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Fostering Critical Writers: The Impact of Integrating Deep and Transformative Learning on Undergraduates' Scientific Writing Competence

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Abstract: Fostering Critical Writers: The Impact of Integrating Deep and Transformative Learning on Undergraduates' Scientific Writing Competence. Objectives: This research aims to examine the effectiveness of integrating Deep Learning (DL) and Transformative Learning (TL) approaches in improving students' scientific writing competence in general Indonesian language courses. **Methods**: A true-experimental design with pretest and posttest control groups was used because it provides strong control, ensuring that changes in outcomes are attributable to the DL–TL treatment. The population consisted of students in elementary school teacher education at IKIP Siliwangi, and 90 were selected via cluster random sampling. The experimental group (n=45) received DL–TL integrated instruction, while the control group (n=45) received conventional instruction. The research was conducted over 16 meetings from March 4 to August 10, 2025. Data were collected using a project-based scientific writing assessment supported by rubrics evaluating content relevance and originality, organization and coherence, argumentation quality, academic language use, and citation accuracy. Observation sheets and a Likert-scale questionnaire further supported the data. Inferential analysis employed the Shapiro–Wilk test, Levene's test, and the independent t-test, while qualitative data were analyzed using the Miles and Huberman model. **Findings:** the experimental group achieved significantly greater improvement (Post-test Mean = 82.11) than the control group (Post-test Mean = 73.11), with a mean difference of 9.00 points ($t(88)=11.112$, $p<0.001$). The N-Gain Score of 0.7782 and N-Gain Percent of 77.8222 indicated a high and effective category of improvement. Qualitatively, students demonstrated increased engagement, reflective disposition, and collaboration. **Conclusion:** DL–TL integration proved more effective than conventional learning in enhancing scientific writing and strengthening students' critical, reflective, and collaborative capacities.

Keywords: deep learning, transformative learning, scientific writing, indonesian language.

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INTRODUCTION

The Indonesian language course, a compulsory general course, plays a fundamental role in developing the academic competency of higher education students, particularly in scientific writing, an essential academic skill. The ability to produce quality scientific work is not only an indicator of learning achievement but also an academic prerequisite for final assessment, thesis writing, and participation in scientific discourse (Ali & Ramana, 2018; Hasanuddin al., 2019; Winarni et al., 2020; Essa et al., 2023). Internationally, academic writing competence is closely related to mastery of higher-order thinking

skills (HOTS), academic literacy, and the capacity to engage in the scientific community (Knight al., 2018; Winarni et al., 2020; Andersen al., 2022; Chan & Hu, 2023).

However, various findings indicate that students' scientific writing skills remain a complex and ongoing problem. The difficulties lie not only in technical aspects such as systematics, grammar, and citation techniques, but more fundamentally in weaknesses in critical, analytical, and reflective thinking when constructing arguments and developing ideas (Abdelouahed, 2019; Georgiou et al., 2020; Andersen et al., 2022). As a result, writing is often characterized by weak argumentation, shallow and disconnected analysis, and reliance on the ideas of others without critical synthesis, which in some cases leads to plagiarism (Gurung et al., 2019; Winarni et al., 2020; Schmohl al., 2020; Rejeb al., 2024). This condition indicates that conventional learning approaches that focus on completing tasks and passively transferring knowledge are not yet effective in building a strong foundation for scientific reasoning (Hasanuddin al., 2019; Bakri al., 2024).

To address these fundamental challenges, a pedagogical approach is needed that not only transfers procedural writing knowledge but also intentionally develops students' cognitive depth and capacity for critical reflection (Hasanuddin et al., 2019; Bakri et al., 2024). In this context, two theoretical frameworks that offer significant potential are Deep Learning (DL) and Transformative Learning (TL).

Deep Learning in the context of pedagogy refers to a learning approach that emphasizes deep conceptual understanding (meaningful learning), interconnections between concepts (knowledge interconnection), and the application of knowledge in authentic and complex contexts (Gonçalves et al., 2018; Hernández-Blanco et al., 2019; Vinayakumar et al., 2019). In contrast to surface learning, which relies on memorization, DL encourages students to engage in analysis, evaluation, and creation (Qu al., 2021; Mirkhail & Xinyou, 2025; Krishna & Kalluri, 2019). In the context of scientific writing, DL principles can, in theory, overcome the limitations of superficial analysis. For example, concept mapping activities and in-depth literature analysis (deep reading) can help students see the relationships between ideas, resulting in a more coherent and compelling synthesis and argumentation, rather than just a fragmented summary (Buczkowski et al., 2018; Vinayakumar et al., 2019; Bal & Öztürk, 2025).

Meanwhile, Transformative Learning developed by Mezirow (2012), focuses on the process of perspective transformation through critical reflection on assumptions, beliefs, and experiences. This process is often triggered by a dilemma or experience that challenges old thinking (a disorienting dilemma), which is then processed through reflective dialogue and reasoning (Taylor, 2017; Fleming, 2018; Frasseto et al., 2022). In the realm of scientific writing, TL offers a mechanism to address the weaknesses of taken-for-granted argumentation. Through activities such as reflective journaling and critical peer dialogue, students are encouraged to reexamine the underlying assumptions in their arguments, evaluate evidence from multiple perspectives, and ultimately develop a more critical and differentiated argumentative position (Ferretti & Graham, 2019; Tsimane & Downing, 2020; Hoggan & Kloubert, 2020).

Previous studies have explored the benefits of DL and TL separately. Research on DL has demonstrated its effectiveness in improving the quality of idea organization and the depth of analysis of written text (Wulan et al, 2025; Qu et al., 2021). At the same time, TL research proves its role in increasing metacognitive awareness and critical attitudes in learning (Christie et al., 2015; Fleming, 2018; Lee et al., 2019). However, empirical studies that intentionally and systematically integrate these two approaches

within a unified pedagogical framework for teaching scientific writing are still very limited, particularly in the context of Indonesian higher education. Most studies tend to focus on one approach or on the integration of technology (e.g., AI for automated feedback) that is technical in nature and does not address the dimension of perspective transformation (Buchori & Setyawati, 2015; El-Sabagh, 2021; Schmohl et al., 2020; Zhang al., 2023). This research gap lies in the absence of a learning model that simultaneously hones the depth of conceptual understanding (DL) and critical reflection skills for perspective transformation (TL) in producing scientific writing.

Based on these theoretical and empirical gaps, this research was designed to investigate the effectiveness of integrating Deep Learning and Transformative Learning approaches in improving students' scientific writing skills. Specifically, this research answers the following questions:

1. Is the integration of Deep Learning and Transformative Learning approaches more effective than conventional learning approaches in improving the scientific writing skills of students in the general Indonesian language course of the elementary school teacher education study program at IKIP Siliwangi?
2. How does the integration of the two approaches affect students' learning engagement, reflective disposition, and collaborative behavior during the learning process of writing scientific papers in general Indonesian language courses?

Based on the first problem formulation, the following research hypothesis, such as the first hypothesis, H_1: $m_1 > m_2$ (there is a significant difference in the initial ability in scientific writing skills between students who learn using the Deep Learning (DL) and Transformative Learning (TL) approaches and those who learn using the conventional scientific writing approach).

METHOD

Participants

The population of this study comprised all undergraduate students in the Elementary School Teacher Education (PGSD) Study Program at IKIP Siliwangi Cimahi for the 2021–2024 intake, totaling 1,496 students. The sample was taken using a cluster random sampling technique, with the sampling unit being classes. Two classes from the 2023 intake were randomly selected, resulting in 90 students as participants. Class A1-2023 (45 students) was designated as the experimental group, and Class A4-2023 (45 students) as the control group. All participants were enrolled in the Compulsory General Course (MKWU) of Indonesian Language in the even semester, which has a final project of writing a scientific article. The selection of the 2023 intake was based on curriculum uniformity and course availability, although this limits the generalizability of the findings to similar academic contexts.

Research Design and Procedures

This experimental research used a true-experimental design with a pretest-posttest control group design. A true-experimental design was chosen because it allows researchers to test the effects of the treatment more validly by strictly controlling external variables and randomizing participants, so that differences in results can be attributed to the DL–TL intervention. According to Sugiyono (2019), this design was chosen because two groups were randomly selected and then given a pretest to determine if there were any initial differences between the experimental and control groups. A good pretest result is one in which the experimental group's scores do not differ significantly from those of the control group. The effect is as follows $(O_2\text{-}O_1) - (O_4\text{-}O_3)$. The research was conducted over one academic semester with 16 meetings starting from March 4, 2025 to August 10, 2025, with the following stages: (1) Pretest, both groups took a scientific writing test to measure initial abilities; (2)

Intervention, the experimental group received learning that integrated Deep Learning (DL) and Transformative Learning (TL) approaches. The control group received conventional learning dominated by lectures and structured writing exercises without a critical reflection component; (3) Posttest, at the end of the intervention, both groups took a scientific writing test with the same rubric as the pretest. To minimize bias, the same instructor taught both classes with a standardized Semester Learning Plan (RPS). Treatment fidelity was monitored through structured observations to ensure consistent in the implementation of the intervention.

Instruments

This research used three types of instruments, including a scientific writing test with a project type (Pretest-Posttest), in which writing ability was measured using an analytical rubric adapted from Andersen et al. (2022). The rubric covers five dimensions: (a) Content Relevance and Originality (score 1-20), (b) Organization and Coherence (1-20), (c) Argumentation Quality (1-20), (d) Use of Academic Language (1-20), and (e) Accuracy of Citations and References (1-20). Content validity was determined through expert assessment. Inter-rater reliability was calculated using Cohen's Kappa Coefficient, yielding a value of 0.85, indicating high agreement. Second, an observation sheet with the type of participant observation (direct involvement) was used, meaning the researcher was directly involved in the experimental activities while observing. The focus of observation covers three indicators: (a) Student Engagement (participation, questions), (b) Reflective Behavior (identifying weaknesses in one's own arguments), and (c) Academic Collaboration (providing feedback to peers). The three student perception questionnaires, a perception questionnaire with three main aspects and nine sub-aspects to measure the perceptions of experimental group students towards the integration of DL and TL. This aspect was adapted from Hoggan & Kloubert (2020), and construct validity was tested using an Exploratory Factor Analysis (EFA), yielding a KMO of 0.874 and a significant Bartlett's test ($p<0.001$). Reliability was measured using Cronbach's Alpha (á = 0.917), which indicates excellent internal consistency. This questionnaire uses a Likert scale adapted from Sugiyono (2019) with the categories: strongly agree (SS) score 5, agree (S) score 4, neutral (N) score 3, disagree (TS) scor 2, and strongly disagree (STS) score 1. The Likert scale assessment interval is set as follows.

Table 1. Perception interval scale

Score Range	Category
81–100	Very high
61–80	High
41–60	Medium
21–40	Low
0–20	Very Low

Data Analysis

Data analysis was conducted quantitatively and qualitatively. Quantitative analysis used inferential statistics in *SPSS 25*. The steps were as follows: (1) Prerequisite Test, test score data were tested for normality with the Shapiro-Wilk and homogeneity of variance with Levene's Test. (2) Hypothesis Test, differences in score improvement between the experimental and control groups were tested with the Independent Samples t-test. Score improvement from pretest to posttest within each group was analyzed using a Paired Samples t-test. (3) N-Gain test to determine the effectiveness of using a treatment. Then categorize it into four interpretations based on the interpretation category of N-Gain effectiveness from Hake, and also the N-Gain Score distribution category from Syahfitri in (Agustini et al., 2024).

Table 2. Interpretation categories of the N-Gain division

N-Gain	Category
≥0.7	High
0.3 - <0.7	Medium
<0.3	Low

Table 3. Interpretation categories of the N-Gain score effectiveness

N-Gain	Category
≥76%	Effective
56% - < 75%	Somewhat Effective
40% - 55 %	Less Effective
<40%	Ineffective

Descriptive Analysis, questionnaire data were analyzed descriptively with the Miles and Huberman model (Data Reduction, Data Display, and Conclusion Drawing/Verification) to calculate percentages and means for each dimension. Qualitative observation data and open questionnaire responses were collected in Excel, using thematic analysis to identify patterns in student involvement, reflection, and collaboration.

■ RESULT AND DISCUSSION

The findings of this research were obtained from three primary sources of data: classroom observations, written tests (pretest and posttest), and student perception questionnaires. A combination of quantitative and qualitative analyses was employed to provide a comprehensive understanding of the effectiveness of integrating Deep Learning (DL) and Transformative Learning (TL) in enhancing students' scientific writing skills. This mixed-method approach is consistent with recommendations that complex cognitive and reflective learning outcomes should be examined through both performance data and perceptual evidence (Fleming, 2018; Hoggan & Kloubert, 2020; Bal & Öztürk, 2025).

Before the test instrument and questionnaire were used in the research trial, they were validated to ensure their feasibility and measurement quality. Construct validity was assessed using an Exploratory Factor Analysis (EFA), and reliability was assessed using Cronbach's Alpha. The analysis results showed that construct validity was met, as indicated by a KMO value of 0.874 and a significant Bartlett's Test of Sphericity ($\div^2(276) = 1324.87$, $p < 0.001$), confirming that the data met the requirements for factor extraction. The EFA yielded three factors with eigenvalues greater than 1, which collectively explained 68.42% of the total variance, with factor loadings ranging from 0.612 to 0.842.

Furthermore, reliability test results indicated that the instrument had high to very high internal consistency, with a Cronbach's Alpha of 0.917. This finding confirms that the instrument used in the research has excellent construct validity and reliability, making it suitable for use in data collection. These results confirm that the instrument met psychometric standards for educational research measurement (Qu et al., 2021; Mustaqim et al., 2025).

Based on the first research question (Q1), integrating deep learning and transformative learning approaches is more effective than conventional approaches in improving scientific writing skills in the general Indonesian language course for elementary school teacher education students at IKIP Siliwangi. The following presents the results of the tests, researchers' pretests, and posttests on writing scientific papers, based on inferential statistical tests. The following descriptive statistics summarize the mean scores for the experimental and control groups, providing a basic overview of performance trends before and after the learning intervention.

Table 4. Descriptive statistics

Class	N	Mean
Pretest Experiment Class	45	70.40
Postest Experiment Class	45	82.11
Pretest Control Class	45	69.76

Postest Control Class	45	73.11

Based on Table 4 showed the data revealed a clear and strong trend. Initially, both groups began with comparable levels of scientific writing proficiency, as indicated by their similar pretest means (Experimental = 70.40; Control = 69.76). This initial equivalence established a valid baseline, ensuring that any subsequent differences in posttest performance could be more confidently attributed to differences in instructional approaches. Following the intervention, both groups showed improvement. However, the magnitude of the improvement differed markedly. The experimental group, which underwent the integrated DL-TL approach, showed a remarkable average increase of 11.71 points. In contrast, the control group, taught with conventional methods, showed an average increase of only 3.35 points. As a result, the two groups' posttest means diverged significantly. The experimental group achieved a final average score of 82.11, significantly exceeding the control group's average of 73.11, a substantial difference of 9.00 points. This descriptive evidence strongly suggests that the DL-TL integration was not only effective but significantly more effective than the conventional approach in improving scientific writing skills. These initial findings form the basis for inferential statistical testing to confirm the significance and generalizability of the observed differences.

Table 5. Pre-test normality test

Class	*Statistic*	Df	Sig.
Control	0.970	45	0.281
Experiment	0.983	45	0.725

Based on Table 5 above, the significance value for the control class is 0.281 > 0.05, and for the experimental class, it is 0.725 > 0.05. According to the testing criteria, the samples for the control and experimental classes are normally distributed. Therefore, the next step is to conduct a homogeneity test.

Table 6. Pre-test variance homogeneity test

Class	Sig.
Control	0.025
Experiment	

Based on Table 6 above, the significance value of the control class and the experimental class was 0.025 < 0.05. According to the testing criteria, the data is not homogeneous. The next step is the t-test (t').

Table 7. Independent sample test (t') pre-test

Class	Sig.	Interpretasi
Control	0.863	H_0 accepted
Experiment		

Based on Table 7 above, the significance values for the control and experimental classes were 0.863 > 0.05. Based on the testing criteria, Ho is accepted, indicating that there is no significant difference in initial scientific writing skills across general Indonesian language courses between students who used the Deep Learning (DP) and Transformative Learning (TL) approaches and those who used the conventional scientific writing approach. Proving no significant initial difference in writing skills between the groups, thus establishing a valid baseline for comparison, is a crucial step in experimental design (Creswell & Creswell, 2018).

After the application of the deep learning and transformative learning approaches in general Indonesian language learning to write scientific papers in the experimental class, while the application of the conventional approach in general Indonesian language learning to write scientific papers was applied in the control class, the researcher gave a final test, namely a post-test, to both classes, the results of which are presented in the following table.

Table 8. Post-test normality test

Class	*Statistic*	Df	Sig.
Control	0.977	45	0.507
Experiment	0.976	45	0.481

Based on Table 8 above, the significance value for the control class is 0.507 > 0.05, and for the experimental class, the significance value is 0.481 > 0.05. According to the testing criteria, the samples for the control and experimental classes are normally distributed. Therefore, the next step is to conduct a homogeneity test.

Table 9. Post-test variance homogeneity test

Class	Sig.
Control	0.863
Experiment	

Based on Table 9 above, the significance value for the control and experimental classes was 0.863, which is higher than 0.05. According to the testing criteria, the data is homogeneous. The next step is the t-test.

Table 10. Independent sample test (t') post-test

Class	Sig.	Interpretasi
Control	0.000	H_0 rejected
Experiment		

Based on Table 10 above, the significance value of the control class and the experimental class obtained a significance value of 0.000 <0.05. In accordance with the testing criteria, Ho is rejected, so it can be concluded that there is a significant difference in the final ability of scientific writing skills in general Indonesian language courses between students who take learning using the Deep Learning (DP) and Transformative Learning (TL) approaches and students who take learning with the conventional scientific writing approach model.

To prove the effectiveness of the above, the next stage is the N-Gain Test (Normalized Gain Score). The N-Gain Score is a measure used to determine the effectiveness of learning or improvement in learning outcomes after receiving a treatment (for example, a new learning method, training, or intervention). The following presents the results of the N-Gain test based on post-test scores from the experimental class on the application of deep learning and transformative learning models to develop general Indonesian writing skills for students in the elementary school teacher education study program at IKIP Siliwangi.

Table 11. Results of the N-Gain posttest of the experimental class

Type	N	Mean
N-Gain_Score	45	.7782
N-Gain_Percent	45	77.8222

Based on Table 11, the interpretation of the N-Gain category shows an N-Gain value of 0.7782 greater than or equal to 0.7 (see Table 2), thus falling into the high category. Meanwhile, the N-Gain Percentage value of 77.8222 ≥ 76%, therefore, falls into the **"effective"** category (see Table 3). The conclusion is that the application of Deep Learning and Transformative Learning approaches has proven effective in improving MKWU Indonesian language learning, especially in students' scientific writing skills in the Elementary School Teacher Education Study Program at IKIP Siliwangi. The following graph compares scores (N-gain) for each DL and TL indicator in the experimental class.

The bar chart above compares N-Gain scores across five indicators, indicating that the Transformative Learning (TL) approach consistently yields greater improvements than Deep Learning (DL) in each assessed aspect. In the Knowledge Construction indicator, TL is slightly superior to DL, and in Critical Thinking, the improvement gap is more pronounced. The Reflection and Collaboration indicators also show a similar pattern, with TL providing a stronger impact on improvement. The highest achievement

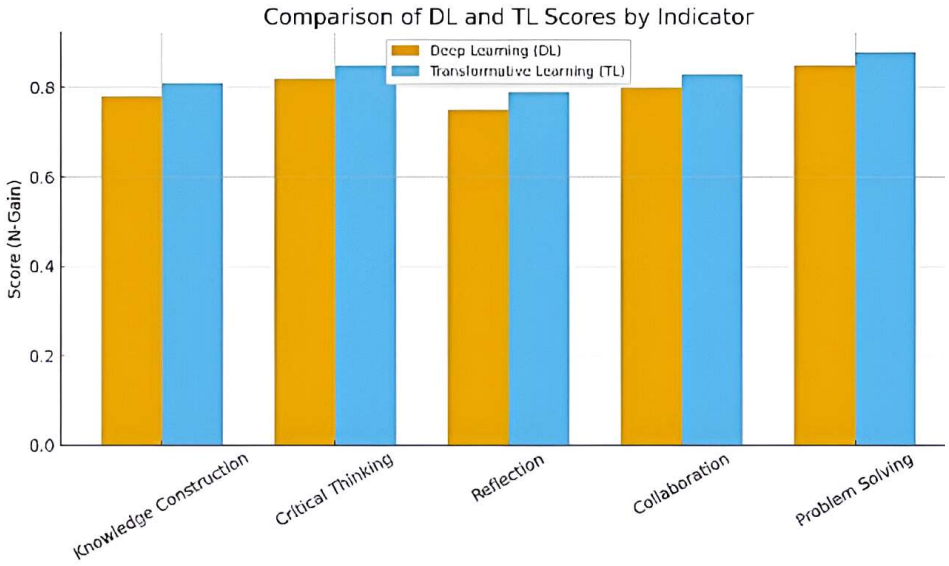

Figure 1. Sub-aspects and positive student responses

is in the Problem Solving indicator, with TL achieving the highest score across all indicators. Overall, the data show that TL has a greater transformational effect on student competency than DL across all five indicators. The results of students' scientific papers (articles) in the general Indonesian language course are available at the following link: https://bit.ly/46PEeqm. One of the results has been published in the proceedings of the International Conference on Language Education (LEIcon), available at the following link: https://bit.ly/46Nijjt.

The results of the second research question (Q2) indicate that integrating the two approaches influences students' learning engagement, reflective disposition, and collaborative behavior during the learning process. The results of the research are based on observations made and student perception questionnaires regarding the application of the deep learning and transformative learning approaches in the compulsory general Indonesian language course.

The analysis of observation sheets and perception questionnaires revealed profound qualitative differences in learning behaviors between the experimental and control groups, providing explanatory depth to the quantitative performance gains. These findings address the second research question, demonstrating that the DL-TL integration significantly influences student engagement, reflective disposition, and collaborative behavior.

Table 12. Summary of qualitative behavioral findings from observations and questionnaires

Behavioral Dimension	Experimental Group (DL-TL)	Control Group (Conventional)	Interpretation & Theoretical Link
1. Student Engagement	Progressive & Active Engagement: Engagement evolved from basic participation to deep cognitive involvement. Indicators included: • Week 1-4: Asking procedural clarification questions.	Static & Receptive Engagement: Engagement remained passive and task-oriented. Primary behaviors were: • Listening to teacher explanations. • Completing individual writing tasks as instructed.	The progressive engagement in the experimental group reflects Deep Learning's core principle of moving beyond information reproduction to active knowledge construction. The shift from passive to

	• Week 5-8: Initiating analytical questions during text critiques (e.g., *"What makes this thesis statement strong?"*). • High involvement in peer-review and concept-mapping, indicating *sense-making* and knowledge construction.	• Minimal spontaneous discussion or questioning. Interaction was largely teacher-dependent.	active inquiry signifies the development of metacognitive engagement.
2. Reflective Disposition	Critical & Transformative Reflection: Students demonstrated metacognitive awareness and used reflection for revision. Key evidence: • Identifying gaps in their own argumentation (e.g., *"My paragraph lacks a supporting example here"*). • Connecting feedback to prior learning (e.g., *"This relates to the coherence principle we discussed last week"*). • Revisions focused on argument strength and structural logic, not just grammar.	Superficial & Technical Revision: Reflection was minimal and non-transformative. Revisions were primarily: • Surface-level language corrections (spelling, word choice). • Lacking in conceptual or structural critique. • Driven by checklist compliance rather than critical self-assessment.	This stark contrast embodies Transformative Learning Theory. The experimental group engaged in *critical reflection on assumptions* (about writing), leading to perspective transformation. The control group's activity remained at the *habitual action* level.
3. Academic Collaboration	Constructive Knowledge-Building Collaboration: Peer interactions were substantive and aimed at collective improvement. Observed behaviors: • Providing specific, text-referenced feedback (e.g., *"Your data on slide three supports point A better than point B"*). • Dialogic discussions to solve coherence issues. • Questionnaire responses highlighted the value of "seeing different perspectives through peer review."	Limited or Transactional Exchange: Collaboration was incidental, not integral to learning. • Peer feedback, if given, was vague (e.g., *"good job"*). • Discussions were limited to logistics or simple clarification of instructions. • A prevailing norm of individual task completion.	The collaborative pattern in the experimental group illustrates how DL-TL facilitates social constructivism. The classroom became a *community of practice* where knowledge was co-constructed through dialog and critical feedback, a known catalyst for higher-order learning.

Triangulation and explanatory power, the qualitative data triangulate with and explain the quantitative results. The marked increase (11.71 points) in the experimental group's post-test score is directly attributable to the observed behavioral shifts (1) The progressive engagement

ensured sustained cognitive investment in writing tasks; (2) The critical reflective disposition enabled students to internalize feedback and make substantive, meaningful revisions to their work, directly improving rubric scores for argumentation and organization; (3) The constructive collaboration provided multiple sources of feedback and exposed students to diverse writing approaches, enriching their own writing strategies. Conversely, the modest gain (3.35 points) in the control group aligns with their passive engagement, superficial revision strategies, and lack of collaborative depth, which limited opportunities for transformative improvement.

Illustrative Evidence, Representative quotes from student perception questionnaires further substantiate the observational data:

On Engagement & Reflection: *"The concept mapping activity forced me to see the connections between my ideas before writing, which I never did before. It changed my whole planning process."* (Student E-22)

On Collaboration: *"Giving feedback to my friend's paper was challenging but helped me recognize similar weaknesses in my own writing. We learned from correcting each other."* (Student E-15)

The integration of deep learning and transformative learning not only transmitted writing skills but also fundamentally transformed the learning culture. It shifted students from being passive recipients of information to becoming active, reflective, and collaborative knowledge builders. This transformed behavioral infrastructure is the key mechanism behind the significant improvement in their scientific writing performance, as captured quantitatively.

Based on Figure 2 above, which shows the results of the Likert-scale questionnaire administered to the experimental group, it can be

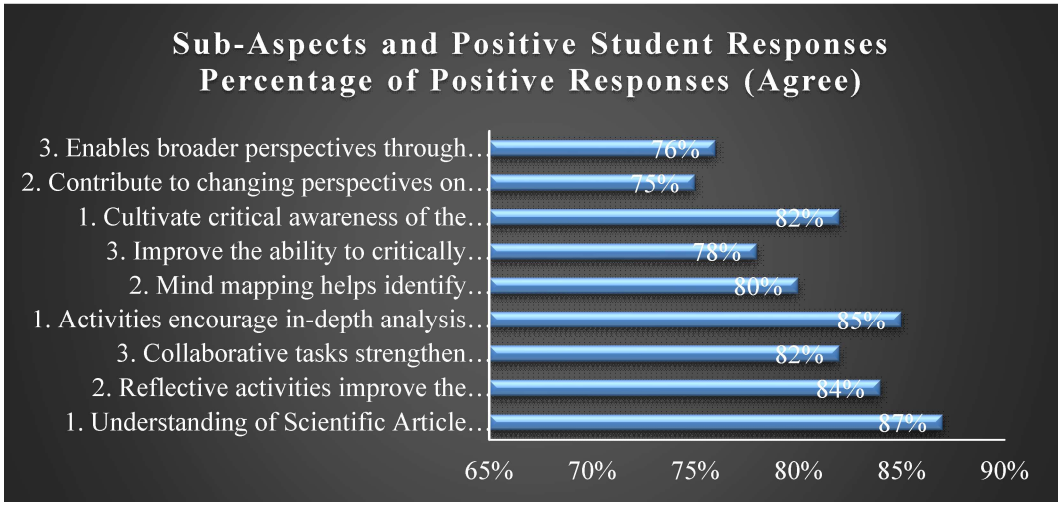

Figure 2. Sub-aspects and positive student responses

concluded that students' perceptions of the applied learning approach were very positive across all measured aspects. Meanwhile, the results for the main aspects are presented visually through the bar chart in Figure 3 below.

In Figures 2 and 3, the majority of students rated the learning experience positively. A total of 84.4% of students fell into the High and Very High categories, with identical percentages at 42.2%, respectively. Only 4.4% fell into the Low category, and one into the Very Low category.

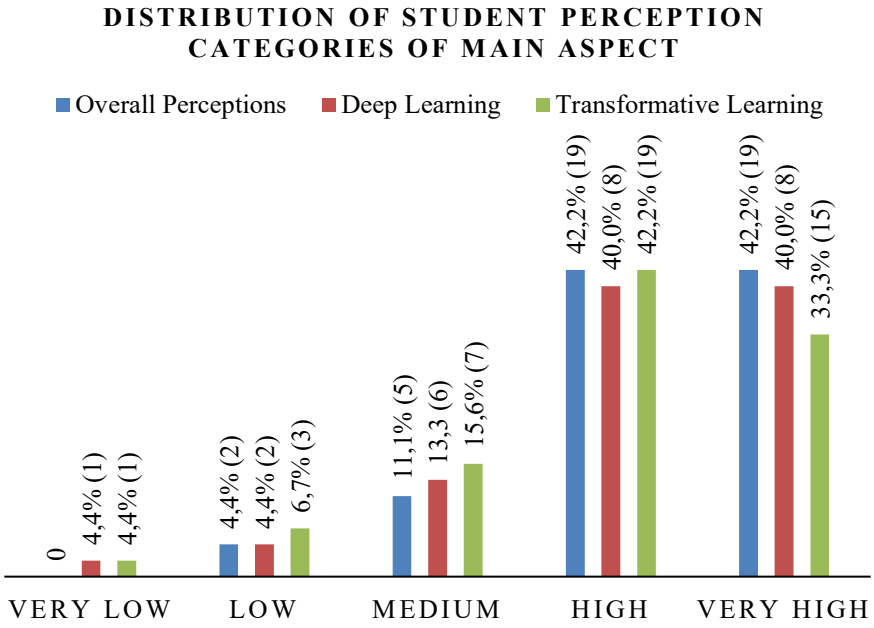

Figure 3. Distribution of student perception categories on main aspects

This data is reinforced by positive responses in related sub-aspects: 87% agreed that understanding of the structure of scientific articles improved, 84% felt that reflective activities improved thinking processes, and 82% stated that collaborative assignments strengthened argument development.

In the Deep Learning aspect, 80% of students were in the High and Very High categories (40.0% each), while 13.3% were in the Medium category, and 6.6% were in the Low and Very Low categories. The sub-aspects were also supportive: 85% agreed that the activity encouraged in-depth analysis of academic texts, 80% felt mind mapping helped identify relationships between ideas, and 78% reported improved ability to evaluate their own writing critically.

For the Transformative Learning aspect, 75.5% of respondents were in the High and Very High categories (42.2% High, 33.3% Very High), 15.6% in the Medium category, and 8.9% in the Low and Very Low categories. The sub-aspects showed that 82% of students felt a growing critical awareness of the weaknesses of previous writing approaches, 75% acknowledged a change in perspective on developing scientific writing, and 76% stated that dialogic and reflective discussions allowed for broader perspectives.

This questionnaire result aligns with findings from test and observation data, which indicate that the Deep Learning (DL) and Transformative Learning (TL) approaches successfully improved students' reflective disposition, academic collaboration, cognitive engagement, and the quality of their scientific writing. This data triangulation supports the conclusion that integrating DL and TL provides significant benefits over conventional methods, in line with previous research findings on the role of DL in fostering higher-order thinking and of TL in transforming perspectives and promoting metacognition.

The results of this research reinforce previous findings on the importance of the Deep Learning (DL) approach for improving academic writing skills. A study by Bal & Öztürk (2025) demonstrated that implementing DL significantly improved the writing skills of K–12 students by enhancing higher-order cognitive processing. Similar findings were also reported by Wulan et

al. (2025), who demonstrated that DL effectively empowered students in written communication. Similarly, this research also demonstrated that DL improved students' ability to develop arguments, paragraph coherence, and use academic language. However, previous research has generally focused solely on cognitive and performative aspects, without integrating the reflective and transformational dimensions as this research does.

From a Transformative Learning (TL) perspective, the findings of this research reinforce the theoretical foundations proposed by Hoggan & Kloubert (2020) and Fleming (2018), who emphasized that transformative learning encourages changes in perspective, critical awareness, and self-reflection in students. However, both studies remain conceptual and have not directly tested the impact of TL on scientific writing skills through an experimental approach. This research fills this gap by presenting empirical evidence that TL not only shapes students' reflective awareness but also directly improves the quality of argument structure, citation accuracy, and analytical depth in scientific writing.

Compared to technology- and artificial intelligence-based research, such as that conducted by Schmohl et al. (2020) and Zhang et al. (2023), both demonstrated that Artificial Intelligence and Natural Language Processing are effective in assisting technical writing improvement through automated feedback. However, these approaches tend to position students as technology users, rather than as learners undergoing a profound cognitive and reflective transformation. Conversely, this research emphasizes that writing skill improvement occurs not solely through the assistance of systems or tools, but through a process of critical reflection, academic dialogue, and collaboration structured within a DL–TL framework.

Furthermore, the findings of this research align with those of a study by Wu & Schunn (2021) on the importance of peer feedback and collaboration in writing, which showed that giving and receiving feedback significantly improved students' writing performance. However, that research did not explicitly integrate the transformative reflection process. In contrast, this research shows that integrating DL and TL improves the quality of texts, shapes students' critical awareness of weaknesses in their arguments, enhances the quality of academic dialogue, and builds a more meaningful collaborative learning culture.

Overall, compared to previous studies that tend to separate cognitive approaches (DL), reflective approaches (TL), and technology-based approaches (AI), this research offers an integrative pedagogical model that simultaneously develops students' depth of thinking, reflective awareness, and the quality of their scientific writing. With a robust experimental design and mutually reinforcing quantitative and qualitative data, this research confirms that integrating DL and TL is not only theoretically compatible but also empirically superior at improving scientific writing competency in higher education.

CONCLUSION

The integration of Deep Learning (DL) and Transformative Learning (TL) approaches proved significantly more effective than conventional learning in improving students' scientific writing skills. The experimental group demonstrated significantly higher final scores (Mean=82.11) than the control group (Mean=73.11), with a statistically significant difference ($p<0.001$). This combination of approaches successfully produced more analytical, coherent, and original writing.

The integration of DL-TL positively influenced students' learning engagement, reflective disposition, and collaborative behavior. Observation and questionnaire data showed a significant increase in active engagement, namely (a) students asked more questions, discussed, and engaged in in-depth analysis, (b) Reflective ability,

namely students were able to identify weaknesses in their own arguments and make substantive revisions, (c) Academic collaboration, namely the formation of peer review practices and constructive dialogue that support collective learning. Thus, this research demonstrates that the integrated deep learning and transformative learning model is not only superior at improving outcomes (written products) but also effective in enhancing the learning process by developing students' critical, reflective, and collaborative capacities. This model is recommended as an effective pedagogical alternative for teaching scientific writing in higher education.

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