by Rebelo (2021, p. 14):

> *One of the most recent developments has been the growth of software-based simulation systems for computers, such as those developed by numerous companies such as UNITEST, Kongsberg, MarineSoft, SSPA, among others. That provide simulation software that, with a simple computer, can provide training options at a lower cost and within the reach of a greater number of institutions.*

Based on the study by Rebelo (2021, p. 15), globalization has led to "the use of machine simulators since they become a useful and effective teaching tool, and relatively accessible".

Currently, some educational establishments in the nautical field have not yet fully embraced the idea of machine simulation, despite recognizing the benefits that navigation simulators can offer. However, this scenario is changing and changing, as producers and distributors of these systems increase their learning efforts and are able to reduce the costs of acquiring and maintaining the simulators. A major influence on the increased use of machine simulators was the introduction by the IMO (International Maritime Organization) in 2017 of course models that are based on the use of simulators in engine rooms. This change has contributed significantly to technological innovation processes (REBELO, 2021).

4. FINDINGS

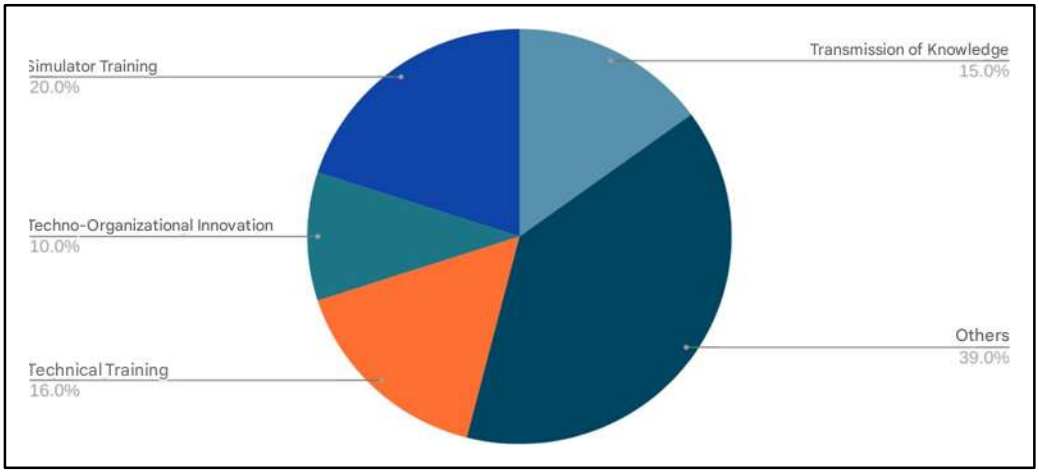
When considering the objective of the present study, data were collected from the experiences of qualified submariners in the SCR, as well as their perceptions about technology transfer in PROSUB. With the completion of the coding process, it was possible to identify the

central or main category and the existing relationships with the other emerging categories (Figure 1). After the last analysis of the coding process, twenty categories emerged, with "Simulator Training" considered as the central category, holding 20% of the total codes generated, and with 90% of the interviewees recorded in the report, as observed in the following fragment:

> *The infrastructure of CIAMA Itaguaí is very good, it has 2 combat system simulators, 1 immersion trainer simulator, a flooding simulator, an escape simulator and a CBT simulator (Computer Based Training - as if it were a Control Strike, in first person) in it you can operate the equipment, the valves, you can qualify 70% to 80% of the systems on a computer, you can eject garbage, prepare an engine; So much so that in the qualification slip many of the items you can qualify in the simulator, which guarantees you a large level of knowledge and sufficient to consider the military qualified and later the military goes on board to fine-tune, but it is already ready, if you do a good simulator step. (Interviewee 01)*

This comment identifies the relevance of simulators and ends with emphasis on the new concept of simulation in the Submarine Force, the CBT. The training in the simulators circumscribes the retention of knowledge of the experiences lived on board the new class of submarine, so important for this period of change and transition. It is in this context that CBT minimizes gaps in specialized knowledge.

Figure 1 - List of Categories



Source: Developed by the Author, 2023

It is in this current scenario that Muirhead (2004) states that the introduction of new technologies is often the catalyst for innovation and evolution of techniques and methodologies, with increased productivity, greater efficiency through cost reduction, increased employee

motivation and job satisfaction, as well as the development of new ideas to achieve specific objectives.

Also according to the GT analytical procedure, 3 other emerging categories related to "Simulator Training" were identified:

a) Knowledge Transmission;

b) Technical Capacity; and

c) Techno Organizational Innovation.

As for the category "Knowledge Transmission", a clear relationship with the central category can be seen through the reports of the interviewees, as shown below, when asked about the biggest challenges in simulators in the technology transfer process. The new class of submarine required greater knowledge in digital technologies. For this, the learning process involved instruction, communication and the didactic process taught by the Frenchman. In the field of instruction related to the SCR Operations Department, greater difficulties were exposed in relation to the Machinery Department.

> *In the qualification of the Riachuelo Class submarine, if I were to summarize it in an expression, it would be the language barrier. (Interviewee 03)*
>
> *In the Alpha 3 phase in CBT, it was complicated because there was a Frenchman, I forgot his name now, he hardly spoke Portuguese, so I learned CBT later with people from the ship because we were maneuvering there and the old version was simpler, not as intuitive as now. (Interviewee 07)*

Thus, the degree of execution in the category of "Transmission of Knowledge" is of paramount importance, corroborating Wisner (2004, p. 74): "Its insufficiency is a very frequent reason for difficulties, caused by an initial error, contract restrictions or communication failures between the seller and the buyer".

Also according to Wisner (2004, p.101): "Knowledge of the language and its cultural references is, in fact, indispensable to succeed in the ergonomic analysis of the cognitive activities of operators".

The category "Technical Capacity" is connected with "Simulator Training", relating concepts that deal with the necessary qualification for submariners, following the arguments of the interviewees:

> *The simulators guarantee you a large and sufficient level of knowledge to consider the guy qualified. (Interviewee 01)*

> *The simulators are excellent for life on board, as we arrive on board with the great know-how of the system software. (Interviewee 04)*
>
> *When the student comes to visit the simulators, starting to operate the system, it becomes possible to develop a deeper knowledge. (Interviewee 04)*

In fact, "Technical Capacity" is present and illustrated in the process of technology transfer, elucidating usual situations of experience on board. According to Wisner (2004, p.100) this category teaches us that, in particular: "from one country to another there is an equivalence of the cognitive capacities of the workforce. However, technical familiarity is not the same everywhere and should be increased."

The "Techno-Organizational Innovation" category was built by the technological differences of the transition from the Tupi Class Submarine (SCT) to the SCR, by the advent of the CBT tool, as well as by the organizational needs, such as the numerical reconstitutions of the teams and the new functions, as described below:

> *I thought it was a very big leap that we took in relation to technological innovation, the system is very good. (Interviewee 04)*
>
> *Nowadays, the systems are practically remotely piloted. Because in the past, for example, the sergeant opened and closed the valves and wrote them down on the plate, that was simple. (Interviewee 01)*
>
> *Regarding the instruction in the CBT, it is very good, it is as if you were inside the submarine (as if it were a game) you enter the submarine through a screen you can open the valve, simulate that you are giving air to the ballasts. (Interviewee 08)*
>
> *The person who manns the Water Officer function on the French submarine is a private, but we don't absorb that from them. (Interviewee 01)*
>
> *The operator that had the most change was the arms dealer (AM), because he guarded the PAC (Plotter and Evaluator of Contacts) function, and it has already been discontinued and so the arms dealer unguarded the contact solution in the PAC. (Interviewee 04)*

The details of this category corroborate the content of Másculo and Vidal (2011), whose results presented by this analysis indicate that there are significant opportunities for improvements in emergency response simulation in areas such as team coordination, simulation design and dynamics, crisis management, and establishment of the necessary technological infrastructure for support.

Over time, work undergoes transformations resulting from organizational innovations, technical and social relations between production and work, as well as the adoption of new technologies in production processes. These transformations occurred in the context of the

evolution of management models (MÁSCULO and VIDAL, 2011). Likewise, in this study the same transformations and adaptations were found during the process of technology transfer from the SCT class to the SCR class.

5. CONCLUSION

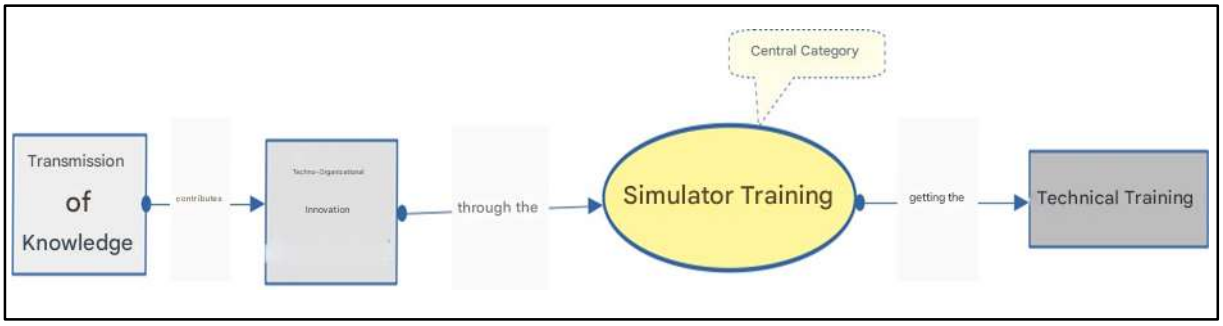
Some of the challenges encountered in the process of technology transfer between Brazil and France in PROSUB could be addressed in this study, among them those associated with training, technology, and organization.

The training of crews, inevitably, was one of the sectors included in the fulfillment of the training program suggested by the French contractor, which adopted a theoretical teaching model, followed by a phase of simulators, and finally tests and tests on board the submarine.

The data collected in the interviews from the application of GT allowed the identification of patterns of perception in submariners about the adaptive processes of technology transfer. These questions made it possible to understand the discursive movement, the tetralogical order-disorder-interactions-organization of the information taken from the participants' reports, capturing feedback, recursions, self-organization, concepts, attitudes, beliefs and experiences (MORIN, 2000).

"Simulator Training" was the most categorized, by the line-by-line coding process, linked to its close interrelation with the other emerging categories (Figure 2), allowing us to understand how they influence the central category, for the emergence of gaps not yet observed.

Figure 2 - Theory elaborated from the perception of the interviewees



Source: Developed by the Author, 2023

Despite this challenge, CIAMA has in its hands a path of possibilities to conduct the appropriation of knowledge and develop future actions, strengthening instruction in simulators, especially in CBT, a key piece to keep crews qualified.

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