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PROBLEM-BASED LEARNING AND 21ST CENTURY SKILLS: A SYSTEMATIC REVIEW[1]

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ABSTRACT: A systematic literature review was conducted in the Theses and Dissertations Database of the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES), covering a period of ten years, from January 2012 to December 2021. The aim was to characterize studies that, through the active methodology of Problem-Based Learning, identified and researched the dimensions and subdimensions of the skills: Creativity, Critical Thinking, Collaboration, and Communication, which are referred to in this article as 21st Century Skills. A total of four studies were found that investigated one or more of the 21st Century Skills. The results indicated that Collaboration was the most frequently addressed skill over this period, and produced indicators justifying the skills during the research stages. Thus, for instance, creativity and critical thinking thrive with authentic and multifaceted problems, collaboration emerges when students are encouraged to explore joint solutions, and communication becomes effective when presenting solutions to complex problems.

Keywords: problem-based learning, creativity, criticality, collaboration, communication.

APRENDIZAJE BASADO EN PROBLEMAS Y HABILIDADES DEL SIGLO XXI: UNA REVISIÓN SISTEMÁTICA

RESUMEN: Una revisión sistemática de literatura se realizó en la Base de Tesis y Disertaciones de la Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) y se restringió a un período de diez años, comprendido entre enero de 2012 y diciembre de 2021. Su propósito fue caracterizar a los estudios que, a través de la metodología activa *Problem-Based Learning*, identificaron

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y investigaron las dimensiones y subdimensiones de las habilidades: Creatividad, Criticidad, Colaboración y Comunicación, las que se han identificado en este estudio como Habilidades del Siglo XXI. Al todo, se han encontrado cuatro estudios que investigaron una o más Habilidades del Siglo XXI. Los resultados señalaron la Colaboración como la que más se abordó a lo largo de ese período, además de que se produjeron indicadores que justificaban a las habilidades durante las etapas de las investigaciones. De esa forma, por ejemplo, la creatividad y la criticidad se desarrollan con problemas auténticos y multifacéticos, la colaboración viene a la luz cuando a los estudiantes se les estimulan a explorar soluciones conjuntas y la comunicación se vuelve eficaz cuando se presentan soluciones para problemas complejos.

Palabras clave: aprendizaje basado en problemas, creatividad, criticidad, colaboración, comunicación.

INTRODUCTION

Learning in the 21st century has increasingly become student-centered, aiming to develop cognitive and socio-emotional skills that are relevant for a constantly evolving world. In this context, Problem-Based Learning (PBL) emerges as a prominent pedagogical approach. The PBL methodology focuses on solving real-world challenges, encouraging students to investigate, analyze, and solve complex problems collaboratively. This methodology not only promotes content mastery but also enhances critical thinking, creativity, collaboration, and communication skills. By involving students in authentic problems, PBL not only prepares them to meet contemporary demands but also stimulates intrinsic curiosity, autonomy, and lifelong learning.

As highlighted by Hmelo-Silver and De Simone (2013), the goals of PBL include knowledge construction, collaboration, and lifelong learning. The approach not only prepares students to tackle complex challenges but also fosters essential skills for collaborative problem-solving and continuous learning.

In this regard, we hypothesize in this study that investigations aimed at identifying and analyzing the indicators that gave rise to the constructs of the 4C's (Creativity, Critical Thinking, Collaboration, and Communication), which adopted the PBL methodology, have the potential to provide meaningful insights into the incorporation of these competencies in educational environments.

In this scenario, the central research question arises: how are the studies that explored the identification and research of the indicators that resulted in the constructs of the 4C's, which employed the PBL methodological approach, characterized in theses and dissertations indexed in the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES), during the period from January 2012 to December 2021? This question seeks not only to understand the foundations of these skills in the Brazilian academic environment in recent years but also to investigate how the methodological approach has been used to promote the development and/or measurement of these skills in students.

The structure of this article addresses the two fundamental themes in the initial sections: PBL and 21st Century Skills. In the first section, we will explore the active nature of PBL, involving students in solving real-world problems, aligned with contemporary demands (Barrows;

Tamblyn, 1980; Lovato; Michelotti; Loreto, 2018). Additionally, we will highlight active learning according to the understanding of Moran (2015), Barbosa and Moura (2013), emphasizing the importance of interpersonal and social competencies. In the second section, we will discuss 21st Century Skills, sometimes driven by information technologies and other times by competencies such as communication and interpretation (Mioto *et al.*, 2019). Grounded in the Partnership for 21st Century Learning, we will address life skills, technological skills, and innovation, including Creativity, Critical Thinking, Communication, and Collaboration (P21, 2015). These interdisciplinary skills are essential for a constantly changing society and are enhanced in modern education (Cevik; Senturk, 2019).

In the third section, we use a qualitative approach through a mixed systematic literature review with qualitative convergence (Galvão; Ricarte, 2019). In this framework, inclusion and exclusion criteria for the texts were analyzed, as well as key search terms and the applied time frame.

In the fourth section, we handle the information using an approach that aligns with the content analysis proposed by Bardin (2020), seeking connections between the texts and the perspective of skills informed by the Partnership for 21st Century Learning. In the final section, we will address the research question, shedding light on the indicators that supported the skills through the analysis of dissertations and theses available on the CAPES platform.

THE ACTIVE METHODOLOGY PROBLEM-BASED LEARNING (PBL)

Discussing the PBL methodology, characterizing it under the aegis of an active methodology, leads us to the need to minimally understand the locus of the active-passive dichotomy. We recognize that this is an initially complex field where both arguments can be supported. Therefore, we will not seek exclusivity in the approach—precisely because we do not believe in mutual exclusion, but rather in possible intersections. However, on the other hand, we believe it is necessary to provide a brief contextualization to ensure the fluidity of the research and to avoid any doubts regarding the positions that will be taken.

Consequently, reflecting on lecture-based or exposition-based classes, commonly characterized as traditional by academia, leads us to consider certain characteristics in the learning process, especially concerning the roles of the student and the teacher. Among these, we will observe the possibility of passive behavior in the student—often associated with the sole role of content recipient—as well as the centrality of the teacher, whether in the transmission of knowledge or as the authorized agent and sole holder of competence, particularly in dimensions that encompass what, how, and at what pace the knowledge/content should be transmitted (Pontes *et al.*, 2022).

As previously mentioned, some researchers, such as Lovato, Michelotti, and Loreto (2018), have addressed the topic of active methodologies, highlighting passivity and its counterpoint in the learning process. Although there is no agreement with respect to the dichotomy of the student's role in lecture-based methodology, as many researchers discuss active engagement while the student participates by attending a lecture, the authors emphasize and base

their arguments on cognitive science studies that point to the need for "something more than simply listening for learning to be effective" (Pontes *et al.*, 2022, p.155, translated by the authors).

Considering also the dimension of meaningful learning, Barbosa and Moura (2013) highlight that students, within this formative process, should perform tasks that go beyond reading, writing, discussing, and problem-solving, also engaging in higher-order tasks such as analysis, synthesis, and evaluation. As a result of this, the characteristic of active learning is grounded in the active attitude of intelligence, whose mental functions can be observed in acts of thinking, reasoning, reflecting, combining, among others.

We will assume, in line with the understanding of these authors and the respective dimensions of their research, that being active requires more than simple presence, listening, and to some extent participation. We align with these viewpoints and would add that the context should not be viewed without considering contemporary elements, such as technology. *Ergo*, we understand that, in addition to the thinking skills that compose this framework, communicative skills and collaborative learning also align within this active and contemporary perspective.

For new educational objectives to be achieved in this information society, one line of thought is characterized by the search for new methodologies that are closely aligned with students' lives, bringing them to the center of the process and making them more proactive, capable of making decisions and evaluating results grounded in critical judgments. In this way, Moran (2015) noted that methodologies coined as active—where the student actively participates in the teaching-learning process—would support "desired competencies, intellectual, emotional, personal, and communicative" and "more advanced processes of reflection, cognitive integration, generalization, and the reworking of new practices" (p. 18, translated by the authors).

Within this amalgam, which seeks a look at new methodologies in contemporary times, is the active methodology PBL. Among several that have emerged over the past decades, this methodology has presented itself as a possibility in the context of what is intended to be achieved—placing the student at the center of the process, providing a bias of self-regulation and self-direction, drawing from problems both in the social and professional fields—and, therefore, will be a focus of the systematic literature review presented throughout this article.

PBL is founded on the premise of investigative learning through real-world problems/situations. As stated by Pontes *et al.* (2022), the involved parties—students and teachers—have well-defined roles in which, through their engagement, they understand, propose, and analyze "clearly defined solutions so that the student acquires the competencies outlined in the school curriculum" (p. 6, translated by the authors). In its implementation, the roles are clearly established. Students work within a structure composed of learning cycles, breaking into groups known as tutorial groups, which are supervised/tutored by the teacher.

Lopes *et al.* (2019) presented in their research a structure, adapted from Hmelo-Silver, which proposes a work configuration organized into cycles. The first cycle focuses on the problematization process (formulation), hypothesis generation, and problem analysis. The second cycle concentrates on individual and self-directed learning initially and later on collaborative learning through discussions with other members. The third and final cycle converges on the application of knowledge, analysis, and conclusion.

Composed of various factors ranging from individual to collective learning, and involving the redefinition of the roles of teachers and students, PBL inherently involves a discussion of a set of elements related to knowledge itself, necessary skills, and imperative attitudes to enhance the method. Among these, we highlight some skills, referred to as 21st Century Skills, which will support the cycles and their effectiveness. These include critical and creative thinking, communication, and collaboration.

TWENTY-FIRST CENTURY SKILLS

Driven by new information and communication technologies (ICTs), the skills and competencies—increasingly present in our knowledge society—are demanding more from individuals and society. The unrestricted presence of the internet and the use of smartphones in our lives has expanded a world of possibilities with more complex and urgent access, requiring a level of technological literacy combined with skills necessary to avoid being overwhelmed by excess innovation.

Mioto *et al.* (2019) advocate for the integration of various elements in our daily lives to fulfill a successful citizenship role. They argue that skills such as good communication practices, interpretation, sharing, and information seeking are currently relevant, even acknowledging that the discussion of these skills—hereafter referred to as "21st Century Skills"—requires a stance with regard to different sources and various skill possibilities, considering the multiplicity of categorizations.

Because of this diversity, the scope of this article's research will focus on skills necessary for learning and innovating in the 21st century, as presented in the model by the Partnership for 21st Century Learning (P21). According to P21 (2015), this framework is a combination of content knowledge, specific skills, expertise, and literacy, thereby describing the skills, knowledge, and experiences that students must master to succeed in life. Supporting this, Cevik and Senturk (2019) affirm the importance of 21st Century Skills and report that these result from combined and synthesized knowledge, and consequently are not limited to isolated skills and knowledge.

The document describes a framework for 21st-century learning, focused on three themes associated with life and career skills, technological and information skills, and learning and innovation skills. The learning and innovation skills, which are the focus of this article, are recognized as those that distinguish students who are prepared for more complex life and work environments. These skills are categorized into: Collaboration (CHART 01), Creativity and Innovation (CHART 02), Critical Thinking and Problem Solving (CHART 03), and Communication (CHART 04).

CHART 01 – Collaboration

Learning and Innovation Skills – Collaboration		
Collaboration	Collaborate with others	Demonstrate the ability to work effectively and respectfully with diverse teams
		Show flexibility and willingness to make necessary concessions to achieve a common goal
		Take shared responsibility for collaborative work and value the individual contributions made by each team member

Source: Partnership for 21st Century Skills (2015).

CHART 02 – Creativity and Innovation

Learning and Innovation Skills – Creativity and Innovation		
Creativity and Innovation	Think creatively	Use a wide range of idea-generation techniques
		Create new and valuable ideas
		Develop, refine, analyze, and evaluate your own ideas to improve and maximize creative efforts
	Work creatively	Develop, implement, and communicate new ideas effectively to others
		Be open and receptive to new and diverse perspectives; incorporate input and feedback from the work group
		Demonstrate originality and inventiveness in work and understand the real-world constraints on the donation of new ideas
		View failure as an opportunity to learn; understand that creativity and innovation are a long-term cyclical process of small successes and frequent errors
	Implement Innovations	Act on creative ideas to make a tangible and useful contribution to the field in which the innovation occurs

Source: *Partnership for 21st Century Skills* (2015).

CHART 03 – Critical Thinking and Problem Solving

Learning and Innovation Skills – Critical Thinking and Problem Solving		
Critical Thinking and Problem Solving	Effective reasoning	Use various types of reasoning (deductive, inductive, systems thinking, etc.)
	Use systems thinking	Analyze how parts of a whole interact with each other to produce overall results in complex systems
	Make judgments and decisions	Effectively analyze and evaluate evidence, arguments, claims, and beliefs
		Analyze and evaluate major alternative points of view
		Synthesize and make connections between information and arguments
		Interpret information and draw conclusions based on the best analysis
		Critically reflect on experiences and learning processes
	Solve problems	Solve different types of unfamiliar problems in conventional and innovative ways
		Identify and ask significant questions that clarify various perspectives and lead to better solutions

Source: *Partnership for 21st Century Skills* (2015).

CHART 04 – Communication

Learning and Innovation Skills – Communication		
Communication	Communicate clearly	Articulate thoughts and ideas effectively using oral, written, and nonverbal communication skills in a variety of forms and contexts
		Listen effectively to decipher meaning, including knowledge, values, attitudes, and intentions
		Use communication for a variety of purposes (e.g., to inform, instruct, motivate, and persuade)
		Utilize multiple media and technologies, and judge their effectiveness in advance, as well as assess their impact
		Communicate effectively in diverse environments (including multilingual settings)

Source: *Partnership for 21st Century Skills* (2015).

LITERATURE REVIEW AND SYSTEMATIC LITERATURE REVIEW

A literature review involves an investigation of academic sources related to a specific topic. This analysis provides an overview of the current state of the subject to be researched, allowing for the identification of relevant theories, methodologies, and gaps in existing research. As a result of this, the literature review is considered essential for writing a scientific text that demonstrates a deep grounding and understanding of the scientific literature.

As mentioned by Mendes and Pereira (2020), cited by Bernardo *et al.* (2023, p. 10, translated by the authors), adopting this method offers numerous benefits. These include a clear and concise presentation of the methodology used in the investigation, an orderly structuring of the steps taken, and the use of well-defined parameters in its construction.

In the view of researchers Galvão and Ricarte (2019), supported by the work of Siddaway, Wood, and Hedges (2019), different typologies can be found for this topic. Among these are classifications such as systematic reviews with meta-analysis, systematic narrative reviews, and systematic reviews with meta-synthesis.

The authors also emphasize the pursuit of a systematic literature review of a mixed nature, capable of recognizing, refining, evaluating, and summarizing qualitative studies, quantitative studies, and mixed-method studies concurrently. Among these approaches is the mixed-method qualitative convergence review, suitable for converting the results of qualitative studies, quantitative studies, and studies using mixed methods into qualitative findings.

Utilizing the general overview previously discussed about the topic and its specifics in the preceding paragraphs, we found, within the scope of theses and dissertations from 2012 to 2021 present in the CAPES thesis and dissertation database, a series of studies on the methodology, albeit with various characteristics. From this point, we will conduct our analysis adhering to a specific type of review which, as outlined by Galvão and Ricarte (2019), requires specific protocols, focusing on reproducibility, search strategy, and selection process, as well as explicitly presenting bibliographic data; in other words, it is a mixed-method systematic literature review of qualitative convergence.

In this context, we face the starting point of the study, for which we undertake the formulation of a research question that encompasses the investigation as well as the relevance of

considering its delimitations. Following Galvão and Ricarte (2019, p. 63, translated by the authors), it is emphasized that to improve the quality of the systematic review, it is crucial to measure the "specification of the population, the problem or condition to be investigated, the type of intervention to be analyzed, whether there will be comparisons between interventions, and the outcome to be studied."

Donato H. and Donato M. (2019) also addressed the topic of question delineation, defining it as crucial and exploring methods that enable this planning. As stated by the researchers, one of the most used methods is centered on the PICO model: Population; Intervention; Comparison; and Outcome. Using this method, we constructed the research question focusing on a population that includes students in the educational system, with the intervention applying the active methodology PBL and the outcome related to the 4C's skills in the learning cycles. Consequently, this is materialized in the following research question: How are the studies that explored the identification and research of the indicators resulting in the constructs of the 4C's skills (Creativity, Critical Thinking, Collaboration, and Communication) characterized, through the analysis of research in theses and dissertations indexed in the CAPES database from 2012 to 2021, which employed the PBL methodological approach?

As an inclusion criterion, theses and dissertations from the CAPES Open Data portal were used—downloaded in Microsoft Excel spreadsheet format—covering the period from January 2012 to December 2021, totaling 785,806 published documents. From this, an initial filtering was performed using the descriptors: PBL, Problem-Based Learning, Problem Based Learning, ABP, *Aprendizagem Baseada em Problema* (which corresponds, in Portuguese, to "Problem-Based Learnin"), *Aprendizagens Baseadas em Problemas* ("Problem-Based Learnings"), *Abordagem Baseada em Problemas* ("Problem-Based Approach"), and *Abordagens Baseadas em Problemas* ("Problem-Based Approaches"). This resulted in a total of 1,309 identified studies. Among this set, 643 were unique. For this strategy, the boolean operator OR *(ou)* was used between the descriptors.

Search 1: PBL OR Problem-Based Learning OR Problem Based Learning OR ABP OR *Aprendizagem Baseada em Problema* (which corresponds, in Portuguese, to "Problem-Based Learnin") OR *Aprendizagens Baseadas em Problemas* ("Problem-Based Learnings") OR *Abordagem Baseada em Problemas* ("Problem-Based Approach") OR *Abordagens Baseadas em Problemas* ("Problem-Based Approaches").

From the 643 studies, those containing acronyms unrelated to the context of our research were removed (first exclusion criterion). In this initial screening, a total of 507 studies were identified as being related to a learning setting involving the methodology.

In the second screening, using these 507 studies, we proceeded to search for the intersection with terms related to the 4C's. So, we excluded (second exclusion criterion) the papers that did not contain the descriptors: Colabora*, Comunica*, Crít*, Crit*, Criat*. This strategy used a combination of the boolean operators AND *(e)* and OR *(ou)*.

Search 2: (PBL OR Problem-Based learning OR Problem Based learning OR ABP OR *Aprendizagem Baseada em Problema* ("Problem-Based Learning", translated from Portuguese) OR *Aprendizagens Baseadas em Problemas* ("Problem-Based Learnings") OR *Abordagem Baseada em*

Problemas ("Problem-Based Approach") OR *Abordagens Baseadas em Problemas* ("Problem-Based Approaches") AND (Colabora* OR Comunica* OR Crít* OR Crit* OR Criat*). In total, 257 studies were found and deemed eligible.

The third and final exclusion criterion for the 257 eligible studies focused on excluding those that either did not provide access to or did not address indicators related to the constructs, or that centered on a specific type of construct. For example, the study included papers that explored the identification of indicators for critical thinking but excluded those that investigated indicators of a particular type of critical thinking, such as reflective critical thinking. Therefore, even if the studies referred to the 4C's, it was essential that they inferred indicators that revealed the underlying skills.

In IMAGE 01, we present the flowchart for the identification and selection of theses and dissertations on the research topic.

IMAGE 01 – Flowchart for the identification and selection of articles for the systematic review on the indicators of 4C's skills employing the PBL methodology
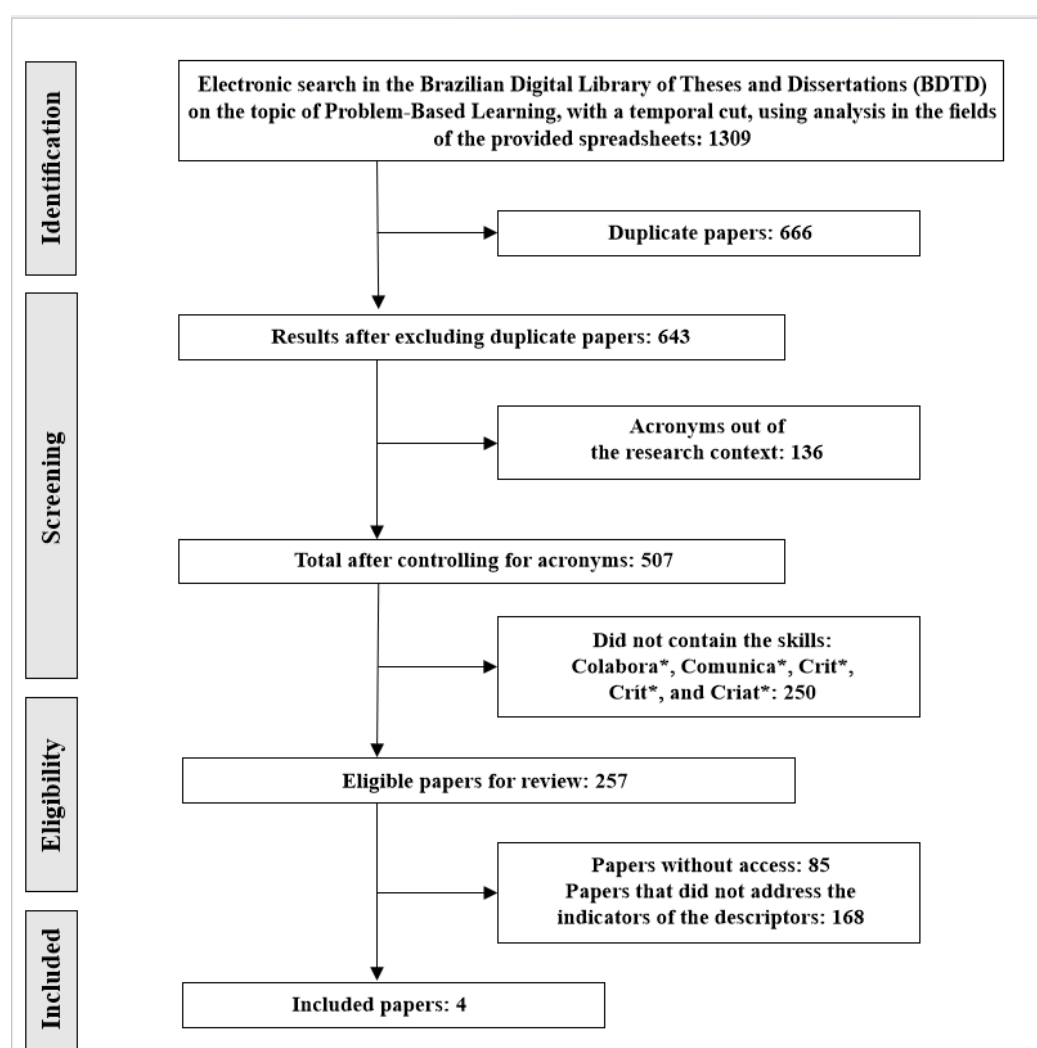
Source: the auctors.

ANALYSIS

The first study is a doctoral thesis defended at the *Universidade Federal de Santa Catarina*, titled "E-PORTFÓLIO: APRENDIZAGEM BASEADA EM PROBLEMAS NO CUIDADO DE ENFERMAGEM NO PUERPÉRIO IMEDIATO/GREENBERG" (which can be translated from Portuguese as "*E-Portfolio: Problem-Based Learning in Nursing Care in the Immediate Postpartum Period/Greenberg*"), written by Ravelli (2012). At the time, the researcher conducted a study with 28 students (experimental group and control group) from the Bachelor of Nursing program at a public higher education institution, who were enrolled in the Maternal-Child Health course in 2011.

The objective of this study was to evaluate the contribution of the Electronic Portfolio (PE) to the training of nursing students, aiming to develop critical thinking and collaborative learning for postpartum care/Greenberg, inspired by the PBL approach. The main objectives of the study were: to demonstrate the results of applying the ePortfolio in the context of higher education over a period of five years, from 2005 to 2009; to develop an ePortfolio structure aimed at postpartum care in collaboration with third-year nursing students, using the Exabis tool within the Moodle learning management environment; and finally, to apply and analyze this ePortfolio/Exabis structure with nursing students at a state public university.

It was concluded that the portfolio has technical characteristics suitable for application in nursing education. Working in groups, with interactivity, the use of the tool proved to be a functional didactic/technological resource with educational features that allowed for sharing and exchange between students and between the researcher/students, as well as feedback and reflections, contributing to the development of critical and collaborative learning.

The researcher applies PBL following a seven-step model by Walsh (2005). The theorist presents the methodology consisting of the following steps: 1. Presentation of the problem, 2. Exploration of prior knowledge, 3. Creation of solution hypotheses, 4. Identification of content and learning, 5. Individual study, 6. Re-evaluation and application of new knowledge to the problem, and 7. Evaluation and reflection on learning.

In CHART 05, we can observe the relationship between the PBL phases and the learning strategies used by the students, drawn from practical examples related to the theoretical conception of critical thinking. The researcher relies on studies by Lai (2011) and Corssetti *et al.* (2009), among others, to interpret critical thinking skills as capable of improvement and learning. This requires considering learning as a continuous and dynamic process that involves acquiring new knowledge as well as refining thinking and problem-solving skills.

CHART 05 – Analysis of qualitative learning strategies of the ePortfolio according to PBL for the development of critical thinking

Phases	Identification	Learning Strategies – Indicators of Critical Thinking						
		Analysis of arguments	Inductive reasoning	Deductive reasoning	Problem -solving	Decision -making	Sharing	Reading and deepening content
1	Presentation of the problem	x	x	x				
2	Exploration of prior knowledge		x	x	x	x		
3	Creation of solution hypotheses	x	x	x	x	x	x	
4	Identification of content and learning		x	x	x		x	x
5	Individual study		x	x	x		x	x
6	Reevaluation and application of new knowledge to the problem	x	x	x	x	x	x	
7	Assessment and reflection on learning		x	x	x	x		

Source: Ravelli (2012).

The research focuses on educational technological production. Using the Moodle® platform (divided into seven modules), an educational technology was structured for higher education, through the Exabis tool version 2.1, the Electronic Portfolio for immediate postpartum nursing care. The platform utilized resources such as: a *forum* for questions and news, a chat for questions with the researcher, a YouTube video and welcome message, PDF and narrated PowerPoint files, a clinical case with links (web page creation), and the use of questionnaires available on Moodle.

In accordance with the dynamics of phase division (modules) and the observation of critical thinking indicators in each phase (CHART 05), it is possible to illustrate their manifestation in specific moments of activity development and resource utilization.

For instance, in the first phase (first module of the platform), resources such as video, *forum*, chat, etc., were used for presenting the clinical case and the problems encountered throughout it. At this juncture, facilitated by the doubts *forum* (an open space between researcher and students) and a real problem—with varied and peculiar characteristics—the researcher observed that engagement with the problem and the interaction among participants made the students more aligned, enabling them to select and analyze the necessary knowledge effectively.

Another notable aspect of our research focus is found in the third module, which is aimed at hypothesis generation. In this case, using a pre-test with questions about the case, students began their activities with guidance towards problem-solving, making decisions about possible solutions to the problems encountered. At this stage, the *forum* tool also played a significant role, as it facilitated sharing with others the student was interested in.

The second scientific papers is related to a doctoral thesis defended at the *Universidade Federal da Bahia*, written by Sena (2014) and titled "COLABORAÇÃO E MEDIAÇÃO NO PROCESSO DE CONSTRUÇÃO E REPRESENTAÇÃO DO CONHECIMENTO POR PESSOAS COM DEFICIÊNCIA VISUAL, A PARTIR DA UTILIZAÇÃO DA APRENDIZAGEM BASEADA EM PROBLEMAS" (which translates from Portuguese as "Collaboration and Mediation in The Process of Knowledge Construction and Representation by Visually Impaired People, Using Problem-Based Learning"). Between 2010 and 2012 (the period of field research), the author conducted a study—with approximately 10 individuals—that aimed to investigate PBL as an educational strategy for collaborative learning in a group of people with visual impairments, through their experiences at a Visual Impairment Support Center in the city of Feira de Santana, state of Bahia, Brazil.

The target group, consisting of five women and five men, had ages ranging from 11 to 80 years, with a higher number of individuals (four) in their fifties. In terms of type of disability, half had residual vision and the other half had total loss of vision. Regarding education level, 50% had completed high school, 10% had incomplete secondary education, 10% had completed primary education, 20% had incomplete primary education, and 10% had no regular school attendance.

The main objective was to evaluate the dynamics of mediation, communication, and knowledge sharing in a group of individuals with visual impairments, through the application and adaptation of the PBL method as an educational strategy, with a focus on individual and collective cognitive constructions and representations. The specific objectives were: to reflect on the results, assess the need for adaptation, evaluate limitations, analyze the experience of the cycle, and the use of assistive technology.

For the PBL cycle, in agreement with Beaumont, Sackville, and Swee (2015), there are four stages (a more simplified model) characterized by: "Understanding the Problem," "Learning Stage", "Problem Solution", and "Reflection".

In CHART 06, it is possible to observe the indicators for each communication and interaction process, categorized by task, relationship, and individual communication skills.

CHART 06 – Indicators of Communication Skills

PBL Cycle – Communication Skills – Indicators			
Indicators	Task communication	Relationship communication	Individual needs communication
Inform	x		
Ask/Search for Information	x		
Organize, Clarify, Synthesize Ideas	x		
Evaluate	x		
Decide	x		
Encourage		x	
Harmonize		x	
Divide Control		x	
Listen		x	
Relieve Tension/Commitments		x	
Blockage Attitude			x
Call Attention			x
Dominance			x
Non-involvement			x

Source: Sena (2014).

We can exemplify the skill during the method when, throughout the first problem addressed in the initial cycle of PBL, specifically in the first stage called "Understanding the Problem," task communications are observed in the discussions. At this point, the search for understanding the problem and the method reveals weaknesses, behaviors, stimuli, and motivations observed during decision-making moments, in searching for information, and in the information itself.

In CHART 07, the issue of collaborative learning is addressed. The researcher observed, through a qualitative approach and with the aid of Bardin's content analysis, the category "Collaborative Learning." Within this category, three core meanings were identified through interaction, mediation, and cognitive aspects.

CHART 07 – Indicators of Collaborative Learning

Category – Collaborative Learning			
Identification	Interaction	Mediation	Cognitive aspects
Interaction	x		
Exchange	x		
Sharing	x		
Interaction with others	x		
Interaction with the group	x		
Intervention		x	
Intercede		x	
Help		x	
Be helped		x	
Memorization			x
Learning			x
Reflection			x
Mind			x
Articulation			x
Thinking			x

Source: Sena (2014).

Collaborative learning is observed at various points in the research. Notably, at the end of the first session of the second problem—during stages two and three, respectively "Learning Stage" and "Problem Solution"—interaction, manifested through exchange and interactions with others and with the group, cognitive aspects, realized through memorization and thinking, and mediation, observed through helping and being helped, were evident in the dynamics of the methodology and in the students' discussions.

The third paper is related to the master's thesis defended at the *Universidade Estadual de Roraima*, written by Silva (2016), titled "AVALIAÇÃO DO DESENVOLVIMENTO DO PENSAMENTO CRIATIVO EM ESTUDANTES DE MEDICINA DA UFRR, FUNDAMENTADA NO ENSINO PROBLEMATIZADOR DE MAJMUTOV" (which, when translated from Portuguese, means "Evaluation of the Development of Creative Thinking in Medical Students at UFRR, Based on Majmutov's Problem-Based Teaching"). During the second semester of 2015 and the first semester of 2016, the researcher conducted a study involving approximately sixteen students and two professors, aged 18 to 27 years. The study employed a case study format, incorporating elements of grounded theory and mixed research methods.

The general objective of this study was to evaluate the development of creative thinking in students of the 1st and 4th years of the Medicine course at *Universidade Federal de Roraima* (UFRR), through the lens of the propositions of Majmutov's Problem-Based Teaching, Galperin's Stage Formation of Mental Actions and Concepts, and Talizina's Teaching Direction Theory. To support the analysis, three specific objectives were established: diagnosing the levels of creative thinking development; identifying the progression of mental action formation stages among students; and analyzing the content of the Guiding Action Bases and their effect on study activities and students' understanding of concepts.

Drawing from Schmidt's (1983) seven steps of PBL, the researcher follows the methodology's stages: 1. Carefully read the problem and clarify unknown terms, 2. Identify the issues (problems) posed by the statement, 3. Offer explanations for these issues based on the group's prior knowledge of the topic, 4. Summarize the explanations, 5. Set learning objectives that lead the student to deepen and complement these explanations, 6. Individual study respecting the established objectives, and 7. Re-discussion in the tutorial group of the knowledge advancements obtained by the group.

In CHART 08, the learning strategies for creative thinking are presented along with their indicators.

CHART 08 – Strategies and Their Indicators for Creative Thinking

Strategies	Indicators
Pertinent selection of data	Identify the data (concepts) present in the problem
	Relates the task data to the concepts already known
	Separates the essential elements of the problem: the known, the unknown, the sought
Determination of the problem conditions	Identifies the peculiarities of the object
	Analyzes the nature and order of operations
	Demonstrates awareness of the essential conditions for problem resolution
Definition of objectives	Identifies the objectives to be achieved with the resolution of the problem
	Demonstrates clarity in defining the objectives
	Actively participates in the discussion and formulation of the list of objectives
	Contributes significantly to the discussion and formulation of the list of objectives
Construction of the conceptual core	Determines the essential properties of the concepts to be studied
	Names the categories and subcategories of analysis
	Builds the conceptual core from the categories and subcategories of analysis
	Analyzes the categories and subcategories present in the conceptual core and their conditions
Construction of the strategy suitable for solving the problem	Selects the method to solve the problem based on the conceptual core
	Selects the strategy that contains the necessary resources
	Solves the problem
Definition of the consulted sources	Uses the references indicated by the professor
	Seeks alternative research sources
	Recognizes reliable research sources
Presentation of the results	Shows depth in handling the data present in the results
	Demonstrates coherence in the propositions presented
	Provides details of the steps taken to achieve the result
	Presents the results achieved in a critical and contextualized manner
	Shows clarity of the result achieved
Interpretation of the solution	Identifies contradictions and units in different forms of data discussion in the consulted sources
	Extracts significant results that relate to the objectives of the problem
	Provides answers to the objectives of the problem
	Writes a report based on the objectives of the problem

Source: Silva (2016).

This research, especially concerning the creative thinking observed in step 7 of the methodology, reports that most students tend to maintain a level capable of formulating an analogical, hypothetical, or heuristic problem, as well as demonstrating and proving the solution independently. It is also emphasized that three students exhibited the ability to develop work requiring creative imagination, analysis, and logical conjecture, as evidenced by the indicator "Shows some depth in data treatment," thereby reflecting an elevation in cognitive independence.

Another notable point is observed in the presentation of results, both in terms of clarity and the critical and contextualized exposition at this step. The researcher notes that these two indicators show similar outcomes. Nevertheless, it is possible to see that, in one case, although the student presented the results with little clarity, they managed to contextualize and discuss them

critically. On the other hand, two students demonstrated clarity in the collected data but did not focus as much on presenting the results in a critical and contextualized manner.

The fourth paper is a doctoral thesis from the *Universidade Estadual de Campinas* (UNICAMP), titled "APRENDIZAGEM BASEADA EM PROBLEMAS NO ENSINO FUNDAMENTAL II: APLICABILIDADE, POTENCIAL E REFLEXÕES DE UMA ADAPTAÇÃO SOB PERSPECTIVAS GEOCIENTÍFICAS" (which is the Portuguese equivalent of "Problem-Based Learning in Middle School: Applicability, Potential, and Reflections on an Adaptation from a Geoscientific Perspective"), written by Finco (2018, translated by the authors).

In 2016, during the field research period, the researcher sought to diagnose how PBL methodology is implemented and its limits and potentials in adapting lessons to the ABP approach through geoscientific curricular content in a ninth-grade class at a public school in Campinas, São Paulo. To achieve this, adaptations were investigated through activities founded on PBL principles, focusing on themes related to the Origin and Evolution of the Universe, Earth, and Life.

The work was conducted with a ninth-grade class in elementary school, consisting of 34 students—20 male and 14 female—aged 13 to 14 years. Among the school classes, the researcher and the Science teacher chose the class labeled "A," as it was the one the teacher was instructing. This class was part of an elementary series, featured double periods, and had a geoscientific focus. The cognitive development was appropriate for the methodology, and there were few records of this methodology being applied at this educational level.

The main objective of this study was to investigate the applicability and functionality of adapting the PBL methodology for the final years of elementary school, focusing on geoscientific curricular content. Specific objectives included developing a learning plan and lesson schedule, creating a plan with content related to Earth and Life Sciences, methodologically supported by PBL principles, analyzing and discussing the possibilities and limitations of the stages, conducting interviews with the teacher, and sharing the experience.

To guide the intended activities in the methodology, the researcher adapted the sequence of guiding points from Finco (2018) cited in Araújo and Sastre (2009), drawing from common PBL elements. These stages are characterized by: "Identification of problems in scientific and everyday reality," "Discussion of a particular issue," "Utilization of one's own knowledge and experiences," "Formulation of hypotheses," "Investigation of hypotheses," and "Preparation of an academic report."

For team work analysis pertaining to social and collaborative skills, the researcher listed six key points (Grouping and organizing in teams, Completing activities within the available time, Attention to teacher instructions, Moderate tone of voice and respect for peers' speech, Personal notes and contribution to the final report, and Fulfillment of role/function in the group) to be answered during self-assessment using a four-point Likert scale, categorized as: "insufficient," "fair," "good," and "excellent."

At this point, the research reports that most students positively assess their performance in their role/function within the group, rating it as "Good." This perception is corroborated by the cross-referencing of notes and video recordings. *Exempli gratia*, the research

highlights a group that, at the final stage of the methodology and during the oral presentation evaluation, demonstrated that information was discussed, shared, and incorporated by all members. This was evidenced when the presenter did not feel comfortable performing their role and was replaced by two group members who performed well.

In the final considerations, the study shows signs of success with regard to the adapted dynamics of PBL variations, as well as identifying minor deficiencies in school infrastructure, recognizing collaboration and autonomy skills, the researcher-teacher's perception and reflection on lesson preparation and the teaching-learning process, changes in subsequent lesson approaches, and a tendency for geoscientific topics to be more addressed in the educational context.

After identifying how each stage of the methodology was implemented, we will proceed with the analysis process, which will include comparison with the original model, intersections between studies, and 21st-century skills as defined by P21.

In comparison with the model known as Zevensprong (seven steps), adopted by Schmidt *et al.* (1979, cited in Servant-Miklos, 2019)—with the aim of restructuring to support students taking on PBL—the four studies are seen as adaptations of the stages, even though the first and third studies are similar in terms of the number of steps for implementation.

It is understood that each option was generated due to the specifics of the research, such as differences in target audience, duration of the research, content addressed, etc. This possibility is entirely plausible, given that the model presented by Schmidt was also an adaptation due to the need to account for differences in maturity between incoming students, compared to the original model applied to bachelor's degree students.

Another important point to observe is the comparison between the steps of each study and the steps of the original model. They each present individual characteristics that often include elements found in more than one step. Therefore, one step in Study X may not be completely aligned with a step in Study Y, but it will be noticeable that there is a significant percentage of similarity between the compared steps. In this sense, CHART 09 will have a purely illustrative and pedagogical role, aiming to understand that differences and similarities are realized through specificities, while generally trying to maintain the original model's standard.

It is noteworthy that aspects such as the use of realistic problems, self-directed learning, small group formation, and tutor guidance seem to have gained more prominence compared to the initial focus on terms and concepts that were not easily understandable. Although it is relevant to note that the McMaster curriculum did not completely prohibit lectures, as clarifications of terms that are not easily understandable were considered appropriate (Servant-Miklos *et al.*, 2019).

CHART 09 – Comparison Between the Steps of the Study Procedures and the Original Model

Steps of the original model	Original Model	Paper 1	Paper 2	Paper 3	Paper 4
1	Clarify terms and concepts not easily understood				
2	Define the problem	Presentation of the problem	Understanding the problem	Carefully read the problem	Identification of problems
3	Analyze the problem	Exploration of prior knowledge and hypothesis creation		Identify the issues – problems proposed by the statement	Discussion of the problem and use of personal knowledge and experiences
4	Make an inventory of the explanations inferred in step 3, proceeding systematically	Identification of content and learning		Explain the issues based on prior knowledge	Formulation of hypotheses, investigation, and indication of solutions
5	Formulate learning objectives		Learning stage	Establish learning objectives	
6	Collect additional information outside the group	Individual study		Individual study, respecting the learning objectives	
7	Synthesize and verify the newly acquired information	Reevaluation, assessment, and reflection	Problem solution and reflection	New group discussion of progress	Preparation of an academic report

Source: the authors based on Ravelli (2012), Sena (2014), Silva (2016), and Finco (2018); translation by the authors.

Some skills were identified in more than one study, indicating a greater presence of collaboration in three of the four studies reviewed. In this case, the first, second, and fourth studies exhibit similarities in indicators for collaboration. Moreover, drawing from this information and adopting an approach aligned with Bardin's (2020) content analysis methodology, categories were defined to help us understand the construct more objectively. These categories include collaborative synchrointeractivity, collaborative intervention, and collaborative cognitive processes.

For the category of Collaborative Synchrointeractivity (CHART 10), we will subdivide it into three subcategories. The first, termed "Exchange," will cover the process of giving and receiving, as information or ideas are transferred back and forth in a reciprocal relationship. The second, called "Dialogue," will encompass active engagement between individuals involving an interactive communication process. The third subcategory, named "Sharing," will include the action of making something accessible, allowing for the use, appreciation, and access to the same resource, information, or experience.

CHART 10 – Units of Analysis and Core Meaning of the Collaborative Synchrointeractivity Category

Category	Meaning Core	Units of analysis
Collaborative Synchrointeractivity	Exchange	Paper 1 - "in a mutual exchange" (p. 109)
		Paper 2 - "relevant information, in the sense that they could exchange experiences, information, sensations" (p. 43)
		Paper 2 - "exchange of ideas and arguments" (p. 55)
		Paper 2 - "exchange of meanings" (p. 105)
		Paper 2 - "exchange between individuals" (p. 113)
		Paper 2 - "exchange between individuals and the world" (p. 113)
		Paper 2 - "through the exchange space" (p. 142)
		Paper 2 - "exchange of experiences and information" (p. 241)
		Paper 4 - "exchange with peers" (p. 47)
		Paper 4 - "exchange of ideas" (p. 81)
		Paper 4 - "exchanges of information" (p. 109)
		Paper 4 - "exchange of perceptions" (p. 125)
	Dialogue	Paper 1 - "the synchrony of interaction requires feedback between the parties" (p. 113)
		Paper 1 - "synchrony of interaction, through immediate responses" (p. 184)
		Paper 2 - "collaborative learning allows for interaction" (p. 118)
		Paper 2 - "dialogue with peers and with oneself" (p. 129)
		Paper 2 - "dialogue with peers and with the teacher" (p. 129)
		Paper 2 - "favoring dialogue" (p. 156)
		Paper 4 - "interaction with information in a differentiated and interesting way" (p. 91)
		Paper 4 - "oral intergroup interaction" (p. 98)
	Sharing	Paper 1 - "shares their constructions, helping everyone" (p. 113)
		Paper 1 - "sharing knowledge" (p. 109)
		Paper 2 - "sharing and representing information" (p. 19)
		Paper 2 - "sharing the generated knowledge" (p. 21)
		Paper 2 - "sharing previously acquired knowledge" (p. 242)
		Paper 4 - "socializing experience" (p. 131)

Source: the authors based on Ravelli (2012), Sena (2014), and Finco (2018); translation by the authors.

Within the category of collaborative intervention (CHART 11), we will divide it into two subcategories. The first, termed "Resolutive Approach," will encompass interventions that involve direct actions to alter or influence the course of events, as well as intermediary actions where intervention is made on behalf of others in a mediation role. The second will be named "Assistance" and will involve mutual help.

CHART 11 – Registration Units and Core of Meaning of the Mediation Category

Category	Core of Meaning	Units of analysis
Collaborative intervention	Resolutive approach	Paper 1 – "mediation of exchange of opinions and viewpoints" (p. 184)
		Paper 2 – "the collaborative process also implies the mediation process, understood as intervention" (p. 118)
		Paper 2 – "requesting my intervention (NS5) and recovering discussed topics" (p. 208)
		Paper 2 – "it was also necessary to mediate between the secretary and the other participants, so they could perceive the writing pace" (p. 229)
		Paper 2 – "tutor, mediating the dialogue between them" (p. 232)
		Paper 4 – "a team that needed the intervention of the teacher-researcher" (p. 83)
		Paper 4 – "the need for a greater degree of intervention by the researcher" (p. 97)
	Assistance	Paper 1 – "collaborates in individual studies" (p. 71)
		Paper 2 – "the teacher can provide 'scaffolding' to help students" (p. 144)
		Paper 2 – "help the student group deal with interpersonal relationship problems" (p. 145)
		Paper 2 – "help and be helped" (p. 182)
		Paper 2 – "help and ask (someone for help)" (p. 192)
		Paper 4 – "one helped the other in the group" (p. 223)
		Paper 4 – "with the help of all group participants" (p. 223)
		Paper 4 – "in group work, one helps the other" (p. 223)
		Paper 4 – "helping more with notes and organization" (p. 223)

Source: the authors based on Ravelli (2012), Sena (2014), and Finco (2018); translation by the authors.

Ultimately, the category titled collaborative cognitive processes (CHART 12) will be subdivided into five distinct sections. The first will be "Memorization" and will address the process of storing and retaining information. The second, called "Learning," will discuss the process of acquiring knowledge and skills through instruction, study, and experience. The third section, titled "Reflection," will focus on mastering experiences, understanding, and perceptions. The fourth section, characterized by "Articulation," will encompass the ability to express ideas and thoughts clearly and effectively. Lastly, the fifth section, "Thinking," will be interpreted as the process that involves organizing, forming, and manipulating ideas, concepts, logic, and epistemology.

CHART 12 – Units of analysis and core meaning of the category collaborative cognitive processes

Category	Meaning Core	Units of analysis
Collaborative Cognitive Processes	Memorization Learning Reflection Articulation	Paper 2 – "searching memory of previous knowledge" (p. 131)
		Paper 2 – "'I am remembering,' P4 (NS6, memorization, recollection, search in memory of previous speeches)" (p. 229)
		Paper 2 – "Unable to memorize. Nonetheless, the free start was interesting because we picked up a bit of everything" (p. 232)
		Paper 2 – "searching memory for what had been studied" (p. 235)
	Thinking Meaning Core Memorization	Paper 1 – "can facilitate teaching-learning" (p. 71)
		Paper 1 – "where everyone learns together" (p. 109)
		Paper 4 – "Learning (more effective or facilitated by team groupings)" (p. 118)
	Learning Reflection Articulation	Paper 1 – "will perform individual and collective reflection" (p. 43)
		Paper 1 – "build their knowledge through discussion and reflection" (p. 46)
		Paper 2 – "reflections on the concepts and ideas addressed" (p. 129)
		Paper 4 – "stimulate reflection on what learning is" (p. 22)
	Meaning Core	Paper 1 – "since knowledge is acquired through the interaction between the individual and the environment and between the individual and their social context" (p. 47)
	Memorization	Paper 1 – "encourages the development of thinking" (p. 184)
		Paper 1 – "collaborative learning through critical thinking" (p. 185)
		Paper 1 – "using inductive and deductive reasoning" (p. 185)
		Paper 1 – "habits of mind include: openness, curiosity, flexibility" (p. 48)
		Paper 4 – "in the process of developing Systemic Thinking (ST)" (p. 22)

Source: the authors based on Ravelli (2012), Sena (2014), and Finco (2018); translation by the authors.

Performing the interpretative analysis of the documented records in the theses and dissertations examined, it becomes apparent that a process of collaborative learning is manifested, encompassing elements of interactivity, mediation, and cognition.

The presentation will unfold through an approach known as the dialogic movement. This approach encompasses an understanding that emerges from exploring and identifying the complex discursive interactions that are intrinsically intertwined within our dataset. These discursive interactions, in turn, function as the connecting threads that link and give meaning to the various parts of our content (Souza *et al.*, 2019).

The first category of analysis, termed Collaborative Synchrony (SC), encompasses twenty-seven recording units, in which the cores of meaning are measured through exchange, dialogue, and sharing.

In this context, exchange assumes a central role within the educational collaborative dynamic, serving as the link that connects participants, allowing them to share their understandings, ideas, and knowledge reciprocally. Through exchange, individuals not only contribute their own perspectives but also benefit from the contributions of others, thereby enriching collective understanding.

It can therefore be stated that the exchange of knowledge and information is the vital engine behind collaborative methodologies. Anchored in user interactivity, these approaches

unfold in a social interaction circumstances, which nurtures the enhancement of capacity for mutual benefits and common goals. Through this interaction, participants are motivated not only to understand but also to delve into the intricate processes of collaboration and communication. This dynamic exchange environment acts as a unifying link, as mutual understanding is fostered and deepened (Boughzala; Vreede, 2015; Carneiro; Garcia; Barbosa, 2020; Rakhudu *et al.*, 2016).

Therefore, we understand that in the collaborative dynamic, exchange goes beyond a simple transfer of information: rather, it involves an active dialogue, in which participants engage in discussions, questions, and answers, jointly exploring topics and issues. This exchange not only promotes the construction of knowledge but also stimulates critical reflection and the deepening of ideas.

Dialogue, in collaborative learning, emerges as a protagonist, unfolding in an environment of synchronized interactions. In this dynamic space, participants actively engage in simultaneous exchanges of ideas, allowing for the joint construction of knowledge through real-time discussions. This synchronized interactivity not only promotes a deeper exploration of concepts but also amplifies understanding by integrating each individual's unique perspectives, resulting in a more comprehensive and enriching learning experience.

The essence of successful collaboration lies in the implementation of clear communication, genuine dialogue, and active listening. Under these circumstances, collaboration with peers provides a valuable opportunity to exercise constructive dialogue skills. By having students jointly assign meaning to a problem, the challenge of establishing collective references arises, allowing for the resolution of differences in interpretation. In the educational context, the role of the dialogic actor is highlighted, encompassing actions that orchestrate, structure, support, and organize the underlying processes of collaborative knowledge construction. Therefore, to optimize the quality of creative collaboration, it is imperative to emphasize stimulating dialogue among all participants in the classroom dynamics (Barron, 2000; Rakhudu *et al.*, 2016).

From what has been said, we interpret dialogue in collaborative learning as a dynamic web of synchronized interactions that stimulates critical reflection and collaborative problem-solving. As participants respond instantaneously to each other's contributions, dialogue becomes an iterative process of analysis and synthesis, where understanding constantly evolves. This non-linear and collaborative approach not only enriches learning but also cultivates essential skills such as active listening, empathy, and the ability to articulate thoughts clearly and persuasively.

Na verdade, o compartilhamento é um dos alicerces fundamentais do aprendizado colaborativo. Ele desempenha um papel crucial ao permitir que os participantes não apenas adquiram conhecimento, mas também o transmitam entre si. É mediante o ato de compartilhar que os indivíduos contribuem com seus pontos de vista e informações, enriquecendo a compreensão coletiva, incentivando os alunos a examinarem e reconsiderarem suas estratégias (Hunter, 2006).

At the heart of collaborative learning lie levels of trust, shared understanding, and the depth of relationships. These elements establish the foundations of this coordinated and synchronous activity, on which the continuous sharing of mutual knowledge construction—enriched with new information, knowledge, and possibilities—serves as the central pillar for co-

construction among participants (Child; Shaw, 2018). Indeed, understanding how members of collaborative learning groups share, assimilate, and co-construct knowledge together can provide valuable insights for identifying situations where facilitation can enhance the effectiveness of group interactions (Soller; Wiebe; Lesgold, 2002).

Therefore, we understand that sharing in the context of collaborative learning transcends mere data transfer, as it stimulates reflection and analysis of knowledge, since participants need to deeply understand the content in order to communicate it effectively. Consequently, sharing not only drives the collaborative learning process but also strengthens the bond between participants, promoting a rich and enriching dialogue of knowledge and perspective.

The second category of analysis, termed Collaborative Intervention (CI), encompasses sixteen recording units, where the cores of meaning are evaluated through the problem-solving approach and assistance.

The problem-solving approach, within the framework of collaborative learning, refers to a strategy or set of actions directed towards the effective and efficient identification and resolution of problems, including overcoming conflicts of understanding. This approach involves a thorough analysis of the situation, exploring viable alternatives, selecting the best option, and implementing measures aimed at resolving the issue at hand. Accordingly, participants not only seek individual resolutions but also work collectively to achieve a shared understanding or find a beneficial solution for the group as a whole.

In the collaborative dynamic, particularly within the Problem-Based Learning (PBL) scenario, the ability to demonstrate high levels of empathy plays a crucial role. When individuals bring empathy to the problem-solving process, they are better able to understand the situations and needs of other group members, which fosters effective interaction and promotes a healthy team-working environment (Child; Shaw, 2018; Darling-Hammond *et al.*, 2020; Hmelo-Silver *et al.*, 2007).

Moreover, the ability to employ effective strategies for resolving conflicts is essential to maintaining a cohesive and productive collaborative dynamic, contributing to an efficient and self-regulating problem-solving approach (Child; Shaw, 2018).

However, it is important to note that during collaborative activities, the introduction of contrasting viewpoints inherent to problem discussions may generate a degree of cognitive conflict in an individual. This conflict, although it may cause discomfort initially, often stimulates a deeper analysis of issues and encourages consideration of multiple perspectives, leading to more innovative and well-founded solutions (Barron, 2000; Child; Shaw, 2018; Dillenbourg *et al.*, 1996).

In summa, the problem-solving approach in collaborative learning goes beyond mere problem resolution and embraces the notion of facing challenges as a cohesive group. From this perspective, this approach fosters collective knowledge construction while enhancing essential skills for effective collaboration and collaborative problem-solving. Additionally, it is important to consider that the problem-solving approach can also be adopted by an external agent, playing a more supportive role in the collaborative process, bringing an impartial view and expertise to help overcome obstacles and promote effective solutions.

Assistance, understood as mutual help, plays a multifaceted role in collaborative intervention. It transcends mere provision of aid, becoming a vital link that connects participants through the exchange of knowledge, perspectives, and experiences. In the context of collaborative intervention, assistance represents an active commitment to collective progress, as participants come together to offer support and guidance to each other, creating a synergy that amplifies the effectiveness of the intervention process.

States related to collaboration, such as satisfaction, cohesion, or group effectiveness, have a significant impact on group learning dynamics. Recent research has shown that when individuals feel psychologically safe in a collaborative environment, they are more likely to seek feedback, ask for help, and engage in constructive discussions, including analyzing misunderstandings and challenges (Edmondson, 2018). Additionally, motivating group members to help each other and fostering positive pressures among them is an effective strategy for maintaining individual engagement in group activities (Child; Shaw, 2018).

As mentioned by Laal *et al.* (2013), collaborative learning, where students help each other, generates a range of benefits. These include promoting creative thinking and joint problem-solving as well as developing crucial skills for team decision-making. In the contemporary context, marked by an emphasis on technology and collaborative work, such skills are increasingly vital, as collaborative interaction not only enriches educational dynamics but also aligns with the demands of the modern world. The ability of students to help each other in a constructive and goal-oriented manner reflects an effective pedagogical approach and equips individuals to face the challenges and opportunities of modern society.

To summarize, assistance is a force in collaborative intervention, transcending the role of simple aid to become a means of enriching, strengthening, and solidifying the bonds between participants. By recognizing that mutual help is a two-way street, participants become more likely to fully engage in discussions and activities, knowing that their contribution is valued and reciprocated. Through this active and generous exchange, assistance fosters a richer, more informed, and results-oriented intervention approach, reflecting the synergy and collective potential of the group.

The third category of analysis, identified as Collaborative Cognitive Processes (CCP), encompasses 17 recording units, where the cores of meaning are outlined by activities such as memorization, learning, reflection, articulation, and thinking.

It is important to note that memory plays a significant role in collaborative cognitive processes, serving as a foundation for joint knowledge construction. It allows participants to access previously learned and shared information, enabling the contextualization, referencing, and application of relevant concepts during collaborative interactions.

In this regard, the intersection between memory and collaborative learning reveals significant relevance. Collaborative recall, as a complex process, involves active collaboration among individuals to forge a consensual interpretation of the past, which is seamlessly integrated into each participant's memory (Hyman *et al.*, 2014). In this context, distributed, collaborative, and conversational recall emerges as a crucial facilitator in the formation and maintenance of

mnemonic communities. This approach not only refines shared understanding but also fosters cohesion around memorable narratives (Fagin *et al.*, 2013).

Additionally, the perspective of collaborative memory focuses on the direct creation of interactions, enriching the learning process as group members engage in joint learning or recollection. This intertwining of memory and collaboration sets a promising stage for future explorations into how shared memories can contribute to deeper and more meaningful learning (Rajaram; Maswood, 2017).

Hence, in collaborative cognitive processes, memory facilitates the retrieval of information, allowing individuals to bring forth past experiences, relevant examples, and significant data to enrich discussions and solve problems. Moreover, memory aids in forming connections between concepts, promoting a deeper and more holistic understanding of the issues at hand.

It is pertinent to remember that learning, which involves acquiring knowledge and skills through instruction, study, and experience, plays an important role in collaborative cognitive processes. It forms the foundation upon which participants build their understanding, interact, and contribute meaningfully during collaborative activities.

From this perspective, collaborative learning, rooted in inquiry, emerges as an active and student-centered approach, promoting a deeper understanding of concepts by developing students' abilities. This pedagogical strategy also aligns with a deep learning approach, associated with comprehension, reflection, and critical thinking, fostering more meaningful engagement with content (Lu *et al.*, 2020).

In this context, collaborative learning plays a vital role in cultivating academic independence. Although group collaboration is central, it does not diminish the importance of the individual role. Each student's unique contribution is validated by the collective, demonstrating the interdependence among group members (Hunter, 2006). This approach is reinforced by recent studies showing the positive impacts of collaborative methods on enhancing students' learning capabilities (Rafique *et al.*, 2021).

In conclusion, learning is the backbone of collaborative cognitive processes, providing the raw material for idea exchange, joint knowledge construction, and collaborative problem-solving. It empowers participants to engage effectively, contributing to a richer and more meaningful learning experience.

Simultaneously, reflection plays an essential role in collaborative cognitive processes, acting as a tool that promotes critical analysis, deeper understanding, and the co-construction of knowledge among participants. Through reflection, individuals are encouraged to examine their own ideas, the contributions of others, and the challenges presented, leading to a more comprehensive and refined understanding of the issues under discussion.

The multifaceted understanding of reflection—whether as a bridge between theoretical propositions and practical situations, critical analysis of political issues, power, and ethics, or the identification of underlying dilemmas—enhances the educational approach. Reflection, intrinsically linked to the learning process, not only nurtures the quality of acquired knowledge but also stands out as a central strategy (Clarà *et al.*, 2019).

In parallel, within the framework of Problem-Based Learning (PBL), one of its pillars is the promotion of reflection. In this context, the alignment between learning settings and their associated functionalities is crucial. Reflection, by fostering a deep and meaningful learning approach, significantly contributes to improving the excellence of the educational process. The intersection of reflection and collaborative learning creates an enriching educational framework capable of shaping a solid foundation for students' intellectual and practical development (Rué *et al.*, 2013).

In brief, reflection is a crucial tool in collaborative cognitive processes, driving critical analysis, joint knowledge construction, and deeper understanding, thereby contributing to more effective collaboration and collaborative problem-solving.

Similarly, articulation plays an important role in collaborative cognitive processes, serving as a bridge between individual ideas and perspectives and as a vehicle for collective knowledge construction. Through articulation, participants can connect and communicate their ideas clearly and effectively, promoting mutual understanding and the joint development of deeper insights.

Accordingly, the harmony between articulation skills and collaborative learning reveals significant importance. Clear and effective expression of ideas and thoughts, characteristic of articulation, finds synergy with the collaborative learning dynamics. The externalization of thought, whether through writing or oral expression, is recognized as a catalyst that not only communicates but also deepens the reflection process. Hence, it transcends mere communication, extending to a cognitive process that encourages the thorough exploration of ideas (Bain, 2011).

Particularly in the problem analysis phase in PBL, articulation acquires a unique and relevant role. This stage is rich in terms of re-articulation and repetition of previously learned concepts, thereby strengthening the deep understanding of knowledge. Engaging in rigorous articulation promotes not only the synthesis of ideas but also the dissemination of knowledge (Yem; Schmidt, 2012).

To put it briefly, we interpret articulation as a valuable element in collaborative cognitive processes, facilitating communication, the integration of possibilities, and collective knowledge construction. It plays a crucial role in idea exchange, the development of shared understandings, and the promotion of effective and enriching collaboration among participants.

Likewise, thinking, as a necessary role in collaborative cognitive processes, represents a fundamental action encompassing the organization, formation, and manipulation of ideas, concepts, logic, and epistemology. In this context, thinking acts as a tool that allows participants to explore topics in depth and in a structured manner, contributing to collective knowledge construction.

In the 21st-century educational landscape, higher-order thinking skills are recognized as an imperative need for students. Given the increasing complexities of modern society, such skills enable students to address challenges reflectively and innovatively, making them better prepared to face the demands of the current world (Lu *et al.*, 2021). To understand the nature of the thinking processes underlying collaborative learning, observational studies, such as those

investigating Problem-Based Learning, offer valuable insights into student interaction and the mechanisms driving knowledge and skill acquisition (Yem; Schmidt, 2012).

It is appropriate to remember that collaborative learning not only promotes interaction among students but also stimulates the formation, organization, and manipulation of ideas, contributing to deeper cognitive development through collective knowledge contribution. By linking learning factors with critical and analytical thinking skills, inquiry-based collaborative learning becomes a vital and dynamic component of the contemporary educational process (Lu *et al.*, 2021).

In this way, we understand that thinking is a primary tool in collaborative cognitive processes, enabling the formation of concepts and the application of logic to develop coherent and well-supported arguments. It contributes to more informed collaboration, a deeper construction of knowledge, and a more powerful exchange of perspectives among participants.

Upon reviewing the material so far, we understand that collaborative cognitive processes involve immersion in shared and interconnected mental activities that permeate collaborative learning. These processes include cognitive actions such as individual and collective reflection, idea articulation, joint learning, thinking, and collaborative memorization. By participating in these processes, individuals not only acquire knowledge but also interact, exchange, and build collective understandings.

Pertaining to the framework of articulation and its intersection with the institution, the approach also encompasses collaboration, but with an emphasis on discussing the role of the "self" in relation to the "other," focusing on effectiveness, responsibility, and flexibility.

By adopting a collaborative approach, as proposed by P21 (2015), which emphasizes the ability to work effectively and respectfully in diverse teams, it becomes possible to explore the richness of varied perspectives and experiences. This not only enriches the collaborative process but also promotes an inclusive environment that values diversity.

Moreover, by practicing flexibility and willingness to make necessary commitments toward a common goal, as outlined by the entity, team members can adapt to changes and challenges that arise during the collaborative journey. The ability to adjust strategies and decisions while maintaining focus on the shared goal demonstrates the team's maturity in handling different situations, making joint work smoother and more efficient.

In conclusion, the notion of shared responsibility, advocated by P21 (2015), underscores the importance of each team member recognizing their role in achieving collective results. Valuing individual contributions within a collaborative context not only strengthens the sense of belonging but also motivates each member to engage and contribute meaningfully, resulting in a more enriching and comprehensive outcome.

Therefore, by internalizing and applying the principles outlined by the institution—working in diverse teams, being flexible in commitments, and valuing individual contributions—it is possible to establish a collaborative work environment that reaps the benefits of a variety of talents while advancing towards shared goals.

Your observations predominantly focus on the individual actions touching on the group, which can be seen, for example, in the sense nuclei involving dialogue, assistance, and

sharing. Therefore, we understand the initial concern directed at the individual, aiming at collective construction. Despite that, it is crucial to remain attentive to other possibilities that may emerge from various internal and external research contexts.

Concerning Creativity, P21 (2015) directs its attention to the domains of thinking, work, and innovation. These three elements intertwine essential in the context of PBL, which aims to enhance not only academic knowledge but also practical skills and personal development of learners.

In the context of Creative Thinking, as outlined by the organization, three essential pillars stand out as the foundations that promote an approach geared towards innovation and problem-solving. The first pillar involves the broad use of idea generation techniques, notably brainstorming, to expand the diversity of creative approaches. The second pillar is centered on creating novel and valuable ideas, whether through incremental or radical concepts, thereby fostering a continuous renewal of creative thinking. The third pillar focuses on the ability to elaborate, refine, analyze, and critically evaluate one's own ideas. This iterative process is essential for enhancing and maximizing creative efforts, leading to the continuous evolution of generated ideas. Together, these three pillars form a robust structure that promotes both individual creativity and collaborative work, creating an environment conducive to innovation and the realization of meaningful solutions to various challenges.

Thus, under the organization's guidance, the synthesis of the three pillars of Thinking highlights the importance of diverse ideation techniques, generating new and valuable ideas, as well as the process of continuous elaboration and refinement, all contributing to an approach that nurtures creativity and the ability to solve problems comprehensively and effectively.

Touching on the ability to work creatively with others, the entity emphasizes the need to advocate openness and receptivity to new and diverse perspectives, through the implementation and communication of new ideas effectively to others. This attitude not only enriches creativity but also allows for the incorporation of contributions and feedback from the group, enhancing the creation and refinement of ideas. The viewpoint that sees failure as a learning opportunity complements this panorama. Recognizing that creativity and innovation are cyclical and long-term processes, P21 (2015) encourages embracing both successes and failures as integral parts of intellectual and creative growth.

Ultimately, the effective implementation of innovations is a central component of Creativity, according to P21 (2015). This aspect involves concrete actions based on creative ideas, aiming to provide tangible and meaningful contributions to the field where the innovation is directed. The institution emphasizes the importance of transforming creativity into real impact, directing it towards generating tangible results. This transformation requires not only the ability to conceive innovative ideas but also the competence to plan and execute actions that realize them. Within this scope, P21 (2015) highlights the relevance of adaptation and flexibility. The ability to adjust approaches and solutions in response to unforeseen challenges or feedback from the environment is fundamental to ensuring the effectiveness of innovations. Summing up, Creative Thinking, in line with P21 (2015), encourages not only the generation of innovative ideas but also

the realization of concrete actions that generate significant and beneficial impact in the realm of proposed innovations.

On the other hand, Silva (2016) delves deeper into the theme, identifying sense nuclei ranging from pertinent data selection, through conceptual core construction, to solution interpretation. The process of elaboration, discussion, refinement, analysis, and evaluation are intersections present in both contexts.

Although Silva's (2016) work reveals other elements for understanding creative thinking in the application of PBL, it is essential to emphasize that P21 addresses topics such as originality and inventiveness, dealing with errors and successes, as well as the notion of failure. This points to the possibility of discussion that is not limited exclusively to creative thinking but also to the potential for learning from creative thinking.

In relation to the dimension of Criticality, both P21 (2015) and Ravelli (2012) highlight the importance of careful argument analysis, exploring various types of reasoning, and the ability to confront complex challenges through problem-solving. Both authors recognize the relevance of cultivating the ability to address complex problems in a structured and methodical manner.

In this way, the competence of Critical Thinking, as outlined by P21 (2015), consists of four interconnected pillars that support the ability to address challenges innovatively and substantiated. The first pillar, Effective Reasoning, focuses on the ability to employ various types of reasoning, such as inductive and deductive. This cognitive versatility provides a flexible approach, allowing a more precise and comprehensive analysis of complex situations.

The second pillar is the emergence of systemic thinking, demonstrating the ability to analyze the interconnections between parts of a complex system and how these interactions culminate in outcomes. This comprehensive understanding fosters a deeper insight into phenomena and assists in formulating more effective approaches.

Concerning the competence of Judgments and Decisions, the third pillar of Critical Thinking, P21 (2015) highlights a series of crucial skills. This involves careful analysis and evaluation of evidence, arguments, claims, and beliefs, ensuring the solidity of the foundations for decisions. Additionally, the thorough analysis of key alternative viewpoints and the ability to synthesize information and arguments contribute to well-informed and critical decision-making.

In the end, the fourth pillar, Problem Solving, emphasizes the ability to tackle a variety of challenges with both conventional and innovative approaches. Identifying questions that lead to clearer and more insightful answers is a fundamental part of this pillar, as it directs the exploration of multiple viewpoints, leading to more robust and comprehensive solutions.

In essence, Critical Thinking, as delineated by P21 (2015), relies on four interdependent pillars: Effective Reasoning, Systemic Thinking, Judgments, and Problem Solving. These sub-skills work synergistically to foster an enriching approach, intrinsically aimed at promoting innovation and effective decision-making in response to the complex demands of the contemporary context.

Regarding differences, Ravelli's (2012) research brings indicators such as decision-making, sharing, and reading with relevance in more than eighty percent of the phases adopted in

its methodology. On the other hand, P21 introduces elements such as synthesis, connections between information and arguments, as well as critical reflection on experience and processes.

With respect to the communication skill, it is interesting to observe that both Sena (2014) and P21 (2015) share convergent contexts. Both approaches emphasize the breadth of communication as a tool for information dissemination, as well as an effective means of listening and interpretation. Both highlight the importance of communication as a vehicle for assessing not only the exchange of information but also underlying attitudes, implicit knowledge, and communicative intentions. The common essence between these views suggests a shared appreciation for communication as a vital pathway to mutual understanding.

For P21 (2015), clear communication competence reveals itself as an essential attribute for human interaction. One of the cornerstones of this skill is the ability to express thoughts and ideas effectively, using oral, written, and non-verbal communication skills in various forms. P21 (2015) emphasizes the importance of conveying information accurately and engagingly, enabling comprehensive understanding by the target audience. Deciphering the underlying meaning, including knowledge, values, attitudes, and intentions, is fundamental for meaningful and appropriate interaction.

The ability to use communication for various purposes also emerges as a key element. P21 (2015) highlights that communication can have distinct objectives, such as informing, instructing, motivating, and persuading. It underscores the importance of not only choosing the appropriate communication tools but also assessing their impact in advance. This informed discernment ensures that communication is effective and achieves its objectives.

In the final analysis, the ability to communicate in diverse environments is a pillar of communicative competence, and P21 (2015) acknowledges that communication contexts can vary, including multilingual environments. In this sense, the ability to adapt communication to meet the specific needs of different audiences is fundamental. A sensitive understanding of cultural and linguistic differences plays a central role in building meaningful communicative bridges and promoting more open and inclusive interaction.

In summary, the competence of clear communication, as outlined by the organization, encompasses effective expression of thoughts and ideas, active listening, intentional use of communication for different purposes, evaluation of media and technologies, and the ability to communicate effectively in diverse environments. These elements come together to create a comprehensive set of communicative skills that are essential for successful interaction and collaboration in an increasingly connected world.

Sena (2014), in his research, proposes observing indicators—both in the implemented phases of PBL and in the perception that communication skills—can be subdivided from the perspective of task, relationships, and individual needs. This prompts us to observe them with greater clarity when applied to PBL methodology. On the other hand, the institution brings relevant elements for contemporary discussion, including the importance of observing the diversity of environments, various communication possibilities—oral, written, and non-verbal—and, finally, the multiple technological means of communication.

FINAL CONSIDERATIONS

In the contemporary educational landscape, 21st-century skills are pointed out as fundamental elements to support students in facing the complex and dynamic challenges of modern society. These skills, encompassing collaboration, communication, critical thinking, and creativity—as defined by the Partnership for 21st Century Learning—are recognized as essential pillars for success in a constantly evolving world. Simultaneously, Methodology emerges as an effective educational approach to cultivate these skills and promote meaningful learning.

The central purpose of this investigation was to explore and deepen the understanding of the connection between the PBL methodological approach and the indicators of the aforementioned skills. As a result, the inquiry arose concerning the characterization of studies that delved into the identification and research of the indicators that culminated in the constructs of the 4C's skills.

The importance of this review lay in its ability to provide a deeper and more comprehensive understanding of the interconnection between methodology and the indicators of the 4C's skills in educational environments. Through this systematic literature analysis, it was elucidated more precisely how PBL contributed to the development and realization of these crucial skills in students.

Not surprisingly, when investigating theses and dissertations exploring the relationship between PBL and the indicators of 4C's skills, the review provided valuable insights into various subdimensions of collaboration, communication, critical thinking, and creativity that emerged when employing the methodology. By gathering and analyzing the research conducted in this area, the review identified specificities—distances and proximities—within the scope of the works when compared to the theoretical perspective adopted with P21. In this way, we understand that the proposed articulations addressed the initial question and the research objective.

In conclusion, the authors encourage researchers dedicated to analyzing the active PBL methodology and 21st-century skills to explore the intersections between these domains. They propose the use of skill indicators in various scenarios and study bases to conduct a more detailed and comprehensive investigation of the perception of this theme from multiple perspectives.

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DATA AVAILABILITY DECLARATION

The content underlying the research text is contained in the manuscript

CONTRIBUTION OF THE AUTHORS:

Author 1 – Research author, conceptualization, data collection and analysis, writing, review, and editing.

Author 2 – Research advisor, supervision, conceptualization, analysis, writing, editing, and validation.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest with this article.