Problem Based Learning as a strategy for teaching algorithms

El aprendizaje basado en problemas como estrategia para enseñar algoritmos

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DOI: 10.35429/EJDRC.2021.13.7.1.9 Received July 26, 2021; Accepted December 23, 2021

Abstract

This study proposes applied research to adopt problem-based learning as a learning strategy for educational programs in computer science. The use of the seven-step methodology is available to implement problem-based learning in a case study within the Autonomous University of Campeche. It refers to the basic algorithmic subject of the logical of programming studied in the first semester of the curriculum map. As an added value and promoting the quality of education, the didactic sequence is added as a technique to apply said strategy and the integration of technological tools that promote, in the same way, educational innovation. The results demonstrate that the adaptability of problem-based learning is efficient and effective in acquiring meaningful learning specifically in the silver case. Likewise, it opens a path for new related research and contributes to the achievement of the graduation profiles of university students. Finally, it is relevant to mention the ease, flexibility and usefulness of the PSeInt software as a tool for algorithm design.

Problem Based Learning, Algorithms, Didactic Sequence

Resumen

El presente estudio propone una investigación aplicada para adoptar el aprendizaje basado en problemas como estrategia de aprendizaje para programas educativos en ciencias de la computación. Se dispone del uso de la metodología de los siete pasos para implementar el aprendizaje basado en problemas en un caso de estudio dentro de la Universidad Autónoma de Campeche. Particularmente, se refiere al tema implementación de algoritmos de la asignatura lógica de la programación cursada en el primer semestre del mapa curricular. Como valor agregado y promoviendo la calidad de la educación se añade la secuencia didáctica como técnica para aplicar dicha estratégica y la integración de herramientas tecnológicas que impulsen, de igual forma, la innovación educativa. Los resultados demuestran que la adaptabilidad del aprendizaje basado en problemas es eficiente y eficaz para adquirir el aprendizaje significativo específicamente en el caso plateado. Asimismo, se abre un camino para nuevas investigaciones afines y se contribuye al logro de los perfiles de egreso de estudiantes universitarios. Es relevante mencionar la facilidad, flexibilidad y utilidad del software PSeInt como herramienta para el diseño de algoritmos.

Aprendizaje Basado en Problemas, Algoritmos, Secuencia didáctica

Citation: HERNÁNDEZ-CRUZ, Luz María, MEX-ALVAREZ, Diana Concepción, FLORES-GUERRERO Mayra Deyanira and MARTÍNEZ-GÓMEZ, Sarahi Del Jesús. Problem Based Learning as a strategy for teaching algorithms. ECORFAN Journal-Democratic Republic of Congo. 2021, 7-13: 1-9

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Introduction

The word algorithm comes from the nickname of a 9th century Arab mathematician, Mohammed al-Khowarizmi, who was recognized for stating step-by-step the rules for basic mathematical operations with decimals (addition, subtraction, multiplication and division). An algorithm is a group of consecutive orders that present a solution to a problem or task. An algorithm "is a method to solve a problem", "it is a detailed, ordered, finite, sequential description of the steps that allow you to reach an objective or solve a problem" (Ferreyra, 2015).

In the area of computer science, an algorithm must be the precise and clear description of the ordered steps to solve a finite problem showing a beginning and an end (Pérez, 2010).

Educational programs in computer science commonly include subjects that allow students to learn to design algorithms and develop skills that allow them to solve problems using the computer.

Given this, the idea of applying Problem-Based Learning (ABL) as a learning strategy in the Logic subject of the programming of the educational program Computer Systems Engineer (ISC) of the Faculty of Engineering at the Autonomous University of Campeche (UAC) arises.).

Problem-Based Learning (ABL) is emerging as one of the most innovative approaches in current professional and academic training, gaining more and more space in the world's leading universities (Sastre, 2008). This learning method allows you to acquire the following generic skills:

– Analyze and solve problems
– Develop critical thinking
– Master interpersonal skills
– Teamwork
– Develop metacognitive skills, self-confidence and self-control
– Manage change
– Learn to learn
– Apply continuous improvement strategies

The difference of the problem-based method with the traditional learning design is that in the latter the trainer transmits information and then seeks its application, while in problem solving, the problem is first presented and then what knowledge is necessary to work it out. In this model, the role of the trainer follows the patterns of the mentor, tutor or facilitator (López Camps, 2005).

The learning strategy, by itself, does not lead to the generation of meaningful knowledge in students. It requires a set of activities, tasks and tools that define the teaching-learning process aligned to the strategy and carried out in a particular context.

Specifically, a didactic sequence is a unit of strategic planning, that is, a design guided by an educational purpose (what is to be achieved) and aimed at helping our students achieve specific learning objectives, considering their needs and possibilities, and the particularities implementation context.

Didactic sequences are sets of learning activities. Learning activities, that is, actions carried out by the student to build new knowledge, are an essential component of didactic proposals. All teaching sequences must meet a series of requirements (Taboada, 2021):

– Each included activity must be meaningful in itself and designed with specific objectives in mind.
– All activities must be articulated and organized in such a way that they work together to allow the fulfillment of a greater learning objective.
– They respond to a design in which each activity constitutes a learning opportunity and in which the sequence of activities proposed to the students is not accidental but intentional, based on the learning objectives set.

On the other hand, the integration of Technologies in education implies taking into account the relationship that must be established between the use of new media and educational innovation. "The differentiation of the successive stages that the teacher goes through before the integration of ICT, can be useful, both for diagnosing the situations in which we find ourselves, and for designing training strategies" (García Valcárcel, 2013) .

The present study aims to present an applied investigation of problem-based learning (PBL) as a strategy in the teaching-learning process. The research covers a specific applied case that follows the seven-step methodology and includes as a technique the didactic sequence integrating technological tools for the development of meaningful knowledge in higher education in the area of computer science. Figure 1 shows the structure of the study.

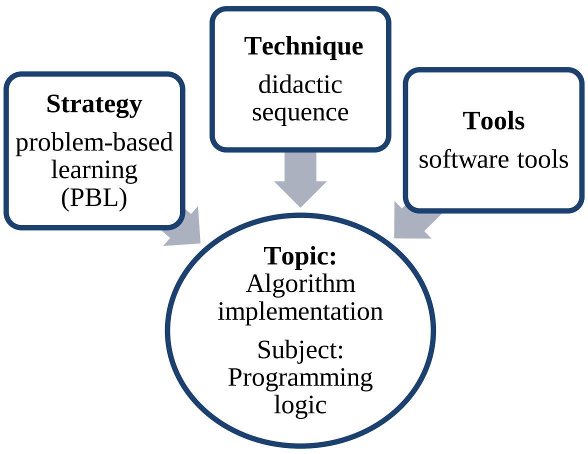

Figure 1 Problem-Based Learning Process
Source: Own Source

Methodology

Problem-based learning begins with the presentation of the problem to which students have to find an answer, continues with the identification of the learning needs that arouses the search for the answer to the problem, and ends with the access to the necessary information and the back to the problem. The process is conventionally developed according to what has been called the "seven steps" and is known as the Maastricht Model (Ortiz Cárdenas, Calderón Ariosa, & Travieso Valdés, 2016).

In the version used by the University of Maastricht, students follow a seven-step process to solve the problem (Moust, Bouhuijs and Schmidt, 2007; Schmidt, 1983), which will be the methodology used in the applied case of the present research:

1. Clarify concepts and terms: It is about clarifying possible terms in the text of the problem that are difficult (technical) or vague, so that the whole group shares their meaning.

2. Define the problem: It is a first attempt to identify the problem that the text raises. Later, after steps 3 and 4, you can go back to this first definition if necessary.

3. Analyze the problem: In this phase, students contribute all the knowledge they have about the problem as it has been formulated, as well as possible connections that could be plausible.

4. Carry out a systematic summary with several explanations to the analysis of the previous step: Once the greatest number of ideas about the problem have been generated, the group tries to systematize and organize them, highlighting the relationships that exist between them.

5. Formulate learning objectives: At this point, students decide which aspects of the problem need to be investigated and better understood, which will constitute the learning objectives that will guide the next phase.

6. Seek additional information outside of group or individual study: With group learning objectives, students seek out and study missing information. The learning objectives can be distributed or they can all be worked on, depending on what has been agreed with the tutor.

7. Synthesis of the information collected and preparation of the report on the knowledge acquired: The information provided by the different members of the group is discussed, contrasted and, finally, the pertinent conclusions for the problem are drawn.

These steps are reflected in Figure 2. The Problem-Based Learning Process (PBL).

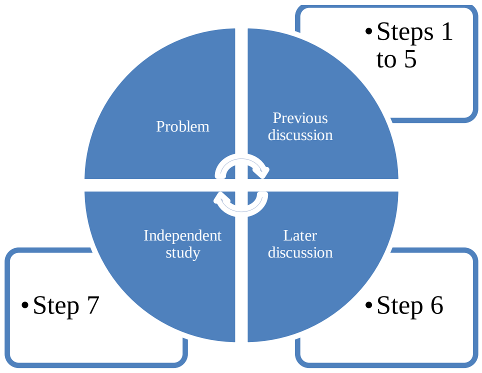

Figure 2 Problem-Based Learning Process
Source: (Vizcarro & Juárez, 2008)

Approach

The research is carried out using an applied case that is developed with the achievement of the methodology indicated in the ABP, applying in turn the construction of a didactic sequence for the topic Implementation of algorithms of the Logic subject of the programming of the educational program Engineer in Computer Systems from the Autonomous University of Campeche, from a qualitative perspective.

Within the didactic sequence, use of technological tools is made:

- Google Classroom. Classroom is part of the set of applications that Google offers under the name of Google Apps for Education (GAFE), an integrated communication and collaboration solution that Google offers to educational centers and that includes its traditional tools, such as email, calendar and chat; It also has the possibility of adding more Google services to adapt it to particular needs (Allueva Pinilla & Alejandre Marco, 2018).
- Google Forms. A Google form (Google Forms) is a web page that allows you to send questions of various types to the target population of students. The responses to the form are collected as a Google spreadsheet. This data can be visualized using automatically generated graphs (collective or individual responses), or you can simply use it (Rebiere & Rebiere, 2020).
- Padlet. It is a board that allows you to invite students to leave their opinions, answer instructions or share images and documents in a simple way. It is widely used to generate virtual interaction. It has a free version (Podestá, 2020).
- MindMeister. It is an application that has a very different and specific purpose that can serve as support when viewing the structure of processes, sections or any other type of element. MindMeister allows the creation of mind maps quickly and efficiently, being able to share and modify them at any time. It has a free basic plan (Corredor Lanas, 2017).
- PSeInt. It is a tool to assist a student in their first steps in programming. Using a simple and intuitive pseudo-language in Spanish (complemented with a flowchart editor), it allows you to focus your attention on the fundamental concepts of computational algorithms, minimizing the difficulties of a language and providing a work environment with numerous aids and didactic resources (SOURCEFORGE, 2021).
- Flipgrid. It is an application belonging to Microsoft where students record videos of variable duration, from 15 seconds to 5 minutes. The main objective is to empower the voice of the student, listening to her voice. The videos are linked to a theme, or topic that the teacher determines within a Grid, which we could equate to a class, or a project to be developed. One of the strengths is the possibilities of sharing a topic, since with our students we can share it with a QR that we project in class, and that our students can enter if we have the application downloaded on the mobile, but also through a link or inserting it into other applications (Microsoft, 2021).

Results

Within the applied case, the didactic sequence proposed by Ángel Díaz Barriga of the National Autonomous University of Mexico is used. The elements included in the didactic sequence are (Díaz Barriga, 2021):

1. Course,
2. General theme,
3. Contents,
4. Duration of the sequence and number of sessions planned,
5. Name of the teacher who created the sequence,
6. Purpose, purposes or objectives,
7. If the teacher considers it, choice of a problem, case or project,
8. General guidelines for evaluation,
9. Line of didactic sequences (opening activities, development activities, closing activities),
10. Line of evidence for learning assessment and,
11. Means.

Table 1 shows the first part of the didactic sequence for the applied case (it covers elements 1 to 8 of the format).

Teaching sequence
Learning Unit: Programming Logic Responsible professor: ISC Luz María Hernández Cruz, MGTI.
Subject: Programming logic
General theme:
Algorithm implementation
Duration of the sequence and number of sessions foreseen:
2hrs, 2 sessions
Purpose, purposes or objectives:
Construct flow diagrams or pseudocodes to solve problems by selecting the control structure, rules, techniques and analytical criteria to express the algorithms.
If the teacher considers it, choosing a problem, case or project:
Problem: showing if a number is positive, negative, or zero.
General guidelines for evaluation:
The activities established for the evaluation of the subject are detailed below and correspond to 20% of the weighting of the first part of the learning unit.

Table 1 Didactic sequence for the applied case (first part)
Source: (Díaz Barriga, 2021)

It is important to emphasize that the data provided in the didactic sequence come from the institutional format of the learning unit program (PUA) of the Logic of Programming subject and, in addition, the Problem is raised for the present applied case (UAC, 2021).

Next, each step of the adopted Methodology is described.

STEP 1: Clarify concepts and terms

Prior to the class session, establish in the didactic sequence as part of the opening activities of the topic "Implementation of algorithms" didactic materials corresponding to:

– Steps for troubleshooting using a computer.
– The definition of algorithm.
– The characteristics of the algorithms.
– Techniques for the representation of algorithms (pseudocodes and flow diagrams).

Define at least one individual activity for the student where they consult various scientific sources and integrate relevant data on the subject. Table 2 shows the opening activities defined for the applied case exposed in the didactic sequence.

Teaching sequence
Teaching sequence line Opening activities The opening activities to the topic, prior to the class session, carry out the following activities:
Activity 1: Consult different sources of scientific information for the definition of algorithm and identify its characteristics. Share the information you collect on Padlet (https://padlet.com/) and you will add a comment to at least three colleagues. It is important to register with your institutional email and add your full name and registration.
Activity 2: Read the teaching material provided in Google Classroom within Resources - Topic: algorithm implementation and design a Concept Map that encompasses all the information reviewed. Didactic material: Topic: implementation of algorithms. • CHAPTER 2 Methodology of programming and software development. P. 45-53. • Algorithmic: Design and analysis of functional and imperative algorithms / Javier Galve Frances, Juan Carlos González Moreno, Ángel Sánchez Calle and J. Ángel Velázquez Iturbide. Editorial Wilmington: Addison-Wesley Iberoamericana, 1993. CHAPTER 1 Introduction to Programming. P. 1-23. •Programming Fundamentals. Algorithms, data structure and objects. 4th. Edition. Luis Joyanes Aguilar. Mc GraW Hill Publishing House. CHAPTER 2 Methodology of programming and software development. P. 63-81.

Table 2 Didactic sequence for the applied case. Didactic sequence line - opening activities
Source: Own Source

STEP 2: Define the problem

During the class session, the teacher presents the thematic content highlighting the main concepts and terms of the topic “algorithm implementation”. It is important to interact with students to stimulate their motivation and interest. Clarify doubts and identify the main elements of the problem to reaffirm your understanding.

The questions What are the input data? What processes are required to perform to solve the problem? What is the output data to be obtained? They will define the problem. Each student will contribute concrete ideas to be able to recognize elements that provide a solution to the problem.

STEP 3: Analyze the problem

The didactic sequence contains the development activities.

Table 3 shows the development activities defined for the applied case exposed in the didactic sequence.

Teaching sequence
Teaching sequence line Development activities At the end of the teacher's presentation. The development activities of the topic, during the class session to be carried out are the following:
During the virtual session, the solution of the problem with the design of the algorithm will be carried out using the specific use software tool PSeInt. The latter can be downloaded from Google Classroom under Resources - Software tools.
Activity 3: Design the algorithm of the problem posed PROBLEM: Show if a number is positive, negative, or zero. – Join teams of 4 members – Read carefully the problem posed and Identify the data of the problem (analysis and definition of the problem - Input (s), Process (s) and Output (s)). – Using a round table or working table, design the algorithm to solve each of them defining the sequence of finite, concrete, and concise steps. – Use the specific use software tool PSeInt to implement the designed algorithm.

Table 3 Didactic sequence for the applied case. Didactic sequence line - development activities. Source: Own source.

Table 4 shows the characteristics of the Workbench.

Work table
Work Table Guidelines
1. The moderator is the team leader or the member designated by the work team for that role. 2. Do not initiate, do not intervene, do not respond to the dialogue until the moderator indicates ("name" intervention) 3. Participants must wait for the moderator to give them the floor and be specific when presenting their contributions. 4. Each participant presents their points of view, comments and / or contributions with their own language and respecting the points of view of the other participants. 5. End the participant's intervention by writing (or saying) "I give the floor" 6. The moderator is responsible for making his annotations for the delivery of the Report.
Workbench process
1. Opening – The moderator provides the welcome, the purpose and the introduction of the participants 2. Dialogue – The moderator gives the floor to the first participant to speak – The participant presents their comments, contributions, criticisms, etc. – Once the intervention is over, the moderator gives the floor to another participant. So hereafter. 3. Closing – The moderator has concluded with the questions of the Topic to be discussed. – The moderator ends the round table, makes a summary or synthesis of the interventions. – Appreciates participation and assistance.

Table 4 Round table or working table of Activity 3 of the development activities in the didactic sequence
Source: Own Source

STEP 4: Carry out a systematic summary

The development activity is summarized in the Workbench report. Figure 3 shows the report format for the Workbench of the applied case. The algorithm resulting from the activity is added in the Conclusions part of the format.

Round table:	
Course:	
Theme:	
Moderator:	
Objective:	
Topics:	
Participants:	
Process:	
Opening **Dialogue** **Closing**	
Conclusions	

Figure 3 Didactic sequence for the applied case Line of didactic sequence - development activities - Work table report
Source: Own Source

STEP 5: Formulate learning objectives

Once the problem has been analyzed and with the design of the proposed algorithm, the result of the previous step. The work team sets itself the objective of implementing the algorithm by applying the pseudo-code managing the specific use software PSeInt.

STEP 6: Find additional information outside the group

Consult various sources to guide you in pseudocode design using the PSeInt software tool. Later implement the pseudocode that solves the applied case. Figure 4 shows the case pseudocode applied in the PSeInt software tool.

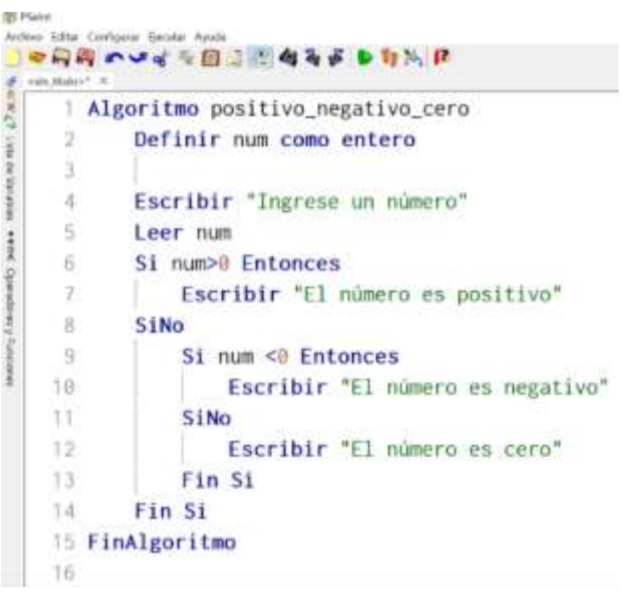

Figure 4 Didactic sequence for the applied case Line of didactic sequence - development activities - implementation of the algorithm using PSeInt
Source: Own Source

STEP 7: Synthesis of the information collected and preparation of the report on the knowledge acquired

Run, test, and document the generated pseudo-code. In order to summarize the main concepts and elements of the algorithm, students are required to document the algorithm. Figure 5 shows the documented algorithm implemented in PSeInt.

Figure 5 Didactic sequence for the applied case Didactic sequence line - development activities - implementation of the documented algorithm using PSeInt
Source: Own Source

Consecutively, the closing activities are established in order to demonstrate the knowledge acquired in the application case. Table 5 shows the closing activities of the didactic sequence of the applied case.

Teaching Sequence
Teaching sequence line Closing activities The closing activities of the topic, after the class session, do the following extra-class activities.
Activity 4: In this activity you will present through a video explain the algorithm designed to solve the PROBLEM: Show if a number is positive, negative or zero. – Using the Flipgrid software tool. – When accessing the link, you will be asked to register, to access it, you will do so with your institutional email. Once on that page, it will be shown as topic Topic: Implementing an Algorithm. – Click the Add an answer button. This will take you to the video recording interface. Explain in detail the algorithm designed for the applied case and its main elements. – Once completed, you must send it and give feedback to at least three of your colleagues**.**

Table 5 Didactic sequence for the applied case Line of didactic sequence - closing activities
Source: Own Source

ISSN 2414-4924

Finally, as part of the didactic sequence and for the benefit of the knowledge acquired, the line of evidence for the evaluation of learning is established, specifying the evidence, percentages and evaluation instruments of the applied case. Table 6 shows the last sections of the didactic sequence proposed by Díaz Barriga (the line of evidence and resources) for the applied case of the investigation.

Teaching Sequence
Learning assessment line
– Activity 1. Evidence: contribution in Padlet. Weighting 15%. Assessment instrument: checklist. – Activity 2. Evidence: Concept Map in MindMeister. Weighting 15%. Assessment instrument: Rubric. – Activity 3. Evidence: pseudocode in PSeInt. Weighting 50%. Assessment instrument: Rubric. – Activity 4. Evidence: video on Flipgrid. Weighting 20% Assessment instrument: Rubric.
Means
– CHAPTER 2 Methodology of programming and software development. P. 45-53. – Algorithmic: Design and analysis of functional and imperative algorithms / Javier Galve Frances, Juan Carlos González Moreno, Ángel Sánchez Calle and J. Ángel Velázquez Iturbide. Editorial Wilmington: Addison-Wesley Iberoamericana, 1993. CHAPTER 1 Introduction to Programming. P. 1-23. – Programming Fundamentals. Algorithms, data structure and objects. 4th. Edition. Luis Joyanes Aguilar. Mc GraW Hill Publishing House. CHAPTER 2 Methodology of programming and software development. P. 63-81.

Table 6 Didactic sequence for the applied case Line of evidence of evaluation of learning and resources
Source: Own Source

Conclusions

The integration of a learning strategy in the educational process contributes to the achievement of learning. In this study, it is concluded that applying the problem-based learning strategy specifically on the subject of algorithm implementation was satisfactory, achieving the development of the following generic competencies: collaborative work, teamwork, cognitive skills and use of ICTs in the professional field. In addition, collaborating with the competence of the logical learning unit of programming "Design computational algorithms for the expression of elementary problems of various disciplines through the formal use of basic techniques".

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