RBAAD Revista Brasileira de Aprendizagem Aberta e a Distância

ABED

ORIGINAL ARTICLE

Framework for the Application of Problem-Based Learning Methodology in Distance and Blended Learning

Márcia de Oliveira Alves[1]
Francisco Petrônio Alencar de Medeiros[2]
Lafayete Batista Melo[3]

ABSTRACT

The academic community has significantly increased studies on active methodologies, such as Problem-Based Learning (PBL), which is applied in face-to-face and distance learning. In response, this research aimed to develop a participatory framework for using PBL in distance and hybrid education (DHE) in a systematic and formalized manner. The study consisted of two stages: first, a systematic literature review to understand how PBL is applied in DHE, virtual learning environments (VLEs), and the tools used. The review revealed that most PBL research and experiences are not integrated with a VLE, and there are few specific initiatives for planning, executing, and evaluating PBL. In the second stage, the researchers conducted workshops, focus groups, and proofs-of-concept to identify the requirements for developing the proposed framework in Moodle and Google Classroom VLEs. The framework aims to guide teachers and tutors in DHE through a logical sequence of activities and tools for applying PBL. The proposal assists teachers in addressing pedagogical practice challenges and contributes to a more systematic and formalized application of the methodology. Therefore, this research presents a significant contribution to the field of DHE, providing a framework for applying PBL that can be adapted to different teaching and learning contexts. Future research could focus on developing an application programming interface (API) to integrate the framework with VLEs, incorporating external tools and resources necessary for the methodology, producing an interactive tutorial for applying the method, and investigating different collaborative tools to support group activities.

Keywords: Distance Education; Hybrid Education; Problem-Based Learning; Framework.

1. https://orcid.org/0009-0009-8851-0518

2. https://orcid.org/0000-0003-2955-6785

3. Postgraduate Program in Information Technology - Federal Institute of Paraíba – João Pessoa Campus. https://orcid.org/0000-0003-2233-8435

Framework para Aplicação da Metodologia Aprendizagem Baseada em Problemas na Educação a Distância e Híbrida

RESUMO

Nas últimas décadas, houve um aumento significativo nos estudos sobre metodologias ativas na comunidade acadêmica, incluindo a Aprendizagem Baseada em Problemas (ABP), que é utilizada tanto no ensino presencial quanto no ensino a distância. Diante dessa realidade, a pesquisa objetivou desenvolver um *framework* participativo para a aplicação da ABP na educação a distância e híbrida (EaDH). O estudo foi dividido em duas etapas, sendo a primeira uma revisão sistemática da literatura para entender como a ABP é aplicada na EaDH, os ambientes virtuais de aprendizagem (AVA) e as ferramentas utilizadas. Constatou-se que a maioria das pesquisas e experiências de ABP não está vinculada a um AVA e que há poucas iniciativas específicas para a aplicação da metodologia no planejamento, execução e avaliação da ABP. Na segunda etapa, foram realizadas oficinas, grupos focais e provas de conceito para identificar os requisitos necessários para o desenvolvimento do *framework* proposto nos AVAs Moodle e Google Classroom. O *framework* proposto tem como objetivo orientar professores e tutores na EaDH por meio de uma sequência lógica de atividades e ferramentas para a aplicação da ABP. Essa proposta contribui para uma aplicação mais formal e sistematizada da metodologia, auxiliando os professores frente aos desafios da prática pedagógica. Portanto, a pesquisa apresenta uma contribuição significativa para o campo da EaDH, fornecendo um framework para a aplicação da ABP que pode ser adaptado em diferentes contextos de ensino e aprendizagem.

Palavras-chave: Educação a Distância; Educação Híbrida; Aprendizagem Baseada em Problemas; Framework.

Framework para la Aplicación de la Metodología de Aprendizaje Basado en Problemas en la Enseñanza a Distancia e Híbrida

RESUMEN

La comunidad académica ha incrementado significativamente los estudios sobre metodologías activas, como el Aprendizaje Basado en Problemas (ABP), que se aplica en la enseñanza presencial y a distancia. En respuesta, esta investigación tuvo como objetivo desarrollar un marco participativo para el uso del ABP en la educación a distancia e híbrida (EDH) de manera sistemática y formalizada. El estudio consistió en dos etapas: primero, una revisión sistemática de la literatura para entender cómo se aplica el ABP en la EDH, los entornos virtuales de aprendizaje (EVA) y las herramientas

utilizadas. La revisión reveló que la mayoría de las investigaciones y experiencias sobre ABP no están integradas con un EVA, y hay pocas iniciativas específicas para planificar, ejecutar y evaluar el ABP. En la segunda etapa, los investigadores realizaron talleres, grupos focales y pruebas de concepto para identificar los requisitos para desarrollar el marco propuesto en los EVA de Moodle y Google Classroom. El marco tiene como objetivo guiar a los docentes y tutores en la EDH a través de una secuencia lógica de actividades y herramientas para aplicar el ABP. La propuesta ayuda a los docentes a abordar los desafíos de la práctica pedagógica y contribuye a una aplicación más sistemática y formalizada de la metodología. Por lo tanto, esta investigación presenta una contribución significativa al campo de la EDH, proporcionando un marco para aplicar el ABP que se puede adaptar a diferentes contextos de enseñanza y aprendizaje. La investigación futura podría centrarse en desarrollar una interfaz de programación de aplicaciones (API) para integrar el marco con los EVA, incorporando herramientas y recursos externos necesarios para la metodología, produciendo un tutorial interactivo para aplicar el método e investigando diferentes herramientas colaborativas para apoyar las actividades grupales.

Palabras clave: Educación a Distancia; Educación Híbrida; Aprendizaje Basado en Problemas; Framework.

1. Introduction

Over the centuries, education has undergone transformations stemming from various factors, among them the evolution of Information and Communication Technologies (ICT). In this context, it is crucial to understand that the changes in contemporary society due to the evolution of ICT have led to the emergence of a new student profile. Today, we must envision a student who acts in an active, collaborative, and autonomous manner, characteristics that should be considered when thinking about didactic-pedagogical strategies that are consistent with these new times (Belloni, 2002). On the teacher's side, Grossi and Vital (2022) discuss the competencies necessary for the pedagogical practice of teachers working in distance education, highlighting the need for pedagogical changes driven by digital technologies in education.

Traditional teaching, which is essentially face-to-face, was strongly impacted between the years 2020 and 2022 by the COVID-19[4] epidemic. Shaken by this global health crisis, the country's education system had to rethink many of its methodologies and pedagogical practices, which had long been in need of reformulation and updating. What was once done in classrooms, laboratories, or open fields began to take place on virtual platforms, revealing the fragility of educational and academic institutions in terms of their technological capabilities, including the inexperience of a significant number of teachers, technicians, and administrators in dealing not only with the new educational context but also with the tools required for its implementation (Moran, 1999).

4. COVID-19 is an acute respiratory infection caused by the coronavirus, SARS-CoV-2, which is potentially severe, highly transmissible, and globally distributed.

Previously face-to-face classes began to be conducted remotely, revealing the lack of adequate equipment, internet access, knowledge of how to use these tools, and familiarity with Virtual Learning Environments (VLEs) among many students, as well as the lack of proficiency in this technological realm among many teachers. Other methodologies had to be developed, and old ones needed to be adapted and restructured. Contrary to this process, which was not necessarily negative, as it exposed weaknesses that needed to be addressed, the creativity of many teachers became evident, as well as an increased appreciation for Distance Education (DE) and hybrid learning tools and methodologies.

According to Valente (2014), the democratization of the internet allowed for the expansion of various teaching modalities: face-to-face, distance, and hybrid, making it urgent to update educational processes. This scenario promotes the application of methodologies that, among other challenges, break the paradigm of the teacher as the main protagonist in the educational process. According to Bacich and Moran (2018), active methodologies are teaching strategies centered on the effective participation of students in the construction of the learning process. These same researchers also state that individuals learn actively based on the context in which they live — a pedagogical concept that encourages the constructive processes of action-reflection-action. Examples of active methodologies include the Flipped Classroom, Group Works, Problem-Based and Project-Based Learning, Peer Instruction etc.

We focus our efforts on discussing Problem-Based Learning (PBL). According to Souza Rabelo *et al*. (2018), this methodology has been increasingly used in the teaching-learning process as it is based on the principle of using real-world problems with strong practical motivation and cognitive stimulation to generate creative solutions. The PBL methodology tends to prioritize students' prior knowledge, encouraging an investigative learning environment through the construction of hypotheses and experimentation.

Based on our research, throughout this study we anticipate that the literature covers many successful experiences in applying the PBL methodology in face-to-face settings. Models such as those proposed by Harold Barrows and Robyn Tamblyn (1980) and the Maastricht University model (Moust; Berkel; Schmidt, 2005) are presented as references for the application of this methodology in face-to-face learning. Barrows' model consists of nine stages and involves everything from the planning phase to the evaluation phase. Originally created for the medical field, this model has been adapted for various disciplines. According to the authors Moust, Berkel, and Schmidt (2005), the Maastricht University model for using the PBL methodology is composed of seven stages. Used by all courses at Maastricht University, it has become the standard in all Dutch higher education institutions and some foreign universities.

Research also indicated that the application of the PBL methodology does not follow a static model, especially since its initial use was in the medical field and it is now implemented in various areas of knowledge, such as engineering, social sciences, and exact sciences, among others (Ribeiro, 2005). A systematic literature review conducted as part of the methodological framework of this research allowed us to identify that, even though there are significant studies on the application of PBL, there is still a lack of a systematic use of a conceptual model that addresses all phases of the methodology,

as well as the application of this model in distance and hybrid education (Alves *et al*., 2020).

In the first instance, from the initial readings and based on what we previously discussed, we were led to understand that there is still a gap in research and experiments capable of recommending a specific PBL model for application in distance education or hybrid courses, and consequently a gap in how these models can be mediated by Virtual Learning Environments (VLE). In the second instance, we could not ignore our perception and experience as teachers and administrators of a higher education institution when experimenting with the PBL methodology in distance education courses, as well as with tools that could motivate and support this methodological practice.

The objective of this research was to investigate and propose a framework for the use of the PBL methodology with adequate support for its application in distance and hybrid education. As a methodological framework, the research stages included: surveying the state of the art of PBL methodology application in distance and hybrid courses; conducting an empirical study for the participatory construction of a PBL application framework in distance and hybrid courses; validating the framework in two distance or hybrid courses at a higher education institution that uses the Moodle VLE and Google Classroom VLE.

1.1. Theoretical Framework on Problem-Based Learning

According to Barrows (2001, as cited in Rodrigues, 2018), there are ten aspects that must be considered in the relationship between the student and their learning process in PBL: student autonomy, problem structuring, the learning process must be contextualized to the disciplines, cooperative and collaborative interaction, understanding the problem, analyzing problem-solving and concepts, cyclical evaluations, real problems, assessments should measure whether learning objectives have been achieved, and PBL as part of the overall curriculum. Hung (2009) proposes nine stages for the application of PBL, following Barrows' guidelines: defining the goals and objectives of the problem, content analysis, context specification, problem presentation, problem analysis, analysis of the relationship between the problem and the student's cognitive skills, conducting the adaptation process, constructing reflection components, and evaluating the relationships.

The first stage of the model consists of defining the learning objectives of the problem, which include domain knowledge, problem-solving skills, and self-directed learning skills. It is important for students to solve the proposed problems, generating hypotheses and possible solutions, and reflect on the learning process. At this stage, it is recommended that teachers or tutors follow the students' work. The content analysis stage aims to understand the concepts and principles of the problem, as well as mastering basic information. The third stage is crucial for the student to identify the factors that influenced the research. The analysis and specification of the real context is one of the essential activities in the PBL process.

The fourth stage involves selecting the problems to be worked on by each group. It is important for students to generate a list of problems to select those that will be used. In the fifth stage, which involves conducting the problem analysis, a complete description of the problem is made, including

understanding the problem, the problem-solving process, the context, and the interconnection of identified concepts. In the sixth stage, it is crucial to select a problem that is appropriate for the students' cognitive abilities. The problem should not be undersized, as this will not provide enough content to achieve the learning objectives or promote problem-solving skills. Conversely, oversized problems tend to overwhelm and frustrate students, as well as divert them from the intended content. Therefore, a balance between content and student skills must be found to ensure the efficient application of PBL.

The seventh stage consists of the adaptation process between the selected/proposed problem and the students' cognitive abilities, if necessary. For this, it is essential to review four components: content, context, research, and reasoning, to ensure that the problem is suitable for the students' abilities. The goal is to achieve a desired balance between content and student skills. The final stage involves evaluating all the elements involved in the learning process. Although there is a proposal for cyclical evaluation, it is essential to synthesize the process at the end.

2. Methodology

This study, both basic and applied in nature, was constructed in two stages. The first stage focused on a systematic literature review, aiming to consolidate our conceptual perspective by using already established studies. In the second stage, we involved voluntary teachers in workshops, focus groups, and proof of concept sessions, with the goal of developing the framework in a participatory and interactive manner. In subsection 2.1, we detail all the procedures related to the framework's construction, as well as the explanation of each activity that composes it.

The Systematic Literature Review (SLR) aimed to investigate the state of the art in applying the active methodology of Problem-Based Learning (PBL) in distance and hybrid courses, as well as to identify which tool supports are used for the application of this methodology. To achieve this, the following research questions were formulated: (Q1) How can the three main phases of the active PBL methodology (planning, execution/application, and evaluation) be applied in distance and hybrid education? (Q2) Which Virtual Learning Environments support the application of PBL in distance and hybrid education? (Q3) In studies that use Moodle as a platform for applying PBL in distance and hybrid education, which tools or plugins provide support? (Q4) What are the main positive impacts of applying the PBL methodology in distance and hybrid education?

The SLR confirmed that PBL has been used in teaching and learning processes beyond the face-to-face modality. In analyzing the 77 studies that employed PBL in distance or hybrid education, approximately 75% of them described experiences or research that utilized PBL without linking it to a Virtual Learning Environment (VLE) or a specific PBL tool. In the analyzed studies, the authors used synchronous and asynchronous messaging tools, social networks, collaborative cloud-based document editing tools, programming tools, and educational games. One hypothesis raised to explain the large number of studies that used external tools, not integrated into the VLE, for conducting PBL in Distance or Hybrid Education is the limited availability of tools that promote

group and collaborative work in the analyzed VLEs, a characteristic essential for the application of the PBL methodology.

In the literature, there are few initiatives for external tools or those integrated into VLEs that are appropriate and specific for planning, executing, or evaluating PBL in distance or hybrid courses. This research sought to access VLEs specifically designed for Problem-Based Learning, such as WoBaLearn, Toth, PBL-Coach, and PBLMaestro, as well as Moodle VLE plugins like DBDesign, ePBL, and NUCLEO, all cited in the SLR. However, none were available for public download, which demonstrates that the scientific research that developed some technological artifact to support PBL in distance and hybrid education remains unavailable to the players involved in the teaching-learning process. The SLR was published in <omitted for review>, so this article will primarily focus on the methodology employed in the framework's development based on workshops, focus groups, and proof of concept sessions.

2.1. Workshops and focus groups for participatory and interactive development of the framework

In this work, four workshops were held with the objective of contributing to the participatory construction of the framework for the application of PBL in distance and hybrid courses, based on Barrows' theoretical framework. Two workshops focused on the application of PBL in the Moodle VLE, while the other two were dedicated to Google Classroom. The workshops were attended by professors from the distance learning degree program in Languages and professors from technology courses in the computing area at the Federal Institute of Paraíba (IFPB), who had experience with the respective VLE being focused on in the workshop.

The workshops were conducted online, using a web conferencing tool and at least one collaborative text editing tool, due to the restrictions on face-to-face academic activities imposed by the COVID-19 pandemic at IFPB in 2022. The workshops followed a PBL approach with two main objectives. The first involved the discussion and construction of propositions related to the stages of planning, execution, and evaluation of a problem based on Barrows' PBL model in distance or hybrid courses. The second objective was to propose tools from the Moodle or Google Classroom VLEs, as well as external tools, recommended for the stages of the theoretical PBL framework used. To collect data on the research object, the focus group technique was used. The data resulting from these discussions were qualitatively analyzed using WebQDA software, allowing the researcher to obtain information about the research object based on real experiences.

To select the participants, two invitations were created in Google Forms: one for the PBL workshop using Moodle and another for the PBL workshop using Google Classroom. The responses to the invitations were tabulated, and four groups were organized: two for PBL using Moodle and two for PBL using Google Classroom, with an expected six participants in each workshop. The workshops planned for Moodle took place on 04/20/2022, one in the morning and another in the afternoon, and the Classroom workshops took place on 04/22/2022, one in the morning and another in the afternoon.

We conducted four online workshops, each lasting two hours, with an expected six participants in each; however, the absence of six participants led to a lower actual number of participants. In the PBL workshop using Moodle, we had six participants in the morning and four in the afternoon. In the PBL workshop using Google Classroom, we had five participants in the morning and three in the afternoon. The workshops were conducted using the web conferencing tools Google Meet and the collaborative text editing tool Google Docs. After analyzing the PBL methodology workshops using Google Classroom, we felt the need to gather more data and held an additional workshop with three participants on 06/02/2022. The workshops aimed to raise participants' awareness of the PBL methodology and its use as a pedagogical practice. They were divided into three stages: 15 minutes for presenting the workshop objectives, requesting authorization for recording, and explaining the workshop's operationalization, 1 hour and 30 minutes for carrying out the workshop activities and presenting the results, and 15 minutes for conducting the focus group.

In the first stage, we opened a room in Google Meet, requested permission for recording, and presented the basic concepts of active methodology, PBL, and Barrows' model, using discursive dialogue and a PowerPoint presentation. Next, we divided the class into two groups to carry out two activities: the first consisted of simulating the application of the methodology based on the participants' experience and the concepts explained; the second activity involved identifying the use of tools within the VLEs (Moodle and Classroom) or external to them for applying the methodology. To record the activities, we used the Google Docs editing and sharing service. After completing the activities, the participants returned to the main Google Meet room to present their results. Then, we conducted interviews with the participants using the focus group technique, and the interviews were also recorded.

In the first workshop activity, participants were invited to describe how they could apply the PBL method in a real context, using seven items, such as learning objectives and problems, necessary content to solve the problem, context and factors that influence the resolution, presentation of proposed solutions, adaptation of the student's cognitive domain, and evaluation method. In the second activity, the participants explored the possibility of using the PBL methodology in the virtual learning environments (VLEs), identifying the tools available at each stage of the methodology and, when necessary, external tools. Six questions were answered to assist in identifying the available tools, including tools for specifying problem planning, conducting and managing group work, supporting group work, publishing results, providing feedback and reflection by the groups, presenting results, and the teacher's cognitive path for using the PBL method in the VLE.

The reflection phase of the workshop included context analysis, activity recording, and the focus group technique for discussion and suggestions for improvements. The data collected included recordings, documents, narratives, and informal observations. The document analysis was guided by three key questions: the steps necessary to apply the PBL methodology in VLEs, teaching practices associated with VLEs, and teaching practices associated with external tools. For the first question, it was possible to create a draft outline for applying the methodology. The second question explored the possibilities of using the tools to apply PBL and identified existing limitations. The third question aimed to determine whether external tools to VLEs were needed for the collaborative activity

within the PBL methodology.

The document presented by each group was analyzed, and its information was synthesized and organized to allow for comparison between the different groups in their use of the PBL method, as well as to identify which VLE tools could be used at each stage of the process, including planning, execution, and evaluation of PBL. Figure 1 represents the summaries of the responses by the workgroups that used the Moodle virtual learning environment (VLE) in their courses. Due to the participation of six teachers in the morning group, the facilitator chose to divide them into two subgroups.

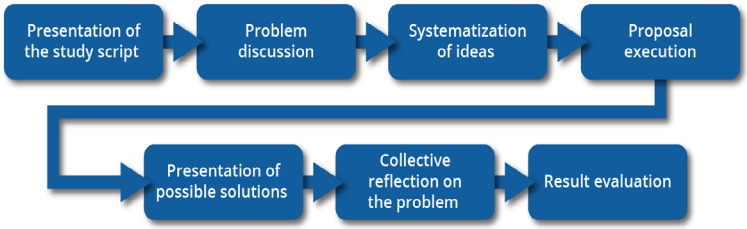
Figure 1. Summary of the responses by the workgroups that use the Moodle VLE

Group	Stages	Moodle tools	External tools
Group 01 - Morning	Planning	URL, page, video	
	Execution	Forum, pages, message box	Google Meet, drive, Flipgrid
	Evaluation	URL	Google Meet, drive, Flipgrid

Application path:

Group	Stages	Moodle tools	External tools
Group 02 - Morning	Planning	Label, pages, videos	
	Execution	Forum, URL	Google Meet, Jamboard, Google Docs, Padlet, social networks
	Evaluation	Forum, URL	Google Meet, Mentimete or Pollev, social networks

Application path:



Group	Stages	Moodle tools	External tools
Group 01 - Afternoon	Planning	File, book	
	Execution	Forum, chats, BigBlue, task	Google docs, blog
	Evaluation	Forum, BigBlue	Google meet, blog

Application path:

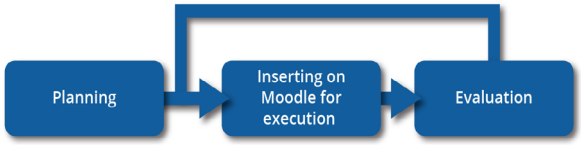


Figure 2 presents the summaries of the responses from the workgroups that used the Google Classroom VLE in their courses. The analyses of the three groups of teachers participating in the workshops, identified as Morning Group, Afternoon Group, and Evening Group, are presented.

Figure 2. Summary of the responses by the workgroups that use the Google Classroom VLE

Group	Stages	Classroom tools	External tools
Morning Group	Planning	Page items, file, video	Google Docs
	Execution	Activities, chat, questionnaires, and forms	
	Evaluation	Link, videos	Podcasts

Application path:

Planning → Execution → Evaluation

Group	Stages	Classroom tools	External tools
Afternoon Group	Planning	File, video, links	Google Docs
	Execution	Board, calendar, videos	WhatsApp, Google Meet, social networks (Facebook, Instagram)
	Evaluation	Link, videos	Youtube, social networks (Facebook, Instagram)

Application path:

Making the instruction plan available → Item creation → making the material available in the item → creation of the the schedule in Google Calendar → Creation of board on Google Classroom → Making the link available to the group → Evaluation of the produced materials

Group	Stages	Classroom tools	External tools
Evening Group	Planning	Board, Google Forms for diagnostic evaluation	Canvas
	Execution	Board, synchronous meeting, Google, Google Forms, Items	
	Evaluation	Posting an image, videos, student self-evaluation activity, and evaluation of the classroom	

Application path:

The same path proposed by Barrows was used

The qualitative analysis of the workshop involved transcribing the focus group interviews, recording participant observations during the workshops, and analyzing the generated documents. These data provided a large volume of information, which was used to analyze participants' perceptions of the PBL methodology after the workshop. The compiled codes were associated with the previously listed questions, considering participants' prior experience, acquired knowledge, and motivation to use the methodology in pedagogical practice.

The transcripts presented in Tables 1 and 2 were of the non-naturalistic/selective type (Azevedo, 2017), meaning that occurrences irrelevant to the interlocutor's context and idiosyncratic elements of the discourse were omitted. We sought information more closely related to specific questions; therefore, irrelevant information was not considered. This method allowed us to obtain a more precise analysis of the data and draw relevant conclusions about participants' perceptions of the PBL methodology. Due to space constraints in the article, Table 1 presents only a portion of the focus group transcripts from the workshops with teachers using the Moodle VLE.

Table 1. Excerpts from the focus group transcripts of teachers using Moodle

SOURCE	EXCERPTS
Interviewee: Professor A PBL used: *Moodle*	"The use of active methodologies is not as new as it seems, and more up-to-date teachers end up using some form of them, even if they do not follow all the steps. From this, the teacher perceives the difficulties and plans and replans activities in a way that can impact the student in the learning process. This methodology fits very well in the virtual environment, and at our institution, we already have an instructional design for it. It is much easier for the teacher to monitor in the virtual environment, where this planning is already systematized, compared to the face-to-face setting, which is developed at the beginning of the year."
Interviewee: Professor B PBL used: *Moodle*	"My perception confirms a bit of what I already know and apply. It is worth noting that the application of this method can be easier depending on the students' academic level. They tend to be shocked when they have three consecutive classes with problems to resolve. From what I can interpret, content exposure is still very present at the higher education level, and when teachers apply practical issues, there is a shock in the class regarding the completion and understanding of the activity. Immediately, you hear very colloquial phrases like 'it's very difficult,' 'I won't make it,' and 'there won't be enough time.' These are the three most repeated phrases by my students when applying PBL."
Interviewee: Professor C PBL used: *Moodle*	"From my side, what is very clear to me is the difficulty I sometimes personally feel in this planning, because it seems like we have the necessary knowledge... but when faced with planning, step by step, I still feel a bit of difficulty in defining each part of this process, and the workshop contributed to this need to study more and stick to planning."
Interviewee: Professor D PBL used: *Moodle*	"For me, I think this presentation made the application of the methodology clearer. It helped me understand how, as a teacher, I can follow the steps for planning, how I should plan, and which skills to select when outlining the activity proposal."
Interviewee: Professor A PBL used: *Moodle*	"I think it would be better to have a more efficient synchronous interaction option, such as Big Blue (slides, recording), and it would be important to improve sharing tools."
Interviewee: Professor E PBL used: *Moodle*	"For me, the difficulty in implementing the methodology is interaction."
Interviewee: Professor C PBL used: *Moodle*	"Improvement in synchronous video lessons and document sharing."

Interviewee: Professor A PBL used: *Moodle*	"I feel very motivated; we end up incorporating this presented path" "... We use email, WhatsApp to improve the tool for managing collaborative activities."
Interviewee: Professor F PBL used: *Moodle*	"From my side, I feel motivated; now my concern is to sit down and improve the instructional plan and try to apply the methodology in the next classes."

Source: The authors.

Table 2 presents excerpts from the focus group transcripts of the workshops with teachers using the Google Classroom VLE.

Table 2. Excerpts from the focus group transcripts of teachers using Google Classroom

SOURCE	EXCERPTS
Interviewee: Professor C VLE used: Classroom	"My perception has changed. Before, when I heard about active methodologies, I thought it was something very complex to apply in the classroom. This workshop managed to demystify that view I had. Now, I can see it as something feasible to apply."
Interviewee: Professor A VLE used: Classroom	"There is a possibility of execution, I think, of course, when we are not specialized in the area we need to deepen the theory, but certainly, the workshop helped to demystify."
Interviewee: Professor B VLE used: Classroom	"I also feel more confident to try applying the PBL methodology. I was already trying, but not with such confidence because I didn't know the sequence of steps. I really wanted to apply the methodology, but was afraid of doing it wrong. Now, I feel that it is possible to apply this methodology correctly."
Interviewee: Professor B VLE used: Classroom	"Just using Classroom is not enough; we need to use other Google resources that are outside of Classroom. It is quite limited compared to Moodle; we noticedthat there are many limitations."
Interviewee: Professor D VLE used: Classroom	"Google suite is complete and offers various tools for teachers to use in teaching, such as Google Forms for presentations and activities, Jamboard for online interaction, and Google Meet. What's important is for the teacher to know how to use the tools to achieve the teaching objectives."
Interviewee: Professor E VLE used: Classroom	"The perception is that it naturally reflects on the students' needs a lot... using a problem to engage the student."
Interviewee: Professor C VLE used: Classroom	"I feel motivated, even more so now. I was quite excited about this issue of solving problems."
Interviewee: Professor F VLE used: Classroom	"I feel motivated to apply the methodology initially in smaller classes where I have a better understanding of who is participating and know the class."
Interviewee: Professor A VLE used: Classroom	"Yes, definitely motivated. I think that currently in teaching, we need to be concerned with moving away from the monotony in education... teachers' restlessness is about trying to improve teaching practice."

Source: The authors.

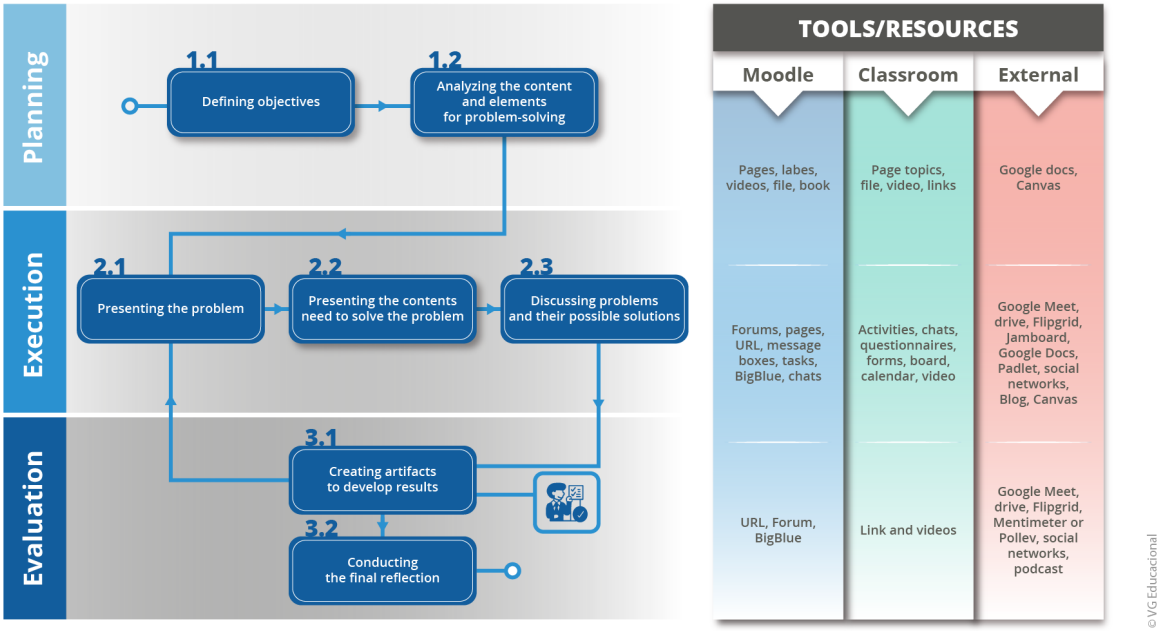
3. Results, Validation, and Discussion

During the workshop, we collaboratively built a framework for the application of PBL through an iterative and incremental process. In the analysis of the documents produced in the workshops, we identified the path for applying the PBL methodology using the Moodle VLE and Google Classroom VLE, in addition to other tools. Analyzing the different workflows presented by the groups, we focused on the common stages and identified tool limitations of the VLEs and external tools, such as group management, parallel meetings, and the creation of shared documents. Based on this analysis, we developed the framework for applying PBL proposed in this work, presented in Figure 3.

The proposed framework for applying the PBL methodology is composed of three phases: Planning, Execution, and Evaluation. In the Planning phase, the instructor/trainer must define the objective of the activity in step 1.1 and identify possible connections between the content and the proposed problems in step 1.2, considering aspects such as the environment and the methodology to be used. The Execution phase consists of three steps: in steps 2.1 and 2.2, the instructor/trainer will present the problems and supporting materials related to the course content to the created groups. In step 2.3, students begin to analyze the problem and formulate hypotheses and solutions, either on their own initiative or through prompting by the instructor/trainer.

The Evaluation phase consists of two steps: in step 3.1, the instructor/trainer should propose self-reflection activities to analyze the individual or collective performance of the participants, including interaction between the groups and sharing suggestions. The students should also create artifacts with the proposed solutions, which will be reviewed by the instructor/trainer. In step 3.2, a general evaluation of the learning process, the proposed solution, and the adopted methodology will be conducted through a presentation with the input of all participants.

Figure 3. Framework for the application of PBL



3.1. Validation of the Framework through Proofs of Concept

According to Silva (2014), there are four distinct situations in which Proof of Concept can be used: 1) when the scope of the research object is not well defined; 2) when there is no prior experience regarding the feasibility of the proposed research object; 3) when the requirements of the researched object are complex; and 4) when there is a high risk that the research will yield unfeasible results. One of the advantages of using Proof of Concept is the ability to avoid abstract perceptions regarding the feasibility of the researched object. Although it is a simple technique, it is necessary that the objectives, instruments, duration, execution criteria, tasks, and result analysis are clearly defined for the technique to be effectively applied.

In this work, Proof of Concept was chosen due to two situations mentioned by Silva (2014): the lack of prior experience with the proposed research object and the complexity of the proposal, evidenced by the systematic review presented. The objective was to validate the feasibility of using the proposed framework through the teacher's perception at the end of the application. To this end, the framework was instantiated in two cases: the first case using Google Classroom and the second case using Moodle. In both cases, after the framework was used by the teachers, both groups were interviewed from the perspective of four questions: (1) Was there any difficulty in operationalizing some of the phases? (2) Besides the tools proposed in the framework, were other tools used? (3) Was there any resistance from the students in implementing the methodology? (4) Which positive and negative factors were identified during the process? Chart 1 presents the planning of the teacher applying the PBL methodology using Google Classroom in a distance learning class on Human-Computer Interaction. The teacher gathered the class synchronously to use the framework, although the class could have been conducted asynchronously.

Chart 1. Planning for the instantiation of the framework in a Human-Computer Interaction course

Activity objective This activity aims to have students practice the concepts learned about conventions and visual hierarchy, web navigation, and interaction styles. The activity should be developed in teams of four or five students using the specification and the steps described below. To optimize time, the teams will be formed by the teacher and listed in the Google Meet chat. This specific activity, which contains two problems, will be carried out synchronously, with support from the teacher and peers as needed. Execution Problem 1: Analyze the Armazém Paraíba e-commerce system https://www.armazempb.com.br/ by identifying the basic navigation conventions (system ID or logo, services, search, main sections, and breadcrumbs). **45 minutes** Steps: 1. Review the Google Slide on the topic "Interfaces" available in Google Classroom. (10 min) 2. Meet using a specific Google Meet room to analyze the Armazém Paraíba e-commerce system. (5 min) 3. Discuss the problem's requirements and respond in a collaborative Google Docs document. (15 min) 4. Review the team's response to the problem and post it in the Google Classroom activity. (5 min)

5. Present to the class in the general Google Meet session. (1 min)

Problem 2: Analyze the subscription functionality in the web streaming systems Netflix, Globoplay, and Disney+. Compare this functionality among the systems regarding the user's cognitive effort to complete the subscription process. Consider interaction design conventions, titles texts, labels, and paragraphs in general (clarity, size), and the areas (sections) of the pages related to the functionality in question. **30 minutos**

1. Meet using a specific Google Meet room to analyze the subscription functionalities of Netflix, Globoplay, and Disney+ with the problem's requirements in mind. (5 min)
2. Discuss the problem's requirements and respond in a collaborative Google Docs document. (15 min)
3. Review the team's response to the problem and post it in the Google Classroom activity. (5 min)
4. Present to the class in the general Google Meet session. (1 min)

Reflection ** 10 minutos **

1. All students must post on a Padlet[5] board (https://padlet.com/petronio3/hw8bmm80lugnd2o1) about what they learned from the activity and what was the biggest challenge in solving the proposed problems in groups and online.

It was possible to identify that all phases and stages of the framework were used by the teachers in the presented planning, as well as the suggested tools and resources. In the interviews, the teachers highlighted the importance of these stages as a relevant instrument for applying the methodology, promoting an approach that involves planning, execution, and evaluation in an activity, completing the learning cycle. In the first proof of concept, whose planning was presented in Chart 1, the three macro phases (planning, execution, and evaluation) were clearly identified. After defining the objectives and content to be covered, as well as dividing the groups, the teacher presented the problem, reviewed the subject, discussed possible solutions with the groups, and concluded the activity with the evaluation of the documents prepared by the groups and a final reflection, recorded on a virtual board. It is important to note that this activity, conducted in Google Classroom, was one of the course assessments and was graded, with 87% of students achieving the highest grade.

The second proof of concept involved an instantiation of the framework in the "Basic Psychological Processes" course of the Distance Undergraduate Degree in Languages. Despite the simpler planning, the framework's stages were also followed, but with the use of few tools from the VLE and no external tools. Based on the results obtained from the proof of concept, it was possible to affirm that the proposed framework is suitable for applying the PBL methodology in distance education courses, meeting the specific objectives of this work by demonstrating that the VLEs Google Classroom and Moodle support the application of the PBL methodology and showing the positive impacts of its application.

5. Online tool that allows the creation of a dynamic and interactive virtual board or wall to record, store, and share content.

4. Conclusion

The approach proposed in this work aims to offer a structured and formalized tool for applying the PBL methodology in Moodle and Classroom VLEs, addressing a gap identified in the SLR. This work provides a significant contribution to the educational field by offering an effective tool for applying the PBL methodology. The SLR conducted revealed that PBL methodology is applied in various ways, with mixed or summarized models supported by computational tools, whether integrated into a virtual learning environment or not. Moodle is one of the most widely used VLEs, which motivated the continued validation of the framework for this environment, along with Google Classroom. The use of workshops and focus groups was crucial for a participatory construction of the framework, and the perceptions of participating teachers guided the entire process. It was possible to propose the use of only 7 steps for applying the framework, instead of the 9 steps defined by Barrows. The proposed validation method demonstrated that the constructed framework is likely to be usable and produce positive results.

For further works, we suggest creating an API to integrate the framework into VLEs, incorporating external tools necessary for applying the methodology, producing an interactive tutorial for methodology application, and investigating different collaborative tools to support group activities. These improvements could further enhance the application of the PBL methodology in Moodle and Classroom VLEs.

REFERENCES

ALVES, M.; MEDEIROS, F. P. A.; MELO, L. B. Levantamento do estado da arte sobre aprendizagem baseada em problemas na educação a distância e híbrida. In: SIMPÓSIO BRASILEIRO DE INFORMÁTICA NA EDUCAÇÃO, 31, 2020, Natal. **Anais** [...]. Natal, 2020.

BACICH, L.; MORAN, J. **Metodologias ativas para uma educação inovadora**: uma abordagem teórico-prática. Porto Alegre: Penso Editora, 2018.

BARROWS, H. S.; TAMBLYN, R. M. **Problem-based learning**: an approach to medical education. Vol. 1. Nova Iorque: Springer Publishing Company, 1980.

BELLONI, M. L. Ensaio sobre a educação a distância no Brasil. **Educação & Sociedade**, Campinas, v. 23, n. 80, p. 117-142, 2002.

GROSSI, M. G. R.; VITAL, F. H. As pesquisas brasileiras e as competências necessárias à prática pedagógica de professores que atuam na EaD. **Revista Brasileira de Aprendizagem Aberta e a Distância**, v. 21, n. 1, 2022.

HUNG, W. The 9-step problem design process for problem-based learning: application of the 3C3R model. **Educational Research Review**, v. 4, n. 2, p. 118-141, 2009.

MORAN, J. M. **O uso das novas tecnologias da informação e da comunicação na EAD** — uma leitura crítica dos meios. Belo Horizonte: COPEAD/SEED/MEC. 1999. Palestra proferida pelo Professor José Manuel Moran no evento "Programa TV Escola-Capacitação de Gerentes".

MOUST, J. H. C.; BERKEL, H. J. M. V.; SCHMIDT, H. G. Signs of erosion: reflections on three decades of problem-based learning at Maastricht University. **Higher education**, v. 50, n. 4, p. 665-683, 2005.

SOUZA RABELO, S. D.; BURLAMAQUI, A.; RABELO, H.; VALENTIM, R.; RABELO, D. A.; SILAS, D. Desenvolvimento de Sistemas Computacionais Utilizando Aprendizagem Baseada em Problemas. *In*: BRAZILIAN SYMPOSIUM ON COMPUTERS IN EDUCATION (Simpósio Brasileiro de Informática na Educação — SBIE), 29, 2018, Fortaleza. **Anais** [...]. Fortaleza, 2018.

RIBEIRO, E. N.; MENDONÇA, G. A. de A.; MENDONÇA, A. F. A importância dos ambientes virtuais de aprendizagem na busca de novos domínios da EAD. In: CONGRESSO INTERNACIONAL DE EDUCAÇÃO A DIST NCIA, 13, 2007, Curitiba. **Anais** [...]. Curitiba, 2007.

RODRIGUES, A. N. **Um framework conceitual para implementação e gestão da abordagem PBL no ensino de Computação**. 2018. 218 f. Tese (Doutorado em Ciência da Computação) — Universidade Federal de Pernambuco, Recife, 2018.

VALENTE, J. A. A comunicação e a educação baseada no uso das tecnologias digitais de informação e comunicação. **UNIFESO - Humanas e Sociais**, v. 1, n. 01, p. 141-166, 2014.