Original article

Problem solving in higher mathematics with an agroecological approach: a necessary professional practice

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ABSTRACT

The objective of this work is to offer a didactic strategy that contributes to the solution of mathematical-professional problems with an agroecological formative approach by Agronomy students. The diagnosis of the teaching-learning process of Mathematics, the review of the basic bibliography and study programs revealed an insufficient didactic-methodological systematization in the interrelation of the contents of the profession, the subject Mathematics and the agroecological contextual. The application of the didactic strategy favored the interest in the study of Mathematics, as well as the use of mathematical models and methods in the solution to the problems under study.

Keywords: Higher mathematics; Problem solving; Agroecology; Agricultural engineering.

Introduction

One of the main problems facing the world today is climate change, which affects all socioeconomic processes in society. In multiple international forums, the international community has spoken out to achieve concrete actions in favor of the care and protection of the environment.

For Cuba, which is also experiencing difficult times for its socioeconomic development, sustainable development is of vital importance, which is why the objectives for the achievement of this purpose have been promoted in the 2030 Agenda.

Higher Education in Cuba dedicates numerous material, financial and human resources to the conscious and participatory training of future graduates, in order to achieve their involvement in the construction of a sustainable future. Ministry of Higher Education, (MES, 2017).

In this direction, it agrees with (Fuentes, 2008), that the training process of professionals is fulfilled when cognitive capacities, spiritual capacities and creative capacities are developed, which allow them to become aware of the reality of the environment, and become agents of social transformation.

In the agronomist engineer, the above has incidence due to the fact that he/she is considered the most integral professional among those in charge of agricultural production, requires knowledge and application of scientific methods and technology in order to manage natural resources rationally and achieve the maximum yield of cultivated species or animals, obtaining productions with quality at the lowest possible cost (MES, 2017).

The Mathematics discipline is part of the curriculum of the Agronomy career, which aims at the treatment of mathematical information and decision making for the solution of agronomic problems, using mathematical and computational methods and procedures, as well as models that allow decision making in problems related to agronomy (MES, 2017).

Thus, the treatment of mathematical content in Agronomy students becomes especially important, starting from a process of understanding and obtaining new knowledge, which implies ensuring that students not only learn concrete elements of mathematical content, but also the connections established between them in a professional context, so that they can explain the content with their own words and use it in the solution of professional problems.

In this sense, it can be affirmed that problem solving is one of the most used methods to achieve active and creative learning; researchers such as (Rizo and Campistrous, 1999), refer to the generalizing procedure for problem solving, which constitute ways for the appropriation of skills, values and knowledge, preparing them to detect problems, reveal conflicts, seek solutions and apply them with cognitive independence.

For his part, (Chérrez, 2023) directs his research to mathematical problem solving in higher education, considering that this is the way to achieve the appropriation of knowledge and the development of skills from the contextualization and logical interpretation of mathematical content and its application in the solution of concrete problems of life and their future profession.

Despite the value of these contributions, it is considered that the particularities that distinguish the dynamics of the professional of the Agronomy career should be deepened through a coherent logic that makes it possible to reach higher levels in the systematization of the functionality of the mathematical content and its contextualized generalization in the environmental demands of the performance environment.

The above causes that in the teaching-learning process of Mathematics there are deficiencies in the application of heuristic strategies, methods and mathematical procedures necessary to solve problems related to the profession, low academic results in the subject and poor quality of the grades obtained by students, as well as insufficient interest in the study of Mathematics, not perceiving its applicability in the solution of professional problems.

According to what has been stated, the problem to be solved is: how to contribute to the formation of the Agronomy student to face the solution of mathematical-professional problems?

Development

For the development of this work, a sample of 25 first year Agronomy students was selected, out of a population of 54.

The study and analysis of the normative documents of the career such as the Study Plan, the Strategic Planning of the country related to food production linked to the territory and the diagnosis of the students' learning towards problem solving were carried out.

Problem solving in the teaching of mathematics enables the acquisition of knowledge with a higher level of solidity, depth, transferability and generalizability in a flexible and independent manner (Suarez and Meléndez, 2023), which is undoubtedly the key to

achieve comprehensive learning in students, so as to enable the future graduate to enhance the perception of risk in the exercise of their profession and in the interaction with society.

Then, the problem-solving methods encourage students, guided by the teacher, to enter into the process of searching for solutions to problems that are new to them, thanks to which they learn to acquire knowledge independently, to use the previously assimilated knowledge and to master the experience of creative activity.

Solution procedures in science education can be classified into two main classes: algorithmic and heuristic (Ballester *et al.,* 2018). This same author pronounces about heuristic procedures by identifying them as actions that support the conscious performance of complex and demanding mental activities. They favor the assimilation of knowledge, their ability to solve problems for which they do not know algorithmic procedures, as well as the development of creative thinking. These can be divided into principles, rules and strategies, which can be general and special.

In the treatment of mathematical contents in Agronomy, the study of typical situations of Mathematics, as well as in the solution of problems are used:

- Principles: analogy, modeling, reduction principle, modeling, generalization and consideration of special cases and limit cases.
- Heuristic rules: which have the character of impulses in the process of analyzing the problem and finding the solution path.
- General rules: separating what is given from what is sought, remembering knowledge related to what is given and what is sought, and looking for relationships between them.
- Heuristic strategies: those that constitute the main procedures to search for the concrete means needed to solve a professional mathematical problem and to search for the solution way, they are: working forward or combination of strategies.

The authors of this work consider that the particularities that distinguish the dynamics of the professional in the agronomy career should be deepened through a coherent logic that makes it possible to reach higher levels in the systematization of the functionality of the mathematical content and its contextualized generalization, being this one of the reasons why difficulties continue to manifest with the resolution of professional mathematical problems in the Agronomy career.

In this sense, the mathematical subject in the study plan of the Agronomy degree encloses an abstract but also practical perspective, therefore it has defined as a task: the treatment of mathematical information related to the functions of the agronomist engineer in the agricultural processes and with the decision making for the solution of the problems that arise in them, using mathematical and computational methods, as well as models that allow evaluating the feasibility or tendency of certain alternatives (MES, 2017).

To achieve such purpose, it should be taken into account that the professional problems in Agricultural Engineering, are focused on the need to generate food and raw materials for the satisfaction of human and industrial needs demanded by society, ensuring the conservation of natural resources available to it and the sustainability of agricultural production systems. (MES, 2017)

Although the problematic method is weighted for such future professionals, it is still insufficient its vision from the integration with a sustainable ecological vision of the formative processes of the future agricultural engineer.

In this sense, professional problems should be connected with mathematical knowledge to transform social needs. This perspective manages to awaken in students the interest for the unknown, the appropriation of the content turning them into a constant need and motivation, from the valuation of professional information, supported by the application of mathematical procedures, which according to (Fonseca, 2023), should become an important tool for their future profession.

The professionalization of the content is a way to solve this limitation, so it is important to take into account what is expressed by Castillo (2001) when defining it as: the process in which the initial training favors the interrelation: theory-practice-communication-motivation of the student, interesting him in his future professional performance, from the solution of tasks that are identified with the most common problems of the exercise of his profession and his social task.

In the case under investigation, in Agronomy professionals, environmental education with a tendency towards agroecology is important, this being the one that recognizes production systems as agroecosystems and, therefore, their sustainable management (MES, 2017); as well as achieving efficient management in the processes that are developed in agricultural production systems contributing to the development of

sustainable agriculture on agroecological bases, which integrate agroenergetic sustainability and food security.

From the professional's model, the need to relate Mathematics with the profession and environmental education is evident when it is stated: it is necessary to propitiate, from the disciplines of the career, the development of new approaches that involve the sustainable management of agricultural production systems, the use of technologies that are adapted to local characteristics and respect for the environment (MES, 2017).

An important process within environmental training is the development of environmental sensitivity; it is a guarantee of the transformation of reality and sustainability as a professional goal, which is notorious for the student of the Agronomy career.

In this regard (Rodriguez *et al.*, 2023), emphasizes the importance of building knowledge about agricultural practices with an ecological approach by identifying the main difficulties and future limitations related to productive, economic and social activity in the community, which encourages students' interest in learning, improves their preparation and enriches their professional skills, although they lack a coherent logic in the reconstruction of such knowledge from the mathematical content, which makes it possible to take knowledge, previous skills and learning strategies to the conditions inherent in new contexts, from an agroecological vision.

It is, therefore, that the student, in his training, has to solve professional problems in which he achieves the apprehension of the mathematical content related to the situations that occur in production agroecosystems.

In this sense, (Leyva and Machado, 2023), define agroecological mathematical problematization as a process that expresses the contradiction between the known and the unknown, it is also an active, dynamic search, inquiry of ways of solution to problematic situations posed by the teacher, which enables the construction of mathematical knowledge in students from the interrelation of previous knowledge and skills, professional content and training needs in agroecological contexts, facilitating the functional understanding of such content.

The particularity of the agroecological mathematical problematization is to show problematic situations in which interdisciplinary contents are integrated, for which a concrete algorithm is required for its solution and questions that allow arriving at conclusions through prediction and decision making.

According to the above, the teacher must pose professional mathematical problems with various levels of complexity and variability in which they model common and frequent situations and conflicts of their future profession, which from different didactic perspectives achieve, in students, a greater cognitive activity, to facilitate their motivation for the mathematical content.

To this end, a didactic strategy is proposed, which is conceived as a system of actions that allows, from the contents of Mathematics, to link to the different professional scenarios, with emphasis on agroecological sustainability, aimed at solving professional problems, which make it possible to efficiently manage the processes that are developed in agricultural production systems.

For the elaboration of the proposed strategy, Study Plan E was taken into account, which allowed articulating mathematical and professional-agroecological contents to achieve professional mathematical transfer.

The strategy aims at structuring the treatment of mathematical contents in Agronomy careers, for the solution of mathematical-professional problems; it has three moments:

1st moment. Assessment of mathematical content with professional-agroecological orientation.

2nd moment. Systematization of the mathematical content with professional-agroecological orientation.

3rd moment. Evaluation of the mathematical content with professional-agroecological orientation.

Strategy actions.

1. Identify in the Study Plan, the interdisciplinary relationship between the mathematical contents and those of the specialty (Articulation Matrix).
2. To guide field activities related to the search for information about agroecological techniques aimed at the sustainability of natural resources.
3. Conducting workshops for the elaboration of professionalized mathematical problems based on the information provided by the students using heuristic procedures and audiovisual resources.
4. Search and discussion of the solution path of the professionalized mathematical problem.

5. Interpretation of the result aimed at decision making and prediction taking into account the risks and benefits in professional scenarios.

Exemplification.

Once the interdisciplinary relationship was identified, the extra-mathematical activities were oriented to future professional scenarios, such as organoponics, farms and CPA, so that they could investigate the main characteristics and application of agroecological techniques. The students investigated the most widely used irrigation techniques to contribute to water and energy savings, among which localized sprinkler irrigation, with spherical nozzles, stands out.

The problem presented below, with an agroecological approach, is the result of a workshop conducted with the students after completing the topic of differential equations and their applications and after having systematized this content.

In an extensive area cultivated with corn, sprinkler irrigation is applied in which spherical nozzles are used (see figure 1) with a large number of equal holes through which the water comes out at speed 0.2m/s, describing a parabolic movement that falls on the ground, so that it can be used to the maximum by the plants. It is known that the horizontal range of irrigation is expressed by the differential equation $\frac{\Delta S}{\Delta \alpha} = \frac{4\pi {V_0}^2}{g^2} sen4\alpha$; if initially the jet comes out at a speed of 0.2m/s, with an angle of 0.5m, and due to the soil conditions the nozzle is regulated with an angle of , what will be the horizontal range of irrigation?

Figure 1: Spray irrigation nozzle

Source: Taken from Google

For the solution pathway search the teacher asks prompting questions related to identifying the type of differential equation and its solution procedure.

For their part the students are able to identify the equation and the solution path.

$$\frac{\Delta S}{\Delta \alpha} = \frac{4\pi {V_0}^2}{g^2} sen4\alpha$$

Solving the separable variable ODE is obtained:

$\frac{g^2}{4\pi {V_0}^2} ds = sen4\alpha d\alpha$ By integrating both members

$$\frac{g^2}{4\pi {V_0}^2} s = \frac{1}{4} cos4\alpha + C$$

General solution of the differential equation

$$s(\alpha) = \frac{4\pi {V_0}^2}{4g^2} cos4\alpha + C$$

From this point on, the teacher, taking into account the conditions given in the problem, induces the students to look for the value of the different parameters.

The students manage to identify the parameters and substitute them in the general solution.

$$\boldsymbol{s(\alpha) = \frac{\pi {V_0}^2}{g^2} cos4\alpha + C}$$

$$s(\alpha) = \frac{3{,}14 * 0{,}2^2}{10^2} cos60^o + C$$

$$s(\alpha) = 0{,}001 * \frac{1}{2} + C$$

$$s(\alpha) = 0{,}001 * \frac{1}{2} + C$$

$$0{,}5m = 0{,}0006m + C$$

$$C = 0{,}50$$

$$\boldsymbol{s(\alpha) = 0{,}001 cos4 \propto + 0.50}$$

Once the parameters have been calculated, the students proceed to calculate the horizontal range with an angle of.

$$s(\alpha) = 0{,}001 cos90^o + 0.50$$

$s(\alpha) = 0{,}501m$, Its graph dilates with respect to the x-axis until it represents a radius of 0.901m

Answer. By adjusting the nozzle at an angle of $22.^{5o}$, a distance of 0.501m is achieved.

Based on the results obtained, students will reflect on the decision that can be made by regulating the nozzles, this being a versatile and flexible method that can be adapted to the type of crop and soil conditions, highlighting that this sustainable use of water can save between 50% and 70%, thus enhancing sustainable agriculture.

Conclusions

The students show a high level of interest and motivation for their specialty, to investigate and deepen their knowledge on how to contribute to achieve agroecological-sustainable food production.

The work provided methodological guidance to mathematics teachers on the agroecological contextualization of mathematical contents.

The strategy offers theoretical-methodological knowledge to teachers to integrate, in a harmonious way, mathematical contents to professional problems and their systematic use in professional scenarios with an agroecological formative perspective.

The use by teachers of the potential of the subject content and modern technology favors the solution of professional problems aimed at the sustainable management of agricultural production systems.