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Activities and learning in aquaculture sustainability.

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ABSTRACT

This study takes some of the basic principles and practices of collaborative modeling, with the aim of analyzing, in a group of Biology students from Mexico University, the influence of metamodeling knowledge in their way of learning how to collaboratively model different interpretations of sustainable in low resources aquaculture farms. There by, we are able to identify the elements that enhance the analytical and critical thinking of students in an educational field thought active learning. The methodology comprised five meetings with interested parties (alumni, officials and producers) to promote sustainable aquaculture production. The study focused on three key collaborative-modeling practices: systemic observation, creation of hypothetic models and negotiation of hot spots. This, through development of metamodeling knowledge allowing the student to completely understand all the progressive processes required to overcome challenges that entails such modeling, as well as incorporation of point of views from different stakeholders. The results showed that metamodeling knowledge increased student learning related to systemic collaboration, as well as their capacities to focus on specific aspects, different from their original point of views, leading to their own analytical operations development. However, restrictions in systemic observation, specifically related to reduction of their capabilities to define relevant evidence, were also found. In the case of hypothetic modeling, restrictions reflected an undervaluation of sustainability complexity. Finally, for hot spots negotiation case, restrictions limit the ability to detect conflict points, as well as consensus areas.

Key words: Collaborative modeling, Metamodeling knowledge, Active learning, Sustainable aquaculture production.

RESUMEN

El presente estudio retoma algunos principios y prácticas de la modelación colaborativa con la finalidad de analizar, en un grupo de estudiantes de Biología en una Universidad de México, cómo influye el conocimiento de meta modelación sobre su forma de aprender a modelar colaborativamente las distintas interpretaciones de lo que es la producción sustentable en granjas acuícolas de bajos recursos. De este modo, se identifican los elementos que potencian el pensamiento analítico y crítico del alumno en este campo formativo a través del aprendizaje activo. La metodología seguida contempló la realización de cinco reuniones con las partes interesadas (alumnos, funcionarios y productores) en promover la producción sustentable acuícola. El estudio se centró sobre 3 prácticas claves de la modelación colaborativa: la observación sistémica, la elaboración de un modelo hipotético y la negociación de puntos de conflicto. Ello mediante el desarrollo de un conocimiento de meta modelación que permitiera al alumno articular el cómo de su práctica, con el qué, el para qué y el sobre qué, como procesos progresivos que mejoran la superación de los retos que conlleva dicha modelación y la incorporación de los puntos de vista de las distintas partes interesadas. Los resultados mostraron que el conocimiento de meta modelación amplió el aprendizaje de los alumnos sobre la observación sistémica y sobre un mecanismo de colaboración que les permitió localizar aspectos concretos y diferentes a sus puntos de vista para realizar sus propias operaciones analíticas. Sin embargo, se encontraron restricciones en el momento de la observación sistémica referidas a la reducción de la capacidad de aprender a definir las evidencias relevantes. En el caso de la modelación hipotética, las restricciones se reflejan en una subvaloración de la complejidad de la situación de sustentabilidad. Finalmente, para el caso de la negociación de conflictos, las restricciones demeritan la capacidad de detectar los puntos de conflicto y los espacios de consenso.

Palabras clave: Modelación colaborativa, Conocimiento de meta modelación, Aprendizaje activo, Producción sustentable acuícola.

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INTRODUCTION

The learning of collaborative modeling

One of the biggest challenges in training towards sustainable is to get students learning how to integrate different points of view and interests form the stakeholders, involved in productive, ecological and environment situations (Coenen et al. 2015). One way to achieve this, is making collective representation trough sustainable situations that constitutes a way in which the different actors involved, express in an agreed way their vision of it. This type of representation could be achieved through collaborative modeling focused in mutual understanding to define terms and share experiences[1]. There are a broad range of approaches for collaborative modeling (Voinvov et al. 2016), each of them with operational proposals to perform such modeling and, therefore, notoriously separated from each other. However, it has been noticed the presence of values and basic practices in this type of modeling (Voinov and Bousquet 2019). This work takes some of this principles and practices with the aim of study in a group of university students, the challenges of learning collaborative modeling, whose importance come from recognize that, in the contexts of sustainability, the participation of all the stakeholders has become a duty, since the problems to resolve are not well describe or been poorly structured (Basco et al. 2017). Sustainable problems are subject to multiple interpretations and is very important to have an interpretation in which all the parties are involve in reach a solution (Özesmi y Özesmi 2004).

Three more reasons to implement collaborative modeling are the followings: a) they increase the possibilities in solve sustainable problems, as long as it assumed that, gain a better understanding of the problems will offer greater possibilities of solving them (Ostrom et al. 1994), b) they help to increase the possibilities of overcome sustainable problems through generating interpretations, that decrease conflicts between the parties involved, also they mark work orientations with greater legitimacy and support (Korfmcher 2001), and c) offer not only a holistic interpretation of the situations, but also a mutual agreement, that lead to a decrease risk of creation adverse effects in all the parties involved.

Because of collaborative modeling is a new and in progress field, there are no many works who deeply analyze the challenges of such learning[2], however their holist nature, transdisciplinary and effortless way to apply, suggests that they are no meager. Those, educational challenges are link to specific modeling practices, here we addressed three of them: systematic observation, the elaboration of hypothetical models, and the negotiation between the stakeholders.

The practice of systemic observation involves the challenges of learning to collect and process relevant evidence, overcoming common limitations such as: the uncritical collection of data, the partial acquisition of biased information by the own understanding and points of view of the observer (Batnaud et al. 2008), or by obtaining irrelevant data, as well as lack of precision and scientific rigor (Özesmi y Özesmi 2004).

The elaboration of hypothetical models implies build a conceptual collaborative model, that involves the challenge of pick up some points raised in the dialoged with the stakeholders, as well as interacting and being reflective with their conceptualizations (Kerkhoff y Lebel 2006). Besides, also involves learning from others (Pahl-Whostl y Hare 2004), to organize their own thoughts and those of others in a framework of standard scientific practice and

1 Participatory modeling and collaborative modeling are terms that have been widely interchangeable used but is has been acknowledge that stakeholder's cooperation in collaborative modeling is generally greater than in the participatory modeling (Voinov and Bousquet 2010), reason why in this work the term collaborative modeling was assumed.

2 There are abundant and propositive studies on the learning of scientific modeling that have nurtured the existing theory about this field (Harrison and Treagust 2000; Grosslight et al. 1991; Snir et al. 2003; Spitulnik et al. 1999), but the studies about learning of a more interpretative modeling, belong to a new area.

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objectivity. Still, the main challenge of this modeling will be, integrate all the point of views, because this could result in disagreements about the importance of system characteristics, or you may have very different views on the desired results.

Common negotiating practice refers to the interaction that take place between stakeholders in search of an agreed representation (Ravnborg y Westermann 2002). Here lies the challenge of questioning the model and discuss the differences and limitation detected by the different stakeholders (Ramsey 2009). It also involves the challenge of analyzing the model and discussing its possible improvements through the critical judgment exercise that recognize cognitive limitations, as well as possible strengths.

Active learning and metamodeling knowledge

Knowing the importance and challenges of practice collaborative modeling involved in their learning, the present works is focus in understand how to promote the analytical and critical thinking of the students in this formative field through active learning, a constructivist educational current characterized by encouraging student's initiatives to participate in their own education (Felder and Brent 2009). This current refers to the teachers requests towards student to carry out activities related with the desired learning. Active learning has several proven advantages in various training fields (Freeman et al. 2014) and covers a range of activities of different complexity, from short and simple ones, such as sharing with other colleagues, to self-regulatory activities such as design, as well as develop and project evaluations (Lord et al. 2012).

Educational studies of scientific modeling have probed that an active learning practice is effective in improving this type of formation, knowing as metamodeling knowledge[3]. For purely educational purposes, a distinction is made between the practice of modeling and such knowledge which includes how the models are used, why they are used and what their strength and limitations are. Through this knowledge, students are asked to perform cognitive activities that contextualize their practice with the purpose of enhancing their critical thinking about what they do and help them to provide a logical significance to their work (Schwarz and White 2005).

This project picks up metamodeling knowledge concepts, born within the framework of the positivist paradigm that promote work to achieve objective representations in different scientific fields (Schwarz and White 2005), to extend its application within a constructivist paradigm that assumes social construction of the realities and promote interpretative modeling (Giordano et al. 2007; Lynam et al. 2007; Checkland 2000). It was applied in its original sense, meaning, with its aspects that allow the student to integrate the how of their practice, with what, what for, and what about, as expert in systematic thinkers do it (Arnold and Wade 2015). The only adjustment made is that the theory about the roles that models scientific research is replaced by knowledge related to the role of collaborative modeling in the interpretation of realities.

Under the exposed framework, we were interested in, how metamodeling knowledge can influence in the learning of collaborative modeling? This question was addressed in a case: in the effort of collaboratively modeling the correct pathway to bring low-income aquaculture farms to a sustainable production. This study case has the socio-educational relevance of being inserted in the professional training of university students, in this manner students get involved in the sustainable development of primary activities such as aquaculture, so necessary in a county like ours. Also, this study case has a scientific relevance, due to, sustainable aquaculture it's the typical case of an undefined or poorly structured problem, where the "what" and the

3 Metamodeling knowledge refers to the contextual knowledge of a specific model and that usually includes: the purpose of modeling practice, the conceptual bases of the model, the nature of the models, the roles they play in scientific research and the use of criteria to evaluate them. Such knowledge can make models more understandable and reusable and less subject to misinterpretation (Keller and Dungan 1999).

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"how" are difficult to define. It is a problem framed in a classic problematic of sustainability because its solution necessarily requires the joint effort of various social actors and because the progress of any of its productive, ecological, and social objectives is equally important, but with the limitation that each of them can happen at the expense of others.

MATERIAL AND METHODS

Methodology background

The research was developed along a full-time course of Biology students in a university in Mexico; it involved 17 students, who were trained at that time in the development of their systems thinking. In addition to the students, 8 representatives of stakeholders interested in the sustainable development of the aquaculture activity of the State of Morelos agreed to participate in the research: two producers and owners of the aquaculture fish farms and six officials: of which two of them worked as promoters of the aquaculture activity, two others exercised their role as environmental regulators, finally the last two were representatives of social development institution.

Development of collaborative modeling practices

All stakeholders, students and officials, were reunited five times to develop three practices recognized as key elements in collaborative modeling (Renger et al. 2008); the systemic observation, the elaboration of a hypothetical model and negotiation of conflict points. For the systemic observation, two meetings were held, in the first one the students had not previous metamodeling knowledge but in the second they already had it. The first task in these meetings was for the entire group to adopt a clear analysis direction before starting to provide information. This direction was to establish the necessary factors for a sustainable aquaculture farm. Subsequently, all interested parties were asked to identify such factors and to weigh their influence within each other.

In the practice of elaborating the hypothetical model, the documented alternative of previously creating a model by the analyst was followed (Andersen et al. 1997), and then presented to the stakeholders, this will allow all the parties to be questioned and propose improvements. Therefore, each student received the instruction to integrate, through a conceptual model, the information collected during the systemic observation. Once the model was elaborated, the students investigated the metamodeling knowledge focus in the construction of models, to later modify their individual proposal. Then, the models were presented to the stakeholders and an interactive process was promoted so that each student will make improvements in his proposal.

In collaborative modeling is frequent to discussed interactively and repeat several phases in the proposals negotiations (Windsor, 2010). In the investigation, the course times allowed the realization of two negotiation meetings. In the first, the students had not yet investigated the metamodeling knowledge of the negotiation, but in the second they had already done so. In both meetings the main task was the identification of conflicts between the interested parties and, if possible, to outline some agreed way of resolution.

Research and debate of metamodeling knowledge.

After each of the initial practices of collaborative modeling, students were assigned to investigate the usefulness, nature and evaluation criteria of each of the practices: systemic observation, elaboration of the hypothetical model and negotiation. Talks with open participation about metamodeling after their research were promoted, here students raised the different uses of modeling practices, as well as they defined the way metamodeling practices should be done from the existing theoretical viewpoints. A final part of these sessions contemplated the identification of the criteria that could be used to evaluate the realization of the modeling practices and, once identified, they were asked to apply them to the realization of their own practices. In Table 1 the criteria identified for each of the modeling practices studied are presented.

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Information processing

The processing followed was qualitative and was developed with the aim of presenting cases that represent the main challenges and learning achievements of collaborative modeling. This representation does not refer to frequencies or statistical probability, but to an analytical type oriented to the interpretation of learning outcomes. The information processing was located within what is known as the multiple case study, whose logic involves exploring and analyzing the similarities or differences between the cases to be studied (Langley and Royer 2006) and whose development involved the following four methodological phases:

1. Exploration and description of each one of cases.
2. Search for new evidence that deepens the understanding of the case to characterize it as accurately as possible.
3. Compare cases applying the same questions to each of them, making a comparison of the answers to reach the conclusions of the comparison.
4. Synthesis of the findings found in the comparison of cases and identification of the most representative case.

RESULTS AND DISCUSSION

Observation from a systemic approach

Aquaculture farms, like any system, can be "definable" in diverse ways (Garcia 2006), as well as the factors that can influence to reach a sustainable production can be established from different points of view. For example, in Table 2 we presented those factors that were perceived in a student first encounter with the stakeholders, represented by the tendency of perception found at that moment[4]. What is observed in the table is that there is no clear notion of "relevant data", since it shows a record of aspects of a diverse nature with a minimum organization, established by the differentiation of the stakeholders.

The information perceived at that initial moment shows a pattern characterized by the lack of hierarchy; for example, "pond maintenance" and "productive technology" are indistinctly mentioned when the former is only a small expression of the latter. In the same ways the lack of inclusion criteria which leads to an indistinction of the data nature, equally combining entities such as "produced organisms", with processes such as "education received" and with flows as "supplied food", only by mention some mixtures. It can also be observed that some perceived factors are pointed out while others are shown in a general way, thus there are descriptive details such as "producer turnover", "water replacements" with abstract and general expressions such as "mercantile security" or "chain of marketing. In general, it can be said that the student sees with few systemic tints, with reduced coding and with data that oscillate from opposite analytical ends.

After researching the relation of metamodeling knowledge to systemic observation, students generally were able to detect the indiscriminate nature of their records, caused largely by the overwhelming situation of interact with diverse sources, which provide them with dissimilar criteria that can lead to the sustainable production of an aquaculture farm. This situation has the effect of obstructing the analytical processing of the data, thereby reducing the quality of the observation. The students discussed the value of having a mechanism that allowed them to capture information, established it with less dissimilar criteria or that allowed them to discriminate the nature of the data obtained. In dialogue with them, the value of a mechanism such as the one mentioned was discussed and that this could be represented by the use, during the observation, of a conceptual structure

4 This statement is not intended to deny that each reading experience is loaded with theory (Hanson 1958) and that the same students highlighted different facts, but the trend refers to the general structure of observation, which did show similar patterns in most of the students.

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Table 1: Criteria identified to evaluate collaborative modeling practices.

COLLABORATIVE MODELING PRACTICES		
Systemic observation	**Hypothetical model**	**Negotiation**
• Components analysis definition	Identified dimensions (subsystems)	Distinction of conflicting points
• Components served	Classification of components	Distinction of knowledge uncertainty
• Nature of the components	Type and nature of established relationships	Distinction of interpretive problems
• Congruence of the analysis	Accuracy of relationships	Troubleshooting and missing
• Balance of the analysis	General structure assigned to the model	Agreed restructuring

Table 2: Example of factors perceived by the students in their first approach with the stakeholders

ACUÍCOLA PROMOTER	ENVIRONMENTAL REGULATOR	SOCIAL WORKER	PRODUCER
Productive effectiveness Net income Organisms produced Education received Salary of workers Maintenance to ponds Productive infrastructure Productive technology Preventive environmental technology Cost benefit relation Proven profitability Commercial security Marketing chain Institutional relations Monitoring of environmental regulation Generated revenue	Native species Existing regulation Production adaptation - load capacity Articulation with economic activities Preventive technologies Cost / expense ratio Production-marketing integration Articulation of the farm to its context Types of sanctions Surveillance mechanisms Environmental self- regulation Distribution of benefits	• Social and ecological productive relevance • Coherence between technology, knowledge and ecological conditions • Income diversification • Profit / earnings ratio • Attention to the consumption needs • Self-regulation to reduce social and ecological conflicts • Contribution of income to the satisfaction of basic needs	Species produced Cost effectiveness Development of productive technology Replacement of players Training received Water spare parts Sanitary measures Water control Supplied food Fingerling production Income diversification Health security Market expansion Access and diversification of supports Cooperative production practices Participation in the normative development

that allowed them to perceive the information in a more discriminated manner.

It was also discussed with students the importance that the conceptual structure was not defined before capturing the records, but the data itself suggesting the structure; otherwise the theory contained in such structure could bias the observation. With the data obtained in their first meeting with the stakeholders, the students settled preliminary conceptual schemes that they later developed during a second observation meeting with the interested parties. It was also discussed with the students the fact that they also included in the interested parties and the convenience of being included in the record.

Table 3 shows an example of the observation made with a basic conceptual structure that differentiated the sources contributions in dimensions, criteria and items. As can be observed in Table 3, the lack of information discrimination did not disappear altogether, but it was reduced because the structure made it possible to systematize the obtaining of records. Thus, the mechanism used in a conceptual scheme form allowed to share the vision of the stakeholder and became a cognitive space that supported direct communication among the

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Table 3: Example of a systemic observation made by a student after researching metamodeling knowledge.

DIMENSION	CRITERION	TOPIC	STAKEHOLDERS				
			Student	**Aquaculture promoter**	**Environmental regulator**	**Social worker**	**Producer**
ECONOMIC	Productive improvement	Productive growth		XXX			XXX
		Technological adaptation to the context	XXX		XXX	XXX	
		Social relevance of the product				XXX	
		Infrastructure and productive investment		XXX	XXX		XXX
		Recognition and development of indigenous technology	XXX				
	Generation and use of income	Productive management	XXX	XXX			XXX
		Articulation with other economic activities	XXX				
		Productive investments		XXX			XXX
		Generation of income		XXX			XXX
		Cost benefit relation		XXX	XXX		XXX
	Market	Productive planning	XXX				
		Productive diversification	XXX				XXX
		Production integration - marketing	XXX				
		Marketing chain		XXX	XXX		XXX
		Mercantile promotion		XXX			XXX
SOCIAL	Social responsibility	Compliance with standards		XXX	XXX		
		Self-regulation	XXX				
	Collaboration	Linkage with groups and institutions	XXX	XXX		XXX	XXX
		Participation in the development of standards				XXX	
		Collective learning	XXX				
	Life improvement	Income diversification				XXX	
		Income and quality of life				XXX	XXX
		Income distribution				XXX	
		Access to the activity				XXX	
ECOLOGICAL	Risk control	Environmental technology		XXX	XXX		
		Waste management and control		XXX	XXXX		
	Ecological responsibility	Rational use of resources			XXX	XXX	
		Adaptation to the ecological environment	XXX				
	Ecological integration	Articulation with the environment	XXX		XXX	XXX	
		Use of ecological services	XXX				

participants. Observation through this mechanism allowed a structured dialogue that not only improved the record balance, but also extended it by allowing participants to detect missing topics, always defined from their points of view. Students extended their learning on systemic observation and on a collaborative mechanism that allowed participants to locate specific and different from its s views and to make their own analytical operations aspects.

Development of the hypothetical model

In modeling, the principal learning of the student is to integrate and relate the different constituents of a system. In a complex system, the

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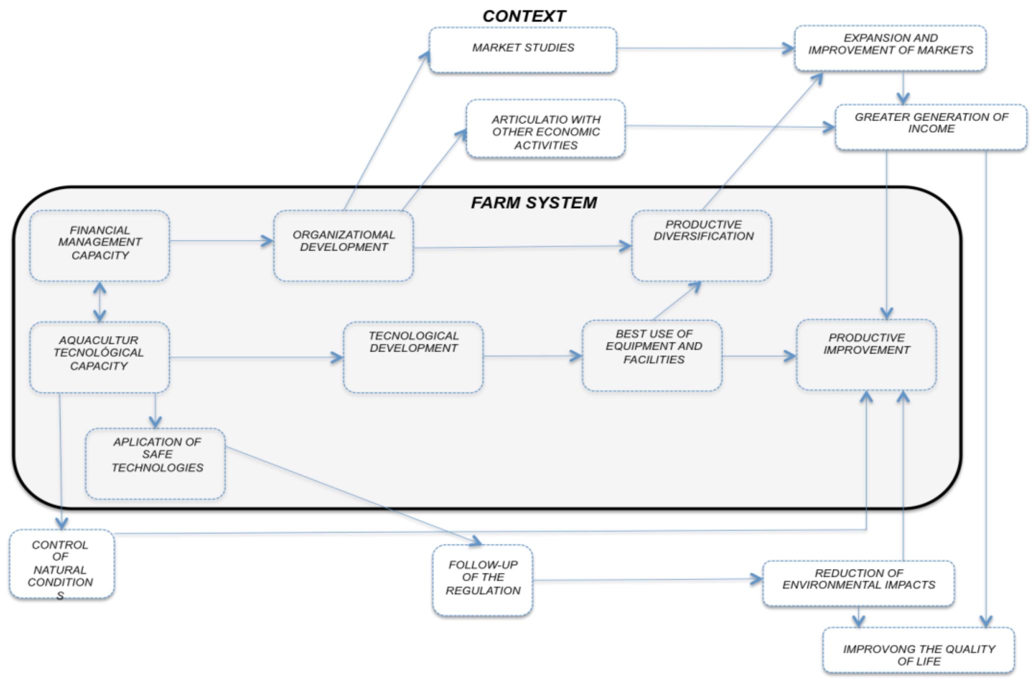

Fig. 1: Representative case of student modeling prior to metamodeling knowledge and before interacting with stakeholders.

relationship of its components requires defining them under some common criteria, for example, in the ecological modeling state variables, which represent the internal constituents of the system, are defined under the criterion of their capacity to accumulate matter and energy (Blanco 2014). But in environmental systems there are no agreed criteria to define the components, which carries the risk of defining them from very dissimilar thinking. The definition of components without an agreed criterion, leads to a constellation of partial views of the same system, a situation found in the studied students in the first requesting modeling attempt. But beyond these differences, trends were also found in the modeling that are summarized in Fig. 1, which presents a typical case in which these trends are reflected with greater clarity.

One of the referred trends is to define the components of the model as processes that involve actions of a specific nature but dissimilar among them. Another trend is the use of an elementary classification of the components, which only distinguishes between internal variables (those of the farm), from the external variables (those of the context). The classification of the components is a crucial process, because the structure of a system is constituted by the relationships that gives them identity to the system[5] and these relationships can be established between individual components, or between sets of components or subsystems.

5 In tangible systems, such as a car, for example, there are relations between its components that give identity to the system and that form an identifiable structure, but in intangible systems, such as the sustainable production of an aquaculture farm, there is no agreed structure which gives rise to the definition of discrepant identities.

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The most notorious tendency in the studied students refers to the way in which they relate the components of the system and that is observed in Fig. 1 in the form of a progressive sequence constituted by linear relationships. When interpreting the system in this way, it is oversimplified because it is based on the following assumption: when introducing a cause X, the Y effect will always happen. But this only happens in structured problems, almost non-existent in the situations of sustainability, that have unstructured problems in where: at introducing a cause X it be can obtain different effects, for example, the "best use of equipment and facilities" will not necessarily lead to a "productive improvement".

When we talked with students about the metamodeling knowledge related to the modeling process, attention was paid to the question of how to link an event with a minimum cause and that this would only be justified if there were consensus among the stakeholders that this would happen. Later, when interacting with the interested parties, the students perceived that frequently the participants, or manifested a low degree of consensus on the causes of the phenomena, or they declared limitations of knowledge to affirm conclusively that a cause X will inevitably produce a Y effect. After these events, the modeling tendencies changed radically, Fig.2 presents the representative case of this change, characterized now by considering the possibilities of causes and effects, as well as by the manifestation of a more cybernetic or circular thought (Garciandía, 2011). At the heart of this thinking is the fact that each answer will be always contextualized, that is, that the response to the introduction of a cause X, will depend on how the system is organized at that moment.

The negotiation between the participants

When students first met with stakeholders to discuss areas of consensus, conflicting points and negotiable aspects, we observed a more detailed and clarified model (by adding new specific information), but the students did not consider or explain trouble spots, uncertainties or interpretive problems. Subsequently, the students discussed the metamodeling knowledge related to negotiation, that touched points such as the intrinsically conflicting objectives of sustainability situations (Zeitou and Mirumachi 2008) that, at a territorial scale, where aquaculture practices generate human well-being, provoke a trade-off service by increasing supply, but generally reducing regulating and cultural services (Outeiro and Villas 2013). In addition, we discussed how these manifests itself at the level of a productive unit, with conflicts between interests, desires and capacities, to directly or indirectly select the characteristics to be developed in the unit, where the main choice is from the producer, and feedback is provided of all the stakeholders involved (Costa-Pierce 2010).

At the second meeting with the stakeholders, the students were able to perceive distinct levels of conflict and uncertainty of knowledge. In table 4, the work of a student who identified seven main conflict points, marked in red, is presented. The first of these refers to "productive growth", which is so vital for the aquaculture promoter, is perceived as a threat to an environmental regulator due to the collateral effects that such growth normally entails (Chu et al. 2010). The "infrastructure and productive investment", valued by aquaculture producers and promoters, is interpreted as a factor of social exclusion by social workers due to the possibility of limiting the incorporation of the most unprotected social sectors into the activity. The "recognition and development of indigenous technology", so recognized in the academic field and resumed by the students, is a possible factor of low productive rates for an aquaculture promoter. The "productive diversification", fundamental for the producer to enter the markets, is a threat for an environmental regulator due to the introduction of non-native species and the increased risk of trans-speciation, a very common ecosystem alteration factor of aquaculture activity (Edwards 2015). Finally, for a low-income producer, "compliance with standards", "environmental technology" and "rational use of resources", which are so crucial for officials, are perceived as factors of increased production costs and hence, restrictors of their already low profit rates.

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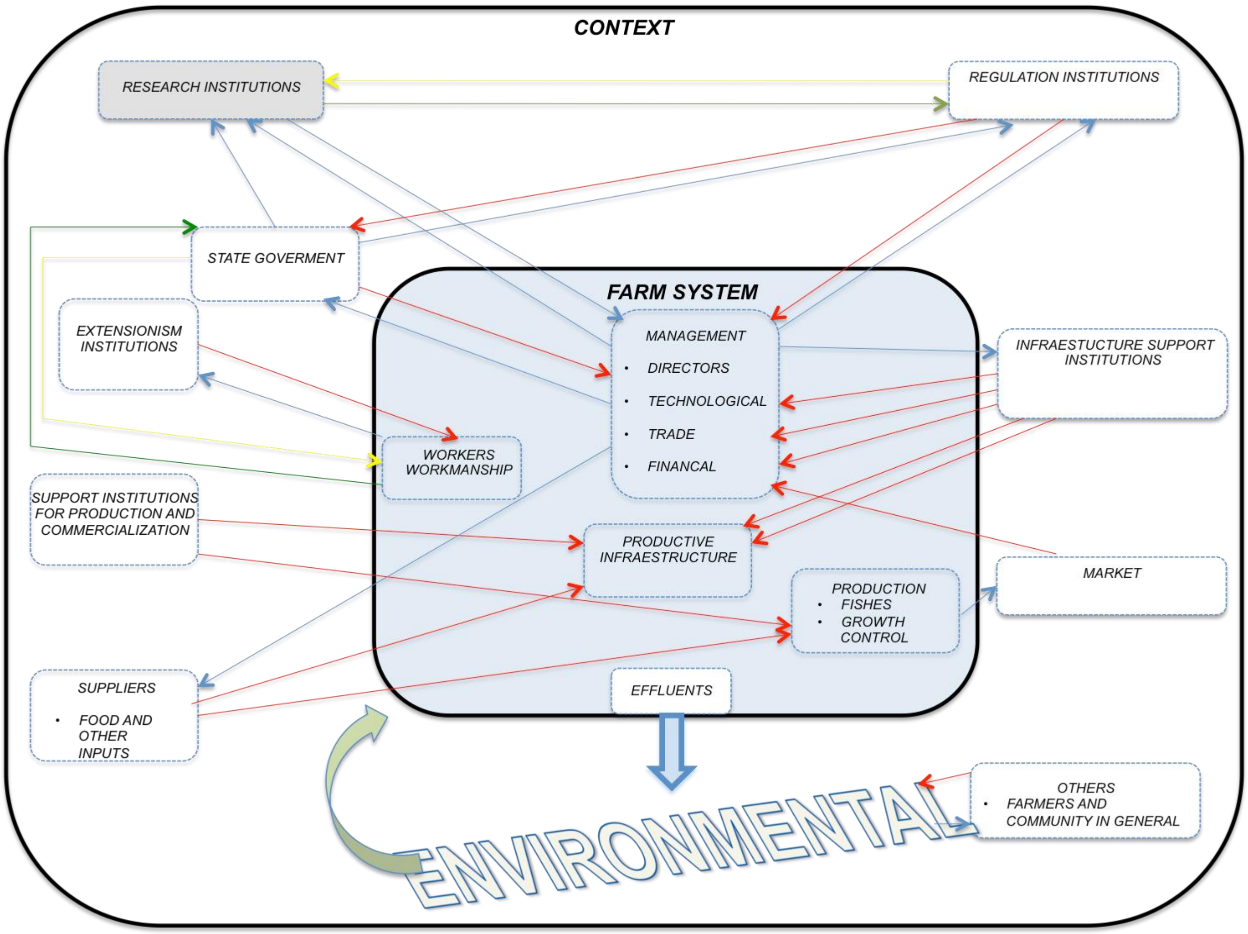

Fig. 2: Representative case of student modeling after metamodeling knowledge and interacting with participants

Table 4: Conflict points identified by a student after researching metamodeling knowledge

Topic	Student	Aquaculture promoter	Environmental regulator	Social worker	Producer
Productive growth		XXX			XXX
infrastructure and productive investment		XXX	XXX		XXX
Recognition and development of indigenous technology	XXX				
Productive diversification	XXX				XXX
Compliance with standards		XXX	XXX		
Environmental technology		XXX	XXX		
Rational use of resources			XXX	XXX	

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CONCLUSIONS

The learning process of collaborative modeling involves the student in the realization of various "instructional" activities, named after their determination by pedagogical discourses, three of them: observation, modeling and negotiation are crucial. In the realization of such activities different restrictions may arise whose sources are diverse, but which may come mainly from the teacher, the participants, the learning environment and the students themselves. For example, in the teacher, the restrictions may be due to the lack of clarity in their discourses; in the participants, they can be generated by the reluctance in their willingness to collaborate; in the environment, they may arise because the existing conditions are not conducive to encouraging dialogue and interactions between participants and, in the student, the restrictions may come from their experience and their cognitive and emotional properties.

Whatever their origin, these restrictions generate the effect of limiting the learning outcomes at the different moments of the collaborative modeling process. What was found in this research is that at the time of systemic observation, the restrictions act reducing the ability to learn to define the relevant evidence. In the case of modeling, the restrictions are reflected in an undervaluation of the complexity of the sustainability situation and in the negotiation, the restrictions detract from the ability to detect points of conflict and spaces of consensus.

In a training process, some of these restrictions can be foreseen and act accordingly, but training towards sustainability is a complex situation and many of these restrictions are unpredictable, arise and are detected in the process itself. The role of metamodeling knowledge is promoting activities that goes beyond its "instructional" activities in students to influence the reduction of the effect of these restrictions. This quality of the metamodeling knowledge of emerge an activity of "support" in the students, is what places it as another mechanism of active learning. This "support" activity, in the particular case of collaborative modeling learning, guides the student's path toward becoming aware of their "instructional" activities and toward criticizing their own assumptions and those of others.

Metamodeling knowledge has a differential effect on the learning of collaborative modeling that depends on the moment in which it intervenes in such process, it does not guarantee defined degrees of learning, but it does increase the probability that students become more involved with their learning. and feeds back its "instructional" activity, thereby expanding its learning capacity. Acts directly or indirectly in the journey from the teaching slogan to the realization of the "instructional" activity, right where the learning constraints appear, aggravated in the collaborative modeling by the interactions that occur between the adults who participate. The metamodeling knowledge, in this case, offers the student means to access information that feeds his "instructional" activity, thus expanding its meaning and scope. It can be said that it takes the student backwards, now of his interpretation of teaching slogan, so that later he can advance more than the first time, thus establishing a circularity of a cybernetic nature.

In didactic terms, knowledge of metamodeling influences by reducing the limitations of adults to learn, since they have a frame of reference (Mezirow 1991), composed of a body of experiences, concepts, values, feelings and conditioned responses that define their structures of assumptions, which in turn selectively define and delimit expectations, perceptions, and ways of understanding new experiences (Cranton 1996). Metamodeling knowledge helps students to recognize their frames of reference and, from there, to redefine problems from a distinct perspective.

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