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Project-Based Learning in Teaching the Safe Management of Pesticides in aRural Community

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Abstract

Project-based learning (PBL) is a teaching method that has proven effective in stimulating student learning through meaningful experiences that focus on solving problems, many of which are part of the learners' everyday lives. Therefore, this research aimed to use PBL as a pedagogical tool to identify environmental problems caused by the inefficient use of pesticides in agricultural communities by implementing and developing a school research project in natural sciences. To achieve the objective, we use a direct sample of 80 students (66.3% girls) aged between 15 and 17 with an average age of 16.1 (SD = 70), and an indirect sample of 338 agricultural workers (57.20% men) aged between 17 and 61, with an average age of 26.9 (SD = 11.12). Our results showed that the PBL is an adequate tool to teach content situated in the population's needs and be adequate to educate rural populations informally. This pedagogical strategy can improve the environmental awareness of the students through their participation in the community. Educational and socio-community implications are discussed.

Keywords: Project-based learning, pesticides, environmental awareness, , rural community.

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Aprendizaje Basado en Proyectos en la Enseñanza del Manejo Seguro de Plaguicidas en una Comunidad Rural

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Resumen

El aprendizaje basado en proyectos (ABP) es un método de enseñanza que ha demostrado su eficacia para estimular el aprendizaje de los alumnos a través de experiencias significativas que se centran en la resolución de problemas, muchos de los cuales forman parte de la vida diaria de los alumnos. Por lo tanto, el objetivo de esta investigación fue utilizar el ABP como herramienta pedagógica para identificar problemas ambientales causados por el uso ineficiente de plaguicidas en comunidades agrícolas mediante la implementación y desarrollo de un proyecto de investigación escolar en ciencias naturales. Para lograr el objetivo, utilizamos una muestra directa de 80 estudiantes (66,3% chicas), con edades comprendidas entre los 15 y los 17 años con una edad promedio de 16,1 (D.T= 70), y una muestra indirecta de 338 agricultores/as (57,20% hombres), con edades entre 17 y 61 años, con una media de edad de 26,9 (D.T=11,12). Nuestros resultados mostraron que el ABP es una herramienta adecuada para enseñar contenidos situados en las necesidades de la población, además, ser resultó adecuada para la formación informal en poblaciones rurales dedicadas a la agricultura. Se discuten las implicaciones educativas y socio-comunitarias.

Palabras clave: Aprendizaje basado en proyectos, plaguicidas, conciencia medioambiental, comunidad rural.

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Chemical pesticides were initially developed in the mid-1930s and 1940s for use as chemical weapons that were preliminarily tested on insects. These products have been classified from mildly to extremely toxic and are currently used to control different types of organisms (classified as pests) (Costa et al., 2008). In addition, they facilitate activities that have an impact on public health, such as agriculture and livestock production, because they reduce the transmission of disease and optimize mass production (de Albuquerque et al., 2018). However, one important characteristic of these substances is that they have a broad spectrum of action, which can inhibit or alter the reproduction of a wide range of living organisms, affecting the food chains of ecosystems. These products are currently being synthesized and marketed worldwide, despite their undesirable and harmful effects on different forms of life (Choudri et al., 2018).

At the beginning of the 21st century, the US Environmental Protection Agency (EPA) registered 620 active ingredients, many of them organic that can be mixed with excipients and diluents to form the different commercial presentations of pesticides. However, many of these compounds or additives can be more toxic than the active ingredients of the pesticide itself (United Nations, 2017; Varona et al., 2016). These chemical compounds are a major public health problem, as they are associated with pathologies such as cancer, chronic respiratory symptoms, and hormonal and reproductive problems, among other disorders (de Albuquerque et. al., 2018).

Therefore, pesticides are potentially hazardous to both farmers and their families since improper handling and prolonged exposure to the chemicals that comprise them pose a high risk to humans and animals (Wilbur, 2011). Even when direct contact does not occur, individuals can be exposed to pesticides in different ways during their lifetimes. Among the rural inhabitants of agricultural communities, children are the most vulnerable group due to organic and metabolic factors.

In the case of Colombia, the highest incidence of exposure to pesticides occurs in rural areas, which in 2014 corresponded to 99.6% of the 114 million hectares that make up the country (Instituto Geográfico Agustín Codazzi, 2019). For that reason, we chose the municipality of Guadalupe - Huila (Colombia) as the work area for this study, as its territorial zoning in terms of its environmental and agricultural components classifies it as clearly rural (Agreement 05 de 2016, 2016). The general characteristics of the municipality is associated with the use of pesticides, which has led to environmental problems due to the inappropriate management of these types of substances, and a negative impact in the agricultural zones of these impoverished communities.

One of the most effective processes for tackling this problem is through education. However, most people involved in agricultural activities in these regions do not have access to education and information on the correct use of pesticides and the consequences of misuse. Nevertheless, high school students in these municipalities have direct or indirect access to a large part of the population. For this reason, pedagogical activities with a social impact are an excellent tool for knowledge acquisition, because they allow students to increase their knowledge and environmental awareness from an early age (Hassan et al., 2010). To that effect, different pedagogical strategies can be applied to address the range of teaching and learning contexts. Among the most significant are problem-based learning, collaborative learning, self-management or self-learning, and discovery teaching and project-based learning (Farahwahidah et al., 2019; Feo, 2010).

Project-based learning (PBL) is an active form of student-centered instruction. This pedagogical tool is characterized by a number of distinct factors: a) it promotes student autonomy, b) it requires constructive inquiry, c) it depends on the establishment of real or near social goals, d) it requires collaboration among students, and e) it promotes communication and reflection about real-world practices (Kokotsaki et. al, 2016). Different approaches and characteristics have been tried in the implementation of PBL in the classroom. However, there is a consensus in the literature on the seven common phases in all the various configurations: I) 'setting the stage' by introducing information to anchor the activity; II) establishing a task or guiding question; III) defining a process or research plan; IV) establishing resources, such as books, digital databases, newspaper archives, etc. V) establishing a scaffolding process, e.g. group tutorials, individual tutorials, expert talks, pre-assessments and progress templates; VI) promoting collaborative activities, including student teams, peer reviews and external content specialists; and finally, VII) providing opportunities for reflection and transfer, such as classroom briefings, school journal entries, outreach activities and the communication of results (Grant, 2002).

The use of PBL in the classroom has demonstrated a range of different benefits for students. For example, a study in 2014 (Pinho-Lopes & Macedo, 2014) found a relationship between the application of PBL and better academic performance, lower dropout rates, and improved problem-solving abilities. In the same study, the authors surveyed students after completing the course and the vast majority considered the assessment methods to be adequate for the defined objectives. Along the same lines, as stated in (Zhou et al., 2013) the combination of information and communication technologies (ICT) with PBL as an alternative tool for knowledge construction in learners. The authors conclude that ICTs make an important contribution to supporting the PBL model because they promote the connection to communities, networks, and resources that are in the best interest of the learners. However, this combination must be applied with special care and must be adapted to the socio-cultural context of the school, because methods and styles of teaching and learning may vary from country to country, or even between regions, as does access to some ICTs. Similar results were reported in Ref. (Sakulviriyakitkul et al., 2020), who designed a learning process to promote teamwork using PBL and the concept of agile software development, finding that as these processes were integrated, students demonstrated higher levels of attention, motivation and interest in exchanging ideas and information. Similarly, in 2017 (Chatwattana & Nilsook, 2017) reported the creation of a web system to improve the student learning process through the combination of project-based learning and imagination, which promoted cooperation among students through the pursuit of innovation. All these studies show that student-centered learning strategies are a useful tool in pedagogical processes and are more effective than more teacher-centered approaches (Radzali et al., 2018).

For this reason, the present study employed a pedagogical strategy that made use of didactic tools and methods oriented towards meaningful learning (Ayala-Valenzuela & Beate Messing-Grube, 2011). In this case, the problem was diagnosed, and knowledge consolidated within the teaching processes of the natural sciences. Thus, the objective of this work was to use PBL as a pedagogical tool to identify environmental problems caused by the inadequate use of pesticides in the agricultural communities of the municipality of Guadalupe - Huila through the implementation and development of a school research project in natural sciences as part of the Ondas program of the Colombian Ministerio de Ciencia, Tecnología e Innovación (MinCiencias).

The results of the study can be used to support research on food webs, and to observe the ecological interactions of highly transformed ecosystems and compare them with forest relics immersed in the agricultural landscape. This is especially significant given that the department of Huila is home to a substantial ecoregion, with different and exuberant floristic diversity (Reyes et al., 2014), which may harbour species not yet reported in the sciences.

Materials and Methods

Participants

The sample consisted of two groups: (A) a direct sample and (B) an indirect sample. The characteristics of each are described below.

Sample A:

Sample A comprised 80 students (66.3% women) aged between 15 and 17 with an average age of 16.1 (SD = 70). The participants were students in the last two years of secondary education at Institución Educativa Nuestra Señora del Carmen, school located in the rural area of the municipality of Guadalupe in the department of Huila (Colombia).

Sample B:
The participants in sample A surveyed the people in sample B, which was made up of 338 people (57.20% men), aged between 17 and 61, with an average age of 26.9 (SD = 11.12). These people are agricultural workers from farms throughout the region.

The rural area where the study was conducted is located in the mountainous area of the northeaster sector of the municipality (Figure 1).

Procedure

PBL was used in the subjects of chemistry and biology in the area of education and environment. The approach was based on the observations of the teachers in the area of natural sciences and on information from the students, who detected an environmental problem stemming from inadequate practices in the handling of pesticides, likely resulting from a lack of knowledge of the harmful effects of these chemicals. The project began with a classroom debate on environmental problems in the municipality in which students identified the situations that cause the greatest environmental impact on rural ecosystems. Then, data was collected through surveys developed with the assistance of the Instituto de Estudios Ambientales (IDEASA) at Universidad Sergio Arboleda in the agricultural communities with the largest rural populations in the municipality. The project was implemented in four stages during the 2017 school year.

Stage 1: The students observed their surroundings for two weeks and identified the environmental problems in their community. They then brainstormed ideas to share perceptions and decided on the most relevant findings to be studied, to decide the problems to be studied; the spokespersons briefings assembly methodology was used.

Stage 2: Once the social problem to be studied had been identified, students searched for bibliographic references using the Google search engine and discussed the background and theoretical concepts in the classroom. Based on that information, the students decided that they should survey the community about their perceptions, beliefs, and knowledge of pesticide use.

To this end, surveys were conducted to collect information, and students were organized into groups of three and distributed by hometown to make the survey process and data collection easier under the criteria of suitability and practicality. Finally, with the support of the research team, the surveys were tabulated, and the information needs of the community were identified.

Stage 3: Using the results of the survey and additional internet queries, pedagogical sessions were held in the classroom to review and analyze the information obtained in order to better understand the data yielded by the surveys. Educational sheets and posters were then created specifying the adequate handling of pesticides and their effects on the environment.

Stage 4: Fun and engaging teaching days were held in the educational and rural community aimed at the students of the school and families working in agriculture. The results of the project were shared, and activities were organized to raise awareness about the importance of bio-controllers in ecosystems and agro-ecosystems. The students showed and explained the objectives and results of the pedagogical-research activity.

*Figure 1.*Northeastern sector of the municipality of Guadalupe with agricultural-type landscape matrices and abundant watercourses

Results

The results obtained in the different stages are described below.

Stage 1: Contamination of water bodies with residues of pesticides used in agriculture (Fig. 2) and their effects on health were identified as the most relevant findings for this research. The students indicated that they have observed and experienced the negative health effects of some agricultural insecticides, as well as the inadequate handling of empty containers.

Figure 2: Streams polluted with sewage, plastic waste, and pesticide packaging.

Stage 2: Once the information from the literature had been assimilated, 338 of the 2,815 inhabitants of the villages in the northeast sector of the municipality were surveyed, corresponding to 12% of the total population, with a 95% confidence interval. The information collected in the surveys is summarized in the bar charts (Fig. 3 to 5) and tables presented below.

From the surveys, a table was initially drawn up with the pesticides used by the agricultural community, classified into six families of chemical compounds, which included frequency of use and class (Table 1), as well as detailed information on each pesticide (not shown).

Table 1
Frequency of pesticides (commercial names) used by farmers and their classification in groups.

N°	Commercial names	Frequency	Compound families	Denomination
1	Lorsban 4 Ec	127	Organophosphorus compounds	Insecticide
2	Roundup	76		Herbicide
3	Cuspide 480 Sl	52		Herbicide
4	Glifolaq 480 Sl	52		Herbicide
5	Estelar 480	49		Herbicide
6	Neguvon	16		Insecticide
7	Fentopen	5		Insecticide
8	Monocrotofos	3		Insecticide
9	Glifosato	2		Herbicide
10	Nuvacron	2		Insecticide
11	Tamaron	2		Insecticide
12	Monitor	1		Insecticide
13	Rafagá 4ec	1		Insecticide
14	Sistemin 40 Ec	1		Insecticide
15	Alto 100	109	Triazines and triazoles	Fungicide
16	Atrazina	26		Herbicide
17	Propital 25 Ec	3		Fungicide
19	Furadan	47	Carbamates and dithiocarbamates	Insecticide
20	Manzate	19		Fungicide
21	Ridomil	9		Fungicide
22	Dithane M 45	4		Fungicide
24	Strike	36	Organochlorine compounds	Fungucide
25	Thiodan (Endosulfan)	19		Insecticide
26	Raid	1		Insecticide
28	Dicloruro (Paraquat)	6	Quaternary ammonium salts	Herbicide
29	Cerrero 200 Sl	1		Herbicide
32	Atta-Kill	13	Other	Insecticide
33	Verdadero	6		Fungi-Insecticide
34	Raticida Campeon	2		Rodenticide
35	Azuco	2		Fungicide
36	Tordon	1		Herbicide

The percentages of each group of pesticides most often used by the farmers and their levels of toxicity (Fig. 3). These results fostered the development of learning processes among the students, demonstrating knowledge that allowed them produce, build, and discuss thoughts and ideas based on situations they have experienced in their rural environments.

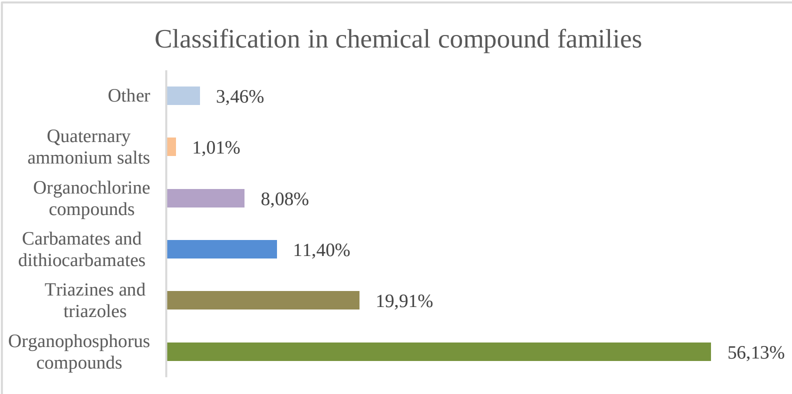

Figure 3. Classification of pesticides by chemical compound families.

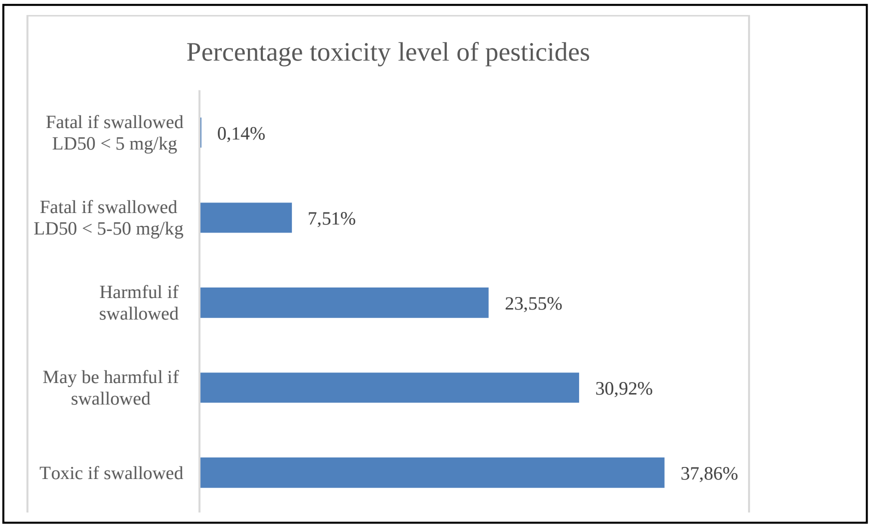

Figure 4. Percentages of the toxicity level of the most used pesticides according to GHS classifications.

The gender of the individuals who work in the agriculture sector was also documented through the surveys. Men accounted for the highest percentage of the farmers, with 57.2% being male and 23% female. Minors also participate in agricultural work: 15.1% of the boys and 4.6% of the girls in farm work were minors. In addition, most of the individuals surveyed declared that they started their work as a farmer before the age of 10 (46%), 38% started in adolescence and the remaining 16% began in adulthood. Of the most common pathologies caused by exposure to pesticides, 72% of the farmers reported the sensation of pain in different parts of the body, of which 40% associated that pain with headache, 25% with body pain, 6% with a stomachache and 1% with chest pain. Less frequent pathologies were also found, such as dizziness and nausea in 10% of the respondents, outbreaks and itching of the skin in 6%, other conditions such as burning eyes in 5% of the respondents, vomiting in 3%, and other symptoms were described by 11% of the people surveyed. All these conditions were described by the respondents as conditions triggered after working in spraying operations or among crops sprayed with pesticides. In addition, the surveys confirmed the inadequate waste management of empty pesticide packaging and containers, which end up dumped in inappropriate sites. The lack of environmental awareness in the management of this waste was observed in most farmers, who throw them into the fields or into nearby bodies of water. Of the people surveyed, 43% indicated poor management of empty containers, followed by 31.1% who recycle, 24.7% who burn these containers, and the remaining 1.3% who bury them.

Stage 3: Fun and engaging educational activities were organized in the classroom to encourage the understanding and analysis of information obtained in the field. Explanatory data sheets were developed containing detailed information on each pesticide, such as chemical structures, functional groups, formulation, application, active ingredients and additives, adverse effects on human health and on the ecosystem in general, and the toxicity of the compound and its ingredients.

Stage 4: The results of the project were shared among the entire educational community, with students presenting exhibitions, informative brochures, and educational posters (Figure 5). The leaflets produced by the students had educational and awareness objectives about the conscious use of pesticides and their environmental impact on the environment. In order for the project to have a greater impact, ecological squads were organized, where researchers visited the houses and rural families living around the school and discussed the importance of safely using pesticides and looking for ecological alternatives that would mitigate their negative impact. They displayed posters and gave talks about the different bio-controllers that are currently known for agricultural ecosystems, and also presented the important role of birds, amphibians, native plants and some fungi and insects in the area that might act as possible bio-controllers for pests.

Figure 5. Educational days for the community on the importance of bio-controllers in agricultural ecosystems.

Discussion

The students first sought to understand the context of the problem in which their rural community is immersed due to inadequate pesticide management. The bibliographic review in Google, which included safety data sheets, environmental regulations and toxicity studies of exposure to these chemical compounds, led to the classification of the data obtained from the surveys, allowing students to discover that farmers in their regions mainly have high exposure to organophosphate compounds (56.1%). These pesticides are associated with neurotoxic effects because they inhibit acetyl cholinesterase catalytic activity (Hernández et al., 2017) leading to clinical effects such as muscarinic, nicotinic and neurological syndromes which culminate in death by respiratory failure (Jaramillo-Colorado et al., 2015; Varona et al., 2007, 2009).

In addition, prolonged exposure to herbicides such as glyphosate leads to pathologies such as diarrhoea, salivation, eye, skin and nose irritation (Salcedo et al., 2012; Varona et al., 2016). Also, several studies have documented the carcinogenic effects of this chemical, as well as the genetic, respiratory, reproductive, and neurological damage it can cause, among other disorders (Guyton et al., 2015). As a result, in 2015, Colombia suspended its use in the control of illicit crops (Apreciación reporte IARe clasificación herbicida glifosato, 2015). Nevertheless, the evidence of harm from glyphosate is still disputed, although the International Agency for Research on Cancer (IARC) has added it to the list of substances likely to be carcinogenic to humans (Guyton et al., 2015).

Another concern of the students at the start of the project was the contamination of water sources by pesticide residues found in atrazine, a causative herbicide with adverse and potentially serious effects on human and animal health, which was banned by the European Union in August 2005 (Stara et al., 2018). Its toxicity is related to the decrease in the population of ammonifying bacteria, nitrosomonas, nitrobacter and algae in soils where it is used; microorganisms mainly needed in the carbon and nitrogen cycles (Lagos et al., 2005). This pesticide belongs to the triazines and triazole group in our classification and was found to be used by 19.9% of the population surveyed.

Similarly, Furadan warns consumers not to use the product near water sources because of its high capacity for contamination, as it is extremely toxic to fish (Costa et al., 2008; Hernández et al., 2017). This is an insecticide belonging to the group of carbamates and dithiocarbamates, the use of which was reported by 11.4% of the population surveyed. People with overexposure to this type of insecticide present pathologies such as headache, sweating, excessive salivation, muscle contractions, nausea, tremors, blurred vision, coma, and even death (Costa et al., 2008; Varona et al., 2009). Milder symptoms such as rhinitis, conjunctivitis, pharyngitis and dermatitis can be caused by dithiocarbamates type fungicides like Manzate, Ridomil and Dithane M45 (Choudri et al., 2018; Jaramillo-Colorado et al., 2015).

Another herbicide that aroused the interest of the students was Paraquat, due to its harmful effects on human health. It affects multiple organs, mainly the lungs, kidneys, and liver (Lans-Ceballos et al., 2018; Viales López, 2014), although the farmers reported relatively infrequent use (1%) of this quaternary ammonium salt. It is similar to Tordon, a herbicide with 51.6% toxicity based on measurements taken using the disc diffusion technique with Bacillus subtillis (Benitez et al., 2009). This result could be attributed to the triisopropanolamine salt of (2,4-dichlorophenoxy) acetic acid, associated with decreased production of adenosine triphosphate (ATP), inhibition of deoxyribonucleic acid (DNA) synthesis and protein synthesis in animals and humans, among other characteristics. This, in turn, is similar to Thiodan, a pesticide that is highly toxic if inhaled and moderately irritating to skin and eyes (Jaramillo-Colorado et al., 2015; Lans-Ceballos et al., 2018), which is consistent with the information provided by the farmers who worked with it.

Finally, a group of pesticides that can be very dangerous to animals and humans is bromadiolone, used by 0.29% of the sample. It is a powerful anticoagulant used in rodent control, for which cases of poisoning have been reported (Zuo et al., 2019). It acts by reducing the synthesis of vitamin K and can be very dangerous if the person who consumes it is not treated within nine hours of ingestion.

The pathologies presented by farmers were discussed in the classroom and contextualized with data indicating that developing countries have the highest rate of acute pesticide poisoning compared to industrialized countries, even though developing countries use these chemicals less (Ambrus & Yang, 2016; Costa et al., 2008). This denotes the need for the training of farmers in the handling of these chemicals, since incorrect work practices and poor disposal can lead to very serious public health problems in a given region (Hernández et al., 2017; Lans-Ceballos et al., 2018; Sagiv et al., 2018) or in industrialized sectors in Colombia such as the cultivation of coffee or flowers (Londoño Franco et al., 2018; Varona et al., 2005). Thus, the lack of knowledge and the generalized mismanagement of pesticides found among the farming communities studied indicates that the training of the population should be directed towards the safe use and final disposal of packaging and waste generated from the handling of pesticides (Kunin et al., 2019). One method for the management of hazardous waste from the use of pesticides is the application of the 'triple wash' technique for the correct disposal of this material (Escobar Lopez, 2019).

The legislation for hazardous waste management protects the environment in terms of the handling, treatment, and final disposal of these wastes (Ministerio de Ambiente Vivienda y Desarrollo Territorial, 2005). It is therefore necessary that the farmers take shared responsibility, since until the hazardous waste generated by the pesticide has been eliminated and its elimination verified; farmers are jointly responsible with the manufacturer of the pesticide for negative consequences, as indicated in article 2.2.7.2.1.4. (Decreto 1076, 2015).

From the information obtained, the students understood that the burning and burying of pesticides by some farmers is a bad practice and is absolutely prohibited. They may only be disposed of safely through facilities duly authorized by the competent authorities. It is therefore essential that post-consumer plans are established for the collection of pesticide containers, allowing a mechanism to be put in place for the return and disposal of containers and other hazardous waste, providing users with information on the health risks that may arise when handling the products and waste resulting from work with pesticides (Resolucion 1675, 2013).

Allowing students to take ownership of research through the project-based teaching model enabled them to understand the issues while being more attentive and motivated (Sakulviriyakitkul et al., 2020). They showed interest not only in wanting to find a solution, but in making connections with their communities (Zhou et al., 2013) by disseminating the results of their research to the educational and rural community, with the aim of using their findings to positively affect the communities in which they live. The results confirm observed in Ref. (Hassan et al., 2010) when they state that the increase in students' interest is established by environmental awareness and the acquisition of knowledge from an early age. All this work was possible because the PBL model encourages cooperative learning (Chatwattana & Nilsook, 2017) through classroom discussions, allowing students to contribute and value the opinions of their peers and teachers.

By finding relationships among the different factors that make up the problem, the students understood the biological-chemical context of public health and the environmental regulations that cover them. In this way, project-based learning became a pedagogical tool that motivated students to learn by building on their daily experiences in the context in which they live and taking observation as an initial reference (Aguirre & Jaramillo, 2015). In addition, the use of project-based learning fostered in students a greater sense of belonging to their culture, territory and rural community (Muñoz Quezada, 2009), and promoted the acquisition of thinking skills, which enabled them to find solutions to the problems they identified (Pinho-Lopes & Macedo, 2014).

Similarly, this research sought to encourage students to address scientific situations and events from the perspective of the context in which they live, because both history and the present time inevitably influence the process of construction of science itself (Ruiz Ortega, 2007). The execution of the project constituted a practical tool for fostering learning processes, since research projects induce students to think, express points of view and share previous knowledge with their counterparts, leading them to generate conclusions and ideas through trial and error (Galeano, 2010). PBL also allowed programmed curricular content to be covered in the subjects of chemistry (nitrogenated compounds, organophosphates, and organochlorine compounds) and biology (food chains, carbon and nitrogen cycles, toxicity, and its effects on teratogenic).

Conclusion

The approach taken during the research described here required the use of formal thinking strategies (observe, classify, extract, conclude and formulate hypotheses) to tackle and solve situations specific to the students' context. Project-based learning proved an effective pedagogical strategy in that it improved the students' learning processes in different subjects related to the environment through the generation of interdisciplinary links, which reinforced their previous knowledge. Likewise, the educational community and families were involved in the students' learning processes, granting them ownership of the process of building their knowledge through the search for solutions and tools to mitigate the harmful impacts of pesticides in their agricultural-rural community leading to an increase in environmental awareness. In addition to innovating in the different pedagogical strategies of teachers and the agricultural practices of young farmers and their families, the foundations were laid for future in-depth environmental studies that would quantify the environmental impacts of pesticides on the human population and on the food chains of the ecosystems of this rural area.

Notes

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