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Aquaponics as a didactic-methodological tool in the teaching of science and mathematics: experiences and teaching proposals in the amazonian context

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ABSTRACT

This article presents some reflections on the pedagogical use of aquaponic systems in science and mathematics teaching, based on theoretical analysis supported by the literature. The way in which this didactic-methodological proposal can engender learning environments conducive to reducing the distance between theory and practice and integrating scientific subjects with technology is discussed. Among the analyzed texts, two didactic experiences stand out, one of them developed by the second author, in his master's thesis (SOUZA, 2018), and the other that was advised by him was carried out in the context of a technical course conclusion project (SILVA *et al.*, 2018). The experiences described in these works involved students from the periphery and rural areas of the city of Itacoatiara, in the countryside of the state of Amazonas. The use of aquaponics in those experiments was justified not only by its potential to allow collaborative and investigative work, but also because it enabled the participants to cater for a social demand in the region: an alternative way of growing fish and vegetables, in a region where water is abundant but the soil is not very fertile. For this article, these experiences were not applied to a new group of students, but analyzed from a new approach, expanding the original perspective of these works for educational purposes: the first, described in the dissertation, was analyzed under the perspective of the possibilities and limitations of the educational use of aquaponics; and the second, discussed in the conclusion project, was analyzed considering the assumptions of mathematical modeling, being re-presented as a teaching proposal. The work concludes by arguing that the pedagogical use of aquaponic systems can contribute to science and mathematics teaching, with an empirical-concrete support in activities organized according to the assumptions of mathematical modeling, and with teaching situations open to questions of social relevance.

KEYWORDS: Aquaponics. Science and mathematics teaching. Mathematical modeling.

INTRODUCTION

Aquaponics is an agri-food production system that integrates hydroponics (growing plants without a substrate) and aquaculture (growing aquatic organisms). This system does not employ fertilizers or antibiotics. It uses water in a rational way to produce fish and vegetables, since nothing is wasted and this results in a sustainable food production system. The are many ways to use aquaponics, in this paper we investigate one of them, namely, its educational potential. Considering that aquaponics-based contexts enable the observation of concepts such as water recirculation, interactions between plants, fish and microorganisms, rational food production, nutrition, sustainability, etc., it gives us the opportunity to develop the didactic-pedagogical potential of this system in the teaching of sciences and mathematics in practice with students and teachers.

Depending on the school level, aquaponic systems might be used with different purposes such as incentivize nutrition and artistic language among young learners, or as an element favoring the integration of different school subjects in the sciences area with technology (GENELLO *et al*., 2015). For this reason, the use of aquaponics to teach sciences and mathematics might provide a consistent empirical-concrete support to activities organized following the principles of questioning, investigations, and cooperation. Therefore, it can be used as a potentially advantageous didactic-methodological tool employed to organize teaching aiming to favor learning.

In the Amazonian context, the use of aquaponics also has a justification of social relevance, since it caters for a regional demand by providing an alternative way of growing fish and vegetable, in a region where water abounds, but the soil is not very fertile. Moreover, from real and interesting problems for the learners, and taking into consideration their previous knowledge, an articulation between the construction and application of concepts can be promoted within and beyond the subjects.

Therefore, this study reports the results of a survey of the literature and proposes some reflections on the pedagogical use of aquaponic systems. We discuss how the use of these systems, mainly when allied to mathematical modelling as a teaching methodology might contribute to the teaching of sciences and mathematics, especially regarding its capability to favor the education of critical citizens, who are participative and aware of the role mathematics and sciences play in the world around them.

METHODOLOGY

Bibliographic research was carried out, since this type of methodology allows “researchers to cover a much broader variety of phenonema than that they coud research directly” (GIL, 2008, p.50). This characteristic makes the bibliographic research ideal for the purposes of this paper, since aquaponics, as a didactic-methodological element presents several facets, making it difficult to observe them all directly.

According to Lima and Mioto (2007, p.38), bibliographic research implies an “organized set of procedures seeking solutions, being attentive to the study object, which, therefore, cannot be random”. Thus, we initially selected and analyzed different scientific texts that reported psychological, historical-epistemological, and didactic discussions about aquaponics. Next, we compared the several perspectives found in these texts, looking for evidence of how the didactic use of aquaponic systems might offer contexts that favor the application, broadening and deepening of scientific and mathematical concepts, and, at the same time, promote the development of students' personal and sociocultural competences.

The two didactic experiences discussed in this paper are part of the dissertation "Aquaponics: a didactic tool in the initial education and continuous development of sciences teachers" (SOUZA, 2018) and the technical course conclusion project "Evaluation of the productive performance of three varieties of lettuce in aquaponic system" (SILVA *et al*., 2018). The dissertation original proposal focuses on the pedagogical use of aquaponic systems, seeking to improve the teaching and learning process in the context of the initial education and continuous development of sciences teachers. The original proposal of the course conclusion project aims to evaluate the productive performance of three varieties of lettuce, grown in aquaponics system, when compared to the convetional production method. The dissertation was written by the co-author of this paper, while the technical course conclusion project was advised by him.

It seems relevant to mention that for the purposes of this paper, the experiences described in both works listed above were not applied to a different group of students. In fact, the experiences were analyzed theoretically, based on the bibliographic research, aiming to put forward some reflections on the pedagogical use of aquaponic systems in the teaching of sciences and mathematics. Both experiences were analyzed with a new focus, broadening the initial perspective of the works to include educational purposes: the first experience, described in the dissertation, was analyzed according to the perspective of the possibilities and limitations of the aquaponics educational use; while the second experience, discussed in the course conclusion project, was analyzed based on mathematical modelling principles and presented again as a teaching sequence that related the pedagogical use of aquaponics with this mathematics teaching methodology.

AQUAPONICS AND THE TEACHING OF MATHEMATICS AND SCIENCES

Aquaponics is an agri-food production system that seeks to establish a relation between the acquatic organisms grown (usually fish), bacteria, and plants, in which the residual nutrients from fish growing are transformed by the nitrifying bacteria into products that are absorbed by the plants, favoring the development of these vegetables (EMERENCIANO *et al*., 2015).

The system presents some advantages in relation to conventional agroecosystems such as greater efficiency in water and area use; use of residues of other crops as source of nutrients; high yield; lower investment in inputs and workforce (SOARES *et al*., 2015; PAULUS *et al*., 2010); maintenance of proper environmental conditions to keep the fish growth all year long; possibility of obtaining several crops during the year, and intensive management ot obtain more homogeneous products (BRAZ FILHO, 2000). In general, aquaponics becomes a real alternative for food production with lower environmental impact due to its characteristic sustainability (HUNDLEY, 2013).

Among the several possibilities that the use of aquaponics might offer, this paper focuses on one of them, namely, its education potential. Since contexts based on aquaponics reveal to individuals in contact with them concepts such as water recirculation; interactions between plants, fish, and microorganisms; food rational production; nutrition; sustainability, etc., they also provide the opportunity to develop this system didactic-pedagogical potential in practice with students and teachers.

Moreover, aquaponics provides students with learning situations in which they can collect data, identify trends, and make correlations between physical, chemical and biological factors, in addition to carrying out simulations in a particularly controlled environment. This process results in better environmental awareness, development of applied skills, scientific knowledge, environmental knowledge, and valuation due to the effort needed to apply these concepts on the field (FREDERICK, 2005).

Williams and Dixon (2013) used gardening as an agricultural activity in schools. Those authors pointed out that this type of learning is aligned with two recent trends that have aroused public interest: health improvement increased awareness, particularly in children, and the growing perception that children should spend more time in contact with nature. Other studies reported that experimental learning through gardening presents a wide variety of impacts on students, including improved performance in sciences, mathematics, and arts, in addition to non-academic results such as increased preference for fruit and vegetables, personal development, cooperation, and environmental awareness (WILLIAMS; DIXON, 2013; PARMER *et al*., 2009).

Gardens or vegetable gardens might become a beneficial component to the educational environment, offering an excellent opportunity to teach nutrition and address other important areas and skills for life (GRAHAM *et al*., 2005). Those authors demonstrated that education programs based on enviroment have a beneficial impact on the performance of students in standardized tests, as well as on their attention and motivation to learn.

Frederick (2005) pointed out that aquaculture might provide learning environments able to connect students to their surroundings, and at the same time, result in an experience of “learning by doing”, upon exposure to processes, scientific concepts, and problem-solving techniques. For this reason, according to that author, it is fundamental to integrate education in sciences with environmental education, for all students, regardless of their specific interests.

In such context, aquaponics appears as a tool to teach natural sciences at all school levels, from elementary school to university, and also facilitates the integration of the community with other activities in the education institution (GENELLO *et al*., 2015; JUNGE *et al*., 2014). Depending on the school level, the system can be used with different purposes such as incentivize nutrition and artistic language in children’s education, or as an element that favors the integration of different scientific subjects with technology (GENELLO *et al*., 2015). In this perspective, Nelson (2007) discussed different examples of educators using aquaponic systems as teaching tools in STEM teaching, a learning context in which these systems become live laboratories for students' research projects or a venue for training and agricultural experience.

Mainly at the international level, the use of aquaponics in education seems to have been attracting teachers' attention. This becomes evident when we verify the number of schools in the USA that are using aquaponic systems, as well as the growing incidence of search on the internet for scientific papers and publications on the topic (HART *et al*., 2013). Those authors reported that this interest is based on the synergy between scientific education and the aquaponic system intrinsic nature, since the use of aquaponics incorporates the knowledge of a variety of topics, including agriculture, biology, engineering, nutrition, chemistry, and technology (GENELLO *et al*., 2015).

AQUAPONICS IN SCIENCES AND MATHEMATICS TEACHING: AN ALTERNATIVE TO TRADITIONAL TEACHING

The use of aquaponics as a didactic-methodological tool is inserted in a context of renovation in sciences and mathematics teaching. In this sense, it raises an underlying critique to the traditional teaching. We are not referring to a radical critique, since even the definition-example-exercise approach can favor some type of learning. Our critique might be synthesized in the following question: In terms of sciences and mathematics education, what do we lose with the traditional approach? This question might provike several answers. However, we would like to highlight one of them: the one that offers a social justification for the pegagocial use of aquaponic systems in the Amazonian context.

Let's consider mathematics. When this subject is taught using the traditional method, teachers are in the center of the education process, in which "they introduce the content orally using definitions and examples, followed by fixation exercises, and imagine that students have learnt through reproduction" (SANTOS; BISOGNIN, 2007, p.101). In such case, the teachers are knowledge transmitters in the sense that they provide their students with mathematical training. Mathematical training is destined to prepare the future mathematician or the professional that might work in math-related areas. This training focuses mainly on "doing mathematics", that is, theorems, demonstrations, formulas, algorithms, and mathematical investigation hypothetical-deductive procedures. To sum up, to the rigor, precision and generalization of mathematics. As a result, the math teacher, in the traditional teaching context, is in charge of communicating to the students the results achieved by researcher mathematicians (the historically constituted mathematical knowledge).

What is wrong about that? Nothing, when the teaching-learning situations are not limited to the work with these formalizations and generalizations. However, if the traditional approach is the only one used by the teacher, students lose a lot, since the results transmitted by the teacher hide the ways of thinking, feeling and acting of the researcher mathematician that enabled the knowledge production process. That is, teaching cannot be confused with knowledge transmission, since teaching is "creating possibilities for its (knowledge) production or its construction" (FREIRE, 2003, p. 47). It is mainly in this context that the use of alternative methodologies is justified, based on socially relevant issues and the principles of inquiry and investigation.

Certainly, when students are involved in activities as the ones described in this paper, they are inserted in a research environment that allows them to experience some of the steps followed by those that produce knowledge such as their countless reflections, unfruitful attempts, and path changes. When contemplating the phases of choice of a theme, preparation of research questions, data collection, problem solving activities, upon the creative construction of mathematical models and critical analysis of results, they experience situations full of pedagogical value, but which are not addressed by the traditional approach.

Therefore, this is not about seeing the students as future mathematicians, but rather using mathematics to respond to their individual expectations and prepare them to live in society. “The challenge is to teach the individuals useful and relevant mathematics without losing the mathematics specificities and structure” (CARVALHO, 1994, p.88).

The principle above, which is in the core of the mathematical education became a relevant factor that motivated the pedagogical use of aquaponics in the contexts described below. Firstly, there is a limited offer of vegetables in the region where the projects were developed, and those products are many times imported from other states (HOMMA *et al*., 2014). Secondly, the culture of consuming vegetables inexisted in the region up to the last decade. This fact resulted from production difficulties due to the hot and moist climate, which favors the incidence of plagues and diseases, and lack of qualified workforce to grow vegetables. Thirdly, the soil of that region is acid, poor in nutrients, presents relatively high amounts of aluminum and low cation exchange capability, making the production of these plants almost impossible without the use of chemical fertilizers and acidic soil correctives, which have to be imported from other regions of the country (FALESI, 1986; VIEIRA; SANTOS, 1987; RODRIGUES, 1996). All these factors make the production of vegetables using conventional methods difficult and expensive, preventing the population from consuming them due to their high prices in the local market. Thus, aquaponics is a way of building up in society an alternative form of cultivation, which is sustainable, simple and economically viable, therefore, promoting the incorporation of the vegetable consumption habit among those involved in the projects.

In addition, the North region, mainly in the location where the projects were developed, presents an estimated consumption of up to 500g fish per person per day, and the commercialization of 40% of the product of fishing in the river Solimões/Amazonas, and 60% of the fishing production is directed to subsistence (SANTOS, 2004). This fact makes the fishing production a relevant socioeconomic issue in the region, which reinforces the importance of an alternative form of production.

Fish farming, fishing and agriculture are well-known activities in the local community, and provide subsistence to many families that live on the river banks. Therefore, the pedagogical use of aquaponics in the Amazonian context creates the opportunity to offer students potentially significant learning environments, and raise their awareness of social, environmental, economic, political, and cultural issues.

To sum up, the observations presented in this section might be useful to clarify the social relevance of projects based on the educational use of aquaponics in the Amazonian context. Other issues might be raised; however, a sociocultural axis, beyond the school subjects, is required to unify the project. Such axis multiplies the chances of valuing students' previous knowledge and create conditions for the teacher to mediate learning, building up a bridge between the students' individual and sociocultural expectations and the object of knowledge.

TEACHING EXPERIENCE ANALYSIS 1: DISCUSSING POSSIBILITIES AND LIMITATIONS OF THE EDUCATIONAL USE OF AQUAPONICS

The experiment reported was carried out in Itacoatiara, a municipality in the interior of Amazonas, as part of a Master's project (SOUZA, 2018). The project implementation occured in one of the state schools in the municipality – the only education institution in the city that has students from the rural area. In that municipality, students from the rural zone, in general, live integrated to aquatic environments (lakes and rivers) in their social context. Their families usually make a living in agricultural and subsistence fishing activities. Those students come to school by bus, and the transportation is provided by the city hall.

The participants in the project were five female undergraduate students that were awarded scholarships from the Programa Institucional de Bolsas de Iniciação à Docência – PIBID (Teaching Initiation Scholarship Institutional Program) of the Federal University of Amazonas – UFAM. All of them were in the sciences teaching undergraduate courses (Biology and Chemistry). In this study, the participants are referred to as PIBID student 1, 2, 3, 4, and 5; UFAM professors; IFAM professor (Federal Institute of Amazonas - IFAM); state school biology teachers, and state school students.

The PIBID students were introduced to the project in a lecture with multimedia resources in a meeting where the project objectives, functioning, phases of implementation and system management were discussed. This initial contact was relevant for the familiarization of the future teachers with aquaponics, so that later on they could elaborate strategic action to use this teaching resource in the lessons they would teach in high school.

From this phase onwards, periodical meetings were held with the voluntary students to discuss topics related to aquaponics and its use as a didactic tool. Studies on the constructivist theory were deepened in the following two months. Another period of two months was needed to design the target plan to be developed throughout the year, contemplating the phases of implementation of the aquaponics project at the school. Later on, the preparation to execute the project started, and its starting point was the assembly of two aquaponic systems in the participating school.

The systems installed in the school were assembled on one weekend. The material was sponsored by the Carlos Chagas Foundation through the call "Gestão para Equidade: Elas nas Exatas" ("Management for Equality: Women in Exact Sciences"). The approved project aimed to incentivize women to follow careers in exact sciences. The assembly was carried out by the PIBID advisor professor, the PIBID students, and volunteer state school students, who were invited to take part in the project and improve their knowledge in the sciences area. After the invitation, nine state school students started to take part in the activities. Initially, the advisor researchers explained to the state school and PIBID students how the system would work and how it would be assembled. Next, the activities were developed up to the system assembly conclusion.

The aquaponic systems installed in the partner school had two water reservoirs, each one with a thousand-liter capacity for the production of aquatic organisms, 12 PVC tubes of 75 mm, which worked as gutter for vegetable production, and two 310-liter water reservoirs used as biological filters. On the filtering box and acrylic screen was placed to remove solic particles in suspension, and inside it, 50 liters of expanded clay for the fixation of nitrifying bacteria. Water pumping from the fish tank to the filtering system was carried using a submerse pump with 2.000-liter/hour flow. The water ran through the vegetable production gutters (PVC tubes), returned following the gravity to the fish production tank, and the cycle was completed (Figure 1).

Figure 1 – Assembled aquaponic system

Source: Souza (2018).

To start the system, each tank received 60 tambaqui (Colossoma macropomum) juveniles, due to the fact that this is a rustic regional fish (Figure 2), weighing around 100 grams each; 30 lettuce seedlings; and 6 jambu (Spilanthes acmella), seedlings. This plant is widely used in the regional cuisine.

Figure 2 – tambaqui juveniles at the end of the project

Source: Souza (2018).

After assembling the system, the PIBID students and the state school volunteer students attended a lecture about its functioning, so that they could plan their activities in parthership with the three teachers that taught biology in the state school. The lecture also aimed at teaching them to carry out the system daily maintenance, by feeding the fish, analyzing the water weekly, and monitoring the vegetable development.

The system maintenance, feeding the fish and the general management were mainly carried out by the state school students, since they were available to develop these activities daily before the start and after the end of their classes, before going home. The five PIBID students took part in the implementation of the aquaponic system at the school, and contributed to all the phases from the system layout to its assembly. During the observation period, the five PIBID students were monitored in the development of their activities. Meetings were held between the researcher in charge and the PIBID students to plan the actions and define how the action plants would be implemented.

PIBID students 1, 2, and 3, along with the school advisor teacher, planned the activities to be developed with the students in the second year of high school regarding the genetics content. In that class, the PIBID students introduced content related to the hybridization of production animals (fish and horses), describing the importance of and the main reason to use cross-breeding and hybridization when growing animals and in vegetable production.

The lesson was divided into two parts: initially, theoretical aspects were approached in the classroom, using multimedia resources and a poster with photos. In the second part of the lesson, the PIBID students took the state school students to the aquaponic system, where they explained in practice the functioning of the system and the possibility of using plants and hybrid animals to improve yield.

PIBID student 4 presented a theoretical-practical lesson to students in the third year of high school, and taught protein use and excretion. At that time, in the theoretical part, the PIBID student showed to the students the nitrogen function to live beings, and the different species' forms of excretion. In the practical lesson, she took the group to the aquaponic system, where they could observe the system and understand how the biological filter worked. Through the water analysis with a colorimetric kit, students could observe the ammonia and nitrite concentration in the water, and realize the nitrogen transformation carried out by nitrifying bacteria within the system.

After assembling the aquaponic system at the school and due to the growing familiarity of students and teachers with the new situation, as well as the sharing of knowledge between teachers (at both levels state school and university), new proposals for the pedagogical use of aquaponics appeared. As mentioned before, the main participants in the project were students in the sciences teaching undergraduate course (biology and chemistry). However, the initial project grew and became fruitful. Therefore, some developments were seen beyond the initial proposal: the PIBID professors along with professors of other subjects built up new proposals for the use the aquaponics in the classroom. Next, the professors' proposals for the use aquaponics in the classroom are described (SOUZA, 2018).

Biology:

- Initial proposal: 1) Comparing the structure and functioning of the different types of tissues, identifying and understanding their structure (1st year of high school); 2) Vegetable and animal embryology, live being reproduction, phases of embryonic annexes and gametogenesis (2nd year of high school).
- Developed proposal: A new proposal was presented due to the lack of time to prepare activities, lack of magnifiers and microscopes, and a lot of mandatory content to be presented throughout the school year. The new proposal focused on clarifying animal and vegetable hybridization. The lessons were taught to the groups in the 1st, 2nd, and 3rd years of high scholl, in partnership with the PIBID students. They produced the teaching material, which included a printed poster with several photos and presented to the students the main benefits of using hybridization in agriculture and animal husbandry.

Matemathics:

- Initial proposal: relating math to the aquaponic system using concepts of plane geometry, area calculation, perimeter of geometrical figures found in the system, calculation of the volume of the water reservoirs and filters (2nd and 3rd years of high school).
- Developed proposal: The initial proposal was not altered.

Physics:

- Initial proposal: 1) Observing heat exchange, temperature, and internal energy. Temperature measurements, thermometric scales, relation between scales, and arbitrary scales (2nd year of high school); 2) Concepts of thermal dilation, superficial area, optics, thrust, and electricity (3rd year of high school).
- Developed proposal: The initial proposal was not altered.

Chemistry:

- Initial proposal: 1) Nutrient cycle, function of nitrogen, phosphorous, and poatassium to vegetables, ways of producing ammonia and nitrite within the system (1st year of high school); 2) Concepts of soil buffer capacity, and pH variations throughout the days of use of the system (2nd year of high school); 3) Biomolecule, mainly protein and its byproducts excreted by fish (3rd year of high school).
- Developed proposal: the chemistry lessons were taught to students in the first year of high school around the aquaponic system. In that practical lesson, the teacher presented the system to the students and explained the functioning of the biological filter, the aquatic organisms' production tank, and the vegetable production gutters. Next, using a water analysis kit, the teacher demonstrated how pH and ammonia analysis were carried out using the colorimetric method, and explained to the students its importance and influence in the aquaponic system.

> The third year groups had their lessons divided into two parts, the first was theoretical, and they were exposed to content presenting the compounds derived from a protein molecule and the organic biomolecules. After this part, students were taken to the aquaponic system, where they could verify in practice the influence of the biological filter in the system, and carry out water analyses, reducing levels of nitrite and ammonia in the system water.

The collaborative potential of aquaponics was exemplified in the teaching experience described in this section. This (disciplinary) activity could be rethought in the context of interdisciplinarity. Let's imagine the interdisciplinary potential of concetps such as nutrition, sustainability, or food rational production. A Science Exhibition focusing on these themes would favor an interdisciplinary study able to involve all school subjects and years. The aquaponics investigative potential is observd when it allows students to select, organize, handle and interpret information. As mentioned before, aquaponic systems enable learning situations in which students can collect data, identify trends, establish correlations between physical, chemical and biological factors, and carry out simulations in a particularly controlled environment. The aquaponics potential to raise issues of social relevance has already been discussed previously.

In addition, one of the main obstacles to the pedagogical use of aquaponic systems in regular classes involves the fulfilment of the formal curriculum. In courses that have a program to be completed, aquaponics might be considered a slow process, which would not allow time for the completion of the whole program, or, seen from another standpoint, teachers' concern in teaching all contents of the program might not leave time for differentiated and integrative activities, which might prevent them from working with aquaponics. For this reason, awareness raising and dialogue for the construction of pedagogical proposals using aquaponics must be considered as fundamental ways of reaching the implementation of this proposal in schools.

TEACHING EXPERIENCE ANALYSIS 2: PRESENTING A MATHEMATICAL MODELLING PROPOSAL ALLIED TO AQUAPONICS

A table with data collected from an aquaponic system installed as part of a technical course conclusion project (SILVA *et al.*, 2018) is presented below. The project main objective was to evaluate the productive performance of three lettuce (Lactuca sativa) varieties. The experiment lasted 28 days, during which the following parameters were evaluated: plant height, number of leaves, root length, and plant mass. All three lettuce varieties were grown in the same conditions (see Table 1).

Tabe 1 – Results of the biometric data of the three varieties of lettuce (Mirella, Mimosa, and Mônica)

LETTUCE VARIETY	BIOMETRIC DATA	19/06 (2017)	26/06 (2017)	03/07 (2017)	10/07 (2017)	17/07 (2017)
MIRELLA	HEIGHT (cm)	16.1	21.3	28.1	29.4	45.9
	MASS (g)	21.1	31.6	39.6	59.7	95.5
	ROOT LENGTH (cm)	13	10.9	13.5	14.5	11.8
	Nº OF LEAVES	8.2	13.1	16.4	18.5	23.4
MIMOSA	HEIGHT (cm)	13.5	24.1	30.2	31.1	44
	MASS (g)	14.8	26.5	13.9	50.7	96
	ROOT LENGTH (cm)	12	10.1	13.9	15.4	16.2
	Nº OF LEAVES	7.7	11.7	14	16.3	20.1
MÔNICA	HEIGHT (cm)	12.1	24	30	31.2	39.9
	MASS (g)	14.5	18.4	19.9	31.4	58.5
	ROOT LENGTH (cm)	11.7	8.4	12.9	14.8	15.1
	Nº OF LEAVES	5.1	7.4	8.6	10	11.1

Source: Silva *et al*. (2018).

From this point onwards, we will use the results obtained in the technical course conclusion project to discuss a proposal to teach mathematics that relates the pedagogical use of aquaponics and mathematical modelling – even if this was not the initial proposal of the project. Our objective is to broaden the original proposal of that project with educational purposes.

Mathematical modelling is an applied mathematics research method used to solve concrete problems in several areas of knowledge. The solution of problems raised, as assumed in this method, involves the development of mathematical models that simulate the real systems being investigated. With the creation of a suitable mathematical representation of these systems, one can predict the behavior of phenomena, using essentially mathematical ideas and techniques. The resolution of the mathematical translation of the problem enables, with certain margin of error, the resolution of the real problem. As summarized by Bassanezi (2010, p. 16), “mathematical modelling consists in the art of transforming real problems into mathematical problems and solve them by interpreting their solutions in the real-world language”.

What is mainly at stake in this process is the validity of the mathematical model proposed as a solution to the problem. If it is not valid, data and hypotheses must be included or modified and the process repeated, generating a cyclic activity of analysis-reflection-construction.

As a process to describe, formulate, model and solve a problem-situation, mathematical model unites the mathematics accuracy, rigor and generalization to the investigative, creative and critical character of approaches based on concrete situations. For this reason, due to its constant appeal to an articulation between formalization and application, mathematical model is understood not only as a method or research process, but also as a methodological alternative for the construction of mathematical knowledge by learners.

As a teaching methodology, mathematical modelling is based on the principles of problematization and investigation (BARBOSA, 2001, 2004). Therefore, it privileges activities based on problems referring to the reality, in which students are invited to raise issues about a certain theme, and seek, select, and organize information that underlie the creative construction of mathematical models (the tools used to solve the problem proposed). This mathematical modelling "can be formulated in familiar terms, using numerical expressions or formulas, diagrams, graphs or geometrical representations, algebraic equations, tables, computer programs, etc." (BIEMBENGUT; HEIN, 2014, p.12).

The characteristics listed above show modelling as an open methodological proposal, in which there is space for adaptations based on the possibilities and limitations found in the school context. In this perspective, it makes sense to think mathematical modelling allied to the pedagogical use of aquaponic systems.

In the context of mathematical education, Burak (2004) pointed out five steps for the development of the mathematical modelling work, as follows: 1) choice of theme; 2) exploratory research; 3) problem survey; 4) problem solving and the development of the mathematics related to the theme; and 5) critical analysis of solutions. Therefore, the project that generated the data presented in Table 1 can be seen as a teaching proposal and scripted as follows, according to Burak's description (2004):

1. Choice of theme. Teachers can suggest, after presenting and assembling the aquaponic system with students, a study on how the three lettuce varieties develop, or different species of fish grow in the installed system, discussing pros and cons of this alternative production method in relation to conventional ones. Regarding the North region, this theme presentes strong socioeconomic relevance, since growing vegetables using conventional methods is difficult and expensive, which makes it impossible for the population, mainly those in the low-income group, to consume them.

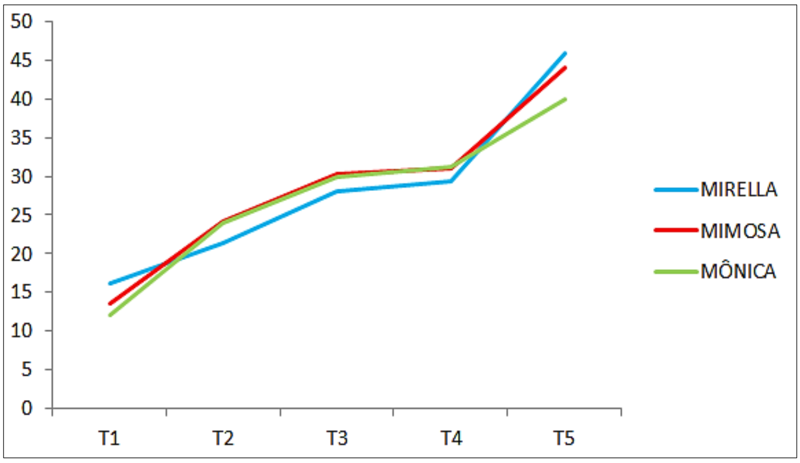
2. Exploratory research. After choosing the theme, students must be instructed to build up a theoretical background. The research must include a bibliographic study and field work, and cover other dimensions that are part of the investigated reality: sociocultural, economic, political dimensions, etc.

3. Problem survey. Information gathered in the exploratory research will support the formulation of problems. As for the previously mentioned project, the following problems could have been proposed: Which of the three varieties presented the best yield performance? Which of them presented the worst yield performance, and why? Is the technique used suitable for the three varieties investigated? Which factors might have influenced the performance of these varieties? It seems relevant to

emphasize that the problems proposed determine the contents to be worked.

4. Problem-solving and development of the mathematics related to the theme. In this phase, all the mathematical tools available are used to solve the problems proposed. Initially, empirical procedures can be used to achieve the first results and approximations and, next, develop analytically mathematical contents, and formalize them. In this phase, the construction of the mathematical models take place. During the problem-solving activities, learners might need mathematical concepts that they have not studied yet, therefore, the teacher must guide them to build up this knowledge. Table 1 and Figure 3, built based on the table data, are examples of mathematical models that might be used to solve the problems proposed.

Figure 3 – Plant height as a function of time



Source: The authors.

5. Critical analysis of solutions. This is the point where the mathematical model validation is at stake and is marked by criticality and reflection upon the results obtained. In this phase, learners justify procedures adopted, analyze, and discuss solutions found, that is, this is a moment when ideas are shared and socialization between groups occurs. This phase provides deepening of mathematical and non-mathematical concepts inherents in the theme, and the analysis of the logical consistence of the mathematical arguments used and their applicability to the situation under study. The main conclusions of that project were the following (SILVA *et al.*, 2018): Among the varieties evaluated, the Mirella lettuce was the one that presented the best results (see Figure 3) when compared to the other varieties, with a 95 g mean weight, while the Mônica lettuce presented the lowest development (see Table 1). Although both varieties received the same treatment, based on residue generated by fish, the Mimosa lettuce, according to parameters of the conventional system, did not show good performance due to etiolation, and its leaves presented the lowest mass, due to excess shade. However, in general, the lettuce grown using the aquaponic system presented the same mean weight as that of the vegetable produced using the

conventional system, that is, the technique is recommended for the three varieties.

FINAL CONSIDERATIONS

Although the resolution of standardized and artificial problems might provide learners with some mathematical and scientific training, this approach does not enable a critical understanding of the contents they are taught. This type of understanding can only be achieved in contexts that require going beyond the school subject. It requires that contents are inserted in a general reference framework, where they are seen in their fair proportion. For this reason, objects of knowledge must be contextualized, timely, and personalized, so that they acquire a historical, cultural, social, and political character, that is, acquire human substance. In this sense, working on problems based on the individuals' and society needs and interestes contributes to make sense of the contents they are studying.

The pedagogical use of aquaponics favors the establishment of more consistent relationships between formal content studied in the classroom, and the informal concepts applied in everyday life, and creates opportunities for the learner to build up a reflexive type of knowledge and to develop ways of thinking, acting, and feeling that are typical of those that produce knowledge. Therefore, aquaponics is inserted in a context of renovation of the sciences and mathematics teaching, since it seeks a process of methodological diversification, in an attempt to meet requirements of the individuals' real life in society.

Going back to the question raised before: In terms of sciences and mathematics education, what do we lose with the traditional approach? Answer: we miss the chance to educate reflexive citizens, who are committed and able to use their scientific and mathematical knowledge to make well founded judgements and necessary decisions. Such result cannot be achieved by the mere acritical accumulation of scientific and mathematical concepts and procedures.

A AQUAPONIA COMO FERRAMENTA DIDÁTICO-METODOLÓGICA NO ENSINO DE CIÊNCIAS E MATEMÁTICA: EXPERIÊNCIAS E PROPOSTAS DIDÁTICAS NO CONTEXTO AMAZONENSE

RESUMO

Neste artigo, apresentam-se algumas reflexões sobre o uso pedagógico de sistemas aquapônicos no ensino de ciências e matemática, fundamentadas em análise teórica com base bibliográfica. Discute-se o modo como essa proposta didático-metodológica pode engendrar ambientes de aprendizagem propícios a diminuir a distância entre teoria e prática e a integrar as disciplinas de caráter científico com a tecnologia. Dentre os textos analisados, destacam-se duas experiências didáticas, uma delas desenvolvida pelo segundo autor, em sua dissertação de mestrado (SOUZA, 2018), e a outra foi por ele orientada, realizada no contexto de um projeto de conclusão de curso técnico (SILVA *et al.*, 2018). As experiências descritas nesses trabalhos envolveram alunos da periferia e da zona rural da cidade de Itacoatiara, no interior do estado do Amazonas. Nelas, o uso da aquaponia justificou-se não só pelo seu potencial de permitir um trabalho colaborativo e investigativo, mas também porque possibilitou atender uma demanda social da região: uma forma alternativa de cultivo de peixes e hortaliças, em uma região onde há abundância de água e o solo é pouco fértil. Para os fins deste artigo, essas experiências não foram aplicadas a um novo público de alunos, mas, sim, analisadas a partir de novo enfoque, ampliando a perspectiva original desses trabalhos para fins educacionais: a primeira, descrita na dissertação, foi analisada segundo a perspectiva das possibilidades e limitações do uso educacional da aquaponia; e a segunda, discutida no projeto de conclusão, foi analisada à luz dos pressupostos da modelagem matemática, sendo reapresentada como proposta didática. Conclui-se o trabalho argumentando que o uso pedagógico de sistemas aquapônicos pode contribuir para o ensino de ciências e matemática com um suporte empírico-concreto em atividades organizadas segundo os pressupostos da modelagem matemática e com situações didáticas abertas a questões de relevância social.

PALAVRAS-CHAVE: Aquaponia. Ensino de Ciências e Matemática. Modelagem Matemática.

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