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SALUD, CIENCIA Y TECNOLOGÍA

ORIGINAL

Transformation of Intelligence Technology Learning through the Inquiry-Scientific Problem Based Learning to Improve Critical Thinking Skills

Transformación del aprendizaje tecnológico de la inteligencia a través de la investigación: aprendizaje basado en problemas científicos para mejorar las habilidades de pensamiento crítico

Yose Indarta[1], Ambiyar[1], Fadhillah[2], Fadhli Ranuharja[3], Margaretha Karolina Sagala[4], Daniel Rinaldi[4], Firas Tayseer Ayasrah[5], Angel Torres-Toukoumidis[6]

[1]Universitas Negeri Padang, Department of Technical and Vocational Education and Training, Padang, Indonesia.
[2]Universitas Negeri Padang, Department of Mechanical Engineering, Padang, Indonesia.
[3]Universitas Negeri Padang, Department of Electrical. Padang, Indonesia.
[4]Universitas Lampung, Faculty of Teacher Training and Education, Lampung, Indonesia.
[5]Al Ain University, College of Education Humanities and Social Sciences, Al Ain, Uni Emirat Arab.
[6]Universidad Politécnica Salesiana, Media Studies and Education Department. Cuenca, Ecuador.

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Corresponding author: Fadhli Ranuharja

ABSTRACT

This study examines the effectiveness of the Inquiry-Based Scientific Problem Learning (PBL) model in enhancing cadets' critical thinking and learning outcomes at the Sekolah Tinggi Intelijen Negara (STIN). Addressing the evolving needs of the intelligence sector, which demands technical expertise and higher-order thinking, the research combines scientific inquiry with PBL to create a comprehensive instructional approach. A quasi-experimental design involved 50 fourth-semester cadets divided into experimental and control groups. Learning outcomes were evaluated through pre-test and post-test assessments, focusing on cognitive, affective, and psychomotor domains. Results showed that using the Inquiry-Based Scientific Problem Learning model, the experimental group achieved significant gains in all areas. Cadets in the experimental group demonstrated enhanced critical thinking and analytical skills in the cognitive domain, increased motivation, communication, and collaboration in the affective domain, and superior practical skills in the psychomotor domain. Statistical analyses, including N-gain, validated the model's impact. These findings suggest that the Inquiry-Based Scientific Problem Learning model effectively develops intelligent professionals, bridging theory and practice while fostering technical and soft skills crucial in the field. This research supports the need for innovative and adaptive educational methods in specialized and dynamic environments like intelligence education.

Keywords: Inquiry-Based Scientific; Problem-Based Learning; Intelligence Technology; Critical Thinking; Educational Innovation.

RESUMEN

Este estudio examina la efectividad del modelo de Aprendizaje Basado en la Resolución de Problemas Científicos a través de la Investigación (PBL, por sus siglas en inglés) en la mejora del pensamiento crítico y los resultados de aprendizaje de los cadetes en la Sekolah Tinggi Intelijen Negara (STIN). Abordando las crecientes necesidades del sector de inteligencia, que requiere habilidades técnicas y pensamiento de orden superior, la investigación combina la indagación científica con el modelo PBL para crear un enfoque instruccional integral. Un diseño cuasi-experimental involucró a 50 cadetes de cuarto semestre, divididos en grupos experimental y de control. Los resultados de aprendizaje fueron evaluados a través de pruebas previas y posteriores, centradas en los dominios cognitivo, afectivo y psicomotor. Los resultados mostraron que, al usar el modelo de Aprendizaje Basado en la Resolución de Problemas Científicos, el grupo experimental logró avances significativos en todas las áreas. Los cadetes del grupo experimental demostraron un pensamiento crítico y habilidades analíticas mejoradas en el dominio cognitivo, mayor motivación, comunicación y colaboración en el dominio afectivo, y habilidades prácticas superiores en el dominio psicomotor. Los análisis estadísticos, incluido el N-gain, validaron el impacto del modelo. Estos hallazgos sugieren que el modelo de Aprendizaje Basado en la Resolución de Problemas Científicos desarrolla eficazmente a profesionales inteligentes, puenteando la teoría y la práctica mientras fomenta habilidades técnicas y blandas cruciales en el campo. Esta investigación respalda la necesidad de métodos educativos innovadores y adaptativos en entornos especializados y dinámicos como la educación en inteligencia.

Palabras clave: Aprendizaje Basado en la Investigación Científica; Aprendizaje Basado en Problemas; Tecnología de Inteligencia; Pensamiento Crítico; Innovación Educativa.

INTRODUCTION

The rapid advancement of intelligence technology has significantly transformed the operations of security and defense institutions globally. Technologies such as artificial intelligence (AI), big data analytics, drones, and advanced sensor systems have revolutionized the accuracy and speed of information gathering [1,2] enabling real-time data analysis and decision-making processes.[3] This integration of sophisticated technologies has markedly improved the efficiency and effectiveness of intelligence work, facilitating faster and more precise threat assessments.[4,5]

Incorporating cutting-edge technology in security frameworks has enhanced the capacity of institutions to monitor emerging threats, analyze trends, and support strategic decision-making.[6] These advancements necessitate continuous adaptation and innovation to address the dynamic threat landscape. Technology integration has proven crucial for effective intelligence gathering and analysis in counter-terrorism efforts, demanding that security agencies remain agile to counter evolving threats.[7]

Indonesia faces unique security challenges as a nation with a complex geographic, political, and social landscape. Practical intelligence in Indonesia requires technical competencies and higher-order cognitive skills, such as critical analysis, innovation, and the ability to navigate uncertainty. Consequently, intelligence education must keep pace with technological progress and consider Indonesia's social and cultural context. The Sekolah Tinggi Intelijen Negara (STIN), the only higher education institution in Indonesia dedicated to intelligence training, plays a pivotal role in equipping future intelligence professionals.[8] However, the challenge extends beyond technical proficiency; it involves developing cadets' HOTS, which is essential for navigating modern security environments' complexities.[9]

As defined by Yee et al.[10], HOTS involves the capacity to engage in deep analysis and tackle novel challenges. HOTS encompasses applying, analysing, evaluating, and creating knowledge rather than merely recalling facts.[11,12] Traditional pedagogies are increasingly seen as inadequate in preparing cadets for the nuanced and multifaceted real-world demands in rapidly evolving educational contexts.

Several innovative learning models are recognized for fostering HOTS, including Problem-Based Learning (PBL). PBL is an instructional approach that reinforces content comprehension and equips students with the skills needed to address complex, real-world problems.[13,14] According to Carrió et al.[15], PBL is a student-centred method that promotes critical thinking, creativity, communication, collaboration, and problem-solving abilities. Moreover, PBL encourages innovative thinking and supports the practical application of knowledge by linking academic content to real-world contexts.[16]

While PBL is well-suited for 21st-century education, the model has limitations that can hinder its effectiveness. PBL requires active participation and problem-solving skills,[17,18] high-level collaboration, and sufficient resources.[19,20] It may not be suitable for all subjects, especially those requiring factual knowledge acquisition [21] [22]. PBL can be time-consuming and demands careful management and appropriate teaching methods.[23,24] The lack of dynamic processes in PBL can lead to student boredom and reduced engagement.[25] Although PBL is designed to develop critical and analytical skills through practical problem-solving, it often emphasizes finding quick solutions rather than rigorously validating them with scientific methods.

This study proposes a more field-appropriate and innovative learning model to overcome these challenges:

the Inquiry-Based Scientific Problem Learning model. This model synergizes the scientific inquiry approach with PBL, focusing on practical problem-solving through scientific processes like observation, experimentation, and critical analysis. This framework encourages students to answer questions and involves them in designing experiments and evaluating data, thereby deepening their understanding of scientific principles and methodologies. The main phases of this model include orientation, investigation, conclusion, and discussion, all aimed at fostering critical thinking and independent inquiry.[26,27,28]

The primary objective of this study is to evaluate the effectiveness of the Inquiry-Based Scientific Problem Learning model in enhancing STIN cadets' critical and analytical thinking skills. This approach seeks to improve cognitive capabilities and ensure a comprehensive understanding of complex intelligence scenarios. By integrating these methods, the study aspires to provide STIN cadets with a robust learning model, equipping them with advanced skills necessary to address modern intelligence challenges, including problem-solving, decision-making, and higher-order critical thinking.

METHOD

This study employs a quasi-experimental design to assess the effectiveness of the Inquiry-Based Scientific Problem Learning model in enhancing student learning outcomes in the Intelligence Technology course at the Sekolah Tinggi Intelijen Negara (STIN). The quasi-experimental design involves two groups: the experimental group, which utilizes the inquiry-based learning model, and the control group, which follows traditional lecture-based instruction. To measure changes in learning outcomes, the study employs a pre-test and post-test design, where both groups are administered tests before and after the intervention.[29,30,31] Data collection was conducted using purposive sampling, selecting 50 fourth-semester students enrolled in the Intelligence Technology course. The experimental group engaged in inquiry-based learning, involving collaborative activities and practical case studies, while the control group followed traditional lecture-based instruction.

Figure 1 illustrates the research procedure utilizing the quasi-experimental design. Following the teaching period, a post-test was administered to measure changes in students' cognitive, affective, and psychomotor outcomes. Data analysis was performed using SPSS software, including descriptive statistics, normality tests, homogeneity tests, and independent t-tests to compare outcomes between the experimental and control groups. In addition, a standardized gain analysis (N-gain) was used to assess improvements in learning outcomes between the pre-test and post-test, with results categorized as high, medium, or low based on the N-gain scores. Table 1 summarizes the data analysis techniques used in this study.

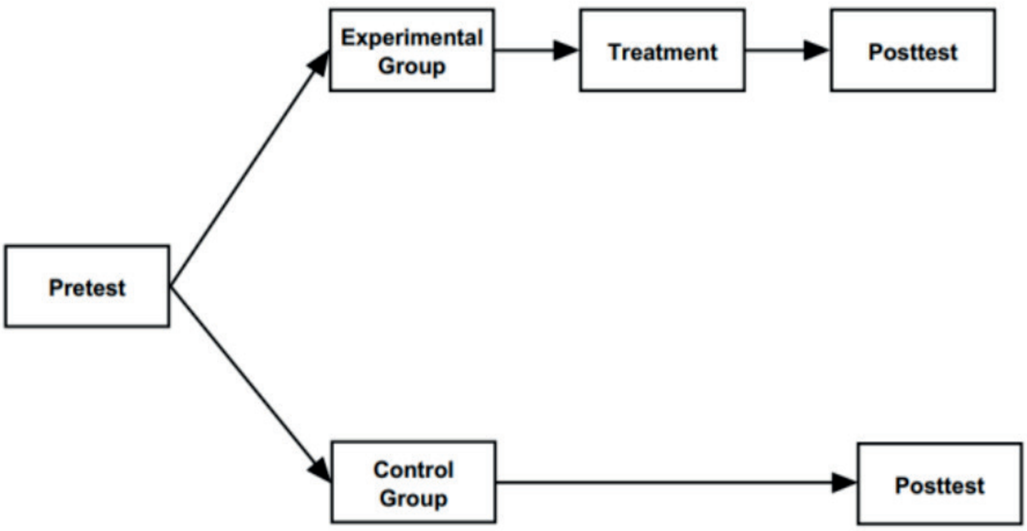

Figure 1. Research Procedure Using a Quasi-Experimental Design

The method used in the Intelligence Technology course is based on the Inquiry Scientific-Problem-Based Learning model, aimed at developing higher-order thinking skills within a student-centered learning environment. In this approach, cadets are engaged in solving complex real-world problems, which stimulate independent exploration, critical thinking, and collaborative learning. The learning process is organized into structured yet flexible instructional stages, gradually developing cognitive, affective, and psychomotor skills. Figure 2 presents the syntax of the Inquiry Scientific-Problem-Based Learning model.

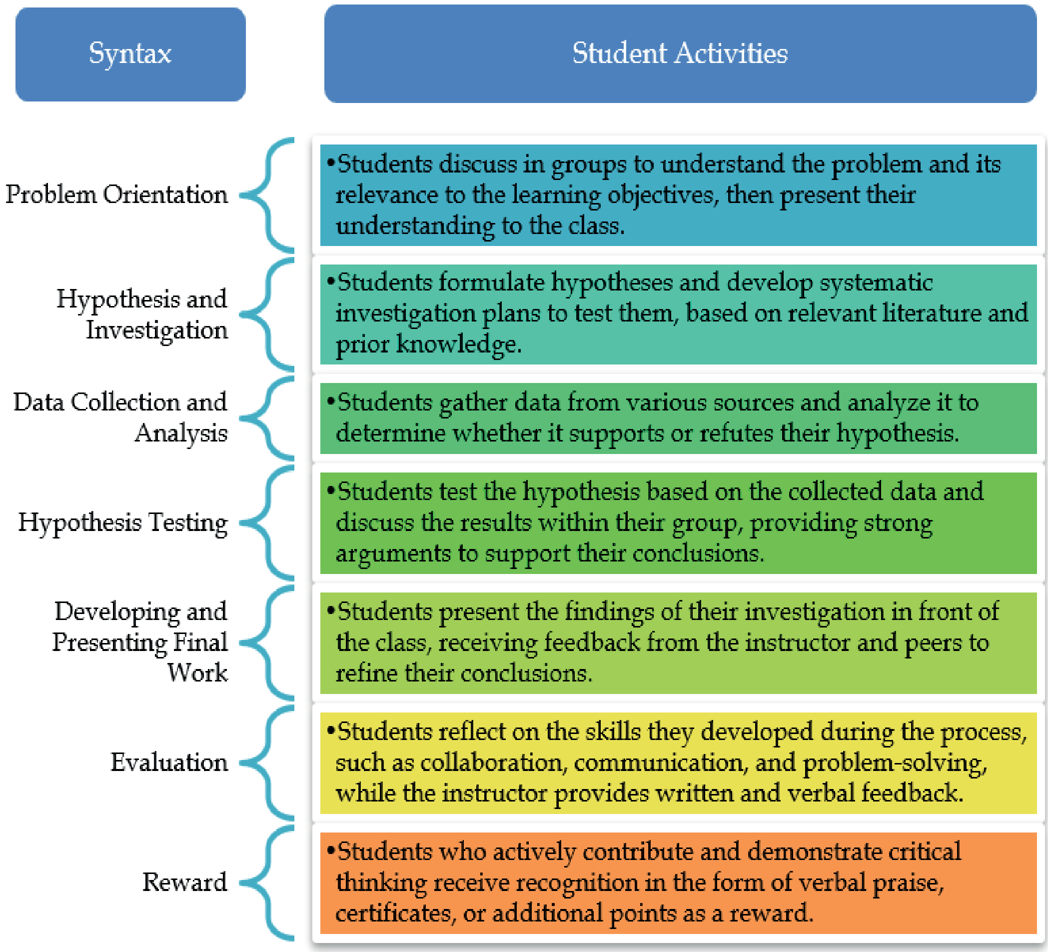

Figure 2. Syntax model inquiry Scientific - Problem-Based Learning

The data were subsequently analyzed using SPSS with descriptive statistical analysis to describe the data, normality and homogeneity tests to ensure data suitability, and independent sample t-tests to compare differences between groups. Additionally, Normalized Gain (N-Gain) was used to measure improvements in learning outcomes by comparing pre-test and post-test scores. The N-Gain index provides an overview of the level of improvement in learning outcomes, categorized as high, medium, or low. The final evaluation of the effectiveness of this model was conducted by comparing pre-test and post-test scores.

The formula employed to calculate the N-gain for students after implementing the Inquiry-Based Scientific Problem Learning model is presented in table 1, which allows for a clear and systematic evaluation of the learning improvements observed.

Table 1. Interpretation of n-Gain

N-Gain Index	Interpretation
N-Gain ≥ 0,7	High
0,3 ≤ N-Gain < 0,7	Medium
N-Gain < 0,3	Low

RESULTS

Scientific Inquiry Model Approach - Problem-Based Learning

The effectiveness evaluation aimed to determine whether the Inquiry-Based Scientific Problem Learning model is an effective instructional strategy for Intelligence Technology. This was assessed by comparing cadets' pre-test and post-test learning outcomes, focusing on improving critical thinking and analytical skills.

Cadets' learning outcomes were measured using a 50-question multiple-choice test, administered as pre-tests and post-tests for the experimental and control groups. The pre-test established baseline competencies, while the post-test gauged the impact of the intervention.

To validate the findings, normality and homogeneity tests were conducted, ensuring the data was suitable for further statistical analysis and confirming the comparability of the groups.

Normality Test

Table 2 presents the normality test results for both pre-test and post-test scores in the control and experimental groups. A significance value (Sig.) of ≥ 0,05 was obtained for both groups, indicating that the data followed a normal distribution. This conformity to normality is a prerequisite for the application of parametric tests, such as the Independent Sample T-test.

Homogeneity Test

The homogeneity test, which assesses the consistency of variance between groups, showed a Sig. Value of 0,682 for the pre-test and 0,955 for the post-test—both above 0,05. This confirms that the variability between the experimental and control groups is comparable, indicating that differences in post-test scores can be attributed to the instructional intervention rather than pre-existing disparities.

The results of the normality and homogeneity tests validate the reliability of the data, supporting the use of the Independent Sample T-test for further analysis. These tests provide a solid foundation for assessing the effectiveness of the Inquiry-Based Scientific Problem Learning model, enabling a comprehensive evaluation of its impact on cadets' cognitive, affective, and psychomotor skills.

Table 2. Descriptive Analysis Results of Normality and Homogeneity Tests

Class	Kolmogorov-Smirnov			Shapiro-Wilk			Homogeneity Test	
	Statistic	df	Sig.	Statistic	df	Sig.	Levene's Statistic	Sig.
Pretest ex	,132	25	,200*	,947	25	,213	0,1693	,682
Pretest con	,172	25	,055	,924	25	,063		
Posttest ex	,167	25	,072	,946	25	,203	1,779	,955
Posttest con	,140	25	,200*	,956	25	,339		

Table 2 presents the results of normality and homogeneity tests for the pre-test and post-test data from the experimental (ex) and control (con) groups. Based on the Kolmogorov-Smirnov and Shapiro-Wilk normality tests, the significance (Sig.) values for both the pre-test and post-test in both groups exceed the 0,05 threshold, indicating that the data are normally distributed. This suggests that the distribution of the pre-test and post-test data does not significantly differ from a normal distribution in both the experimental and control groups.

Furthermore, the homogeneity test using Levene's Statistic reveals significance values greater than 0,05 for all groups (pre-test and post-test), both for the experimental and control groups. This confirms that the variances between the experimental and control groups are consistent or homogeneous, indicating that the differences observed in the post-test scores can be attributed to the instructional intervention provided, rather than to pre-existing differences between the two groups.

The results of these normality and homogeneity tests provide a robust basis for proceeding with further analysis using the Independent Sample T-test, which will be employed to assess the effectiveness of the Inquiry-Based Scientific Problem Learning model.

Table 3. Independent Sample T-Test Results

Independent Samples Test								
		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Results	Equal variances assumed	,182	,671	12,134	48	,000	1 530,000	126,095
	Equal variances are not assumed.			12,134	47,956	,000	1 530,000	126,095

Table 3 presents the results of the Independent Sample T-Test, performed using SPSS software to evaluate the model's effect on cadets' cognitive outcomes. The analysis revealed a significant difference in average cognitive performance between the experimental and control groups, with a t-value of 12,134 and a p-value of 0,000 (p < 0,05). This indicates that the instructional intervention strongly impacted the experimental group's cognitive abilities, demonstrating the model's success in enhancing higher-order thinking skills.

Figure 3 demonstrates that the experimental class improved from a Pre-test score of 39,78 to a Post-test score of 90,30, with an N-Gain score of 0,83. In contrast, the control class increased from 40,80 to 75,00, with an N-Gain score of 0,58. These results confirm the superior effectiveness of the model in enhancing learning outcomes.

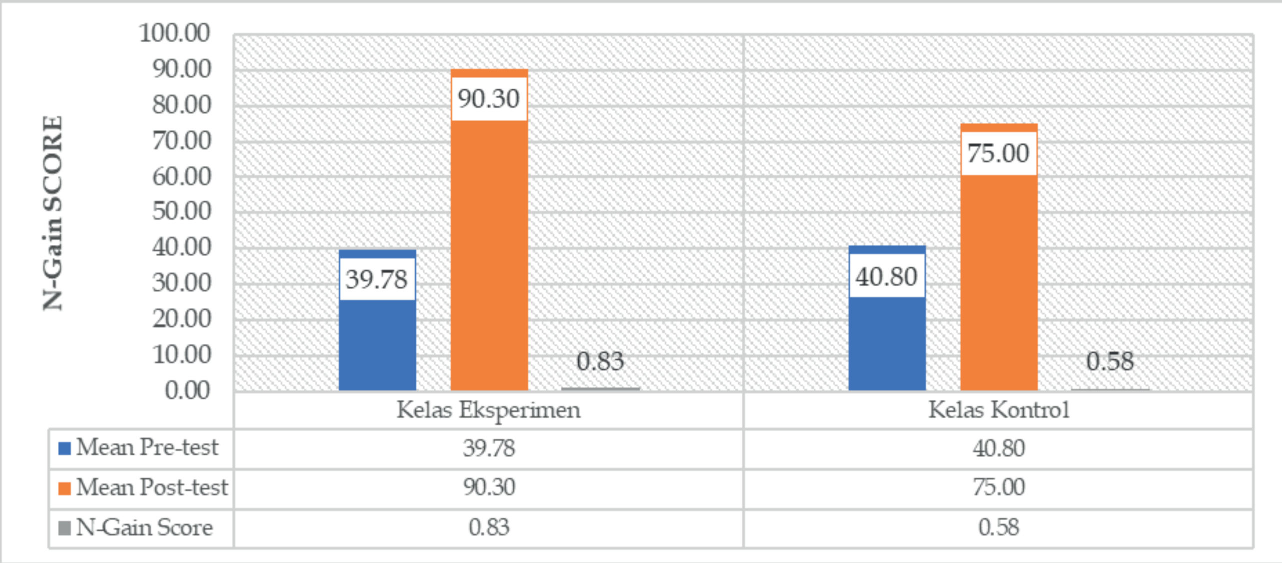

Figure 3. N-Gain Score Analysis

The results demonstrate that the Inquiry-Based Scientific Problem Learning model significantly impacted the experimental class more than the control class. While both groups improved after the pre-test, the increase in the experimental class was notably more significant, indicating that the model was far more effective than traditional instruction in enhancing learning outcomes.

Affective Domain

The affective domain, which encompasses attitudes, values, and social-emotional skills, was evaluated through systematic observations during the instructional period in the experimental class. This assessment focused on key affective skills, including critical thinking, creativity, communication, and collaboration. Data was collected throughout presentations and interactive class sessions, capturing the cadets' engagement and development in these dimensions. Table 4 provides a summary of the results, offering a detailed comparison of affective skills between the experimental and control groups:

Table 4. Affective Domain Assessment Results

No	Dimension	Experimental	Control
1	Discipline	85,2	86,8
2	Manners & Ethics	86,4	82,6
3	Critical Thinking Ability	86,6	86,0
4	Problem-Solving Ability	87,4	84,0
5	Creativity	83,8	83,2
6	Communication Ability	84,2	82,6
7	Collaboration Ability	86,8	84,2
Mean		85,77	84,2

The results in table 4 demonstrate that the experimental group achieved higher average scores across most affective dimensions than the control group. Notably, the Manners and ethics, Problem-Solving Ability, Communication, and Collaboration scores were significantly higher in the experimental group, highlighting the positive impact of the Inquiry-Based Scientific Problem Learning model on the cadets' affective skills. The overall average score of 85,77 for the experimental group, compared to 84,20 for the control group, underscores the model's effectiveness in enhancing social-emotional competencies, essential for success in the Intelligence Technology field.

Psychomotor Domain

The assessment of outcomes in the psychomotor domain was conducted through observations of the skills performed by the instructor on the cadets in both the experimental and control groups. The focus of this assessment is on competencies relevant to the Intelligence Technology course. The evaluation was based on specific indicators and utilized a grading rubric to achieve more objective and comprehensive results.

The results of the psychomotor assessment for both groups are presented in figure 4, which illustrates the analysis of the average skill level achieved by both the experimental and control groups.

Figure 4. Psychomotor Domain Graph Analysis

Figure 4 shows that the experimental group achieved an average score of 86,43, which is higher than the average score of 83,18 attained by the control group. This difference in scores indicates that the experimental group, which utilized the Inquiry-Based Scientific Problem Learning model, demonstrated superior practical skills compared to the control group. The higher score in the experimental group suggests that this learning model is more effective in enhancing psychomotor skills, which could positively impact the mastery of practical competencies and the application of knowledge relevant to the course material.

DISCUSSION

Based on the results of this study, it can be concluded that the implementation of the Inquiry-Based Scientific Problem Learning (PBL) model in the Intelligence Technology course demonstrated significant effectiveness in enhancing the critical thinking skills and learning outcomes of cadets at the Sekolah Tinggi Intelijen Negara (STIN). Using an inquiry-based and PBL learning model positively contributed to the student's cognitive, affective, and psychomotor domains.

These findings are supported by Hmelo-Silver(32), who emphasized that PBL encourages active participation in problem-solving and critical reflection, fostering the development of higher-order thinking skills. Furthermore, found that PBL helps learners better understand the concepts, particularly in real-world applications. The research by Bybee(33) demonstrated that the inquiry-based model enables students to think critically and solve problems scientifically, which is particularly beneficial for mastering complex concepts. This aligns with the current study's findings, where the application of the inquiry model in the Intelligence Technology course enabled students to connect theory with practical application.

In the affective domain, the Inquiry-Based Scientific Problem Learning model enhanced critical thinking skills and increased student engagement and motivation. Using this approach, the experimental group exhibited higher average affective scores compared to the control group, with improvements in collaboration, problem-solving, and communication. Saunders-Stewart(34) highlighted that an inquiry-based approach can drive students to engage more deeply in the learning process, fostering curiosity and independence. According to Dolmans(35), integrating PBL with an inquiry-based method is also instrumental in enhancing social interaction among students, leading to positive impacts on learning motivation and interpersonal skills. This aligns with the findings of this study, where the experimental group demonstrated superior collaboration and communication skills compared to the control group. In the context of intelligence education, effective collaboration and communication skills are crucial for analyzing and solving the complex challenges encountered in the field.

The study also revealed that the implementation of the Inquiry-Based Scientific Problem Learning model resulted in a significant improvement in psychomotor skills. Practical skills essential in intelligence technology, such as data analysis and the use of advanced technology, were more developed in the experimental group compared to the control group, with an average psychomotor score of 86,43 compared to 83,18.

This aligns with the findings of Schmidt(36), who reported that an inquiry-based PBL approach helps students connect theory and practice more effectively. Norman and Schmidt(37) also found that PBL allows students to develop superior psychomotor skills through direct involvement in practical activities. This is particularly crucial in the context of intelligence technology, where students are expected to understand theoretical concepts and apply them in practical scenarios.

Additionally, research by Kolodner(38) showed that integrating inquiry-based methods with PBL encourages students to develop technical skills and problem-solving abilities through experiments and practical simulations. In this study, the more significant improvement in practical skills observed in the experimental class compared to the control class indicates that this approach can effectively help cadets master skills relevant to the Intelligence Technology course.

Interestingly, this study found that the control group scored slightly higher in the discipline dimension than the experimental group. Kirkpatrick and Kirkpatrick(39) explained that shifting from a more structured teaching method to a more independent approach can affect student discipline, as learners require time to adapt to increased autonomy. This is also supported by Schmidt(40), who noted that transitioning to a PBL model can temporarily decrease aspects like discipline, as students need to adjust to an approach that demands active participation and collaboration.

This study innovatively explores the effectiveness of Inquiry-Based Scientific Problem Learning in the Intelligence Technology course by assessing cognitive, affective, and psychomotor dimensions. It plays a crucial role in facilitating critical thinking and scientific inquiry. This novel approach uses N-gain as an innovative evaluation method to measure the success of the Inquiry-Based Scientific Problem Learning model, highlighting its strengths in boosting learning motivation, developing practical skills, enhancing student engagement, fostering critical problem-solving, and promoting collaboration.

CONCLUSIONS

This study demonstrates that the Inquiry-Based Scientific Problem Learning model has a significant impact on improving cadet learning outcomes at the Sekolah Tinggi Intelijen (STIN). The model has proven effective in enhancing cognitive, affective, and psychomotor skills among the cadets, which are essential to meet the demands of the intelligence field. In the cognitive domain, the experimental group showed significant improvements in critical thinking and problem-solving skills. The affective results indicated increased engagement and collaboration, while the psychomotor assessment confirmed the model's superiority in developing relevant practical skills. Although the control group exhibited higher discipline scores, the shift from a traditional learning structure to an active learning environment may have contributed to this outcome. Overall, the PBL model proves to be an effective holistic learning strategy that not only improves technical skills but also soft skills, with broad potential applications in technical and professional training.

REFERENCES

1. Hanafi M, Almasri. Design and Implementation of an Arduino-Based Bluetooth-Controlled Shopping Trolley with Ultrasonic Sensor Integration. J Hypermedia Technol Enhanc Learn. 2024 Oct 17;2(3):320–37.

2. Kusuma RW, Faiza D, Thamrin, Anori S. Automatic Light Control System for Bathroom Using Arduino Uno. J Hypermedia Technol Enhanc Learn. 2024 Oct 17;2(3):229–44.

3. Samala AD, Rawas S, Wang T, Reed JM, Kim J, Howard NJ, et al. Unveiling the landscape of generative artificial intelligence in education: a comprehensive taxonomy of applications, challenges, and future prospects. Educ Inf Technol [Internet]. 2024 Aug 13 [cited 2024 Nov 9]; Available from: https://link.springer.com/10.1007/s10639-024-12936-0

4. Turgut H. Data Science And Artificial Intelligence In Agriculture. In: Pulak Kumar Patra Dr, Seval Sevgi Kirdar ProfDr, Das T, Yawale P, editors. Futuristic Trends in Agriculture Engineering & Food Sciences Volume 3 Book 7 [Internet]. First. Iterative International Publisher, Selfypage Developers Pvt Ltd; 2024 [cited 2024 Oct 23]. p. 332–60. Available from: https://iipseries.org/viewpaper.php?pid=6211&pt=data-science-and-artificial-intelligence-in-agriculture

5. Mubarok AS, Susandi A, Mantoro T. Applications of Artificial Intelligence and Big Data for Strengthening the Role of Intelligence in Human Security. In: 2022 IEEE 8th International Conference on Computing, Engineering and Design (ICCED) [Internet]. Sukabumi, Indonesia: IEEE; 2022 [cited 2024 Oct 23]. p. 1–5. Available from:

https://ieeexplore.ieee.org/document/10010514/

6. Shortland N, Forest JJF. Tracking Terrorism: The Role of Technology in Risk Assessment and Monitoring of Terrorist Offenders. In: Fox B, Reid JA, Masys AJ, editors. Science Informed Policing [Internet]. Cham: Springer International Publishing; 2020 [cited 2024 Oct 23]. p. 57–76. (Advanced Sciences and Technologies for Security Applications). Available from: http://link.springer.com/10.1007/978-3-030-41287-6_4

7. Jensen NJ. Technology and intelligence. Journal of Money Laundering Control. 2005 Jul 1;8(3):227–42.

8. Sya'ban AN, Faiza D, Thamrin, Jasril IR. Rancang Bangun dan Tingkat Akurasi Trainer Hukum Ohm dan Hukum Krichoff. Journal of Hype and TEL. 2024 Jan 23;2(1):59–73.

9. Kusuma MD, Rosidin U, Abdurrahman A, Suyatna A. The Development of Higher Order Thinking Skill (Hots) Instrument Assessment In Physics Study. IOSRJRME. 2017 Jan;07(01):26–32.

10. Yee MH, Yunos JM, Othman W, Hassan R, Tee TK, Mohamad MM. Disparity of learning styles and higher order thinking skills among technical students. Procedia-Social and Behavioral Sciences. 2015;204:143–52.

11. Mahendra IWE, Parmithi NN, Jayantika IGANT. Factors Affecting Teachers in Collecting HOTS Questions: A Description Analysis. INTJECSE. 2022 Mar 17;14(1):1005–12.

12. Jihannita J, Prasetyo ZK, Wilujeng I. How to Prepare HOTS to Face the 21st Century? jppipa, pendidikan ipa, fisika, biologi, kimia. 2023 Aug 25;9(8):486–92.

13. Deniş-Çeliker H, Dere S. The Effects of The Problem-Based Learnıng Supported by Experiments in Science Course: Students' Inquiry Learning and Reflective Thinking Skills. J Sci Learn. 2022 Mar 1;5(1):14–27.

14. Mahendra IWE, Sugiharni GAD. Problem-Based Learning: Learning Approach Solutions in Crisis Period. Journal of Education Research and Evaluation. 2022;6(3):415–22.

15. Carrió M, Baños JE, Rodríguez G. Comparison of the Effect of Two Hybrid Models of Problem-Based Learning Implementation on the Development of Transversal and Research Skills and the Learning Experience. In Frontiers Media SA; 2022. p. 875860.

16. Rehmat AP, Glazewski K, Hmelo-Silver CE. Contextualizing problem-based learning: An overview of research and practice. 2018;

17. Ginanjar H. Improving Students' Opinoning Ability and Learning Outcomes Through Problem-Based Learning in VIII grade. JED (Jurnal Etika Demokrasi). 2023;8(4):483–96.

18. Ujulu I, Umar MK, Mursalin, Odja AH. Students' Problem-Solving Profile in Overcoming Sound Wave Concepts Based Students' Academic Abilities on Online Class: In Yogyakarta, Indonesia; 2021 [cited 2024 Oct 29]. Available from: https://www.atlantis-press.com/article/125953681

19. Pamungkas GP, Siregar R, Lilulidesi M, Sutono S. Peningkatan Kemampuan Pemecahan Masalah Dengan Model Problem Based Learning. Laplace: Jurnal Pendidikan Matematika. 2023;6(1):269–82.

20. Smith G, Ichda MA, Alfan M, Kuncoro T. Literacy studies: Implementation of problem-based learning models to improve critical thinking skills in elementary school students. KnE Social Sciences. 2023;222–33.

21. Gonzalez L. The Problem-Based Learning Model. In: 2019 Eighth International Conference on Educational Innovation through Technology (EITT). Biloxi, MS, USA: IEEE; 2019. p. 180–3.

22. Ernawati E, Ferdian F, Zur R. Improving fashion design learning outcomes by problem based learning model in vocational high school.

23. Ghufron MA, Ermawati S. The strengths and weaknesses of cooperative learning and problem-based learning in EFL writing class: Teachers' and students' perspectives. International Journal of Instruction. 2018;11(4):657–72.

24. Salam M, Ndia L, Misu L, Jafar J, Suhar S, Hasnawati H. Applying scaffolding technique in Problem Based Learning (PBL) model on students' mathematics problem solving ability. World J Adv Res Rev. 2024 Mar 30;21(3):1372–9.

25. Jayanti DD, Arif QN, Marlina M. Penerapan Model Pembelajaran PBL (Problem Based Learning) Materi Daur Air Pada Pelajaran Biologi. ASPIRASI. 2024 Mar 14;2(2):54–61.

26. Alarcon DAU, Talavera-Mendoza F, Paucar FHR, Caceres KSC, Viza RM. Science and inquiry-based teaching and learning: a systematic review. Front Educ. 2023 May 5;8:1170487.

27. Mieg HA, Ambos E, Brew A, Galli D, Lehmann J, editors. STEM. In: The Cambridge Handbook of Undergraduate Research [Internet]. 1st ed. Cambridge University Press; 2022 [cited 2024 Oct 29]. p. 189–238. Available from: https://www.cambridge.org/core/product/identifier/9781108869508%23PTN-bp-6/type/book_part

28. Andre J, Ramadhani W, Syahril S, Purwanto W, Irfan D, Basri IY. Development of an e-module for sensors and transducers using Kvisoft Flipbook to enhance 4Cs skills in vocational education students. Jurnal Pendidikan Teknologi Kejuruan. 2024;7(3):126–39.

29. Rosenström TH, Czajkowski NO, Solbakken OA, Saarni SE. Direction of dependence analysis for pre-post assessments using non-Gaussian methods: a tutorial. Psychotherapy Research. 2023 Nov 17;33(8):1058–75.

30. Chen M. Empirical likelihood methods for pretest-posttest studies. 2015;

31. Fauzani AR, Ampera D. Development Interactive Video Media Using Study Strategies Groups for Facial Skin Care Learning not Problems Beauty Cosmetology SMK Negeri 3 Pematang Siantar.

32. Hmelo-Silver CE. Problem-based learning: What and how do students learn? Educational psychology review. 2004;16:235–66.

33. Bybee RW, Taylor JA, Gardner A, Westbrook A, Landes N. The BSCS 5E instructional model: Origins and effectiveness. 2006;

34. Saunders-Stewart KS, Gyles PD, Shore BM. Student outcomes in inquiry instruction: A literature-derived inventory. Journal of advanced academics. 2012;23(1):5-31.

35. Dolmans DH, De Grave W, Wolfhagen IH, Van Der Vleuten CP. Problem-based learning: Future challenges for educational practice and research. Medical education. 2005;39(7):732–41.

36. Schmidt HG, Rotgans JI, Yew EH. The process of problem-based learning: what works and why. Medical education. 2011;45(8):792–806.

37. Norman GR, Schmidt HG. Effectiveness of problem-based learning curricula: Theory, practice and paper darts. Medical education. 2000;34(9):721–8.

38. Kolodner JL, Camp PJ, Crismond D, Fasse B, Gray J, Holbrook J, et al. Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design (tm) into practice. The journal of the learning sciences. 2003;12(4):495–547.

39. Kirkpatrick D, Kirkpatrick J. Evaluating training programs: The four levels. Berrett-Koehler Publishers; 2006.

40. Schmidt HG. Foundations of problem-based learning: some explanatory notes. Medical education. 1993;27(5):422–32.

AVAILABILITY OF DATA AND MATERIALS

The datasets used in this study are publicly accessible and have been appropriately cited in the datasets section to ensure transparency and facilitate replication.

CONFLICT OF INTEREST

The authors declare that this research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

FINANCING

None.

AUTHORSHIP CONTRIBUTION

Conceptualization: Yose Indarta, Ambiyar, Fadhilah, Fadhli Ranuharja.
Formal analysis: Margaretha Karolina Sagala, Daniel Rinaldi.
Research: Yose Indarta, Fadhi Ranuharja, Margaretha Karolina Sagala.
Methodology: Yose Indarta, Fadhli Ranuharja.
Project management: Yose Indarta.
Resources: Yose Indarta, Fadhli Ranuharja, Angel Torres-Toukoumidis.
Data analysis: Margaretha Karolina Sagala, Daniel Rinaldi.
Supervision: Ambiyar, Firas Tayseer Ayasrah, Angel Torres-Toukoumidis.
Validation: Ambiyar, Fadhillah, Firas Tayseer Ayasrah.
Templating: Daniel Rinaldi.
Drafting - original draft: Yose Indarta, Fadhli Ranuharja.
Writing - proofreading and editing: Fadhli Ranuharja, Angel Torres-Toukoumidis.