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Los animales de nuestra región: secuencia interdisciplinaria con docentes de preescolar en el marco de la Nueva Escuela Mexicana

The animals of our region: Interdisciplinary sequence with preschool teachers according to the New Mexican School

Os animais da nossa região: sequência interdisciplinar com professores de pré-escola no âmbito da Escola Nova Mexicana

Angelina Alvarado Monroy
Universidad Juárez del Estado de Durango, México
aalvarado@ujed.mx
https://orcid.org/0000-0001-6063-1822

Flor Monserrat Rodríguez Vásquez
Universidad Autónoma de Guerrero, México
flor.rodriguez@uagro.mx
https://orcid.org/0000-0002-9596-4253

María Guadalupe Ríos Laguna
Centro de Investigación y Estudios Avanzados del IPN, México
mgrios@cinvestav.mx
https://orcid.org/0000-0002-6104-6593

Carmen Delia Mares Orozco
Centro de Investigación en Matemáticas, México
mares@cimat.mx
https://orcid.org/0009-0004-0708-024X

Fabiola Lizbeth Pichardo Avila
Universidad Autónoma de Guerrero, México
23501033@uagro.mx
https://orcid.org/0009-0003-9198-0891

Resumen

Con el objetivo de asegurar la calidad educativa, la Nueva Escuela Mexicana (NEM) propone integrar el conocimiento en el aula. Por eso, el objetivo de la presente investigación es explorar y proponer principios para el diseño de secuencias de aprendizaje (SdA) que estén alineadas con la NEM. Para ello, se describe el codiseño de una SdA en colaboración con un grupo de docentes de preescolar para investigar cómo anticipar la enseñanza y el aprendizaje de las matemáticas, e integrarlas con el conocimiento comunitario, el arte, el diseño de ingeniería y las ciencias. Específicamente, se empleó una metodología cualitativa, siguiendo un diseño multiseriado de tres fases: 1) diseño de la secuencia, 2) experimentación de la secuencia con docentes y 3) análisis de datos. En el estudio participaron 24 docentes y los datos se recolectaron a través de videos, notas de observadores (participantes y no participantes), fotografías y producciones escritas del grupo y de sus estudiantes. Los resultados muestran que la secuencia diseñada promueve el aprendizaje en la infancia, así como estrategias docentes factibles para su implementación. Además, se encontró que el diseño multiseriado apoya los lineamientos de la NEM al colaborar con los docentes para integrar conocimientos y asegurar el trabajo por proyectos. En definitiva, se puede asegurar que la SdA sirve como guía para el diseño de nuevas secuencias.

Palabras clave: codiseño de secuencias de aprendizaje, educación interdisciplinaria en preescolar, aprendizaje CITeM (ciencia, ingeniería, tecnología y matemáticas).

Abstract

To guarantee educational quality, the New Mexican School proposes to address integrating knowledge in the classroom. This research aims to develop principles for designing learning sequences that align with the New Mexican School. Therefore, we describe the co-design of a learning sequence with a group of preschool teachers to investigate ways to anticipate the teaching and learning of mathematics linked to community knowledge, art, engineering design and science. The methodology was qualitative, following the multitiered design in three phases: 1) design of the sequence, 2) experimentation of the sequence with teachers, and 3) data analysis. Twenty-four teachers participated. Data were collected through videos, participant and non-participant observers' notes, photographs and written productions of the group and their students. The results show that the designed sequence promotes children's learning and provides feasible teaching strategies for its implementation. The multitiered design was found to support the New Mexican School guidelines by co-designing with teachers to integrate knowledge and ensure project work. In addition, the learning sequence serves as a guide for the design of new sequences.

Keywords: co-design of learning sequences, kinder garden interdisciplinary education, STEM learning.

Resumo

Com o objetivo de garantir a qualidade educacional, a nova escola mexicana (NEM) propõe a integração do conhecimento na sala de aula. Portanto, o objetivo desta pesquisa é explorar e propor princípios para o projeto de sequências de aprendizagem (SdA) que estejam alinhados com o NEM. Para este fim, é descrito o co-design de um SdA em colaboração com um grupo de professores de pré-escola para investigar como antecipar o ensino e a aprendizagem da matemática e integrá-lo com o conhecimento da comunidade, arte, design de engenharia e ciência. Especificamente, utilizou-se uma metodologia qualitativa, seguindo um desenho multisserial de três fases: 1) desenho da sequência, 2) experimentação da sequência com professores e 3) análise dos dados. Participaram do estudo 24 professores e os dados foram coletados por meio de vídeos, anotações de observadores (participantes e não participantes), fotografias e produções escritas do grupo e de seus alunos. Os resultados mostram que a sequência desenhada promove a aprendizagem na infância, bem como estratégias de ensino viáveis para sua implementação. Além disso, constatou-se que o design multisseriado apoia as diretrizes do NEM ao colaborar com os professores para integrar o conhecimento e garantir o trabalho do projeto. Em suma, pode-se garantir que o sequências de aprendizagem serve como um guia para o desenho de novas sequências.

Palavras-chave: co-desenho de sequências de aprendizagem, educação interdisciplinar na pré-escola, aprendizagem CITeM (ciências, engenharia, tecnologia e matemática).

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Introduction

The recent educational reform in Mexico proposes restructuring the curriculum based on the interaction among different disciplines and the problem solving in contexts close to the student body (Secretaría de Educación Pública [SEP], 2022). This is because, in the particular case of basic education, children attending preschool will face complex problems and challenges corresponding to a changing reality derived from the reform. Therefore, this scenario suggests the need to design learning sequences that help teachers develop skills in children to solve relevant real-world problems, by the postulates of the New Mexican School.

One of the challenges of the reform is that the mathematics taught in the classroom has meaning in daily life and is related to knowledge of other subjects. Thus, to harmonize with the *New Mexican School* preschool educational program (SEP, 2023), curricular integration and the community as a core have been considered as articulating axes. Furthermore, to promote greater unity between knowledge, the training fields have been incorporated: knowledge and scientific thinking; ethics, nature, and societies; as well as human and community. Finally, it has been proposed to contribute to the graduation profile so that students recognize and value diversity, and their cognitive, physical, and emotional potential, develop their own way of thinking, perceive themselves as part of nature, and interpret cultural, natural and social.

Several studies have focused on early childhood education with the premise that children at this age already possess complex reasoning about the world based on their own experiences. These experiences are seen as a springboard for their future learning and development. In this sense, Alsina and Salgado (2021) have suggested mathematical modeling to help 4 and 5-year-old children create their first models to analyze, explain and understand reality using mathematical knowledge. The authors asked questions like "What is your favorite food?" and specifically focused on potatoes to provide an experience for the children to explore in depth. This approach begins with observing and appreciating the differences in the potatoes and then progresses to categorizing them by weight. Specifically, the strategy leads to understanding how a balance scale works.

For his part, Tank *et al*. (2013) explore the ability of preschool students in engineering design in complex scenarios with multiple feasible solutions due to the number of variables and interrelationships between them, which must be analyzed and modeled. In your experience, a customer or end user, real or fictional, needs to use the solution or design (such as a hamster habitat, paper baskets, or an organizing box) for a purpose. The authors propose early education in STEAM (science, engineering, technology, mathematics, and art) using engineering design to motivate interaction between disciplines, focusing on iterative thinking — that is, students try something, try it, and learn from what doesn't go well and try again— as well as in teamwork and the communication of ideas. The proposal of Tank 's *et al*. (2013) show that engineering is a good alternative to enriching and expanding the natural talents of young children.

In the present study, like Alsina and Salgado (2021) and Tank et al. (2013), discusses the integration of early learning environments in engineering and modeling to merge different disciplines to solve real problems of interest to students. Likewise, an attempt is made to explore with teachers how to take advantage of children's natural ways of thinking about the proposed situations to enhance them.

In congruence with the expressed intentions, the first commitment of this research is to design a learning sequence so that teachers can involve children in meaningful activities that go beyond the descriptive models that apply the mathematics already learned to the real-world phenomena (Doerr *et al.*, 2017). A second commitment is to assist teachers in preparing children to develop and utilize representations and corresponding language when learning complex mathematical content in interdisciplinary scenarios (Temple and Doerr, 2012).

The proposed objective is to develop and show principles for designing of learning sequences that align with the New Mexican School. It contributes to experiences that involve creating learning progressions and offers integrative contexts of knowledge from different disciplines. In these contexts, it will be necessary to make decisions about the choice of relevant variables and ways to relate them, in addition to generating a range of alternative solutions focused on the personal meanings that can be extracted from contexts close to childhood.

Framework

This work is part of integrated science, engineering, technology, and mathematics (STEM) education. In this regard, Moore *et al*. (2014) define integrated education as an effort to engage students in engineering design (for example, in this proposal, building a model representing an animal's habitat) as a means to develop technologies that require the application of mathematics and science, which results in meaningful and relevant learning.

According to these authors, STEM-integrated education aims to provide a comprehensive approach to establishing disciplinary connections and achieving this type of learning.

The approach to integration assumed here is to merge multiple STEM content areas into a learning sequence where engineering design is relevant. According to the National Academy of Engineering (NAE) (2010), engineering design is an “iterative process that begins with the identification of a problem and ends with a solution that takes into account the identified constraints and meets the specifications for the desired performance” (p. 6–7).

Specifically, to examine and describe cognition in the engineering design process, the phases proposed by Grubbs *et al*. (2018) and Moore *et al*. (2014) are considered for the cycle: problem identification (definition and understanding of the problem), development of possible solutions (planning a solution), selection of the best solutions, construction of prototypes, testing, and evaluation (determining the sufficiency of the solution), communication of solutions and redesign (if necessary). These authors highlight the importance of collaborative work throughout the process, including discussions about how designs meet the client's criteria and needs, and considering of different points of view within the team.

Harmonizing with the above, the principles of Moore *et al.* (2014) have been adopted as a framework for planning the tasks of the learning sequence:

1) The context must be motivating and attractive.
2) Possibilities to participate include design engineering challenges with relevant technology.
3) Activities should provide opportunities to learn from mistakes.
4) The main objective is to build mathematical and/or scientific content.
5) The pedagogies called for must be student-centered.
6) Teamwork and communication should be emphasized.

Materials and methods

The methodology used in this research was qualitative, with a multitiered design (Zawojewski *et al*., 2008), which involves the joint work of groups of researchers, facilitators, teachers, and students to create artifacts for more effective learning and educational innovations. That is, the research approach was based on the experiences of the teacher and the student in the classroom, where the process involves expressing, testing and reviewing functional objects, procedures and theories. In multitiered design research, useful models or tools emerge that can be shared and reused in similar scenarios. To achieve this, all actors must interact to propose changes that may arise during the application of the proposed design.

Furthermore, it can be indicated that the focus of this research is formative, since a teaching artifact is designed, developed and refined through iterative cycles that include design conception, observation, analysis and redesign, accompanied by systematic feedback from users. Here, a first iteration is presented considering three phases: 1) co-design of the sequence, 2) experimentation of the learning sequence with teachers, and 3) analysis of the experimentation phase.

The first phase of the research consisted of planning a sequence focused on raising children's awareness about the value of living beings that share space with human beings in order to promote respect and care for their habitat, and understanding of its role in the balance and conservation of the environment. To achieve this, the following activities were designed:

a. The group researches and describes the traits of animals from the region to classify them.
b. A plan for its care is proposed, and collaborative teams design a plan to build a model of the appropriate habitat for the animal.
c. A representative animal of the region or group is selected by reasoned voting; the preferences are then recorded, and the results are displayed in a bar graph.

The second phase consisted of experimenting with this sequence with 24 teachers: 22 in-service teachers, one primary school teacher, and one retired educator. These teachers participated in a workshop titled “Animals and Flowers: Community Knowledge Associated with Mathematical Learning,” for which they registered through social networks. In a three-hour session, the workshop was held in person at the facilities of the National School of Higher Studies-UNAM, Morelia campus.

In this second phase, the objective of the meeting was to analyze with the teachers how to help the boys and girls develop appropriate language and representations to express their mathematical ideas and other disciplines so that they could relate them to the situation presented and its community. Subsequently, to familiarize the group with some of the knowledge, skills, and tasks associated with the sequence of “The Animals of our Region” presented in the workshop, activities similar to those proposed in the design were carried out to be carried out in the classrooms. This form of experimentation is known as *the homologation strategy* (Houdement, 2013).

Then, in the third phase, the collected data were analyzed, which included photographs, videos, narratives from an observer researcher who did not participate in the sequence design team, and productions from the workshop participants. This evidence was fragmented into eight key moments:

1. Inquiry about regional animals.
2. Share characteristics of the selected animal.
3. Habitat conditions for planning engineering design.
4. Habitat construction.
5. Share the habitat.
6. Vote and justify the vote for the animal.
7. Collective evaluation of the learning sequence.
8. Evidence of applications in the classroom after the workshop.

The researchers separately reviewed and selected evidence that showed how knowledge was integrated and how design principles were met so that they were harmonized with the New Mexican School. Finally, with the selected extracts, a triangulation of the evidence between the researchers was carried out.

Results

Below are presented the results of the learning sequence experimentation with the participating population and the contributions derived to validate and redesign it. The strategies anticipated collectively are also presented, enriched with the results of implementation in the classroom with students. The results were organized according to the eight moments in the methodology’s third phase.

Moment 1. Inquiry about regional animals

From the observer's notes there is evidence that, first of all, each participant shared their findings with the group, and active listening led the different teams to become involved in further inquiry for the consensual choice. Different criteria emerged when choosing the animals: “one that we don't know that much about.” Research records included texts, drawings, clippings, and models. Each team organized a presentation about the selected animal, emphasizing its special attributes, such as flying backwards, living in multiple habitats, and being powerful, symmetrical, or perfect.

It should be noted that each team established a bond with the chosen animal; for example, “We don't have to chase the turtle, we don't know how to protect it,” or it was narrated as if it were a character, as in the case of butterflies, described as travelers and very intelligent. In addition, an explicit connection was established with the personal relevance of each team member; for example, “butterflies support pollination, they do not attack humans, they are powerful like us, they represent us as Michoacans,” or implicitly (“The lanternfish males are parasites of the females [laughs]; the female has a harem "). Regional criteria, such as being Mexican or being a regional insect, were also recognized.

Moment 2. Share characteristics of the selected animal

Each team analyzed the characteristics and made agreements on the option that best represented them as a whole. Subsequently, they presented in plenary the reasons why the animal represented their team (table 1).

Table 1. Characterization of the animals to argue the choice of the animal that represents the team

Selected animal	*Characteristics to justify your choice presented by the teacher who represents the team*
Land turtle	The little one that we can have at home is a reptile, it has a shell, it is vegetarian, we do not have to chase it to feed it, it lives for many years (between 50 and 60), it is green or brown, it does not require much care, it is harmless, tender and that is appropriate for the girls and boys in the classroom.
Axolotl	It is a salamander, it is in danger of extinction, it lives up to 15 years of age, it eats larvae, and it is special because it can regenerate. We like it because it is rare, powerful and its pink color. It would be something new for the children to know about.
Hummingbird	It is a small bird, 10 *cm* long, very colorful, it flies very fast, and does not live in captivity, if it is kept locked up for 1 minute it will die shortly after. They like it for its colors, with the reflection of the sun it changes color, it has a lot of beauty and aesthetics, its brain is very large, it is the only bird that can fly in reverse, what makes it special is the fact that it is essential for the ecosystem and pollination.
Red fox	It is an adaptable animal, its shape is beautiful, it is found in various habitats, they are carnivorous, they look like dogs, they live in burrows, and they do not attack humans. They have 3 to 5 fox cubs. They are cunning, skillful, and full of wisdom. Its tail is very characteristic and that is why they liked it a lot (figure 1).
Lantern fish	It is a surprising and extraordinary animal. It is a fish that lives in the depths of the sea. They have many sharp teeth. The female is much larger than the male, only the females have light, the males are parasites of the females, they cannot eat and they are attached to the females and feed on the females through blood vessels. A female can have up to 6 parasites in her body. It can eat animals up to 2 times its size. It is difficult to know much about them, since they live in the depths of the sea. Through bacteria, they emit light, which serves to attract prey. It is uncommon, surprising and extraordinary. Only through phenomena like “the child” have we known them, since that is how they were able to come to the surface.
Lioness	It represents wisdom, power, dignity, beauty, and leadership. The characteristics are similar to those of a woman; We are wise, beautiful, powerful and leaders, providers in the pack. They choose whether the males belong to the herd or not.
Monarch butterfly	They are very beautiful, they travel, they are large, they live in forests, and they feed themselves since they are caterpillars. Females and males are different, females are brighter, and males are larger and darker. They have this very beautiful process that is metamorphosis, it is symmetrical, their wings are perfect, and they are very intelligent enough to make the trip they make, and to maintain their species, the butterfly that leaves is not the one that arrives at the forest, it changes. It is a regional animal, an insect that helps the state's economy by attracting tourism.

Source: ownership of the authors

Figure 1. The teacher leans on a red fox made of plasticine so that its beauty can be appreciated.

Source: ownership of the authors

Moment 3. Habitat conditions to plan the engineering design

At this time, the teams designed a plan to care for their animal, considering aspects such as housing, food, and ecosystem, among other elements, to build a model of the appropriate habitat.

The habitat design activity proposal strongly focused on STEAM-integrated education, which allowed for the development of a work plan that addressed the shelter, climate, feeding, and social development characteristics necessary for the selected animal. Based on this, a design was developed in harmony with the animal's care requirements, and a habitat was built that met all its needs. During the activity, teachers were asked to use specific criteria for their design. After reaching a consensus, the key elements were established: food, water, shelter, suitable climate and community. This is reflected in the transcript of the teams' plenary session and in Figure 2:

Workshop Leader (T): To design a habitat for your animal, we will establish criteria for all animals. Let's first think about what animals need to live.

Teacher (D): Food, space.

T: Spaces with what characteristics?

D: That they allow him to live.

D: Specific to its characteristics.

D: Water.

D: Refuge.

D: It's just that we said that its space had to be considered according to its characteristics, and we said about the fish, the fish needs water, if not, it doesn't survive.

T: What else do you need?

D: To your colleagues, …, to your community.

D: Its climate, its temperature, its shelter.

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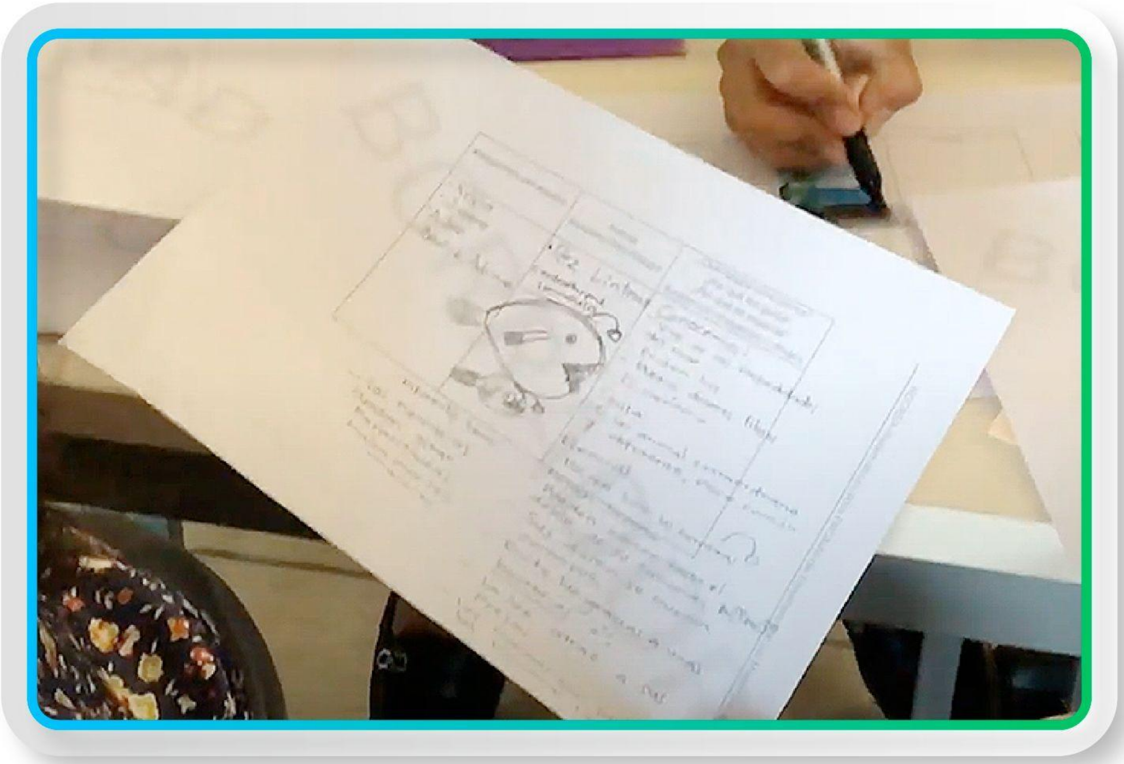
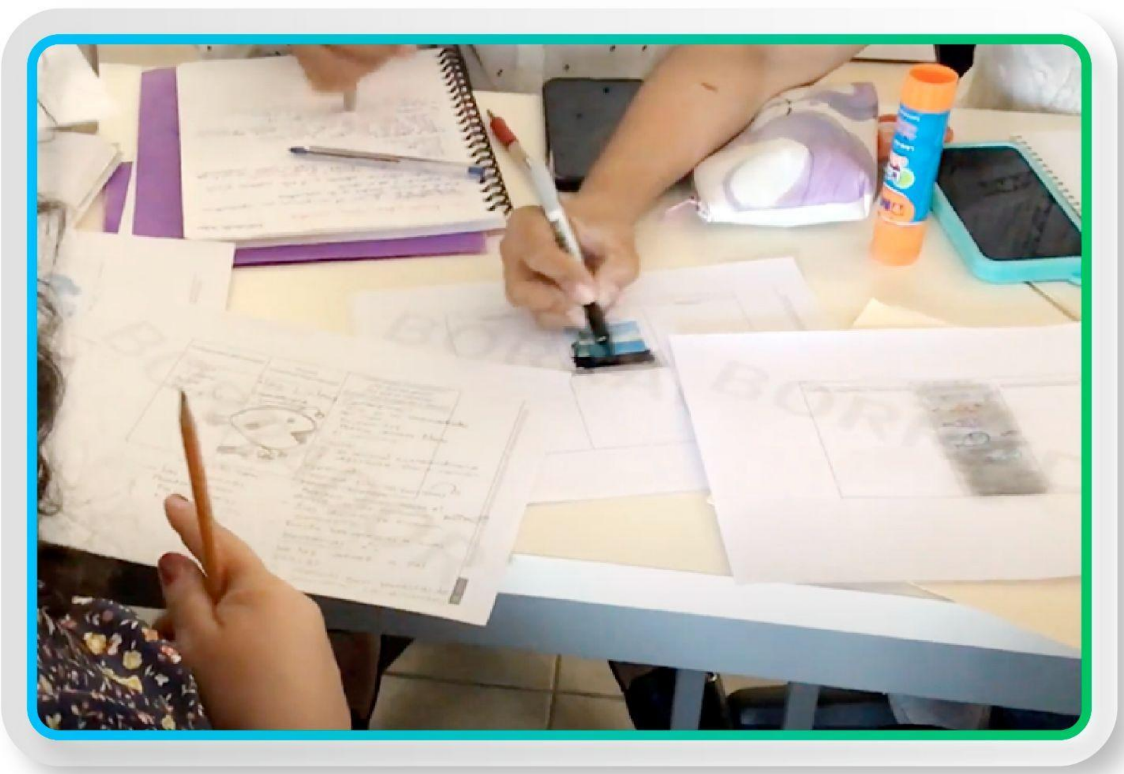
Figure 2. Habitat characteristics for lanternfish





Source: ownership of the authors

Moment 4. Habitat construction

Once the teams had the design for the habitat's construction, they made different materials available to the group, such as plastic and wood blocks, molding dough, and foam material figures, among others. Following the dynamics commonly used in preschool classrooms, the materials were distributed to be visible and available.

Initially, some teams tried to take the flashiest materials, such as colorful Legos, hoarding most of them and leaving few available for others. Teachers from other teams expressed their discordance and pointed out that distributing the materials equally would have been better. However, this strategy of taking a lot of colorful materials did not work for these teams, since as they built the habitat according to the characteristics of their animal, they realized that they needed other simpler materials, such as simple blocks of wood, which allowed them to play and build in a more versatile way. The teams resolved the situation (table 2).

Table 2. Description of the habitats built for the animal that represents each team.

Animal	*Description*
Axolotl	This team used blue wooden blocks to create a river, and they also built an axolotl with pink fomi blocks. Because they were clear about the type of animal and its habitat, they were able to build quickly and easily, becoming the first team to finish their design.
Hummingbird	It was characterized by the use of foam construction materials to quickly create its habitat. They used green blocks to represent the little trees. However, it was not the most striking habitat either, so the team needed to explain it so that others could understand the parts of the habitat.
Lioness	This team had the opportunity to have more colorful Lego pieces available to build his habitat. This allowed them to create a habitat with different spaces, such as rivers and trees. However, it was not the most understandable habitat for the other teams, so the team needed to explain each part.
Monarch butterfly	Although this team did not have enough materials available to choose from, they creatively used the wooden sticks, which were plentiful, to create logs and forest trees for the monarch butterfly. They used green modeling clay to create the leaves of the trees and branches. The complexity of its design meant that it took this team the longest to finish its habitat, but it was the one that impressed the rest of its colleagues the most.
Lantern fish	Since the lanternfish's habitat had specific characteristics, such as the depth and darkness of the ocean, the teachers chose to create their materials with markers and leaves, cutting them out and gluing them onto some blocks of wood and foam.
Land turtle	This team also did not have a variety of materials; However, they made the most of the available wood blocks and moldable putty. They used the blocks to create a pond and the putty to represent water, and creatively made a detailed turtle with the moldable putty.
Red fox	The team also resorted to the use of simple wooden blocks that they used to put up drawings of the habitat features. They did not draw but used the cutouts that had been provided to them for the design part, in this way they simplified the work.

Source: ownership of the authors

Finally, it is important to highlight that all teams worked harmoniously to design the habitat. The time each team spent on their habitat varied widely, with some, like the axolotl, finishing in just a few minutes, while others, like the butterfly and lanternfish, took longer due to creating detailed drawings, cutting, and gluing components.

In addition, it is necessary to mention that the habitats with greater creativity and detail attracted more attention and were recognized by the rest of the group, especially those of the lanternfish and the monarch butterfly. This shows that the important thing in design and construction is not to have the most attractive and striking materials but to know how to take advantage of the available resources to convey the idea of the habitat with the specific characteristics of each animal.

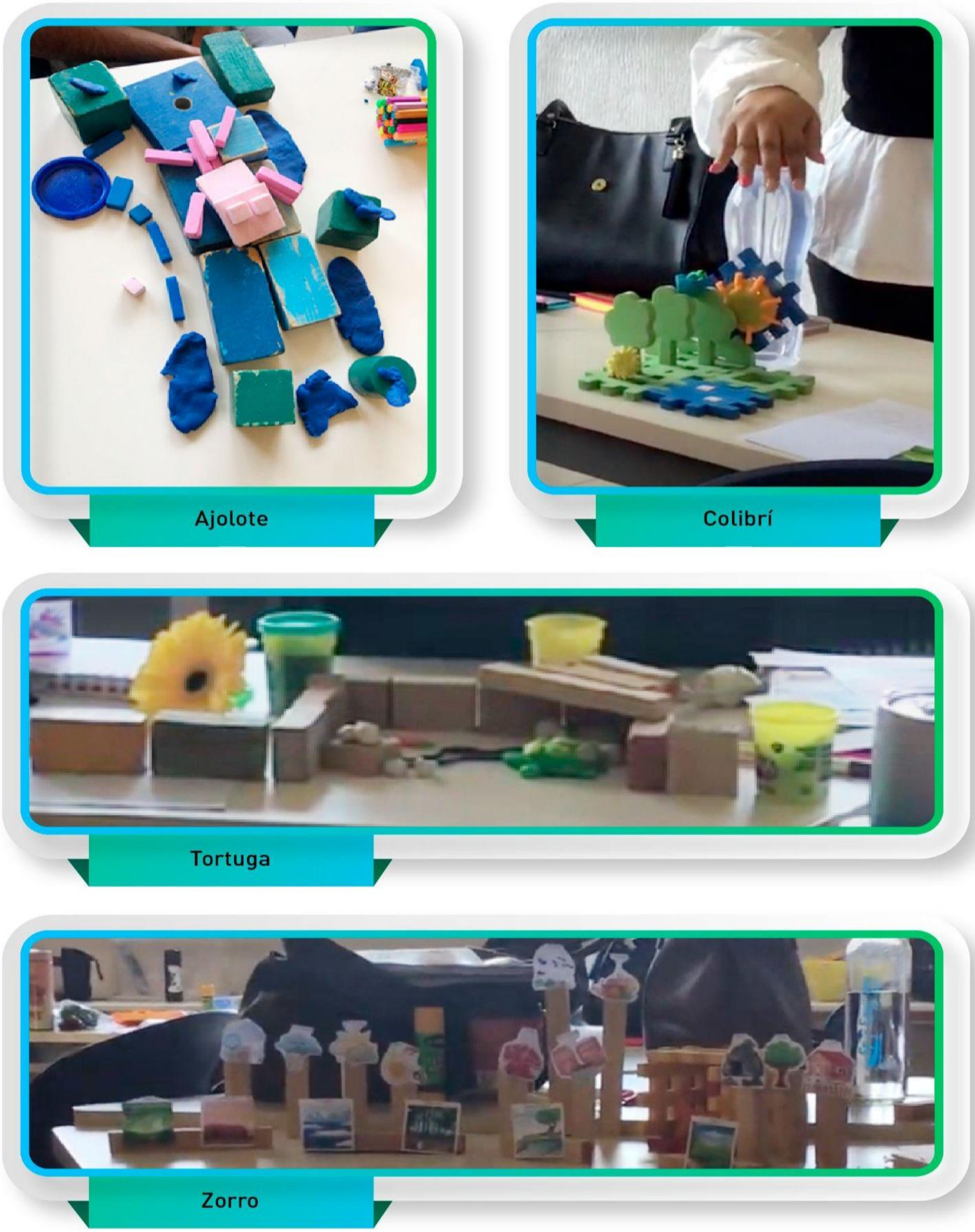
During the assembly of the models, the mathematical activity is made explicit. Arguments of comparison are recovered from the observer's notes, such as “we need a longer stick for the waterfall [than the trees in the forest]” and “we need more blue color for the water.” Arguments of symmetry are also noted when assembling the axolotl habitat, which involves arranging the pieces in pairs in equal quantities and corresponding figures. In the same way, when presenting the butterfly's habitat, the appropriate management of the space is appreciated: “For the tall fir trees, we are at the top. For the lantern fish [in this part the] temperature is high [he points out] and we go down towards the deepest, deepest part of the sea [he points out].”

Finally, connections with the environment are recognized in which comparisons are established with close references, such as "foxes can be given dog food, is the Xochimilco axolotl a cousin of the Michoacan achoque?"

Moment 5. Share the habitat

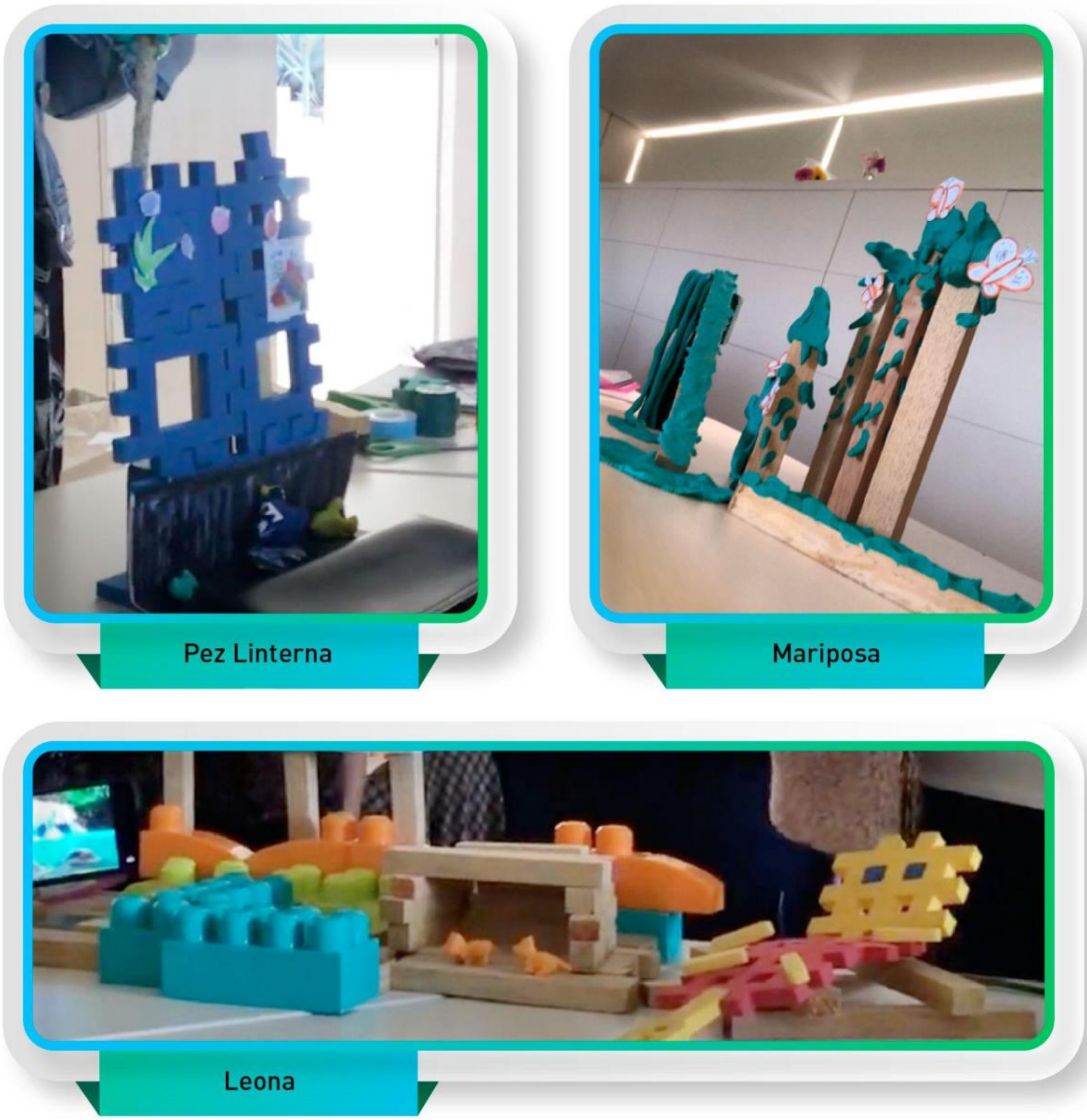
After selecting the materials and collaborative work, the teams prepared to show their habitats to the rest of the teams (figures 3a and 3b).

Figure 3a. Habitats generated by the teams: axolotl, hummingbird, turtle and fox



Source: ownership of the authors

Figure 3b. Habitats generated by the teams: lantern fish, butterfly and lioness



Source: ownership of the authors

For the presentation of the habitat, each team selected a person who would present its characteristics and explain why it met the criteria requested in the tables (food, region where it lives, in which element it moves, ideal climate); some teams used extra information to justify their habitat proposal (table 3).

Table 3. Information to evaluate the prototype of the animal's habitat that represents the team.

Animal	*Feeding*	*Region and Element where it moves*	*Ideal climate*
Axolotl	Larvae Fish Charales Floors	Lakes in Xochimilco, its element is water	Tempered
Humming bird	Nectar of flowers Small insects including spiders.	Areas with trees, plants and flowers America	Warm Some subspecies can live in different climates
Additional hummingbird information: They are polygamous (they can have up to 6 partners) and have a special reproduction cycle.			
Lioness	Dead animal (food)	Savannah, semi-desert regions, mountainous area	Warm Rain
Monarch butterfly		Forest with tall fir trees. Forests in South America and rivers. Elements: oxygen and water	Warm weather
Lantern fish		We find them in the deep part of the ocean, it is dark	Very cold
Land turtle		Rocky areas, requires shade and requires elements such as light, water, air	
Fox	Fruit Seeds Dog/cat food	They can live anywhere in the world. In captivity they live longer (almost twice as many years as in the wild)	They are very adaptable so they can live in different climate conditions.
Additional information about the fox: Regarding their adaptability, they can live anywhere in the world, they are the most inhabited species on the planet after human beings. Hunters: they have the customs and habits of hunters. Reproduction: they are monogamous, living in pairs or small groups.			

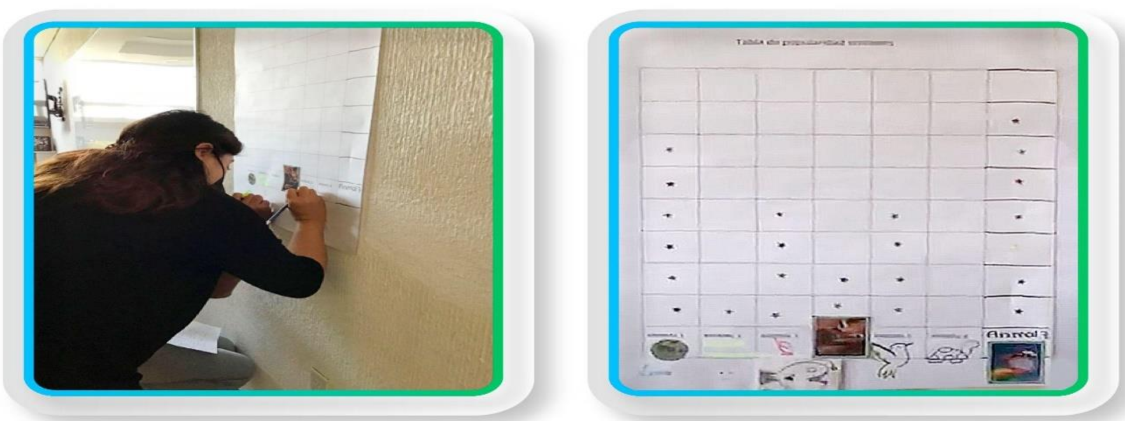
Source: ownership of the authors

Moment 6. Vote and justify the vote for animal

Once the characteristics of all the animals and their habitats were known, the choice of an animal was requested to represent the entire group. The record of preferences was presented in a graph. The participants voted for the animal that best represented them, and showed their affection and ties with it, regardless of the team in which they participated. In the bar graph (Figure 4), the results were organized taking the horizontal axis to order the animals (from left to right: lioness, axolotl, lantern fish, fox, hummingbird, turtle, and monarch butterfly), while on the axis Vertically, each star represented one vote.

In the end, the axolotl and the turtle had no votes, so one participant voted for the axolotl, justifying her feelings by empathizing with the team that had not received votes, thinking that this would not affect the popularity of the others, but a value would be given to the axolotl: "I saw that he did not have any votes for you, I thought it was because he was ugly and I thought about valuing the virtues he has, to regenerate, for example".

Figure 4. Bar graph representing the trend in group preference for each animal



Source: ownership of the authors

Moment 7. Collective evaluation of the post-workshop sequence

To validate the learning sequence, the six criteria of Moore *et al*. (2014) were considered for designing of STEAM integrative learning environments.

1) The context must be motivating and attractive

The arrangement of various materials stimulated creativity in the teams and allowed them to select those necessary to build the habitat corresponding to the conditions of the animal represented by their team. The space facilitated active listening and decision-making to choose the animal that best represented the team's interests. In addition, it encouraged research to justify the choice based on the elements detailed in Table 1: the contribution of the animal to the balance of the ecosystem, its membership in the local community, and the values attributed to the species, which were sometimes based on their gender and specific skills or behaviors, such as leadership, adaptability, resistance, social integration, among others.

2) Possibilities to participate include design engineering challenges with relevant technology

At moment 3 (Habitat conditions for planning engineering design), teams used engineering principles as motivation while designing a model to represent the habitat of the selected animal. They identified the problem to be solved—providing an adequate space for their animal—and, to do so, they needed to investigate the species' characteristics (Table 1).

In addition, they developed possible parts of the habitat that they compared to select the best solutions, although this meant leaving aside the materials that initially seemed attractive to them. Subsequently, they built their prototype, tested it, and evaluated its ability to satisfy the animal's needs (Table 3). It is worth noting that in the teams with a smaller variety of materials (butterfly, lantern fish, and turtle), greater creativity was evident in the construction of the prototype (Table 2). Finally, at moment 4 (Habitat construction), they presented the solutions to the rest of the group and had the opportunity to redesign or make small suggested adjustments to obtain the appropriate habitat.

3) Activities should provide opportunities to learn from mistakes

While selecting animals from the region, traits, beliefs, and information obtained through a research process in various sources were recovered, which allowed the group to review errors to characterize the animals more accurately. Another time when mistakes were recognized that contributed to learning was during the construction of the habitats, as they participated in a continuous comparison process to ensure that their model was coherent. For example, they cared for the animal's proportion concerning its habitat's components (trees, reefs, beehives, among other elements).

4) The main objective is to build mathematical and/or scientific content

In the plenary discussion, with people sitting in a circle to review the process of building the models that represented the habitats, the workshop facilitator asked the group to identify the mathematical content or learning achieved. The following interventions were recovered from the different teachers in the group:

D: Recording information in a bar graph.

D: Count and compare quantities to decide which animal represents us more or less.

D: The classification is seen in the characteristics of each animal: what they ate, where they lived...

D: The spatial location to determine how to organize and build the habitat.

D: The organization of the information is important because they have to think about the criteria that correspond to the animal and its habitat.

On the other hand, in the videos of the experience, the following words or phrases related to scientific thinking were repeatedly recovered:

D: The use of different representations of the situation (images as support to communicate ideas, diagrams to imagine the habitat, model, among others).

D: Opportunities to organize thought.

D: Structure sentences more completely.

D: Make decisions according to the information available.

5) The pedagogies called for must be student-centered

Active pedagogies were put into play so that people could talk, investigate, and make decisions about choosing an animal that represented them. With this, they developed a plan to create their habitat. However, the observer of the experience considered it important to move towards the pedagogy of care: Take affection into account, care for ideas and people, and reduce competition in the group.

> Observer: There are emotional aspects in the ideas of democracy and game (where you win and lose) associated with quantifying and comparing quantities. [...] It makes me think about the distinction between the personal pain of losing in a game and the distance with the board, where using it will make the difference. Maybe you have to reflect [...] if presenting [your animals] to defend them is putting them in competition. What happens if two stars (or more) are given to each person in the vote? Could that reduce or displace the tension of competing?

6) Teamwork and communication should be emphasized

This experience in the final discussion helped those who participated in the sequence in two directions:

1. Work collaboratively to investigate and make agreements on the knowledge of the animal that best represents your team, as well as to plan, design, and build the habitat taking into account all contributions and monitoring your behavior and that of the other people involved.
2. Develop communication skills by emphasizing the presentation of models, since this covers the need to support students in better communicating their ideas and organizing their thinking.

In the evidence recovered in the reflection and plenary discussion we find richness in the social and emotional spheres. The phrases related to socio-emotional skills that the group considered to be developed with learning sequence were the following:

D: Social skills are developed.

D: You learn to express yourself and ask questions.

D: Emotional skills are presented in the management of frustration and emotions.

D: Social criteria influence the decision, such as considering the animal proposed by a friend. As in this case [...], the axolotl was seen as very alone, and it was decided to give it one vote.

D: Also, to give the majority of votes to the monarch butterfly because it is the one that best represents Michoacán and for its independence and resistance.

Moment 8. Evidence of application in the classroom

Below, evidence is given of applying of the learning sequence of three teachers with their second-grade preschool groups. Here the experience of one of them is resumed.

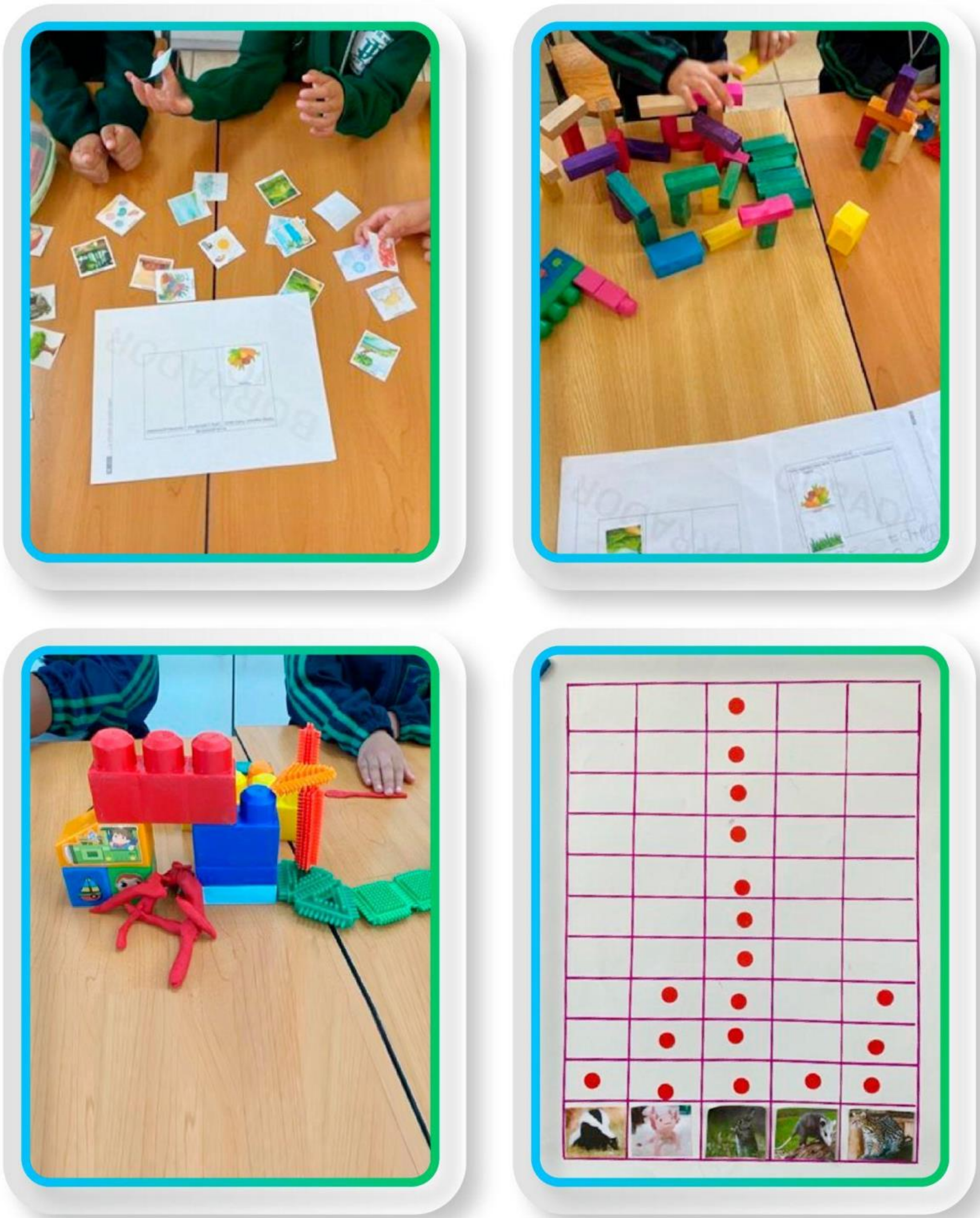
The first organized the work in three days, connecting with the theme of “Fantastic Animals of Mexico” (axolotl, teporingo, raccoon, skunk). He mentioned about the learning environment generated with the learning sequence:

> It was a situation that [my students] undoubtedly enjoyed a lot because their prior knowledge of activities, such as tables and graphs, and their background of inquiry about animals gave a special touch and fluidity.

Regarding the moment of execution of the plan, the teacher commented:

> It was without a doubt, the student body's favorite part. It is worth mentioning that everyone turned to the sheets to see that the criteria were being considered [where they live, what they eat, etc.], in addition to searching and choosing materials that would serve what they wanted to achieve.

Figure 5. Evidence of application with a second-grade preschool group



Source: ownership of the authors

Finally, regarding the generated prototypes and their presentations, the results of the models were diverse. It is necessary to mention that their explanations maintained a close relationship with the information in the tables and with that which had been shared with them.

Discussion

This study has recovered principles for designing a learning sequence (Moore *et al*., 2014). In this sense, it can be assured that experimenting collaboratively between teachers provided confidence to implement it in their classrooms, as reflected in the final assessment of how the sequence supports student learning in the proposal of implementation strategies and in anticipating possible scenarios in the classroom.

The experimentation with teachers had two advantages. On the one hand, it allowed us to collectively learn about the characteristics of the learning sequence, its strengths, weaknesses, and didactic potential from the errors that emerged in the workshop. On the other hand, it allowed them to anticipate possible mistakes on the part of the students and, therefore, identify opportunities to intervene and improve the learning of the proposed contents.

Regarding the first advantage, a retrospective analysis of the experimentation showed that the learning sequence is sufficiently adaptable for phase 2 (preschool), according to the New Mexican School (SEP, August 18, 2023; SEP, 2023). This could be confirmed by the comments made in the workshop and later when some teachers implemented the situation in their classrooms. The flexibility with which they made adaptations for their students without losing sight of the purpose of the learning sequence was notable. For example, in the evidence shown at moment 8, a teacher took advantage of the learning sequence to link it with previous experiences of her group and chose the animal that represented the group based on others they had previously studied.

Likewise, it is recognized as an advantage that the learning sequence is modifiable and adaptable, always ensuring that the disciplinary contents are not diluted in the integration process with community knowledge. As Laguna and Block Sevilla (2020) mention, "a flexible and open situation can be more robust to the extent that it is more feasible for teachers to act as those responsible for the reconstruction, knowing what is important to preserve meaning" (p. 349). This is because each learning sequence will go through a stage of appropriation by the teachers, where each one makes their own interpretation of the sequence (Block Sevilla, 2018; Laguna, 2016).

Regarding the second advantage, during the workshop the group anticipated the possible classroom errors that students could face. Comparing the size of an animal to the elements of its habitat helped check the proportion and determine which elements are relevant in the model. The teaching community must be aware that students must face situations that allow them to learn from their errors so that these errors can be used didactically (Moore *et al*., 2014).

Likewise, the results show that the group of teachers worked collaboratively and with autonomy following the purposes of the New Mexican School (SEP, August 18, 2023; SEP, 2023), as they identified ways to involve girls and children in scientific practices to investigate the animals in their environment and study their characteristics. This provides them with elements to make decisions about the choice of relevant variables and the ways to relate them, for example, when sizing spaces and making comparisons between the elements of the model that represent the habitat of the chosen animal to determine the appropriate size of each one. In addition, the autonomy and collaboration of teachers is recognized by generating various alternative solutions focused on the personal meanings that can be extracted from the contexts close to the students.

Regarding the sequence structure, some difficulties encountered in its first version helped us reflect on how to make adjustments. The teachers, for example, emphasized the importance of first designing and constructing the habitat and then choosing the animal that would represent the group. In this way, their preferences could be recorded in a bar graph for closure, allowing them to take advantage of progression in mathematical content.

Finally, both the findings with teachers and students, as well as the research by Alsina and Salcedo (2021) and Tank *et al*. (2013) offer a vision of how girls and boys can simultaneously learn content from different disciplines and transform their learning into a resource to understand their environment through a complex and significant topic.

Conclusions

This article reported on the design and experimentation of the learning situation “The animals of our region”, which represents a product that can be used by kindergarten and first grade teachers in harmony with the approaches of the New School Mexican. In this regard, the document on activities, dosage, and teaching guidelines can be consulted at https://bit.ly/3V2Z5C0.

Regarding access and the complexity of implementing the sequence of activities with children, this study concludes that it is possible to carry it out in all three preschool grades. For first-grade students, it is advisable to emphasize the presentation of models since students are better at communicating their ideas and organizing their thinking.

Likewise, in collaboration with the workshop facilitators, the teaching group recognized the curricular alignment of the learning situation with the New Mexican School, contributing to an experience that exemplifies learning progression in an integrative context of science, engineering and mathematics knowledge. Thus, considering what is reported in this article, the learning sequence is appropriate for teachers of phases 1, 2 and 3 to implement it in their classrooms. This can also be used as a guide to designing new proposals harmonizing with the New Mexican School.

Finally, the methodology used makes it was possible to build teacher development opportunities for them to use these activities and, simultaneously, help increase their own knowledge of the content, develop a deeper understanding of how students learn mathematical concepts in an integrated way with other disciplines, and use that knowledge to make educational decisions adapted to the conditions of their classrooms.

Future lines of research

This research revealed some aspects that could be explored further in the future. The first would be to follow up with more teachers to observe how the homologation strategies proposed during the co-design are implemented in the classrooms to guarantee their replicability and foster confidence in others to implement them in their contexts.

A second aspect suggests conducting experimental studies to test the sequence and evaluate the mathematical learning that emerges in students, for example, in proportionality when sizing spaces, and explore possible ways to expand this learning. This would contribute to the discussion on the criticisms of the methodologies suggested in the New Mexican School for integrating knowledge in which there is a risk of diluting mathematics. Therefore, it would also be worth exploring sequences with other content considered difficult to integrate, in order to assess the scope and limitations of these methodologies.

A third aspect proposes conducting case studies with groups of students to investigate the socio-emotional development observable in the sequence and the development of disciplinary knowledge. Additionally, case inquiries with teachers could explore the impact of this approach on transferring design principles and proposing new learning sequences that align with the New Mexican School.

Finally, the multitiered design is suggested to promote rigorous research that produces didactic sequences for effective learning that can be shared and reused in various educational settings.

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Contribution Role	Author(s)
Conceptualization	Angelina Alvarado Monroy (Main) Flor Monserrat Rodríguez Vásquez (Same) María Guadalupe Ríos Laguna (Same) Carmen Delia Mares Orozco (Support) Fabiola Lizbeth Pichardo Avila (Support)
Methodology	Angelina Alvarado Monroy (Main)
Software	Does not apply.
Validation	Angelina Alvarado Monroy (Main) Flor Monserrat Rodríguez Vásquez (Same) María Guadalupe Ríos Laguna (Same) Carmen Delia Mares Orozco (Support) Fabiola Lizbeth Pichardo Avila (Support)
Formal Analysis	Flor Monserrat Rodríguez Vásquez (Principal) Angelina Alvarado Monroy (Same) María Guadalupe Ríos Laguna (Same) Carmen Delia Mares Orozco (Support) Fabiola Lizbeth Pichardo Avila (Support)
Investigation	María Guadalupe Ríos Laguna (Principal) Angelina Alvarado Monroy (Support)
Resources	Does not apply.
Data curation	Does not apply.
Writing - Preparation of the original draft	Angelina Alvarado Monroy (Main) Flor Monserrat Rodríguez Vásquez (Same)
Writing - Review and editing	Angelina Alvarado Monroy (Main) Flor Monserrat Rodríguez Vásquez (Same) María Guadalupe Ríos Laguna (Support)
Display	Angelina Alvarado Monroy (Main) Flor Monserrat Rodríguez Vásquez (Same) María Guadalupe Ríos Laguna (Support)
Supervision	Angelina Alvarado Monroy (Main) Flor Monserrat Rodríguez Vásquez (Same)
Project management	Angelina Alvarado Monroy (Main) Flor Monserrat Rodríguez Vásquez (Same)
Fund acquisition	Angelina Alvarado Monroy (Main) Flor Monserrat Rodríguez Vásquez (Same)