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ORIGINAL

Methodological Bases for the Development of Students' Analytical Abilities using Research Activities

Bases metodológicas para el desarrollo de las capacidades analíticas de los estudiantes mediante actividades de investigación

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ABSTRACT

Introduction: the study investigated the influence of research-oriented learning methods—Project-Based Learning (PBL), Laboratory-Based Learning (LBL), and STEM-Based Learning (SBL)—on the development of analytical skills (AS) among higher education students.
Method: a total of 331 students were selected through persuasive sampling. Data were collected using a self-developed MBAS questionnaire (appendix-1). The instrument's reliability was confirmed (Cronbach's α = 0,933). Descriptive statistics (mean and standard deviation) and inferential statistics (correlation analysis) were employed.
Results: PBL emerged as the most preferred approach (M = 3,8731, SD = 0,84314), attributed to its interactive nature. SBL exhibited the strongest correlation with assessment scores (r = 0,781, p < 0,001). All observed correlations between PBL, LBL, SBL, and AS were statistically significant at the 0,01 level, confirming robust positive relationships among these pedagogical strategies and analytical skill development.
Conclusions: the findings support the integration of structured research activities, particularly SBL, into academic curricula to enhance analytical thinking. These approaches offer effective pathways for promoting higher-order cognitive competencies in higher education.

Keywords: Cognitive Skills; Learning Strategies; Higher Education; Students' Research Activity; Preschool Education.

RESUMEN

Introducción: el estudio investigó la influencia de los métodos de aprendizaje orientados a la investigación —aprendizaje basado en proyectos (PBL), aprendizaje basado en laboratorios (LBL) y aprendizaje basado en STEM (SBL)— en el desarrollo de las habilidades analíticas (AS) entre los estudiantes de educación superior.
Método: se seleccionó a un total de 331 estudiantes mediante muestreo persuasivo. Los datos se recopilaron mediante un cuestionario MBAS de elaboración propia (apéndice 1). Se confirmó la fiabilidad del instrumento

(α de Cronbach = 0,933). Se emplearon estadísticas descriptivas (media y desviación estándar) y estadísticas inferenciales (análisis de correlación).
Resultados: el PBL se reveló como el enfoque preferido (M = 3,8731, DE = 0,84314), debido a su naturaleza interactiva. El SBL mostró la correlación más fuerte con las puntuaciones de la evaluación (r = 0,781, p < 0,001). Todas las correlaciones observadas entre el PBL, el LBL, el SBL y el AS fueron estadísticamente significativas al nivel 0,01, lo que confirma la existencia de relaciones positivas sólidas entre estas estrategias pedagógicas y el desarrollo de las habilidades analíticas.
Conclusiones: los resultados respaldan la integración de actividades de investigación estructuradas, en particular el SBL, en los planes de estudios académicos para mejorar el pensamiento analítico. Estos enfoques ofrecen vías eficaces para promover competencias cognitivas de orden superior en la educación superior.

Palabras clave: Habilidades Cognitivas; Estrategias de Aprendizaje; Educación Superior; Actividad Investigadora de los Estudiantes; Educación Preescolar.

INTRODUCTION

The agility of the mind is necessary for the success of every modern student. It helps students critically assess data, solve problems, and make creative decisions.[1] The relevance of critical analytical skills is increasing in an age of saturated information. It enables the learner to optimally learn, swim through the ocean of data, and draw inferences from them.[2] Therefore, it becomes imperative for education systems to place the development of analytical skills within students in the mainstream agenda.[3] To cultivate these analytical skills within a curriculum, advanced teaching methods like problem-based learning, case studies, data analysis exercises, collaborative projects, flipped classrooms, simulations, and open-ended questioning can be effectively integrated, encouraging students to critically evaluate information, identify patterns, draw conclusions, and justify their reasoning. Research activities are the most promising ones in developing these competencies as they stimulate active and critical engagement with the material.[4] Through research, critical analysis, complex problem-solving, and knowledge creation become ingrained in students.[5,6] However, a large number of educational institutions face very serious problems regarding the inculcation of analytical skills.[7,8] The number one reason is the inadequate methodological training the students are receiving. Countless conventional methods of teaching emphasize rote learning techniques and do not produce any critical or problem-solving abilities.[9,10] It has also been found that research activities are not often systematically integrated into curricula, thus depriving the students of the tools to develop their analytical abilities properly.[11,12,13] Research-based methods followed by learning, such as Project-Based Learning (PBL), Laboratory-Based Learning, and STAMB-Based Learning, enhance critical and problem-solving abilities. In PBL, students are taught the art of experiencing a real-world problem while applying what they know.[14] According to modern research laboratory-based learning involves critical observation and data analysis, which is necessary to develop analytical skills in students. STEM-Based Learning also encompasses science, technology, engineering, and mathematics to create analytical skills.[15,16,17] It thus promotes the critical thinking of students in complex, multifaceted problems.[18]

Moreover, students need analytical skills for their studies as well as their careers.[19] Analytical skills enable students to think critically, solve problems, and make informed decisions. However, traditional methods of teaching do not develop these skills Modern research examined the impact of inquiry-based learning on students' critical thinking skills.[20]

Unfortunately, most students are not familiar with such research methods, including LBL, PBL and SBL, so they benefit few. Research-based teaching faces underutilization due to barriers like teacher mindset, inadequate training, rigid curricula, and institutional inertia, as evidenced by a study. Therefore, the present study is specific as it evaluates how research activities build analytical ability among students. This part of the research will help in understanding analytical thinking for teachers as part of teaching techniques. It facilitates the schools in preparing the students against the challenges they expect in their careers by integrating research into their curriculum.

Hence, the purpose of the article is to investigate the impact of research-oriented teaching methods (in particular, project-based learning, laboratory classes, and the STEM approach) on the development of analytical abilities of students of higher education institutions, as well as to substantiate the effectiveness of integrating these methods into curricula for the formation of high-level thinking skills. Therefore, the present study may prove to be a potential contribution to facilitate improvement in education and student analytical skills.

Research Objectives

1. To explore the impact of Project-Based Learning on the development of students' analytical skills.
2. To examine how Laboratory-Based Learning contributes to enhancing students' critical thinking and problem-solving abilities.

3. To assess the role of STEM-Based Learning in fostering analytical skills among students.
4. To identify methodological approaches that effectively integrate research activities into the learning process.

Research Questions

1. How does Project-Based Learning impact the development of students' analytical skills?
2. In what ways does Laboratory-Based Learning contribute to enhancing students' analytical skills?
3. What is the role of STEM-Based Learning in fostering analytical skills among students?
4. What methodological approaches effectively integrate research activities into the learning process to develop students' analytical skills?

Literature review

Analytical Skills (AS)

According to modern studies, analytical skills help in assessing data, evaluating situations, and making informed decisions.[21] Analytical thinking, on the other hand, entails logical reasoning and critical assessment of information.[22,23] In this regard, students should actually develop analytical skills in modern education. Analytical skills are defined by Susiaty et al.[9] as processing information critically and logically. This is related to the ability to examine facts, evaluate arguments, and generate solutions. The main constituents of analytical thinking include in-depth search, data analysis and evaluation, problem-solving, and decision-making.[24,25] Another aspect of analytical skills is given up concerning the criteria to evaluate and solve stemming problems.

According to Hujjatusnaini et al.[14], analytical thinking is one of the most important 21st-century skills. Analytical ability allows high school students to analyze real-life issues, think critically, and seek various alternative solutions.[26,27] Here, analytical abilities lay the groundwork for higher-order thinking since they allow one to apply knowledge to novel situations and may contribute to solving complex problems in a systematic manner.[28,29] Unfortunately, these kinds of competencies are needed to face realities in the contemporary world, where rapid growth in knowledge and complexity forces learners to think critically and adjust accordingly to new situations.[30]

Bloom's Taxonomy, as a popular framework, describes higher-order thinking cognitive processes, including Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation,[31,32] with analytical skills being developed through analysis, synthesis, and evaluation.[33] This framework of analytical thinking intentionally includes many complex cognitive abilities.[34] Analytical skills develop for synthesis and evaluation through understanding, application, and analysis.

Vygotsky's Sociocultural Theory is also important. According to [35], social and cultural interactions give rise to higher forms of cognitive functions like analytical thinking. Learning, as Vygotsky claimed, involves students talking, exchanging thoughts, and solving problems. It develops abilities such as complex forms of thinking, including analysis and evaluation. Vygotsky's theory implies that group activities, such as group discussions, debate competitions, and problem-solving tasks, can hone students' analytical skills through critical thinking and expression. Piaget's[36] theory of cognitive development also explains analytical thinking in children and adolescents. According to Piaget[36], as time progresses, children's thinking becomes more and more difficult. An adolescent is still able to think abstractly and hypothetically during formal operations, which start around the age of 12 and onward, according to his theory.[37] This has led to the development of very advanced analytical skills, such as multiple perspectives and abstract concepts. Piaget generally believes that analytical thinking develops as students grow and become able to deal with more complex problem-solving and evaluation.[38,39]

Analytical skills are essential for STEM students as well. STEM students must analyze data, test hypotheses, and conclude inquiry-based learning. Science requires analytical skills to understand complex theories, conduct experiments, and solve technical problems. Analytical thinking is important to the scientific method.[40] Students committing to the STEM career pathway need to practice developing analytical skills.[40]

Research Activities (RA)

Research activities are the most important activity that fosters the growth of any individual's analytical skills.[41] The students also do inquiry-based learning, which empowers them to analyze real-life problems and then find solutions through structured research.[42] It improves critical thinking and learning by actually applying the knowledge in real contexts. Many different ways and forms of research activity bites have been explored in the literature.[17] Among the more widely known are Project-Based Learning (PBL), Laboratory-Based Learning (LBL), and STEM-Based Learning (SBL).[43] In this case, students will complete long-term projects that deal with real-life problems. D. Karki and R.Lamichhane[44] say that PBL promotes teamwork as well as critical thinking in the sense that students are put to work doing independent research, data analysis, and conclusion-making. PBL is an excellent method for developing analytical skills because it requires students to apply theoretical

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knowledge to the problem in order to find solutions.[31] The PBL students exhibited improved problem-solving, critical thinking, and use of scientific concepts in real-world scenarios.[45]

From the above findings, it can be stated that PBL is a major enabling factor for developing students' analytical skills by presenting them with real-world experiences in a structured and collaborative way. Laboratory-Based Learning (LBL) provides an alternative view of an educational event; it allows experimentation of scientific principles through hands-on activities within a controlled environment.[46,47] LBL experiences provide students with opportunities to have real experiences that add empirical weight to theoretical knowledge in building up their analytical skills.[43]

According to [48], the LBL strategy enhances and chiefly increases students' analytical skills in chemistry education. Participating in laboratory-based learning significantly improved the students' analytical ability in chemical reactions, interpreting experimental results, and problem-solving with the application of scientific principles. V. Kolil et al.[49] have pointed out that LBL becomes a valid tool in nurturing the analytical skills essential in equipping the students with the tools and experiences they would require to carry out scientific inquiry and problem-solving. STEM-based learning (SBL) is an integrated mode of learning that focuses on science, technology, engineering, and mathematics so that students can experience interdisciplinary thinking and problem-solving.[50,51] M. Baran et al.[21] argue that the partnership of these three approaches is fundamental in proving the current skills for the 21st century necessary for working in companies. In fact, analytical thinking, creativity, and collaboration are among the few traits highly valued by different employers across industries, from technology to healthcare. Most research on the development of analytical skills has been focusing more on how some learning modes, like Project-Based Learning (PBL), Laboratory-Based Learning (LBL), and STEM-Based Learning (SBL), contribute to the development of analytical skills. Although some researchers [21,24], have pointed out methodologies' effectiveness in improving critical thinking and problem-solving, few have tracked how these skills evolve or contribute to students' professional success after graduation. Students are aware of the contributions of PBL, LBL, and SBL individually, but unfortunately, there is so little research done on the synergy of these with regard to their influence on a large set of cognitive and psychomotor skills. These gaps could yield interesting insights into the best ways to promote analytical skills in different educational contexts.

Conceptual Framework

The theoretical basis of the study is classical approaches, in particular Bloom's taxonomy[31,32] and Lev Vygotsky's[35] sociocultural theory, which provide a deeper understanding of cognitive development and the role of social interaction in learning. At the same time, to take into account modern educational challenges, it is advisable to integrate the latest theoretical models that reflect the current needs of educational practice.

One of these is Garrison's Critical Thinking Model, which considers analytical thinking as a process of cognitive presence, reflection and problem solving.[52,53] This model emphasizes the active role of the student in building knowledge through research, integration and formulation of conclusions, which is harmoniously consistent with approaches focused on research activities.[54,55]

In addition, the development of analytical abilities is directly related to the requirements of the modern labor market and global educational trends.[48] The OECD Framework for 21st Century Competencies identifies critical thinking, information analysis and problem solving as key skills needed for full participation in economic and social life. These competencies involve flexibility of thinking, the ability to work with large amounts of complex data and make informed decisions - precisely the qualities that are actively developed through project-based, laboratory-based and STEM-oriented learning.[53]

The integration of Harrison's model and the OECD approach allows not only to expand the theoretical basis of the study, but also to emphasize its practical significance in the context of developing cognitive skills that meet modern global challenges.

Moreover, the conceptual framework of the current study is designed to explicate the importance of research activities in developing analytical skills (AS) for students through the application of three specific learning methodologies, namely Project-Based Learning (PBL), Laboratory-Based Learning (LBL), and STEM-Based Learning (SBL). PBL seems to be the first aligned consideration under RQ-1 as it compels students rather than favors them to relate the theories to real phenomena through doing a project to find solutions or develop arguments. It, in turn, leads to the fulfillment of an objective of developing real-world relevance to the solutions-based reasoning within the topic. It means that LBL connects the student's opportunity to try out concept learning they have been studying, okay, and observe, analyze data, and interpret under RQ-2. Hence, supporting the aim of cultivating an experiential learning environment materialized in an active engagement of students with the material.[56]

SBL, which links RQ-3, presents problems with a combination of science, technology, engineering, and mathematics, thus taking an interdisciplinary approach. These learning approaches join through research activities (RQ-4), which serve as the heart to enhance student's ability to analyze and critically evaluate information. These research activities include inquiry-based learning that allows students to create links

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between theoretical knowledge and its practical aspects, ultimately arming them for real-life problems. The study examines the best possible implementations of these interconnected research activities to achieve the general objective of enhancing students' analytical skills.

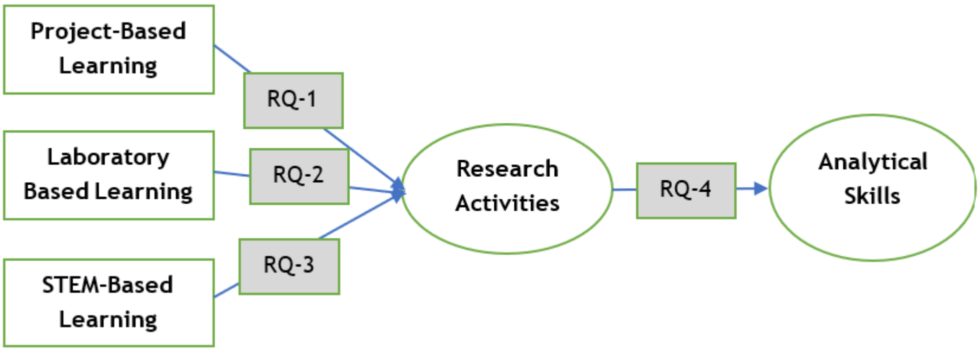

Figure 1. Conceptual Framework of the Study

METHOD

This cross-sectional study examines the impact of project-based learning (PBL), laboratory-based learning (LBL), and STEM-based learning (SBL) on students' analytical skills at a point in time as a result of research activities.

331 university students with a variety of cognitive abilities and educational backgrounds were selected using purposive sampling. Purposive sampling is a non-probability sampling technique in which a researcher intentionally selects participants based on certain characteristics or attributes relevant to the study, seeking to collect in-depth data from a targeted subset of the population rather than from a representative sample of the whole. The main argument in favor of this method was the desire to recruit only those students who have direct experience of participating in educational environments using research approaches (e.g., PBL, LBL, or STEM approaches), which ensures relevance and focus of the study.

Probabilistic methods (e.g., random sampling) were rejected due to the risk of including participants without relevant experience, which could distort the results.

Possible sampling bias was partially mitigated by covering several academic programs and faculties, which allowed for some variability in the demographic characteristics of the respondents (gender, course of study, specialty). Therefore, aware of the potential risk of sampling bias, the researchers recruited students from different faculties and educational programs (engineering, humanities, natural sciences), as well as different years (from 1st to 4th).

Students' analytical abilities were determined using the self-assessment questionnaire (MBAS) (appendix 1).

To check the validity and reliability of the instrument, a pilot test was conducted on a sample of 30 students who did not participate in the main study. Participants represented different educational fields (engineering, social sciences, natural sciences) and courses (from 2nd to 4th).

Exclusion criteria for the pilot sample:

1. Students who had previously completed similar questionnaires within other studies.
2. Students who had no experience participating in educational courses with research components.
3. Students with insufficient proficiency in the language of the questionnaire.

Based on the results of the pilot study, the wording of individual questions was refined to improve their comprehensibility. The reliability of the scale after pilot testing was Cronbach's α = 0,933, indicating high internal consistency of the instrument.

Students' analytical skills are tested by MBS in three learning modes, namely PBL, LBL and SBL. The first page of this instrument presents a set of demographic questions before moving on to four sections covering student engagement and skill development within the three learning modes. The final section assesses core analytical competencies covering problem analysis, critical analysis and pattern recognition.

The questionnaire contained a total of 37 items, but after pilot testing, items that had the least reliability due to being vague, repetitive or irrelevant were eliminated, leaving a final questionnaire consisting of 30 items. It provides insight into how each approach contributes to the development of students' analytical skills. The MBS uses Likert scale items to assess students' ability to analyse data, identify patterns and propose effective solutions. This allows students to determine their competence by analysing data with given solutions and making decisions. The MBAS shows how analytical skills were developed through PBL, LBL and SBL. Both descriptive and inferential statistical methods were used to examine students' engagement in PBL, LBL and SBL and analytical skills.

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The mean and standard deviation were used to summarize and understand the students' analytical skills scores for PBL, LBL, and SBL. The mean and standard deviation give a clear picture of how the majority of respondents responded. In inferential statistics, the strength and direction of the relationships between learning activities and analytical skills were examined using correlation analysis. This study uses a correlation test to identify and measure the relationship between two or more variables without manipulating them, including LBL, PBL, and SBL, which helps researchers understand potential relationships and patterns in their data without establishing a cause-and-effect relationship. These methods were chosen because of their ability to provide an overview of the distribution of data and an understanding of how specific research activities develop analytical skills and how these research activities together affect analytical skills.

In addition, to confirm the stability of the results over time, a test-retest reliability was conducted on a subsample of 40 students (at an interval of 2 weeks), which yielded a correlation coefficient of r = 0,879 (p < 0,001), indicating the stability of the measurement. To confirm the construct validity of the questionnaire, expert assessment was applied: four experts in the field of pedagogy, psychology, and educational assessment provided their reviews of the content of the scale, after which editorial changes were made to individual wordings.

Study limitations stem mainly from the chosen scope and methods used. One of these limitations is that the study is based on selected learning experiences such as PBL, LBL, and SBL, which cannot cover all methods that induce analytical skills. These methods were deliberately chosen for their established efficacy in engendering critical thinking, problem-solving, and interdisciplinary learning. Restricting methods to these few integrates a manageable scope with core objectives in modern education. Other instructional methodologies may also advance the development of these skills but deserve not to be covered in this study. Furthermore, schools, universities, or colleges indeed have their own ways of implementing these learning activities, which is another limitation.

RESULTS

Demographic of the study

Table 1 presents the demographic breakdown of the respondents. The majority of participants fall within the age group of 23-27 (137 respondents), followed by the 18-22 age group (125 respondents). There are fewer participants in the older age categories, with only 6 respondents each in the 33-37 and 38-42 age groups. In terms of gender, a larger proportion are male (206) compared to female (125). Regarding the department, the highest number of respondents are from Engineering (166), followed by Sciences (105) and Social Sciences (60), making up a total of 331 respondents.

Table 1. Interpretation of Demographics of Respondents

Age	
18-22	125
23-27	137
28-32	57
33-37	6
38-42	6
Gender	
Male	206
Female	125
Department	
Engineering	166
Sciences	105
Social Sciences	60
Total	331

Descriptive Statistics

Table 2 shows that PBL (M: 3,8731, SD: 0,84314) is slightly preferred because of its interactive character, and this implies more engagement than LBL (M: 3,8526, SD: 0,87221) and SBL (M: 3,8423, SD: 0,83566). However, AS (M: 3,8236, SD: 0,80885) shows the minimum mean, but it also has the least variation, indicating consistent but slightly less powerful engagement, possibly through individual performance. This reveals the preference for PBL among the participants, whereas the uniformity of AS implies limited variability in participant experience.

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Table 2. Interpretation of Descriptive Statistics		
Research Activities	**Mean**	**Std. Deviation**
Project-Based Learning	3,8731	0,84314
Laboratory-Based Learning	3,8526	0,87221
STEM-Based Learning	3,8423	0,83566
Analytical Skills	3,8236	0,80885

At the same time, the marked variability in standard deviations (e.g., SD = 0,84314 for PBL, SD = 0,87221 for LBL) may indicate heterogeneity of experiences among participants. This opens the door for in-depth subgroup analysis by variables such as faculty, educational program, course of study, or gender to identify potential determinants of the level of engagement in particular research activities. In particular, students from the Faculty of Engineering showed slightly higher average scores for all three types of learning, particularly for LBL and SBL, which is consistent with the specifics of technical education. The Faculty of Humanities had the highest scores for PBL, perhaps due to the more interactive nature of this method. The level of analytical skills (AS) among students from all faculties is relatively homogeneous (table 3).

Table 3. Subgroup analysis by faculty regarding engagement in PBL, LBL, SBL and analytical skills development

Indicator	The Faculty of Humanities (n=110)	The Faculty of Engineering (n=115)	Faculty of Natural Sciences. (n=106)
PBL (M ± SD)	3,90 ± 0,82	3,85 ± 0,86	3,82 ± 0,85
LBL (M ± SD)	3,80 ± 0,88	3,90 ± 0,86	3,86 ± 0,85
SBL (M ± SD)	3,78 ± 0,80	3,88 ± 0,82	3,82 ± 0,85
AS	3,75 ± 0,81	3,84 ± 0,79	3,85 ± 0,82

Results of the analysis by gender:
- PBL (M ± SD): 3,85 ± 0,84 (men), 3,87 ± 0,84 (women).
- LBL (M ± SD): 3,83 ± 0,87 (men), 3,86 ± 0,87 (women).
- SBL (M ± SD): 3,80 ± 0,83 (men), 3,85 ± 0,83 (women).
- Analytical skills (AS): 3,79 ± 0,81 (men), 3,85 ± 0,80 (women).

Therefore, the differences between men and women are insignificant, which is confirmed by the results of the t-test for independent samples:
- PBL (t = 0,34, p = 0,73).
- LBL (t = 0,47, p = 0,64).
- SBL (t = 0,63, p = 0,53).
- Analytical skills (AS) (t = 0,85, p = 0,40).

Thus, the results of the subgroup analysis indicate that the level of involvement in laboratory and STEM activities may depend on the faculty where the student studies. At the same time, gender does not have a significant impact on the indicators of involvement and the development of analytical skills.

Inferential Statistics

The correlation analysis in table 3 and figure 2 ascertained significant positive relationships among Problem-Based Learning (PBL), Lecture-Based Learning (LBL), Simulation-Based Learning (SBL), and Assessment Scores (AS). The correlation analysis demonstrates all statistically significant results at the 0,01 level (2-tailed). The strongest correlation is observed between SBL and AS (r = 0,781, p = 0,000), highlighting those interdisciplinary approaches integrating science, technology, engineering, and mathematics are particularly effective in fostering analytical skills. Similarly, PBL and AS (r = 0,765, p = 0,000) and LBL and AS (r = 0,764, p = 0,000) also demonstrate strong associations, indicating that these methods are crucial in developing problem-solving, critical thinking, and systematic reasoning abilities.

The interrelationships among these research activities further highlight their complementary nature. PBL and LBL correlate with r = 0,708, PBL and SBL r = 0,742, and LBL and SBL r = 0,688 (all p = 0,000). These suggest synergistic relationships depending on each technique's contribution toward fostering analytical skills. The large correlation between SBL and AS can be attributed to the interdisciplinary nature of SBL itself, which demands students to cross domain boundaries to solve complex problems.

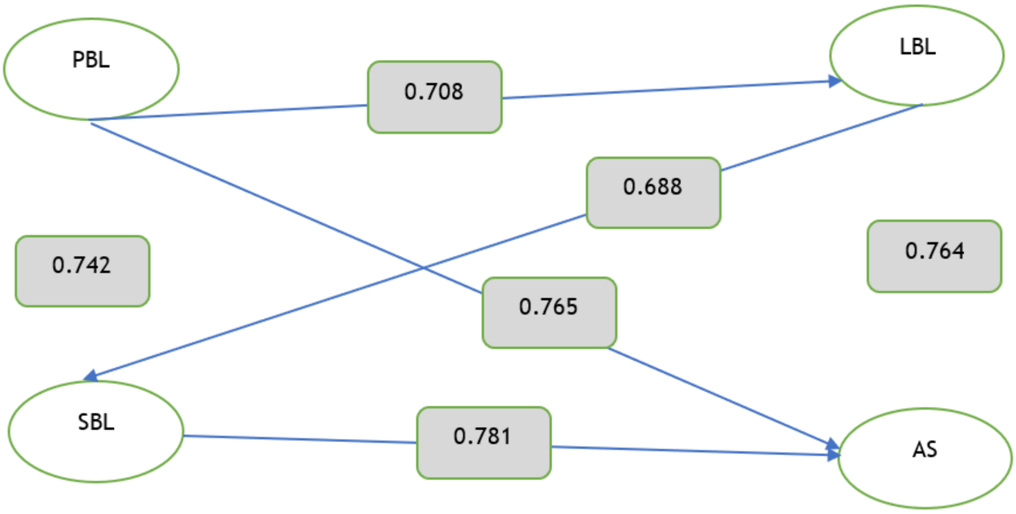

Figure 2. Correlation Network Diagram

Conversely, this solid correlation for PBL has been concluded based on the real-world problem-solving approach in PBL. At the same time, LBL integrates theory and practice through active student experimentation. The resistance to the null hypothesis was established at p = 0,000, signifying the strong empirical power of relationships. Hence, it is concluded that these research activities find space in the education curriculum by targeting analytical skill development deficiencies.

Table 4. Interpretation of Correlation among PBL, LBL, SBL and AS

Dimensions		**PBL**	**LBL**	**SBL**	**AS**
PBL	Pearson Correlation	1	0,708**	0,742**	0,765**
	Sig. (2-tailed)		0,000	0,000	0,000
	N	331	331	331	331
LBL	Pearson Correlation	0,708**	1	0,688**	0,764**
	Sig. (2-tailed)	0,000		0,000	0,000
	N	331	331	331	331
SBL	Pearson Correlation	0,742**	0,688**	1	0,781**
	Sig. (2-tailed)	0,000	0,000		0,000
	N	331	331	331	331
AS	Pearson Correlation	0,765**	0,764**	0,781**	1
	Sig. (2-tailed)	0,000	0,000	0,000	
	N	331	331	331	331

Note: **Correlation is significant at the 0,01 level (2-tailed).

DISCUSSION

The present study aimed to establish relationships between three project-based learning (PBL), lecture-based learning (LBL), and STEM-based learning (SBL) and to determine how these relationships will help to develop students' analytical skills (AS). The research problem originates from the need to fill some gaps in present education systems that do not immeasurably foster the growth of certain analytical skills among its practitioners, instead focusing on rote learning practices other than those fostering critical thinking and creativity. The intent of this study was to contribute to the rapidly growing literature base by looking into these relationships and stating the pedagogically important implications of PBL, LBL, and SBL integration in higher education. This study affirms and extends the findings of previous studies focusing on active and research-based learning methods. There is a strongly positive and statistically significant relationship between PBL and AS (r= 0,765, p < 0,001). This corresponds to the findings laid down by Rohm et al.[1], who stated that interactive and project-based approaches significantly contribute to critical thinking and engagement. This implies that students particularly liked PBL activities (M: 3,8731, SD: 0,84314), hence very interactive and engaging, which is consistent with [40], where PBL was found to significantly enhance the critical thinking skills of students through real-world problem-solving activities. This corroboration affirms the berth of PBL regarding

AS enhancement. In the same vein, the correlation between SBL and AS (r = 0,781, p < 0,001) confirms that STEM-based approaches are able to overcome the gap between theory and practice. In line with [41], wherein STEM-based learning autonomy as a medium to stimulate critical and creative thinking, findings interestingly suggest that interdisciplinary approaches afforded by SBL are fundamental to the development of analytical skills. The relationship between LBL and AS (r = 0,764, p < 0,001) correlates well with the perspectives[43] and Nainggolan et al.[49], who saw laboratory-based learning as the means to grow analytical and technical skills. LBL allows students to actively experiment and analyze their results, hence allowing them to relate theoretical concepts to real-world applications. This implies further the necessity of hands-on learning environments to formulate the critical mindset. The particularly strong correlation observed between SBL and analytical skills (r = 0,781) is explained by the intrinsic interdisciplinary nature of STEM-based learning. By integrating concepts and methods from multiple scientific and technological disciplines, SBL promotes the application of theoretical knowledge to complex real-world problems, thereby promoting higher-order cognitive processes such as synthesis, evaluation, and creative problem solving. This convergence of disciplines allows students to see connections between fields, the practical impact, and the transferability of their analytical skills.

The findings of this study strongly support PBL, LBL, and SBL in developing analytical thinking skills. The very high correlation between SBL and AS (r = 0,781) implies that interdisciplinary approaches have significant effects. SBL's integration of various disciplines helps students apply theoretical knowledge in real-world settings, in turn fostering creative problem-solving. Hence, these findings substantiate the theoretical framework of STEM, emphasizing the convergence of critical thought and creativity to resolve complex issues.

A strong correlation (r = 0,765) between PBL and analytical skills indicates the power of project-based methods to engage students truly with practical and real-world problems. This finding agrees with [54], who argue that PBL allows students to develop their critical thinking by requiring them to analyze problems and synthesize information to propose possible effective solutions. The mean score preference for PBL (M: 3,8731) was further evidence supporting students' popularity as demonstrated in its interaction and hands-on approach, while unexpectedly, a slightly lower correlation for LBL with AS (r = 764) compared to SBL, emphasizing that LBL involved hands-on experimentation. The findings of the study depicted that SBL and PBL have the strongest effect on developing the analytical skills of the pupils, including problem-solving abilities, critical thinking, and creative skills.[55,56] These findings underscore the need to implement these research learning activities into pedagogy for more reliable and long-term improvements among students. Teachers must involve students in PBL, SBL and LBL teaching methods to enhance analytical skills among students.

However, relying on self-reported data introduces the potential for widespread methodological bias, which may overstate the observed correlations between learning approaches and analytical skills. Participants' subjective perceptions of their engagement and skills may be influenced by social desirability or response consistency biases. Future studies using objective measures of effectiveness or mixed methodological approaches will confirm the validity of these findings.

The low standard deviation for AS (SD: 0,80885) indicates that students in the sample generally showed homogeneity with respect to engagement and development of analytical skills. This finding is further supported by [42], who showed that assessing students individually can lead to effective learning outcomes for all students. The consistent experiences of students boost the reliability of the research activities explored within this study.

This study has many strengths, but some limitations must also be mentioned. First, the study considers only a selected range of research activities—PBL, LBL, and SBL—while other potential methods could also be used to foster skills in analysis. Second, other contextual factors such as institutional resources, teacher training, and student demographics do influence the effective application of these methods. For instance, institutions with limited laboratory facilities or STEM resources would find it difficult to adopt LBL and SBL appropriately. Differences in teacher training and student preparedness would also figure somewhere in the equation.

Moreover, the cross-sectional design of this study limits the ability to determine causal relationships between teaching methods and the development of analytical skills. Longitudinal or experimental methods are needed to more clearly establish causal relationships. Furthermore, differences in resource availability, such as access to well-equipped laboratories for LBL and SBL, may affect the generalizability of these findings across educational settings.

These limitations need to be addressed in further research studies that should investigate the overall influence of these contextual factors on the generalizability of the findings.

Nevertheless, this study has made important contributions to the field of education. First, it tests the effectiveness of PBL, LBL, and SBL in developing analytical skills, providing some evidence for the role of active and research-based learning approaches. Correlations found in this study between the approaches and the development of analytical skills allowed for the validation of these approaches as a means of addressing some of the challenges faced by modern education systems. Second, the study emphasizes that PBL, LBL, and SBL complement each other in enhancing learning and indeed show the potential for integrating these approaches for a more wholesome learning environment. The various methods and their interrelationships speak strongly in favor of stimulating their unique strengths in order to better harness their common positive synergy with student learning outcomes.

CONCLUSIONS

The current study convincingly explains how the different learning methods—PBL, LBL, and SBL—affect a student's ability to gain AS. PBL scores highest, meaning that it is the most desired method because it is highly interactive, as demonstrated by its highest mean score (M = 3,8731, SD = 0,84314); SBL has a strong correlation with assessment performance (r = 0,781, p < 0,001). The results give credence to integrating various teaching methods in the curriculum for the development of thinking, engagement, and other learning stars. Notice the little variance in the AS (SD = 0,80885), demonstrating that individuals are doing consistently well, which could be a strong indicator of reliability for the methods. This should be incorporated into the curriculum with research activities to best induce analytical skills and to take full advantage of PBL, LBL, and SBL. One way of practical incorporation of this is through designing project-based assignments that emphasize problem-solving and applications to real-life situations. Critical thinking and creativity may be developed by exposing students to projects that require actual problem-solving by theoretical application. In conjunction with these project assignments, laboratory-based experiments serve to connect theoretical concepts with firsthand practice. These allow students to see the outcome of what they have learned, which strengthens their grasp and increases analysis. This hands-on activity can be further supported by incorporating simulation-based exercises, which prepare learners for some of the practical challenges they will face while doing their own jobs in the future. Simulations operate in a safe, controlled environment where students can experiment and solve problems without worrying about real-world consequences. Finally, to run these research-based pedagogical techniques, there has to be an investment in professional development programs for teachers. Such programs will help train educators in all the skills required for the effective application of such methods in teaching. With this, the students will enjoy the full benefit of research-driven learning experiences. Altogether, these will manifest a comprehensive strategy to augment analytical skills and prepare students for real-life difficulties. It is important to evolve methodological recommendations for educators that should include aligning learning objectives with analytical skill development, facilitating collaborative projects, and practicing reflection. It would make sense for future studies to take a longitudinal approach in order to reveal where analytical skills development has changed with time. Tracking students along different educational pathways would give evidence of the long-term effectiveness of such efforts. It can be utilized by future research in areas where the study fell short, as it primarily focused on specific instructional methods like PBL, LBL and SBL. Future research work could include an expanded scope concerning other pedagogical methods, which may also consider developing analytical skills. Another line of future research for consideration is how the effectiveness of PBL, LBL and SBL is influenced by contextual factors such as institution resources, teacher experience, and student demographics. Furthermore, because of the demographic difference across student populations, future studies could investigate how socio-economic background, prior knowledge, and learning preferences affect the impact of PBL, LBL, and SBL. Also, increasing the size of the sample for future research and varying the settings would also push the limitation of generalizability. Future studies should also consider the impact of PBL, LBL and SBL based on qualitative research design. In such a way, the set of findings would be stronger and more balanced, leading to increased reliability as well as validity of research outcomes.

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ANNEXES

Appendix 1: Questionnaire for Students (MBAS)

Demographic Information:

1. Name: ________________________
2. Institute: ________________________
3. Age: a) 18-22 b) 23-27 c) 28-32 d) 33-37 e) 38-42
4. Gender: a) Male b) Female c) Other
5. Department: a) Engineering b) Science c) Social Sciences

Sr #	Project-Based Learning (PBL)	1	2	3	4	5
1	I regularly engage in Project-Based Learning (PBL) activities.					
2	PBL has helped me think critically about real-world problems.					
3	PBL has improved my ability to analyze complex situations.					
4	Through PBL, I have learned how to work collaboratively to solve problems.					
5	My involvement in PBL has contributed significantly to my analytical skill development.					

Sr #	Laboratory-Based Learning (LBL)	1	2	3	4	5
1	I frequently participate in Laboratory-Based Learning (LBL) activities.					
2	LBL activities have improved my ability to analyze experimental data.					
3	LBL has enhanced my problem-solving abilities in scientific contexts.					
4	Laboratory experiments have helped me think critically about research results.					
5	LBL has contributed to the development of my analytical skills.					

Sr #	STEM-Based Learning (SBL)	1	2	3	4	5
1	I have participated in STEM-Based Learning (SBL) activities.					
2	SBL has encouraged me to think analytically across multiple disciplines.					
3	STEM activities have enhanced my ability to synthesize information from different fields.					
4	SBL activities have improved my ability to solve complex, interdisciplinary problems.					
5	Participation in SBL has been beneficial for the development of my analytical skills.					

Sr #	Analytical Skills	1	2	3	4	5
1	I can easily break down complex problems into smaller, more manageable parts.					
2	I often analyze information critically before making decisions.					
3	I can quickly identify patterns or trends in data.					
4	I find it easy to evaluate and compare different ideas or solutions to a problem.					
5	I am comfortable drawing conclusions from complex or incomplete data.					
6	I am able to identify the strengths and weaknesses of different arguments or solutions.					
7	I can think critically about the results of experiments or research findings.					
8	I can synthesize information from multiple sources to form a well-rounded understanding.					
9	I can predict outcomes or solve problems based on the available data.					
10	I feel confident when applying analytical skills in real-world scenarios.					

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