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Article

Developing 21st century skills: A proposal for a didactic sequence with a STEAM approach and active methodologies for basic education students in the Mexican Southeast

Desarrollando habilidades del siglo XXI: Una propuesta de secuencia didáctica con enfoque STEAM y metodologías activas para alumnos de educación básica en el Sureste Mexicano

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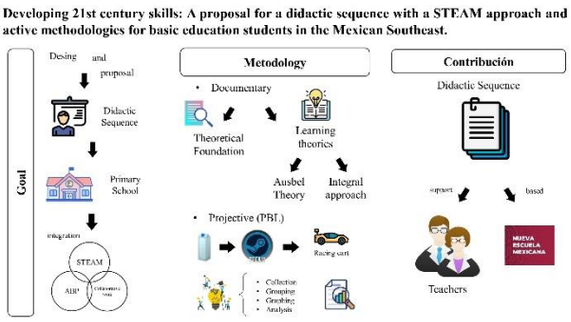
Abstract

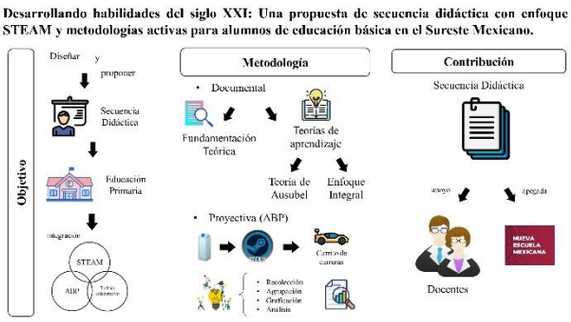
The objective of this article is to develop a didactic sequence to work on teaching in the classroom, comprising successive activities in order to teach educational content in basic education, in the context of a rural school in the Mexican Southeast; based on the theories of David Ausubel and adapting the model of a didactic sequence with a comprehensive approach; integrating Project Based Learning (PBL) and Collaborative Work with the STEAM methodology. This didactic sequence will be useful as a planning instrument for Basic Education teachers to improve their educational practice by making use of transversality between subjects so that the student can transfer learning to their environment and daily life, as well as reflect. on their actions and have the ability to make proposals for improvement.



Teaching proposal, STEAM, Comprehensive Approach

Resumen

El presente artículo tiene como objetivo elaborar una secuencia didáctica para trabajar en el aula la enseñanza, comprendiendo actividades sucesivas con el fin de enseñar un contenido educativo en educación básica, en el contexto de un escuela rural del Sureste Mexicano; fundamentada en las teorías de David Ausubel y adaptando el modelo de una secuencia didáctica con enfoque integral; integrando el Aprendizaje Basado en Proyectos (ABP) y el Trabajo Colaborativo con la metodología STEAM. Esta secuencia didáctica le será de utilidad como instrumento de planeación a los docentes de Educación Básica para mejorar en su práctica educativa haciendo uso de la transversalidad entre asignaturas para que el estudiante logre realizar la transferencia del aprendizaje a su entorno y vida diaria, así como reflexionar sobre su actuar y tener la capacidad de realizar propuestas de mejora.



Propuesta didáctica, STEAM, Enfoque Integral

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Introduction

Since its inception in 2000, the Programme for International Student Assessment (PISA), an assessment conducted by the Organisation for Economic Co-operation and Development (OECD), measures student performance in reading, mathematics and science. According to the results of the latest PISA test (OECD, 2023), in the case of Mexico, the educational performance of Mexican students is below the international average.

These results indicate that there is still a very marked gap in educational performance between Mexico and OECD countries, as no Mexican student was considered a high performer, especially in Mathematics. Therefore, there is a need to improve the quality of education and reduce educational inequalities to ensure that all students have the opportunity to acquire the skills and knowledge that are critical for long-term academic success from the earliest years of school.

Given the need to improve educational performance in Mexico, it is crucial to awaken students' interest in mathematics, science and technology from an early age. To achieve this, it is necessary to transform current educational content, adapting it to an increasingly interconnected world that demands skills that schools are not adequately developing.

It is essential to design educational activities that allow students to acquire basic skills in STEAM (Science, Technology, Engineering, Art and Mathematics) disciplines through active teaching methodologies.

These methodologies include Project Based Learning, Problem Based Learning, Inverted Classroom, Gamification and Cooperative Learning, among others. Implementing these strategies will not only foster greater interest in key areas of knowledge, but will also prepare students to face the challenges of the future with practical and relevant skills.

For this reason, education today requires new teaching methodologies to prepare students for an increasingly complex and changing world, largely due to technological progress, so that they acquire the knowledge and skills to face the challenges of the 21st century (Díaz, 2023).

In this context, STEAM (Science, Technology, Engineering, Arts and Mathematics) methodology emerges as an innovative strategy that seeks to integrate these disciplines in a cross-cutting and interdisciplinary manner to promote the development of skills and competences in students through the development of learning projects (Santillán-Aguirre et al., 2020). In this sense, the implementation of active teaching methodologies integrated with STEAM, such as Project Based Learning (PBL), as well as Collaborative Work, have become an effective strategy to promote meaningful learning and the development of skills in students, in addition to fostering critical thinking, creativity and teamwork in students (Castro, 2022, Cifuentes Piedrahita et al., 2022).

For García-Varcálcel, Muñoz-Repiso and Gómez-Pablos (2017), one way to implement these active learning methodologies is through Project Based Learning, which benefits and facilitates students to work proactively and collaboratively, based on conversations between participants.

In a study by Vargas, Vega and Morales (2020) proposed the application of Project Based Learning (PBL) through Information and Communication Technologies (ICT) to overcome difficulties in learning mathematics and focus on basic operations in sixth grade students in public schools in Colombia with learning difficulties in three skills: concepts, logical reasoning and solution operations; they conclude that PBL and ICT are excellent learning strategies for students with learning difficulties to acquire mathematical knowledge.

For the integration of STEAM with the active methodologies mentioned above, it is necessary to integrate them into a didactic sequence or learning sequence; according to Zavala (2008), a learning sequence is an ordered, structured and clear set of activities to achieve an educational objective with a starting point and an end point.

Objective

The objective of this article is to design and propose a didactic sequence in the context of a school in Southeast Mexico based on the theories of David Ausubel with the adaptation of the model of a didactic sequence with an integral approach.

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This didactic sequence integrates Project Based Learning (PBL) and Collaborative Work with the STEAM methodology, focused on the topics of basic statistics present in the new textbooks of the Ministry of Public Education (SEP).

Methodology

The methodology used is documentary, because it requires the search, analysis and interpretation of different sources, in this case to establish the theoretical foundation. It is also projective, since it requires the creation, design and elaboration of a specific project; in this case it is the development of a didactic sequence.

For Yuni and Urbano (2014) cited in Meleán et al., (2020), 'documentary research is based on the search, critical analysis and interpretation of secondary data in bibliographic sources, articles, videos, films, among others' (p. 951). For Hurtado (2010) cited in Meleán et al., (2020), 'projective research consists of the elaboration of a proposal that can lead to the solution of a problem' (p. 951).

Results

Theoretical foundation

The proposal of a didactic sequence comprising successive activities in order to teach an educational content in basic education is based on the theory of David Ausubel and adapting the model of a didactic sequence with an integral approach (Barraza, 2020).

Ausubel (1968, as cited in González et al. 2022) proposed that knowledge has a hierarchical structure that can be reorganised and prioritised through meaningful learning.

This is why a person, based on reflections on new knowledge and other psychological processes, begins to take a new position on certain issues or change their perspective on a general level based on how they perceive the environment. In the field of education, we assume that infants, regardless of their age, already carry with them a comprehensive set of prior knowledge that they acquire from various sources when they first enter the classroom, and will eventually consolidate and apply the knowledge acquired during their academic training.

Ausubel proposes meaningful learning, which consists of acquisition by relating new information to the previous knowledge that the subject has in his or her memory. In this sense, Contreras Oré, (2016) mentions that, 'this substantive and non-arbitrary incorporation produces an interaction between the new and the presence of ideas, concepts and propositions that are clear and available in the mind of the learner, which precisely endow the new content with meaning' (p. 132); that is, meaningful learning occurs when something is already known, involves acquiring a new meaning and allows transferring it to new problem situations (Meleán et al., 2020).

Ortiz et al., (2020) propose a learning sequence model with an integral approach that combines three aspects that they consider necessary in the formation of students, from the ability to feel the feeling of a satisfied and happy person, to the ability to think and act creatively.

That is, a person, despite adversity, is able to find solutions to his or her problems and those of society, his or her actions are guided by universal values and he or she is recognised as a capable person, aware of his or her abilities and limitations.

To achieve this goal, teachers should consider planning and organising a series of activities in a logical way to guide students along this path, using diverse and transversal learning resources, supporting teamwork, encouraging assessment activities and using problems that involve students in transferring learning both to their environment and to their everyday life, as well as questions that allow students to reflect on their own behaviour and the ability to suggest improvements as mentioned by Ortiz et al.

The didactic sequence

A learning sequence or didactic sequence is a set of activities designed by the teacher to organise the learning situations that students will develop mainly in the classroom, but also outside it.

Díaz-Barriga (2013) defines a learning sequence as an ordered series of learning activities that the teacher plans to use students' prior knowledge. When students learn a topic, they connect it to contextualised real-world problem situations to make the information meaningful to them.

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The learning sequence cannot be limited to solving routine exercises or applying simple formulae as a recipe, it requires students to engage in problem-solving activities, relate their knowledge to previous experiences and pose real-life problems and information.

Likewise, Díaz-Barriga (2013) proposes three types of activities: opening, development and closing, so the didactic sequence implemented was designed based on these activities indicated by the author, for each selected topic.

Given the theoretical foundations, this article proposes a didactic sequence that includes both the theoretical foundations of Ausubel and the adaptation of the didactic sequence model with an integral approach of Ortiz et al., (2020), which also integrates STEAM with active learning methodologies, Project Based Learning and Collaborative Work.

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In the proposed didactic sequence, the objective is for students to acquire knowledge and skills to measure, collect, graph and analyse data, in accordance with the basic statistics topics found in the new textbooks of the New Mexican School (NEM). To do so, students will build a race car from a Tetra Pak carton, measure the distance travelled by the constructed car, organise the data from the measured distances, graph the data and analyse the graphs obtained.

The proposed didactic sequence is developed over 15 sessions; integrating Project Based Learning (PBL) and Collaborative Work with STEAM methodology; the didactic sequence is structured in three phases: Beginning, Development and Closing. The following is a description of the activities carried out in each of the sessions, as well as the resources and materials used.

Start phase:

At the beginning of the activity, teacher intervention is suggested, which is considered important because with teacher intervention, students can make connections between what they know and new learning, for which the teacher will use different strategies, both descriptive and comparative.

These might include meaningful questions or other problem situations designed to allow students to draw ideas from their own cognitive structures from everyday experiences or previous learning in school and discuss them with peers and teachers (Meleán et al., 2020).

The Start phase takes place in sessions 1 to 4, and aims to present the challenge to the students, form the collaborative teams and define the project to be developed.

Session 1: Diagnosis. In this session, an evaluation instrument (test) is applied to find out the students' previous knowledge on the topic of measurement, data collection and analysis. The classroom and an evaluation instrument developed by the researchers are used.

Session 2: Starting point. In this session, the challenge is presented to the students through a PowerPoint presentation, in which some questions are shown to find out what they know about the topic and to motivate them in the development of the project. A computer, a projector and the classroom are used.

Session 3: Formation of collaborative teams. In this session, students are organised into working teams of 3 or 4 members, and each team is assigned a name. The classroom, a blackboard and markers are used.

Session 4: Defining the final challenge. In this session, the activities that the students will have to carry out during the development of the project are defined, such as the construction of the trolley, the measurement of the distance travelled, the organisation and analysis of the data obtained. A PowerPoint presentation, a computer, a projector and the classroom are used.

Development Phase:

Development activities aim to allow students to interact with new information through activities that add meaning and significance to the information.

The Development phase consists of sessions 5 to 14, and aims at building the race cart, measuring, collecting and analysing data obtained from experimenting with it.

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Session 5: Organisation and planning. In this session, students in teams define a role for each of the following activities: drawing the design of the racing trolley, organising the materials for the construction, building the trolley and decorating the constructed trolley. The classroom, a computer, a PowerPoint presentation, a projector, white paper, pencil and coloured pencils are used.

Session 6: First exchange of ideas. In this session the students, organised in teams, exchange ideas for the construction of the racing trolley to make it functional and eye-catching. The classroom is used.

Session 7: Searching for and collecting information. In this session, with the help of a family member (dad, mum or older siblings), each team member conducts a search for information on how to build a racing trolley from a Tetra Pak carton and other recycled materials. They also find out how to measure the distance travelled by the trolleys, how to organise the distances in a table and how to make a graph with the data in the table. Students work on this at home.

Session 8: Analysis and synthesis. In this session, according to the research done by each of the team members, the information is shared, discussed and decisions are made for the construction of the racing trolley; they draw their prototype. The classroom is used.

Session 9: Production. In this session, students organised in teams use their creativity to build and decorate a racing cart, which is fast enough to cover a longer distance, based on the roles assigned beforehand. They use a Tetra Pak container, 4 screw caps, 2 plastic straws, 2 skewer sticks, 5/16’ electric silicone gun, silicone sticks, pencil-type soldering iron, mini comfort grip tweezers, scissors, cutter, classroom, acrylic paints (different colours), colouring board, paintbrushes.

Session 10: Carrying out tests. In this session each team performs the tests (5 attempts) with their constructed trolley, they measure the distance travelled in each attempt, collect the distance of each attempt in their notebook. They use the constructed racing cart, track, tape measure, notebook, pencil, eraser.

Session 11: Second brainstorming session. In this session the students organised in teams exchange ideas for a second time to make improvements to the constructed cart in order to make it go further. The classroom, a blackboard and markers are used.

Session 12: Implementation of the improvements. In this session, after brainstorming with their team, the students proceed to make the improvements. The classroom and the necessary materials are used to make the improvements.

Session 13: First teacher intervention. In this session the teacher teaches students how to organise data in tables and how to graph them for analysis. The blackboard, markers and classroom are used.

Session 14: Competition between teams. In this session each team with their constructed cart competes with the other teams in a single attempt, they collect the distance of each team in their notebook. They use the constructed racing cart, track, measuring tape, notebook, pencil, eraser.

Session 15: Second teacher intervention. In this session the teacher teaches the students how to organise data in tables and how to graph them in Microsoft Excel, in order to analyse them.

The, blackboard, computer, projector, tablets with Microsoft Excel, markers, classroom is used.

Closing phase:

This last phase can be an event where students present their work in a group and teachers are advised to describe the context in which the work is presented, e.g. whether it should be concluded in a plenary group, or involve parents or the whole school community.

The Closing phase takes place in session 16 and 17 and aims at presenting the final project and evaluating the learning acquired.

Session 16: Presentation of the project and evaluation. In this session each of the teams presents their final project in a public way, sharing experiences on how they improved their trolley and on learning about measuring, organising, graphing and analysing data. The classroom is used.

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Session 17: Application of the instruments. An evaluation instrument is applied to measure the learning acquired by the students during the development of the project and a survey is carried out to know the perception of the students about Project Based Learning and Collaborative Learning. Data collection instruments, pencil, eraser, classroom are used.

Conclusions

The proposal presented overcomes the traditional predominantly expository model for another, where the student is the protagonist of his own learning. Because a didactic sequence was generated for the development of learning schemes in the subjects of basic statistics for primary education, which was based on a literature review where the elements and strategies that were considered most appropriate were selected, taking as a basis Ausubel's theories of meaningful learning and the model of didactic sequence with an integral approach.

The didactic sequence included elements such as cooperative learning through the construction of a racing car from a Tetra Pak carton, which can enable the student to develop the necessary competences to face real-life problems.

The didactic sequence proposal presented aims to enable teachers to conduct courses that, in addition to taking into account the students, their needs and interests, also focus on the fundamental aspects of a complete, responsible and lasting education so that students are able to accept new challenges and work in teams to help others and society; that despite the heterogeneity that may exist in the classroom, it is important that the sequence is inclusive and that cooperative learning groups can be integrated.

With this, teachers will be able to enrich their teaching work through transversal activities (this was one of the reasons for adapting the integral approach in the proposal), in addition to having learning resources that stimulate the interest and motivation of students, and using reflective questions in which students analyse, think and reflect. The latter requires teachers to be trained in STEAM methodology in order to impart knowledge focused on the acquisition of competences, guiding students through any process.

This involves optimising the use of time, as well as planning activities in order to create a positive and motivating learning environment that can encourage students to continue progressing towards new goals.

Annexes

The proposed didactic sequence is attached at the end of the article.

Declarations

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that could have influenced the article reported in this paper.

Authors' Contribution

Trejo-Trejo, Gilberto Abelino: Contributed with the project idea, methodological approach, research design and writing; review of the theoretical background, literature review to define the model of the Didactic Sequence proposal, design of the Didactic Sequence proposal and writing of the article.

Domínguez-Gutú, Jesús: Contributed to the review of the theoretical foundation, literature review to define the model of the Didactic Sequence proposal, the methodological approach and writing of the article.

Gordillo-Espinoza, Emmanuel: Contributed to the literature review to define the model of the Didactic Sequence proposal and revision of the article.

Constantino-González, Fernando Exiquio: Contributed to the design of the Didactic Sequence proposal and revision of the article.

Availability of data and materials

The Escuela Primaria Rural Marcos Villanueva López made available the data and materials for the development of the teaching sequence.

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Abreviaturas

OCDE	Organisation for Economic Co-operation and Development
PISA	International Student Assessment Programme
STEAM	Science, Technology, Engineering, Arts, Arts, Mathematics
ABP	Project Based Learning
SEP	Ministry of Public Education
NEM	New Mexican School

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Background

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Support

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Annexes

Proposal of the didactic sequence			
School:			**School year:**
Teacher:			
Subject: Our knowledge	**Grade: 4th**.	**Group:**	**Her:** Measurement, data collection and analysis.
Competition	Students acquire knowledge and skills to measure, collect, graph and analyse data through Project Based Learning (PBL) and Collaborative Work using STEAM methodology.		
Expected Learning	Students will construct a racing trolley from a Tetra Pak carton, measure the distance travelled by the constructed trolley, organise the data from the measured distances, plot the data and analyse the graphs obtained.		
Materials, equipment and resources	1 litre Tetra Pak containers, screw cap, plastic straws, 30 cm bamboo skewer stick, 5/16" electric silicone gun, silicone sticks, pencil soldering iron, mini comfort grip tweezers, scissors, 6' cutter, 100 ml red acrylic paint, 100 ml black acrylic paint, 100 ml white acrylic paint, 100 ml yellow acrylic paint, 100 ml white acrylic paint, 100 ml acrylic paint blue, flat wooden paintbrush #2, whiteboard marker, small plastic caps (to make colour combinations), projector, tablet or smartphone, laptop, software (Excel), colour chart, flexometer or tape measure, notebook, pencil, coloured pencils, eraser, classroom, chart to generate a slope, extension cords, etc.		
Mainstreaming	Using STEAM methodology and active teaching methodologies, topics from the content of the new textbooks will be integrated into the development of the project. **Science).** - Students will gain new knowledge through observation, measurement, experimentation, analysis and modification during project development. **(Technology).** - Students will use ICT in education, through the use of Microsoft Excel. **(Engineering).** - Students will build a racing cart with the appropriate tools and recycled material. **(Arts).** - Students will design and decorate the race cart for the competition. **(Mathematics).** - Students will measure, organise and graph the distances travelled by the trolleys. - Students will analyse graphs for decision-making.		
Learning model	Learning through the STEAM model with active methodologies: Project Based Learning (PBL) and Cooperative or Collaborative Learning.		
Role of the teacher ● Guiding students in the development of activities. Giving students a leading role in the construction of their learning. Being aware of the achievements of the students. ● Acting as a guide or facilitator of learning when learners need it. The main role is to provide learners with a variety of learning opportunities. Helping your learners to think critically by guiding their reflections and asking important questions.		**Role of the student** Taking responsibility for learning. ● Work with different groups and manage any conflicts that arise. Have a receptive attitude towards the exchange of ideas with peers. Share information and learn from others. Be autonomous in learning (seek information, contrast it, understand it, apply it, etc.) and know how to ask for help and guidance when needed. Have the necessary strategies to plan, monitor and evaluate the steps they take in their learning.	

Didactic Sequence integrating PBL and Collaborative Work					
Sessions		**Project phases**	**Resources and materials**	**Description of activities**	**Weather**
Home	1	**Diagnosis.**	Assessment instrument (test), classroom.	Apply the diagnostic test, prepared by the teacher, to find out previous knowledge on the topic of measurement, data collection and analysis.	60 minutes
	2	**Starting point.**	PowerPoint presentation, computer, projector, classroom.	A PowerPoint presentation shows some questions to find out what they know about the topic: measurement, data collection and analysis, as well as to arouse the interest and motivation of the students in the development of the project of building a racing trolley with recycled material from a Tetra Pack. The questions could be the following: - What do you understand by measuring or metering? - What do you understand by data? - What do you understand by collecting data? - How do you think data is analysed?	30 minutes
Development	2	**Starting point.**	PowerPoint presentation, computer, projector, classroom.	- How do you think data is analysed? - How do you build a trolley with a Tetra Pak package? - How do you make the cart you build go the longest distance and win the competition? - How can we know which car will win the race? - How can the distance travelled by the constructed trolley be measured? - How can the distances travelled by the trolleys be organised? - How can the distances travelled be graphed? These questions should be posed to the students for them to answer and brainstorm.	30 minutes
	3	**Collaborative team building.**	Teacher, students, classroom, blackboard, markers.	Organise the students into teams, preferably of 3 or 4 members. Each team should be given a name consisting of a single word, e.g. Friends, Hares, etc. Write the names of the teams and their members on the board.	30 minutes
	4	**Defining the final challenge.**	PowerPoint presentation, computer, projector, classroom.	Students should: - Build a racing trolley from a Tetra Pak carton. - Measure the distance travelled by the constructed trolley. - Organise the data from the measured distances. - Graph the data. - Analyse the graphs obtained.	30 minutes
	5	**Organisation and planning.**	Teacher, computer, PowerPoint presentation, projector, classroom, white paper, pencil, coloured pencils, eraser, pencil sharpener.	The students in teams should define a role for each of the following activities: - Draw the design of the racing cart. - Organise the materials for the construction. - Construction of the trolley. - Decorate the constructed trolley..	30 minutes
	6	**First exchange of ideas.**	Teacher, collaborative teams, classroom	Students organised in teams should brainstorm ideas for the construction of the racing cart to make it functional and eye-catching.	30 minutos
	7	**Search and collection of information.**	Teacher, collaborative teams, classroom	With the help of a family member (dad, mum or older siblings), each team member will search for information on how to build a trolley from a Tetra Pak carton and other recycled materials. In addition, how to measure the distance travelled by the trolleys, how to organise the distances in a table and how to make a graph with the data in the table. In the student's notebook, the process of building a racing trolley should be written down.	Task
	8	**Analysis and synthesis.**	Teacher, collaborative teams, classroom.	Based on the research of each of the team members, they should share information, discuss and make decisions for the construction of the racing cart.	30 minutes

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