Aquaculture and innovation based on interactive learning processes: Pacu Project in Terenos, MS

Aquicultura e inovação com base em processos de aprendizagem interativa: Projeto Pacu em Terenos, MS

Acuicultura e innovación basada en procesos de aprendizaje interactivo: Proyecto Pacu en Terenos, MS

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Abstract: This paper describes the Pacu Project innovation technologies during its trajectory related to aquaculture, as well as the impacts on its structure and dynamic. The research object is the Santa Rosa Farm production unit in Terenos, Mato Grosso do Sul. The influence of the interactive learning processes on the innovative act has been evaluated in this work. This case study uses the descriptive and explanatory methods used concerning the origin and dynamics of the company, through access to bibliographic and documentary sources, associated with data collection which was supported by a questionnaire applied to the executive manager, and visits to the unit. The research allowed the authors to verify the importance of the role played by interactive learning in the company, since its origins, be it either in processes of systemic innovation, as well as in the incorporation of competencies that enhance its resilience and the possibility of propagating knowledge systemically.

Keywords: family entrepreneurship; interactive learning; innovation.

Resumo: Este artigo descreve as tecnologias de inovação do Projeto Pacu durante sua trajetória relacionada à aquicultura, assim como os impactos em sua estrutura e dinâmicas. O objeto de pesquisa é a unidade produtiva da Fazenda Santa Rosa em Terenos, Mato Grosso do Sul. A influência dos processos de aprendizagem interativa no ato inovador foi avaliada neste trabalho. Este estudo de caso faz uso do método descritivo e explicativo da origem e dinâmica da empresa, mediante acesso a fontes bibliográficas e documentais, associadas à coleta de dados com apoio de um questionário ao gerente executivo e visitas diretas à unidade. A pesquisa permitiu verificar a importância do papel da aprendizagem interativa exercida pela empresa, desde suas origens, seja em processos de inovação sistêmica, seja na incorporação de competências que potencializam sua resiliência e a possibilidade de propagar os conhecimentos de forma sistêmica.

Palavras-chave: empreendedorismo familiar; aprendizagem interativa; inovação.

Resumen: Este documento describe las tecnologías de innovación del Proyecto Pacu durante su trayectoria relacionada con la acuicultura, así como los impactos en su estructura y dinámica. El objeto de investigación es la unidad productiva de la Granja Santa Rosa en Terenos, Mato Grosso do Sul. En este trabajo se ha evaluado la influencia de los procesos de aprendizaje interactivo en el acto inovador. Este estudio de caso utiliza el método descriptivo y explicativo del origen y la dinámica de la empresa, a través del acceso a fuentes bibliográficas y documentales, asociadas a la recolección de datos, respaldada por un cuestionario al gerente ejecutivo y visitas directas a la unidad. La investigación nos permitió verificar la importancia del papel del aprendizaje interactivo ejercido por la empresa, desde sus orígenes, ya sea en procesos de innovación sistémica, ya sea en la incorporación de competencias que mejoren su capacidad de recuperación y la posibilidad de propagar el conocimiento de manera sistémica.

Palabras clave: emprendimiento familiar; aprendizaje interactivo; innovación.

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1 INTRODUCTION

Fishing, based on the extraction of underwater organisms from the natural environment, is one of the oldest activities in human history. Currently, however, as Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) states the extractive fishing cannot be considered anymore an adequate way to meet the quality and quantity demands of the current competitive market in guaranteeing food security. For this reason, aquaculture has been used, based on fish farming, which is generally characterized by a confined and controlled space (EMBRAPA, 2014). Although fishing has existed for 5,000 years, it was only in the last century that knowledge about controlling the reproduction of some fish and shrimp species was mastered (DIAS, 2009).

Besides, in Brazil and abroad, the consumption of proteins from fish meat has been highly valued, due to its nutritional value (RAIMUNDO; GENTILI, 2014). According to the United Nations Food and Agriculture Organization (FAO, 2017) report, 815 million people suffer from hunger and millions of children are threatened with malnutrition. Between 2015 and 2016 alone there was an 11% increase in the number of malnourished people.

In this context, aquaculture emerges as the new world frontier in food production (SCHULTER; VIEIRA FILHO, 2017). Indeed, to bring quality fish meat to the consumer's table, it is necessary to increase the quality of fish handling and raising, similar to what occurs with other animal protein sources such as cattle, pigs and birds. Therefore, aquaculture plays a fundamental role in supplying this demand. Although aquaculture has enjoyed many technological advances in recent decades, fish handling and breeding process still lacks technological innovation increases fish farmers' production and makes the business more competitive (EMBRAPA, 2014).

In the state of Mato Grosso do Sul, the Pacu Project was a pioneer in the production and sale of fingerlings of native fish species through aquaculture. It has over 30 years of market experience, leading the export of fish in Brazil for several years, and the export of fingerlings in the state (GRILLO *et al.*, 2016). Pacu, piaussu, piraputanga, curimbatá, jiripoca, jurupensém, and jaú fingerlings were exported for ornamental purposes to the USA, Germany, and Japan (CARVALHO FILHO, 1996). For these and other achievements, the project received several awards and honours.

The Pacu Project has a modern structure of tanks and equipment at Santa Rosa Farm, which is used both for the production of native fish for market consumption, and for research on fish reproduction, rearing, and fattening. Most of the skills acquired in this area of activity related to production techniques and processes have been developed within the family that is responsible for this enterprise and by the company's professionals. Thus, the general objective of this paper is to explore and describe the innovative technologies of the Pacu Project, which mark its trajectory, structure, and dynamics related to aquaculture, built on interactive learning processes.

The text of this paper was structured, besides the introduction and final considerations, in five parts. In section 2, we presented the theoretical framework. Section 3 dealt with materials and methods. Finally, in section 4, the observed results are presented and discussed by the authors.

2 THEORETICAL FRAMEWORK

2.1 Fish consumption in the current market context

Aquaculture consists of the cultivation of underwater organisms, at least in part of their life cycle, whose practices may involve fish farming, shrimps, frogs, oysters, mussels, algae and mollusks (KATO; SOUSA, 2017). Fish farming has gained more and more space in the food market in Brazil and the world, mainly because they are a source of protein considered healthier (MACIEL *et al.*, 2015). Nevertheless, the World Health Organization (WHO, 2003) pointed to a sharper increase in fish meat consumption since 1961, whose annual rate has been higher (3.6%) than world population growth (1.8%). Consumption, which was 9 kg per person per year in 1960, rose to 17 kg per person in 1997. The availability and consumption of fish and meat products over about 40 years have almost doubled relative to population growth (WHO, 2003).

Although consumption of fish meat has increased in recent decades (OECD-FAO, 2014), consumption in Brazil is still low compared to beef, pork, and poultry. Among the main reasons given by Brazilian consumers, the following stand out: the high price, lack of knowledge of preparation methods, preference for other meats, and lack of disclosure of origin and quality information (MACIEL *et al.*, 2015; SCORVO FILHO, 2004).

The World Health Organization's comparative study of the risks and benefits of fish consumption (WHO, 2010) has shown that fish is an important food for its richness in protein and nutrients to make a healthy and balanced diet with beneficial effects for reducing cardiovascular diseases and strokes. On the other hand, they also found that such diseases may be motivated by the ingestion of potential chemical contaminants such as methylmercury and dioxin compounds (polychlorinated dibenzo-p-dioxins [PCDDs], polychlorinated dibenzofurans [PCDFs] and polychlorinated biphenyls [PCBs]). The studies of Carvalho Filho (2014) also showed that children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD), who were supplemented with a polyunsaturated omega-3 family fatty acid (DHA), found in the river and sea algae, consumed by certain fish species, showed improvements in cognitive and perceptive activities.

2.1 Aquaculture perspectives for Brazil

On the report on fishing and agriculture, presented in 2017 by the United Nations Food and Agriculture Organization (FAO, 2017), over the next decade, due to significant investments in the sector, Brazil was considered the country that should present above-average growth compared to other emerging countries. On the other hand, it must be acknowledged that Brazil is privileged, not only for the great quantity and diversity of rivers but also for the great extension of its maritime coast. The biodiversity of fish species also enables development of aquaculture in its various genres.

As stated by Instituto Brasileiro de Geografia e Estatística (IBGE, 2017), Brazil recorded an increase in production of fish from aquaculture, between 2015-2016, of 4.4%, totalling 507.12 thousand tons, considered an alternative for both small, medium and large producers. Additionally, more recent data indicate an estimated production in 2019 of 800 thousand tons with predominance in the cultivation of freshwater fish and marine shrimp, impacting the national production of about US$ 1 billion of gross revenue (VALENTI *et al.*, 2021). The entry of new producers in this market has been increasing, with investments in fingerlings, chemical products (fertilizers), rations, technical assistance and manpower (OSTRENSKY; BOEGER, 1998).

According to Zion (2012), the fingerling production process is usually done manually. However, to make the business competitive, technological investment has been necessary throughout the production chain, from raising the quality of larvae to delivering fish to the final consumer.

2.3 Precision aquaculture

Precision aquaculture is the use of technologies to precisely monitor and control production to reduce production costs, increase productivity and consequently, the profitability of the business while maintaining environmental sustainability. In this scenario, in fish production, it is quite common to have the presence of precision equipment to monitor water quality such as temperature, oxygen, ph and ammonia levels, besides feed quantity, weight, and growth of the fish (TOWERS, 2014). In this context, Auburn University (Alabama, USA) in conjunction with USSEC (American Council of Soybean Exporters) created the Integrated Pond Aquaculture Technology (IPAT) project. Among the new technologies practised by IPAT are the growth rate, mortality and fish feeding monitors, water quality monitor, control over production, productivity and cost-benefit ratio, among other leading technologies (MAGADA, 2017). From these initiatives based on high precision technologies, the term Smart Farming eventually emerged to refer to agricultural, livestock, and fish farming units that use these high precision technologies.

Considering this, automation and the use of computer technologies, in the case of fish farming, are praised by Brito *et al.* (2017) because it favours the accuracy of research and the development of expert decision-making systems, especially regarding water quality monitoring and fish feeding control. Hence, precision fish farming, according to Fore *et al* (2018), makes use of engineering principles that enable the ability to monitor, control and document biological processes in fish farming. Allows for better accuracy, precision, repeatable farming operations, and more independent and continuous monitoring of fish, providing more reliable decision-making support. Also, it favours reducing dependence on manual labour and subjective assessments, as well as providing better security for employed personnel (FORE *et al.*, 2018).

The use of more intensive technologies can cover all stages of fish life. However, the incubation phase is usually the most practised in tanks, aiming to control better the environmental conditions and even some external factors that affect the fish. However, while some species are reared in inhouse tanks until reaching market size, most of them are transferred to open-air tanks, ponds or sea, in the final phase of growth. This is because fish require a larger volume of water as it grows as its size increases (FORE *et al.*, 2018). However, these authors point out that most tasks are still performed manually in fish farming. Technological solutions are being used at one or some stages of the production process.

According to the authors, this process moves from the previous regime based on local competences built by experience, to a regime based on knowledge. According to Fore *et al.* (2018), the adoption of automation technologies in fish farming covers a four-phase cycle: observation, interpretation, decision, and action.

Observation concerns the use of intelligent fish-sensing technology solutions that enable online monitoring. Examples include submerged cameras and computer vision methods, which allows one to check animal count, skin color, size, lice manifestation, and behaviour monitoring. It is also possible to observe the physical environment to verify, for example, the number of feed pellets. However, there are still new observation technologies, such as hydroacoustic devices, among others.

Interpretation, previously based on the fish farmer's personal experience, now has the technological support of simulation systems and predictive models, usually based on mathematical modelling, which aggregate data from different sources.

In decision-making, which managers of fish farms are always carrying out, the decision support systems are now supported by artificial intelligence and information technologies. For each situation or problem detected, the system combines inputs from various information and historical experiences of similar situations or problems previously experienced as a basis for suggesting an appropriate decision.

The action concerns using advanced technologies that do not require manual operation of mechanical equipment (e.g. winches, cranes, nets) in favor of remote-controlled and centralized actions. In this way, drones with remote control can replace divers, supported by acoustic positioning methods and computer vision-based systems, increasing the accuracy of operations.

2.4 Interactive learning in innovation processes

It is essential to point out that the advance of aquaculture, in relation to the simple use of skills built upon practice, for the adoption of innovation processes based on new technology-intensive knowledge, presupposes, in principle, an interactive learning, involving the members of the enterprise among themselves, as well as with professionals outside the unit, who work with science and technology. This can be explained since, according to LLORÉNS (2008), the innovative process occurs as stakeholders interact and articulate using creativity, different knowledge, and information collaboratively in the territorial environment. In this way, the act of innovating consists in breaking the frontier of knowledge, bringing a new idea, a novelty, through a technological solution that results in a new product or service, or the improvement of existing ones (SHUMPETER, 1983).

There are essentially two models of applying innovation methodologies in large companies: linear and interactive models (also known as non-linear model, or systemic approach) (JOHANNESSEN, 2009). The linear model of innovation follows a continuous flow with arduous pre-planning that minimizes external factors that may impact the end result of a product or service. This model sustained itself for a few decades, but it needed to be revised since changes in the inputs of the creation process are constant, and communication with customers is fundamental.

Thus, the interactive model has been used by large companies around the world as a fast and effective strategy for obtaining results in the short and medium-term (JOHANNESSEN, 2009). This occurs because in the interactive model the authors maintain communication throughout the process and the deliveries occur at the end of each cycle, and if there are failures and distortions the feedback is informed so that in the following steps the errors are corrected, all in a short period (BARRAS, 1990). This interactive nature of the innovation process, which involves not only one of the interested parties but all stakeholders, favors the construction of innovative knowledge (MANLEY, 2003).

Knowledge, according to the theoretical approach of interactionists, is always built based on the interactions that the subject establishes in his or her world, and each new learning stage developed from what was previously built (PIAGET, 1970). Vygotsky (2007) also adds that this process involves social relations and that it manifests itself according to the values and beliefs of each culture.

The knowledge that is being built and incorporated by each subject was called tacit knowledge by Polanyi (1966). According to him, it is the potential that each person presents to learn and incorporate new knowledge, as well as to be able to adjust it to their needs. To differentiate tacit knowledge from technical and scientific knowledge, Polanyi (1966) called the latter explicit knowledge. It concerns knowledge already properly organized by technical and scientific means, made available as information, whether in the form of a technical manual, a book or article, a lecture, a class, chart, table, technical demonstration, among others. But for those who are learning, this information only becomes knowledge when properly incorporated to be put into action. Tacit knowledge, therefore, as stated by Gibbons *et al.* (1994), is that effectively gives companies the marketing potential to compete globally. From the perspective of Guile (2008), the company's resilience is being conquered from the discovery and incorporation of new knowledge. Once embedded, tacit knowledge becomes a competitive advantage for the company.

Interactive learning in knowledge construction, according to Nonaka and Takeuchi (1997), occurs in a spiral form, through four processes: socialization, externalization, internalization, and combination. Socialization concerns the relations lived as practices between subjects and the productive unit, within it. It can also be between subjects with the same practices as other units. Externalization refers to the explicitness of tacit knowledge incorporated into the enterprise environment, in interaction with external subjects. Internalization, in turn, concerns the process of incorporation of technical and scientific information by members of the enterprise, brought by technicians and researchers from external institutions. It should not be forgotten that the partners of this production unit also maintain their networks of interaction with other partners with technical and scientific knowledge, a process that Nonaka and Takeuchi (1997) call combination. The authors consider that knowledge, therefore, is constructed in a spiral, since through these interactive processes, knowledge can expand from the local scale to broader scales.

This spiral behavior of knowledge incorporation is difficult to happen in the linear model of innovation (waterfall model), since communication is scarce and feedbacks are slow, which can cause damage to the process as a whole, with extended deadlines and high costs due to task refactoring, which affects the final quality of the product or service. On the other hand, in the interactive model, as the process occurs in a spiral way, with constant exchange of information and after each cycle delivery is made and there is feedback on it when confronted with the expected goals, favoring the time-cost factor of the process as a whole (ALEKSEEVNA, 2014).

Knowledge then is transformative, moving from the mere industrial economy to the knowledge economy, in which it has three key factors: high mobility of knowledge; a high availability of knowledge; and a high capacity to use knowledge effectively to achieve a goal (DRUCKER; MACIARIELLO, 2008).

3 MATERIALS AND METHODS

The research object is the Pacu Project, located in Santa Rosa farm, in Terenos, Mato Grosso do Sul, near Campo Grande, the state capital. The research used descriptive and explanatory methods, to understand the main interactive learning processes to which the project was submitted to, selected as a research object, by the innovation process and the incorporation of knowledge.

In this context, bibliographic and documentary sources were consulted about the research object and its contextualization, as well as the selected theoretical framework. Primary sources of data were based on a structured interview with the Pacu Project executive manager. Thus, this research is characterized as a descriptive case study since it deals with a contemporary issue of collective interest and uses many of the techniques of historical research plus a combination of direct observation and systematic series of interviews in order to contribute to the understanding of individual, social, organizational and political phenomena (YIN, 2005). For this purpose, a form was applied to the manager of the Pacu Project to obtain answers to the guiding questions of this paper.

The questionnaire was structured in ten items, related to: (1) the origin and trajectory of the business; (2) the diverse partnerships with science and technology institutions in search of innovation; (3) partnerships considered fundamental to the business; (4) the various competencies built in the process; (5) the business framework for precision aquaculture; (6) workforce qualification; (7) the concern with environmental sustainability in aquaculture practice; (8) the positive economic and social impacts that the company has on the community living in the municipality of Terenos; (9) the types of innovation introduced; and, (10) future projects for aquaculture. Chart 1 shows the questionnaire applied in full.

Chart 1 – The complete questionnaire containing ten questions applied to the executive manager of the Pacu Project

1 - Can you stipulate different moments in the conduction of this business since its creation? If yes, identify in the chart below the years that marked these moments, their characteristics, and observations that you think are interesting to point out about these moments.

Years	Characterization of the stage experienced by the business	Obs:

2 - Aquaculture in the Pacu Project, for having been a pioneer in the place and even in Brazil, must have required various forms of learning. First, write in the box below, at the beginning of the business, who did you use to incorporate specific knowledge related to aquaculture/pisciculture, such as research organizations and institutions, or contact with other producers (name them) or others (specify). On the other hand, put beside it how this learning happened, such as training courses, search for information in literature or in specialized institutions, partnership relations, research carried out in the enterprise, technical visits to other fish farms, participation in events in the sector, among others (specify):

Type of knowledge about	From whom you learned	How did you learn

3 - List below the partnerships you considered fundamental to the advancement of the business:

4 - Include in the chart below the types of specific competencies that the company has subsequently gained through contacts and partnerships related to precision aquaculture, including equipment that could provide more accurate information and decisions, to achieve a more efficient production system, with higher productivity and profitability:

Competencies on	From whom you learned	How did you learn

5 - Would you classify your business as precision aquaculture?

( ) yes ( ) no. Why?

6 - How have you been doing to find skilled labor or to train it?

7 - What has been the way to ensure environmental sustainability in the practice of aquaculture?

8 - What are the positive impacts of economic, social, among others, the Pacu Project already provides to Terenos?

9 - Besides the practices in precision aquaculture, what nature of innovation has been introduced at Santa Rosa Farm related to aquaculture?

10 - Are there future projects related to the Pacu Project?

( ) yes ( ) no. Can you tell us what it is about?

Source: Elaborated by authors, 2021.

On-site visits to the Santa Rosa Farm, Pacu Project headquarters, allowed direct observation of the project structure and to complement the information collected.

The sources consulted favored the obtaining of objective and, even, subjective data, which allowed for the adequacy of their analysis and interpretation.

4 FAMILY ENTREPRENEURSHIP OF THE PACU PROJECT

Emphasis has been placed on understanding how knowledge and innovation construction takes place and what impact the new challenges in aquaculture must face on the path to entrepreneurship.

4.1 Knowledge building and innovation

The first experiences with family businesses, by the responsible for the Pacu Project, were with hotel and restaurant. Undertaking a fish farming project meant the pursuit of a dream that complemented the businesses the family had at the time. Thus, the idea of creating the venture came in 1987, aimed at producing pacu for leisure and own consumption. However, the family knew nothing about this activity and sought to learn about it in an interactive process with a professor and technicians from the Federal University of Mato Grosso do Sul, who provided technical information on fish farming for some varieties of fish. Other complementary information was obtained in the international literature thanks to the self-teaching skill of one of the sons. Facing economic difficulties in the businesses already owned by the family (hotel and restaurant), the captive fish breeding venture was created in 1991 and named Pacu Aquaculture Project Ltd.

Pacu was the first fish of choice because it is considered one of the native species in the Rio da Prata basin (River Plate Basin) and the easiest to breed, which adapts easily to various environments, and has tasty and popular meat. The biggest challenge was still how to feed an omnivorous species.

Therefore, new learning was being sought by the family with outside experts, trying to advance to the practice of feeding carnivorous fish in an aquaculture environment. This process began in 1997, interacting with two researchers from ESALQ / University of São Paulo, with postgraduate studies in the USA (KUBITZA; CYRINO; ONO, 1998; KUBITZA; CAMPOS; BRUM, 1998), specialists in fish nutrition and fish feeding training. Thus, the first innovation within the project was reached, that is, a technology for the conditioning of carnivorous fish to consume regular ration. The work was considered a pioneer in the production of fingerlings, especially in commercial-scale fattening of several Brazilian carnivorous fish species (pintado, cachara, dourado, tucunaré, and trairão). Because of these initiatives, the Pacu Aquaculture Project became a pioneer in large-scale reproduction of more than 20 species of fish from the River Plate, San Francisco, Araguaia-Tocantins Basins, and, in particular, the Amazon Basin. It also became recognized for its great knowledge about South American catfish. The Pacu Project gained notoriety in the media in 1997, especially due to its mastery of the captive pintado production technique. Thus, between 1997 and 1998, Project Pacu set up another fish farming unit in the Dourados area, within the state.

The option to operate in the international fingerling market occurred at the turn of the millennium when a market potential for the sale of fingerlings for various purposes (fish breeding, raising and fattening), including for export (ornamentation in aquariums) was envisioned. The company had already incorporated some degree of tacit knowledge in the production of fingerlings. To continue advancing, in addition to technical support, there was an organized consultation of available international technical literature on the subject.

However, dealing with export trade also meant a new learning effort. New executives and two professionals who worked as managers at Banco do Brasil (Brazil Bank) were hired so that the interaction with the knowledge incorporated by them took place within the company. Besides, the family sought to qualify two of its members, both in Business Administration and through SEBRAE's Technical training courses. The two brothers, better qualified, ended up leading the company's management.

In any case, the knowledge embodied in export trade courses was not specifically about how to pack and transport fingerlings (KUBITZA, 1997). At that point, knowledge had already been, to some extent, acquired with the support of two previous researchers, but it was not enough to master the procedure. To go further, it was essential to receive a North American intern technician in 2000, who was pursuing a master's degree in aquaculture in the USA. Interaction with him and, through him, with his teachers, allowed access to strategic information, which not only helped to improve fingerling production and reproduction techniques but also to know the proper procedures for packaging, labeling and for the safe transportation of fingerlings to anywhere in the world (KUBITZA, 2007).

Between 2000 and 2001, the Pacu Project ranked among the five largest Brazilian companies and the only one in its category to receive from the Ministry of Science and Technology the Finep Technological Innovation Award[3] 2000 (Production Process) and 2001 (Company), as well as an Honorable Mention for the investments made in the technology of production of surubim (*Pseudoplatystoma corruscans*) fingerlings.

Until 2008, the Pacu Project was busy preparing its feed due to the lack of suppliers. But in that year, in an interactive partnership with Nutron Alimentos Ltd. from the Cargill group, it managed to formulate the first fish feed in Brazil. In this case, the interaction took place from the tacit knowledge already accumulated by Project Pacu with the technical knowledge of that company.

Also, in 2008, the Pacu Project, in a species crossing initiative, created the Pintado Real®. In 2012, advances were made in the genetic improvement of this new species through experiments carried out within the unit, thanks to the knowledge already incorporated. According to the company, it is a more docile and resistant fish, can be slaughtered earlier (about seven months), which means that there can be two production cycles in a year, with high carcass yield and no degree of cannibalism.

In 2014-2015, the company attracted investments from a new company, Copacol, a cooperative that operates as a slaughtering industry (including fish). The purpose of this partnership was the search for another innovative technological solution, that is, the biological control of unwanted tilapia fingerlings with the use of the dourado in tilapia fattening nurseries. Since the dourado is carnivorous, placed in the tank, it eats part of the tilapia spawning, contributing to its biological control. This innovation was recognized in 2019, with the third place in the "Aquaculture Innovation Award" of the 10th Aquishow Brazil, considered the largest aquaculture event in the country, which features what there is in terms of modern and technological advances in the area.

According to the information provided by the company, through knowledge already incorporated and supported by interactive learning processes, it already makes use of technologies and equipment among the most used in the world, such as the French fish classifier, US net reel, fingerlings incubator, among others. According to the company's executive manager, the internet is an important source of information for buying new equipment.

[3] Awards available at: http://www.projetopacu.com.br/premios/.

4.2 Pacu Project structure and dynamics: facing new challenges

In this trajectory of existence, as it turned out, the Pacu Project was able to incorporate a quite significant body of knowledge about aquaculture, especially about native species, whether it is to operate in the national or international markets. The company has incorporated various competencies in the various areas of aquaculture, from the design of productive structures to reproduction, creation, and operation. It mastered cutting-edge technologies, especially through patents and software registrations not only associated with equipment, but also with fingerling production and reproduction techniques. Internally, thanks to interactive learning processes, both within the production unit and with external specialists of various natures, its staff has been able to conceive, elaborate proposals and act in practically all stages of the production chain. Also, the Pacu Project continues to train and qualify personnel, in its processes, to support projects involving catfish and various exotic species.

The Pacu Project unit has a modern structure, equipped with sophisticated larviculture and fingerling production, fish breeding stock, a raceway structure for intensive fattening (CARVALHO FILHO, 1996), in addition to handling market demands, research work and scientific experiments (PROJETO PACU, 2019). Committed to the development of new technologies, the company maintains laboratories with several partnerships with competent science and technology agencies, in search of solutions of their own that can be implemented along with companies interested in services such as native fish restocking, reproduction and raising for harvest. Figure 1 shows part of the Pacu Project facilities at Santa Rosa Farm.

Figure 1 – Pacu Project Facilities at Santa Rosa Farm

Source: Pacu Project (PROJETO PACU, 2013).

While fingerlings are mostly sold to fish farmers in other states, farmed fish are mostly traded with supermarkets in Campo Grande and several cities in the state. The company has also been promoting ways to interact with the consumer market with such practice. On the one hand, this is practised through a business centre, favoring the meeting between buyers and sellers of fish grown around the country. On the other hand, the Pacu Project has established market cooperation with the group of Carrefour Comércio & Indústria Ltda, which owns brands such as Atacadão, Carrefour (hypermarkets), Carrefour Bairro (supermarket), Carrefour Express (proximity retail), Carrefour.com (e-commerce), among others.

The Pacu Project has been building knowledge to become a reference, by 2025, in the development of technology and innovation at all stages of the production chain of farm-raised fish in South America. In this sense, the values touted on its website are related to a development of a collective nature, based on continuous systemic innovation, respect for biodiversity and the environment, maintaining the noble spirit in institutional relations. Chart 2 shows the commitments to Mission, Vision, and Values.

Chart 2 – The company commitments to Mission, Vision, and Values

Mission	To develop, produce, and market quality services and technological solutions for aquaculture, with respect for the individual, the society, and the environment.
Vision	To become a reference in the development of technology and innovation for the productive chain of aquaculture in South America by 2025.
Values	- Effective interdisciplinarity; - Collective technological development; - Systemic and continuous innovation; - Respect for the environment and biodiversity; - Ethics in institutional relations.

Source: Translated of Pacu Project website: Who we are? (PROJETO PACU, 2022).

The concept and construction of the reproduction structure of Santa Rosa farm in Terenos/MS have been a reference for several fingerlings' producers in Brazil and neighbouring countries. As a result, members of the company have been invited to work in the planning, design, monitoring, and training for the operation of public and private enterprises focused on the reproduction and breeding of native fish, production of balanced fish feed and processing, and industrialization of fish.

These Pacu Project professionals work with the concept of industrial complexes, seeking to optimise the synergy throughout the main links in the aquaculture chain, promoting efficiency gains and greater profitability for the enterprise. In this process, the company is also involved in actions in the hydroelectric sector, serving the governments of neighbouring countries and large private producers in Brazil, Argentina, Peru, Bolivia, and Colombia. It is also qualified to offer services with its machinery and specific implements for earthmoving of aquaculture projects. New technologies disseminated to customers also focus on designing plans that encompass the entire fish farming production chain, in particular for the fish breeding, feed industry, and fish processing. It is possible to infer, from what has been reported, the outsourcing of tacit knowledge, incorporated over time, in the form of explicit knowledge. Also, as can be seen in this process, skilled personnel are prepared to interact directly with the production process, while in training, including dealing with machinery. A summary of the technological advancements and skills developed over the years is presented in Chart 3.

Chart 3 – Technological advances and skills developed by the Pacu Project

Technologicals Advances and Skills	Description
Larvae Production	On-demand production of larvae of the various native species, with safe and reliable packaging and transportation.
Species hybridization (genetic improvements)	The Pintado Real is an excellent hybrid species developed by the Pacu Project, with high commercialization potential.
Tanks and cages	Construction of tanks and cages for producers who want to start fish farming, providing all the necessary advice.
Earthwork and construction	It has a comprehensive operational structure of machinery and equipment that helps new producers who want to invest in fish farming. Besides mentoring, they have workshops for maintenance and repairs.
Self-cleaning filters, bio-filters (SBP), recirculation system (RAS)	They are equipment developed to assist in the management and raising of fingerlings. The self-cleaning filters assist in the removal of solid waste in expanding tank water; the single pass biofilters (SBP) increase water oxygenation; and the recirculation system (RAS) enables the farmer to save water.
Classifiers	It develops classifiers for fingerlings and juveniles that make it possible to separate them into different size classes.
Water Monitoring	Although they have them in books usually in English and Spanish, they have learned from the American technicians who arrived in 1998 onwards.
Fingerlings weight control	Evaluation and construction of the growth curve that makes it possible to follow the growth of the fish and verify whether it is within the expected size and weight or not.
Feed supply	In partnership with Nutron, they formulated the first fish feed in Brazil that did not exist at the time. In the beginning they did it because they had no one to buy it from. They used chicken feed.
Transportation and Packaging	All the technique came with Americans.
Fingerling traceability, counting (ALBUQUERQUE *et al.*, 2019; GARCIA *et al.* 2020) and weighing (OLIVEIRA JUNIOR *et al.*, 2021; PACHE *et al.*, 2022)	These are techniques that have been developed in partnerships with universities (UCDB and UFMS) and the Federal Institute of Mato Grosso do Sul (IFMS).

Source: Elaborated by authors, 2022.

However, even in the face of advances in the incorporation of knowledge, the uncertainty has given the acceleration of events in today's networked world puts on alert a company that has learned to learn interactively, both to face threats and to glimpse new opportunities. It needs to be resilient in the face of these possibilities.

In this sense, as the executive manager pointed out, just as a product has a life cycle, so has fish. An example given by him is the raising of pacu, the species that gave its name to the company. This species´ production was stopped about fifteen years ago, while the dourado became the fish of the moment. On the other hand, as he added, fish farming is focused on three items: rapid production, better feed conversion and more biomass in the smallest possible space. One example is the fish pintado-real, a species developed in the Pacu Project, which is slaughtered earlier, in seven months, instead of fourteen. The new technology also meant reduced production costs, increased productivity and greater profitability for the business. Another fact to be considered is that although Project Pacu was the national leader in the export of fingerlings for ornamentation purposes to countries such as the USA, Germany, and Japan

(CARVALHO FILHO, 1996), exports were stagnant at the time of the interview, mainly due to its low profitability at that moment.

The company also recognises that, as much as it has advanced technologically in aquaculture, such advances do not make it fit into a model of precision aquaculture. In its view, Brazil is still behind in this process. One of the most common problems in the region has been the counting and weighing of fingerlings. It is still done manually, slowly and inaccurately, often involving several employees. This counting is done by sampling, which does not guarantee that the negotiated quantity is precisely correct. Weighing, in turn, subjects fingerlings to physical stress that can hinder growth and even lead to their death, reducing the quality of production. There are still few electromechanical and computerised devices in Brazil suitable for counting fish of various sizes, or for measuring their size and estimating their mass.

Foreign technology is available, but prices are inaccessible to the small and medium producer. As a result, those responsible for the Pacu Project established a recent partnership with the Universidade Católica Dom Bosco, through the research group Computer Vision in Fishery and Aquaculture (FISCHCV), of which one of the lines of research consists of "Computer Vision in Fishing and aquaculture", for the elaboration of a fingerling counter, based on computer vision. The project should result in the development of software aimed at automating the processing of images captured by a high-resolution camera. It identifies and counts fingerlings that pass through a duct containing a small trickle of water (ALBUQUERQUE *et al.,* 2019). This new interactive learning experience is in progress.

From another angle, the technological innovations that are being incorporated into the production unit also derive from these interactive learning processes. For this reason, innovation is no longer understood as an isolated and linear phenomenon, but as a result of complex social relations, in a systemic, integrated and territorial process. They are not only based on technical and scientific knowledge but also the dialogue of this knowledge with the knowledge built on daily practice (MENDEZ, 2001). Through these interactive processes, specific knowledge of the territory in which they manifest themselves is generated, which is incorporated by the subjects, the project itself, and the institution involved.

5 CONCLUSIONS

The research results, presented and discussed, allowed us to verify the importance of the role played by interactive learning in Project Pacu, not only in technological innovation processes but also in the incorporation of knowledge adjusted to the situation experienced by the enterprise. As can be seen, given the interactivity of today's networked world, interactive actions are also proving to be the most appropriate for building new technological solutions in the face of constant changes in the speed of events, in the process of sustainable development. In turn, the knowledge that is being incorporated as tacit does not only expand the possibilities of new learning, but also the systemic spread of new knowledge. There is no doubt yet that the tacit knowledge present and protected by employees and family members ensure competitiveness and business resilience, which are characteristics of a smart territory.

The company has demonstrated the ability to pioneer and lead in connected aquaculture technologies, especially in the production of fingerlings, fish farming, and in genetic improvements. However, it has already been able to foresee the need to advance to new challenges linked to precision aquaculture.

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