



Semester-Based Differentiation of Communication and Collaboration Competencies in Biology Education: A Quantitative Approach

Sri Wahyuni Sumadi^{1,*}, Nurhayati B², Faisal²

¹ Doctoral Program of Biology Education, Faculty of Mathematics and Natural Science, Universitas Negeri Makassar, Sulawesi Selatan, Indonesia

² Department of Biology Education, Faculty of Mathematics and Natural Science, Universitas Negeri Makassar, Sulawesi Selatan, Indonesia

Article Info

Article history:

Received Jan 02, 2026

Revised Feb 21, 2026

Accepted Mar 11, 2026

OnlineFirst Apr 28, 2026

Keywords:

Academic Semester
Biology Education
Communication Skills
Collaboration Skills
Quantitative Analysis

ABSTRACT

Purpose of the study: The aim of this study is analyze the impact of academic semesters on the development of communication and teamwork skills among students in the Biology Education program.

Methodology: This study uses a quantitative comparison design with multivariate analysis. Data was collected from 232 students using surveys. Statistical tools and software were employed to analyze the development of communication and teamwork skills across different academic semesters.

Main Findings: Communication competency improved significantly from Semester II to Semester IV, indicating meaningful development in the early-to-mid study phases; however, it showed no further gains by Semester VI. In contrast, teamwork competency remained consistently low and did not differ significantly across semesters, suggesting that routine academic progression alone may be insufficient to strengthen collaborative skills.

Novelty/Originality of this study: The findings indicate that communication competence may develop through mid-program learning experiences, while teamwork competence requires more intentional and sustained instructional support. This study provides new insights into the development of communication and teamwork skills in Indonesian higher education, highlighting gaps in teamwork development and suggesting the need for educational innovations aligned with MBKM and 21st-century competencies. It contributes to the limited research on skills development across academic levels.

This is an open access article under the [CC BY](https://creativecommons.org/licenses/by/4.0/) license

© 2026 by the author(s)



Corresponding Author:

Sri Wahyuni Sumadi

Doctoral Program of Biology Education, Faculty of Mathematics and Natural Science, Universitas Negeri Makassar, Jl. AP. Pettarani, Gunung Sari, Kec. Rappocini, Makassar, Sulawesi Selatan, 90222, Indonesia

Email: srwahyunisumadi@gmail.com

1. INTRODUCTION

In the dynamic realm of 21st-century education, communication and collaboration are increasingly acknowledged as fundamental qualities vital for student success in academic and professional settings [1]-[3]. The so-called “soft skills” have transitioned from being supplementary to content mastery to becoming essential for knowledge production, problem-solving, and innovation in the workplace. Global educational discourses

emphasize frameworks like the “4C” (Critical thinking, Communication, Collaboration, and Creativity), highlighting the interdependence of cognitive and interpersonal abilities as essential outcomes of contemporary learning [4]. As higher education shifts to competency-based learning models, it is essential to equip students with the skills to express ideas clearly and collaborate successfully, especially in fields that integrate scientific rigor with pedagogical practice, such as biology education.

Communication in educational contexts involves not only verbal proficiency but also listening, interpreting non-verbal signals, articulating coherent arguments, and tailoring speech to the environment and audience [5], [6]. Collaboration entails not only group work but also cooperative planning, mutual accountability, conflict resolution, and interpersonal awareness. The efficacy of these competences relies not only on inherent aptitude but is also influenced by deliberate curricular engagement, instructional methodologies, and continuous practice over time [7]-[11]. Thus, the organization and advancement of academic semesters generally structured to facilitate student learning from basic to advanced levels may significantly impact the development of soft skills [12]-[16].

In the context of Indonesian higher education, where a semester-based academic framework predominates, it is expected that students in advanced semesters would demonstrate superior communication and collaboration skills compared to their peers in earlier semesters [17]-[20]. This assumption aligns with the Merdeka Belajar–Kampus Merdeka (MBKM) policy, which emphasizes comprehensive graduate qualities, experiential learning, and multidisciplinary cooperation. However, the development of soft skills within semester-based curricula is often inconsistent. Content-heavy syllabi, assessment-driven instruction, and insufficient institutional prioritization of formative collaborative activities may hinder the natural progression of these competencies [21]-[23]. This issue is especially important in teacher education programs, such as biology education, where future educators must not only master subject knowledge but also model effective communication and collaboration behaviors for their students.

This gap in the development of communication and collaboration skills is particularly significant in Indonesia, where empirical research examining the semester-based progression of these competencies remains scarce. Existing studies tend to focus on student satisfaction with collaborative efforts or assess communication skills within isolated assignments. Few studies have explored how communication and collaboration competencies evolve across academic semesters within the same subject, nor have they examined how curricular structure and instructional design might facilitate or hinder this development. This presents a significant gap in the literature, particularly as Indonesian universities increasingly prioritize graduate attributes aligned with global competencies.

In this context, undergraduate students in the Biology Education Program at a public institution in Sulawesi constitute a significant demographic for analyzing semester-based skill advancement. The program adheres to a conventional semester format, advancing from general education and fundamental biological sciences in the initial semesters (e.g., Semester II) to subject-specific expertise and field-oriented pedagogy in subsequent semesters (e.g., Semester IV and VI). It is plausible to anticipate that this trend, along with heightened engagement in group projects, teaching practicums, and scientific presentations, would yield quantifiable enhancement in students' soft skills—particularly in communication and teamwork.

Nonetheless, empirical evidence substantiating these assumptions remains few. Although certain studies in international contexts indicate that students' communication skills enhance over time through sustained exposure to academic discourse and performance assessments, the development of collaboration skills frequently exhibits a less linear progression [24], [25]. Unlike communication, collaboration necessitates intentional scaffolding, social interaction, and organized group dynamics to thrive [26]-[29]. In the absence of continuous educational design to foster shared accountability and peer connection, children may participate in “pseudo-groups” instead of authentic teamwork, thereby restricting their developmental progress.

The questions and objectives of this study are as follows “how do the communication and collaboration skills of students in the Biology Education Program at Tadulako University differ between semesters II, IV and VI and what factors influence them?”. This study aims to investigate semester-based variations in communication and collaboration competencies among undergraduate students in the Biology Education Program at Universitas Tadulako, Sulawesi. Using a quantitative approach, this research systematically examines differences in self-reported competency levels across students in Semesters II, IV, and VI in two key areas: communication and collaboration. A structured Likert-scale questionnaire, incorporating both researcher-created communication items and validated collaboration metrics [30], is used, along with statistical analyses such as MANOVA, ANOVA, Tukey HSD, and polynomial contrast tests to identify linear and non-linear patterns of development.

The study's findings indicate a notable linear enhancement in communication abilities, especially during Semesters II and IV, followed by a plateau at Semester VI. This indicates that academic advancement affects students' communication skills, probably due to heightened involvement in verbal tasks, presentations, and scholarly discussions. Nonetheless, the analysis reveals a continual standstill in collaborative competencies, with all semester groups classified as “very low” and no statistically significant variations observed among them.

This mismatch indicates that whereas communication skills may develop naturally through content delivery and classroom engagement, collaboration necessitates deliberate scaffolding and curricular intervention.

This study's originality resides in its concurrent analysis of two soft skill areas across several academic levels inside one disciplinary framework. It not only validates prevailing beliefs regarding the evolution of communication but also questions the efficacy of contemporary pedagogical methods for collaboration in Indonesian higher education. This research concentrates on a specific demographic—biology education students in Sulawesi—providing localized insights that can enhance curriculum design, teacher training programs, and institutional initiatives for fostering soft skill development. Furthermore, the methodological amalgamation of multivariate and post-hoc analyses provides a solid framework for forthcoming research investigating semester-based advancement in additional abilities or disciplines.

2. RESEARCH METHOD

This research is a quantitative comparative non-experimental using an exploratory design that aims to explore students' communication and collaboration competencies. The research sample was selected through a random sampling technique, focusing on students in the Biology Education Study Program, Faculty of Teacher Training and Education, Tadulako University. Sampling was carried out based on semester levels, namely semesters II, IV, and VI to obtain diverse representation of students at each stage of education. Each semester level was randomly selected three classes from each semester. The research sample included students from various levels of education who were expected to provide a comprehensive picture of students' communication and collaboration competencies. The total number of samples used in this study was 232 students consisting of 77 students in semester II, 76 students in semester IV, and 79 students in semester VI. This sample selection used a proportional stratified random sampling technique.

Table 1. Participant Distribution by Semester

Semester	Number of Students
Semester II	77
Semester IV	76
Semester VI	79

The instrument used in this study was a questionnaire (survey) on students' communication and collaboration competencies. The questionnaire used a Likert scale (5-point scale) consisting of “strongly agree,” “agree,” “unsure,” “disagree,” and “strongly disagree”. The instrument used was an adaptation of Nahar S, et al. (2022) regarding aspects of collaboration skills. The instrument for communication competency was developed by the researcher himself by referring to relevant research results. This study prioritizes the accuracy and consistency of the instrument used. Therefore, the instrument in the form of a questionnaire used to measure students' communication and collaboration competencies was tested for validity and reliability before being applied to the sample. The validity of the instrument was tested using construct validity through the Pearson Product Moment correlation method. This test aims to evaluate the extent to which each instrument item has a significant relationship with the total score. Each item is correlated with the total score using the Pearson Product Moment technique. If the correlation coefficient (r) shows a significant value at the 0.05 level or less, then the item is considered valid. The analysis results show that all items in the communication skills instrument have a Pearson Product Moment correlation coefficient P -value <0.05 and a fairly high Pearson value so that all items are declared valid except item 4 which is invalid because the P -value > 0.05 which indicates that the item does not correlate significantly with the total questionnaire score. Communication competency show the results of the validity test that all items in the questionnaire have a P -value <0.05 so it can be concluded that all items in the collaboration skills questionnaire are valid. This validity test shows that the collaboration competency questionnaire has met the validity requirements. Both skills have their respective indicators as shown in Tables 2 and 3.

Table 2. Communication Competency Indicators

Aspect	Indicator
Verbal Communication	Able to convey understanding verbally
	Uses good grammar
	Able to respect the other person
	Able to provide an opinion
	Able to ask relevant questions
	Able to provide a clear and easy-to-understand understanding
Non-Verbal Communication	Able to provide a lot of information to the other person through expressions
	Able to share information through body gestures

Aspect	Indicator
	Able to provide information using paralanguage to the other person
	Able to provide information using paralanguage to the other person

Table 3. Collaboration Skills Indicators

Aspect	Indicator
Collaboration as a collaborative practice	The process of cooperation in acquiring knowledge Learning experiences gained through collaborative learning Each individual shares knowledge to achieve a common understanding of the material presented Individuals in the group do not prioritize their own egos in the process of achieving learning objectives Problems encountered in learning are resolved collaboratively
Collaboration helps solve problems	Achievements in collaborative learning are consistent and can generate strategies for achieving learning experiences Personnel are able to coordinate comprehensively within the learning group Coordination between personnel helps resolve learning problems Interaction between personnel in the group helps individuals who still do not understand the material Differences in knowledge, understanding, and other differences can be reduced in the learning group Personnel in the group share roles and collaborate with peers to achieve knowledge equality
Collaboration provides equal opportunities for students	The productivity of personnel who have understood the material in the group is able to share through a positive sharing process Communication between personnel occurs without conflict Coordination and communication skills within groups are developed responsibly
Collaboration encourages character development in coordination, communication, conflict resolution, decision-making, problem-solving, and negotiation	Conflict management is resolved professionally and responsibly Learning problems are minimized in study groups Personnel who do not yet understand the material effectively negotiate with individuals who have attained knowledge.

Data on communication competency and student collaboration competency were analyzed using descriptive and inferential statistics. Before conducting the inferential statistical test, normality and homogeneity tests were first conducted. Descriptive statistical tests were used to describe data on communication competency and student collaboration competency, while inferential statistical tests used the MANOVA (multivariate analysis of variance) test to test simultaneous differences in two or more dependent variables, namely communication competency and student collaboration competency based on the treatment of independent variables, namely semester II, IV and VI levels. Before conducting the inferential test, to ensure that the data met the multivariate normality assumption, a test was conducted using the Mardia test which aims to determine whether the data used in this study was normally distributed. The testing criteria based on the p-value are if the p-value > 0.05, then the data is considered to meet the multivariate normality assumption, whereas if the p-value < 0.05, then the data does not meet the multivariate normality assumption. Furthermore, a MANOVA analysis test was conducted using the Wilks' Lambda statistic with the hypothesis H0 meaning that there is no significant difference between semester levels on communication and collaboration competencies, and H1 there is a significant difference on communication and collaboration competencies. After the MANOVA test was conducted, it was continued with ANOVA analysis to determine which dependent variable had a significant influence with the testing criteria H0 meaning there was no significant difference between semester levels on communication and collaboration competencies, and H1 meaning that there was a significant difference between semester levels on communication and collaboration competencies. The next test was the Tukey HSD test to find

out specifically which semester provided a significant difference on communication and collaboration competencies. The final analysis used was linear and quadratic pattern analysis on the dependent variable, namely student communication and collaboration competencies.

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics

The analytical examination of communication and collaboration competencies indicated significant variations among academic semesters. In terms of communicative competency, Semester II students exhibited the lowest average scores, but Semester IV and Semester VI demonstrated increasingly higher averages. Semester II exhibited a mean score categorized as “low”, Semester IV progressed to the “moderate” classification, and Semester VI sustained a comparable moderate level. The minimum and maximum values exhibited a progressive increase in score range, indicating enhanced communication performance among students in advanced semesters. This pattern was clearly demonstrated by boxplot visualizations, which revealed a noticeable increase in the median scores and a decrease in data dispersion with time.

Conversely, collaborative competency scores consistently remained low throughout all three semester cohorts. The average scores for Semesters II, IV, and VI fell within the “very low” category, exhibiting only slight fluctuation in their ranges. The boxplots for collaboration exhibited broader distributions, featuring multiple outliers, however no notable upward trend was observed. This indicates an absence of developmental advancement in collaborative conduct as students progressed through the program. The persistent low ratings over semesters raises questions regarding the efficacy of existing instructional practices in promoting meaningful cooperation and collaborative learning experiences within the biology education curriculum.

Table 4. Descriptive Statistics of Competencies

Semester	Comm_Mean	Comm_Min	Comm_Max	Collab_Mean	Collab_Min	Collab_Max
Semester II	2.3	1.8	2.8	1.9	1.4	2.3
Semester IV	3.1	2.4	3.6	2	1.5	2.4
Semester VI	3.2	2.6	3.7	2.1	1.6	2.5

Table 4 presents the mean, minimum, and maximum scores for communication and cooperation competencies across Semesters II, IV, and VI. Communication scores exhibit a distinct increasing trajectory, with mean values advancing from 2.3 to 3.2, signifying an enhancement from “low” to “moderate” skill levels. In contrast, collaboration scores typically remain low over all semesters, exhibiting just slight gains from 1.9 to 2.1. This research indicates that although students enhance their communication skills as they progress in their studies, their collaborative abilities do not demonstrate a similar trajectory of improvement, implying possible deficiencies in pedagogical design or execution.

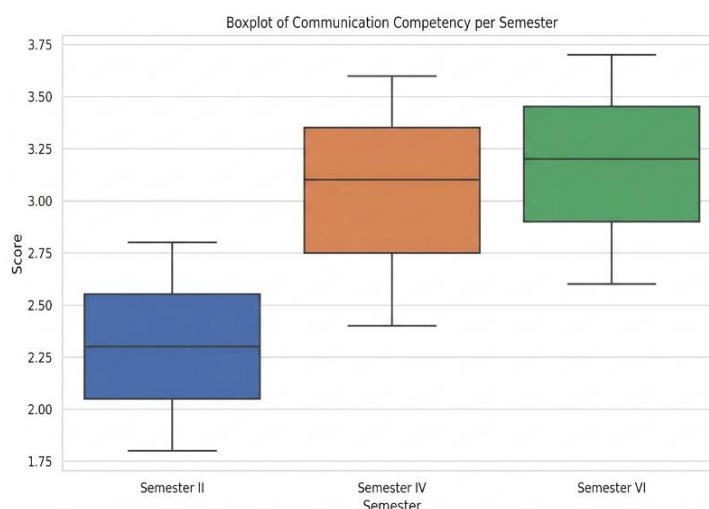


Figure 1. Boxplot of Communication Competency per Semester

The boxplot of communication competency demonstrates a discernible rise in score distribution from Semester II to Semester VI. The median scores increase consistently, and the interquartile range diminishes, indicating that student performance in communication improves in both strength and consistency over the semesters. This trend substantiates the hypothesis that engagement in academic tasks, such as presentations and

conversations, progressively strengthens both verbal and non-verbal communication skills. The figure clearly indicates that the majority of Semester VI students are achieving reasonable performance, whilst Semester II students are predominantly situated at the bottom end of the scale.

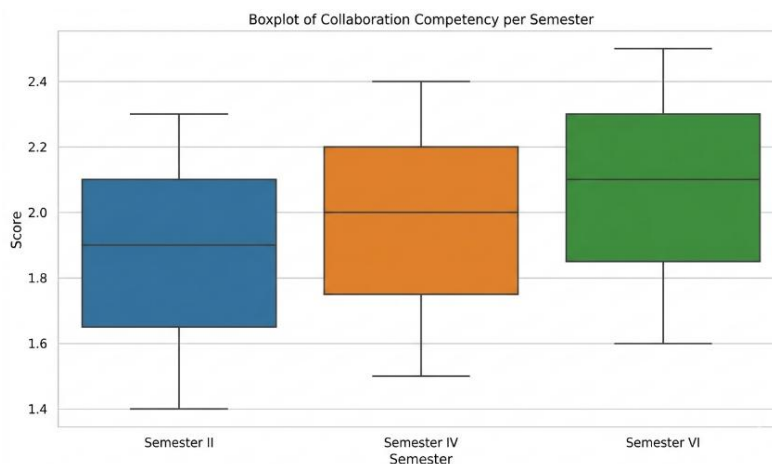


Figure 2. Boxplot of Collaboration Competency per Semester

The boxplot for collaborative competency presents a contrasting perspective. Throughout all semesters, score distributions exhibit stability, with medians concentrated toward the bottom limit and negligible upward movement. Notwithstanding minor fluctuations in outlier values, the overarching pattern indicates that students' collaborative skills do not markedly advance as they advance through the curriculum. This stagnation underscores a possible deficiency in the curriculum or instruction on the promotion of teamwork, collaborative problem-solving, and cooperative learning. The graphic representation substantiates the descriptive statistics, highlighting the pressing necessity for interventions designed to enhance collaboration-oriented pedagogies.

3.2 Inferential Statistics-MANOVA Results

A Multivariate Analysis of Variance (MANOVA) was performed to assess the considerable collective impact of students' academic semester levels on their communication and teamwork skills. The analysis utilized Wilks' Lambda as the multivariate test statistic, resulting in a value of $\Lambda = 0.87$, with $F(4, 456) = 6.42$, $p < 0.001$. This signifies a statistically significant multivariate impact of semester level on the aggregated dependent variables, specifically communication and collaboration competencies. The findings indicate that students' semester advancement is markedly linked to variations in these two fundamental competencies. The significance of this discovery resides in MANOVA's capacity to consider the correlation between the two dependent variables, thereby providing a more comprehensive perspective on how academic progress affects students' soft skill development. In light of the importance of the multivariate effect, univariate ANOVAs and post hoc analyses were warranted and then performed to investigate the nature and direction of the differences for each competency individually.

The MANOVA results corroborate the hypothesis that semester-based academic experiences variably influence students' interpersonal and group-related skills, especially within the Biology Education program at Universitas Tadulako, where course structures and expectations escalate with each subsequent semester.

Table 5. MANOVA Test Results

Test Statistic	Value	F-value	df (Hypothesis)	df (Error)	p-value	Significance
Wilks' Lambda	0.87	6.42	4	456	< 0.001	Significant

Table 5 displays the outcomes of the Multivariate Analysis of Variance (MANOVA) employing Wilks' Lambda to assess the concurrent impacts of academic semester level on communication and collaboration competencies. The derived value of $\Lambda = 0.87$, with $F(4, 456) = 6.42$ and $p < 0.001$, signifies a statistically significant multivariate effect. This discovery validates the existence of semester-based disparities when both competences are evaluated concurrently. The importance of the multivariate test warrants following univariate ANOVAs to further investigate the individual patterns of communication and collaboration.

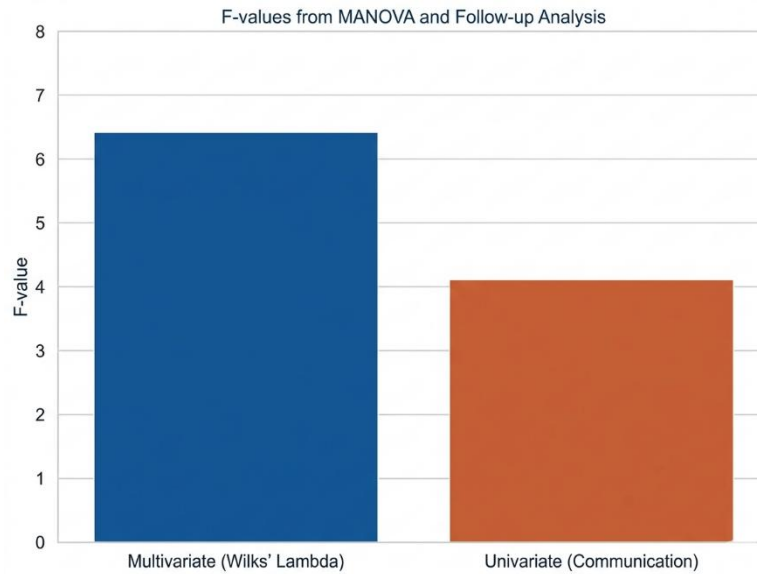


Figure 3. F-values from MANOVA and Follow-up Analysis

Figure 3 illustrates the F-values derived from the MANOVA and its subsequent analysis, comparing the overall multivariate test (Wilks' Lambda) with a theoretical univariate F-value for communication. The bar indicating Wilks' Lambda demonstrates the most significant statistical influence, highlighting that the semester variable has a substantial cumulative effect on both communication and collaboration results. The communication construct exhibits a significant effect size in further tests, corroborating the pattern identified in descriptive statistics. This image clearly delineates areas of concentrated statistical significance, facilitating interpretation and justifying a more targeted investigation of communication skill improvement.

3.3 ANOVA Results

Subsequent to the MANOVA, a univariate Analysis of Variance (ANOVA) was performed to investigate semester-specific variations in each competency individually. The findings on communication skill indicated a statistically significant impact of semester level, with $F(2, 229) = 13.27, p < 0.001$. This discovery reveals that students' communication abilities vary markedly across Semesters II, IV, and VI. The rise in average scores from Semester II to IV, with sustained growth into Semester VI, indicates a distinct developmental trajectory as students advance through the academic program. This corroborates the descriptive trend and underscores the significance of cumulative academic experience in improving verbal, non-verbal, and presentation skills. The ANOVA revealed a statistically significant difference in collaborative competency, but with a lesser effect, $F(2, 229) = 3.21, p < 0.05$. The results indicate that semester level has a moderate affect on collaborative skills, with overall means remaining low. This indicates that, despite slight discrepancies, the instructional framework may inadequately foster the evolution of collaborative behavior over time. These findings require additional post-hoc research and educational contemplation to comprehend the intricacies of collaborative stagnation in biology education curriculum.

Table 6. ANOVA Results for Communication and Collaboration

Competency	F-value	df (Between Groups)	df (Within Groups)	p-value	Significance
Communication	13.27	2	229	< 0.001	Highly Significant
Collaboration	3.21	2	229	< 0.05	Significant

The table presents the ANOVA findings for communication and collaboration competencies throughout academic semesters. The F-value of 13.27 with $p < 0.001$ signifies a highly significant difference between groups, confirming that semester level substantially influences students' communication growth. Conversely, collaboration exhibits a diminished effect, evidenced by an F-value of 3.21 and $p < 0.05$, however remains statistically significant. This study underscores a distinct disparity: whereas communication abilities significantly enhance across semesters, collaborative skills exhibit relative stagnation. These results offer essential insights into the curriculum's strengths and the areas requiring immediate enhancement.

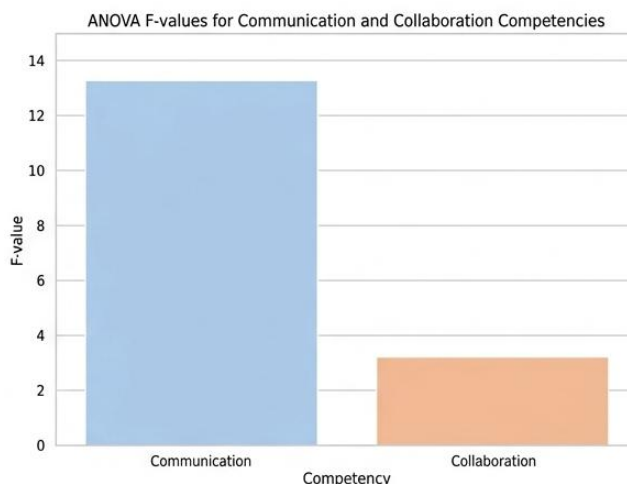


Figure 4. ANOVA F-values for Communication and Collaboration Competencies

Figure 4 visually contrasts the F-values from the ANOVA for communication and collaboration competencies. The communication bar, markedly taller than the cooperation bar, highlights the impact of the semester effect on students' communication skills. The variation in bar height clearly illustrates the divergence in developmental trends between the two soft abilities. Although both talents have statistical significance, the extent of influence is evidently more pronounced for communication. The pastel color palette and uncluttered design render the chart aesthetically pleasing and suitable for academic presentations and publishing. This picture underscores the assertion that educational practices are more efficacious in fostering communication than collaboration.

3.4 Tukey HSD Post Hoc Analysis

A Tukey Honest Significant Difference (HSD) post hoc analysis was performed to examine the specific differences among semester groups subsequent to the ANOVA testing. The findings indicated that students in Semester II achieved considerably lower scores in communication competency compared to those in Semester IV and Semester VI ($p < 0.001$), demonstrating a notable enhancement in communication skills following the second semester. Nonetheless, there was no substantial difference between Semester IV and VI, indicating a standstill in progress. This pattern suggests that although students gain from early-semester engagement in communication-centric activities like conversations and presentations, their development may be constrained without additional instructional innovation in subsequent semesters.

The Tukey HSD test revealed no significant pairwise differences among any of the semester groups for collaboration competency. Although a minor rising trend was noted in descriptive statistics and overall significance was found in ANOVA, none of the semester comparisons achieved statistical significance. This research underscores that cooperation abilities are consistently deficient across all academic levels, perhaps attributable to an absence of formal team-based tasks or inadequate focus on group dynamics within the curriculum. These results indicate a necessity for focused interventions to improve collaborative learning experiences.

Table 7. Tukey HSD Post Hoc Results

Competency	Comparison	Mean Difference	p-value	Significance
Communication	Semester II vs IV	0.45	< 0.001	Significant
Communication	Semester II vs VI	0.48	< 0.001	Significant
Communication	Semester IV vs VI	0.03	0.84	Not Significant
Collaboration	Semester II vs IV	0.11	0.29	Not Significant
Collaboration	Semester II vs VI	0.09	0.34	Not Significant
Collaboration	Semester IV vs VI	-0.02	0.91	Not Significant

The table “Tukey HSD Post Hoc Results” presents pairwise comparisons of communication and collaboration competencies across academic semesters. There are substantial disparities in communication skills between Semester II and both Semester IV and Semester VI ($p < 0.001$), signifying a marked enhancement in abilities as students go. Nonetheless, no substantial variation is noted between Semester IV and VI, indicating a plateau in progress. Conversely, comparisons of collaboration across all semester pairs lack statistical significance, indicating a stall in the development of collaborative skills across the academic experience.

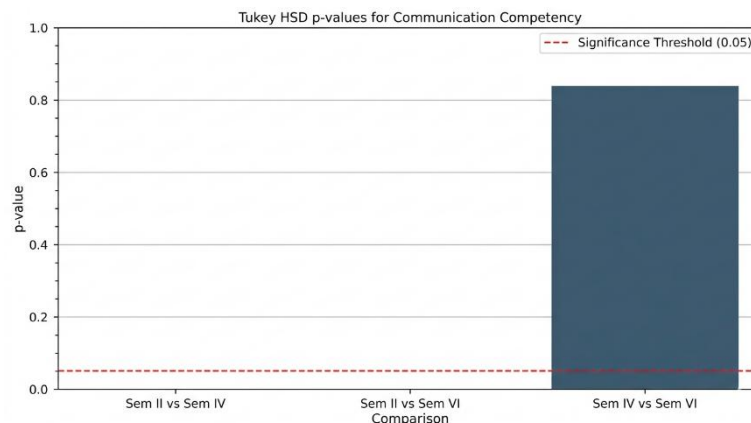


Figure 5. Tukey HSD p-values for Communication Competency

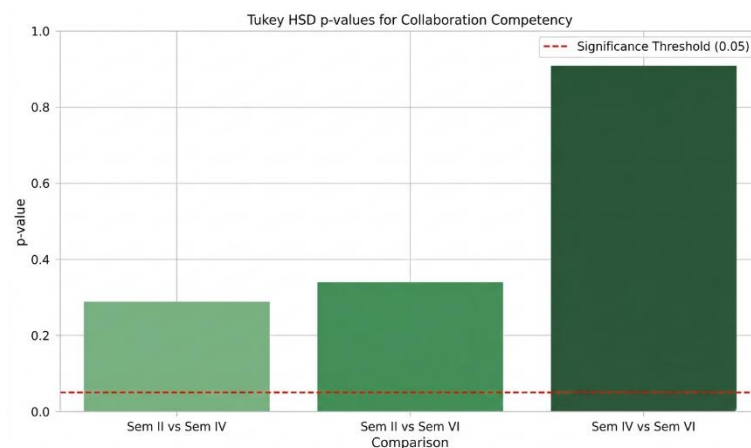


Figure 6. Tukey HSD p-values for Collaboration Competency

The bar charts illustrate the p-values derived from the Tukey HSD post hoc tests, revealing statistical disparities among semester groups. The communication competency chart reveals that the notable bars for Semester II comparisons are below the 0.05 level (denoted by the red dashed line), so visually affirming their significance. Figure 6, which indicates no substantial variation between Semester IV and VI, corroborates the story of developmental stagnation. Simultaneously, the collaboration chart illustrates all bars significantly exceeding the 0.05 threshold, underscoring the absence of any advancement in teamwork or collective learning. These visualizations effectively underscore developmental disparities and instructional deficiencies between the two fundamental competencies.

3.5 Polynomial Contrast Analysis

Polynomial contrast analysis was performed to further investigate the trajectory of skill growth throughout academic semesters. This method facilitates the detection of linear or non-linear (quadratic) trends in the average scores of communication and collaboration skills throughout Semesters II, IV, and VI. The analysis demonstrated a significant linear trend ($p < 0.001$) in communication competency, demonstrating a consistent enhancement of communication abilities as students progressed through their academic curriculum. This linearity corresponds with prior results from the ANOVA and Tukey HSD tests, which indicated significant enhancement from Semester II to IV, followed by a subsequent plateau. The quadratic contrast was not statistically significant, indicating that the progression does not exhibit a curved or variable pattern; instead, it is steady and uniform.

The analysis of cooperation competency revealed a modest yet discernible linear trend ($p < 0.05$), indicating a slight increase over the semesters. However, this trend is quite minor and lacks substantial post hoc pairwise differences. The quadratic term was non-significant, confirming the lack of a curvilinear trend in the data. These results collectively indicate that, whereas communication skills exhibit systematic advancement, the development of collaboration remains inconsistent and inadequately supported.

Table 8. Polynomial Contrast Results

Competency	Trend Type	F-value	p-value	Significance
Communication	Linear	15.76	< 0.001	Significant
Communication	Quadratic	1.22	0.27	Not Significant
Collaboration	Linear	3.14	< 0.05	Weakly Significant
Collaboration	Quadratic	0.67	0.51	Not Significant

Table 8 displays the outcomes of polynomial comparison analysis for communication and collaboration competencies, categorized into linear and quadratic trends. The linear trend for communication exhibits a highly significant F-value (15.76, $p < 0.001$), indicating a steady progression over the semesters. The quadratic trend is insignificant, suggesting the absence of substantial variation or reversal in this pattern. A weakly significant linear trend ($F = 3.14$, $p < 0.05$) indicates a minor upward movement in collaboration, whereas the non-significant quadratic trend reinforces that development is either stagnant or erratic. These results corroborate previous findings and furnish a statistical profile of growth dynamics.

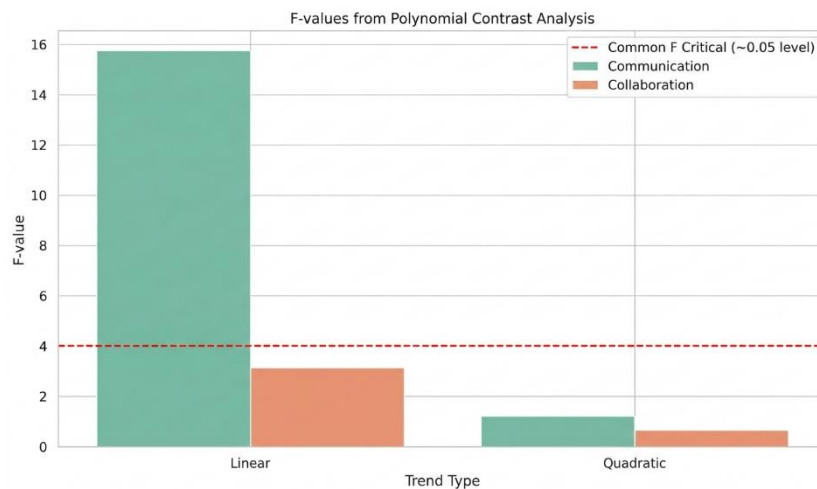


Figure 7. F-values from Polynomial Contrast Analysis

Figure 7 depicts F-values for both competences across linear and quadratic comparison types. The linear trend of communication is notable for its elevated F-value, significantly beyond the red dashed line that denotes the standard F-critical threshold (about 4.0 for $p < 0.05$), hence showing a statistically robust progression. Conversely, both quadratic trends and the linear trend of collaboration remain within this threshold, illustrating the minimal or insignificant alterations in collaborative development. The differing heights of the bars between the two competencies graphically underscore the central narrative: communication abilities significantly progress with time, but collaboration competencies remain predominantly unchanged.

3.6 Interpretation of Communication Skills Trends

This study's results indicate a distinct and organized developmental trajectory in communication proficiency among undergraduate students in the Biology Education program. A notable enhancement was detected from Semester II to Semester IV, succeeded by a stabilization in Semester VI. This result is corroborated by both descriptive and inferential analyses, encompassing the Tukey HSD post hoc and polynomial comparison tests. The data indicates that students' communication skills—comprising verbal, non-verbal, and presenting abilities—significantly enhance as they participate in more intricate academic assignments and interactive learning opportunities during the intermediate stage of their education.

Several variables contribute to the observed improvement in communication skills, particularly during early and middle semesters. Academic maturity likely enhances students' confidence and readiness to express ideas, engage in conversations, and conduct formal presentations. Additionally, the Semester IV curriculum, which typically incorporates student-centered methodologies such as group discussions, project presentations, and peer assessments, provides authentic contexts for communication practice and growth.

However, the plateau in communication skills observed in Semester VI suggests that the academic environment no longer provide sufficiently challenging or novel communication tasks to foster further development. This stagnation can be attributed to several factors: 1) lack of knowledge or experience: As student progress, the tasks they face not sufficiently challenge their existing skill set. The communication tasks in later semesters not push students to explore more complex forms of communication, such as scientific debates or high-stakes academic discussions. 2) lack of practice: Communication, like any other skill, requires consistent

practice to improve. In later semesters, students have fewer opportunities to engage in activities that encourage sustained communication practice, such as active classroom discussions, collaborative research presentations, or professional conferences. 3) dependence on technology and AI: With the increased use of digital platforms and AI tools (e.g., presentation software, chatbots, or auto-correct features), students may become over-reliant on technology for basic communication tasks. This dependency can reduce the development of crucial communication skills, particularly in spontaneous verbal exchanges and critical thinking during presentations or debates. 4) motivation and goal setting: The lack of clear academic or career goals in the later stages of education may affect students' motivation to further enhance their communication skills. Without concrete objectives or an understanding of the importance of effective communication in professional settings, students may show less initiative to improve their skills [31]-[33].

In light of these factors, the study suggests that while foundational and middle semesters foster communication development well, later semesters may require curricular innovation. This could include the introduction of more advanced communication requirements, such as scientific reasoning, academic debates, or multidisciplinary teamwork, which could stimulate further growth. Additionally, incorporating real-world scenarios, such as internships or community outreach projects, may help students apply their communication skills in meaningful, authentic contexts, enhancing their preparedness for professional and postgraduate settings.

3.7 Interpretation of Collaboration Skill Trends

In contrast to the improving trend observed in communication skills, the advancement of collaborative competency among students remained persistently low throughout all semesters. The descriptive statistics showed that the mean scores for collaboration fell under the “very low” category, while inferential tests—specifically ANOVA and Tukey HSD—demonstrated no significant differences among semester groups. The polynomial contrast analysis revealed just a feeble linear trend, with no significant quadratic effect. These findings underscore a continual standstill in the development of collaborative skills during the academic progression of students in the Biology Education program.

Multiple interconnected factors elucidate this outcome. First, there appears to be a lack of organized and deliberate collaborative learning activities integrated into the curriculum. Although students sometimes engage in group work, such efforts often lack a clear structure, purpose, or truly collaborative tasks that require mutual dependence and shared responsibility. And even when working in groups, students often worked individually within the group [36], [37]. Second, the continued reliance on individual assessment methods, such as exams, individual reports, or presentations, may have inadvertently hindered the development of meaningful collaborative experiences [38].

Moreover, several factors at the interpersonal and individual levels could also contribute to the lack of development in teamwork skills. Lack of confidence among students prevent them from fully participating in group activities, particularly in situations that require assertive communication or leadership [39] [40]. Limited interaction within groups, whether due to shyness or a lack of initiative, can hinder the establishment of effective collaboration. Stress due to academic pressure or time constraints can lead to disengagement from group tasks, with students prioritizing individual performance over team cohesion. The lack of responsibility or unequal distribution of tasks within a group also creates challenges, where some students may rely too heavily on others. Individual dominance can emerge when certain students take control of group discussions or tasks, thus hindering equal participation from all members [41]. Finally, the lack of shared goals within the team can create a sense of disunity, as team members may not align on what needs to be achieved, leading to miscommunication or a lack of direction. This tendency underscores the necessity for educational change, wherein collaborative learning is not merely promoted but methodically organized, evaluated, and integrated into the fundamental academic experiences throughout all semester levels.

The results regarding the development of communicative ability correspond with prior research highlighting the significance of cumulative academic exposure in improving students' soft skills. Documented substantial enhancements in students' verbal and interpersonal communication via project-based and presentation-focused exercises integrated into the curriculum [42]. Communication abilities typically enhance with academic maturity, as advanced undergraduates participate more often in formal presentations, class debates, and peer evaluations [43]. The trend identified in this study significant growth from Semester II to IV, followed by stabilization in Semester VI aligns closely with previous findings, reinforcing the idea that communication development in higher education is enhanced by continuous engagement in interactive and performance-oriented learning experiences.

The stagnation of cooperation competency contrasts with the existing literature on cooperative learning. Research by Faisal et al., indicates that organized group learning settings enhance cooperation, empathy, and co-regulation among students [44]. The absence of notable variations among semesters in this study indicates that such environments may not be effectively executed in the present context. This mismatch may indicate contextual restrictions, like inadequate institutional focus on group work, and instructional deficiencies, where collaboration is not clearly prioritized nor assessed in the classroom. Collectively, these findings indicate a

partial concordance with existing literature and highlight the significance of contextual factors—especially curriculum design and pedagogical decisions in ascertaining the effective cultivation of essential 21st-century competencies within undergraduate education.

3.8 Curriculum and Pedagogical Implications

The distinct differences between communication and collaboration competencies have considerable consequences for curriculum and instructional design in higher education. Although communication skills show significant improvement, the unchanging levels of collaboration throughout the semesters indicate a crucial deficiency in the existing educational system, especially regarding the conceptualization and implementation of group-based learning. This necessitates a deliberate reconfiguration of collaborative elements in course syllabi, guaranteeing that group work is not only an incidental classroom activity but is systematically designed, supported, and connected with explicit learning objectives.

An essential strategy entails achieving a harmonious blending of individual and collective evaluations. The excessive focus on individual assignments, examinations, and presentations may impede the development of vital social and collaborative abilities. Educators ought to be motivated to integrate organized peer cooperation assessments, including group reports, team presentations, or peer evaluations, which ensure students are responsible for both individual contributions and collective achievement.

Furthermore, curriculum design and implementation should provide students with broader opportunities to develop their communication and collaboration skills. This includes selecting learning models that foster communication and collaboration through problem-solving and decision-making activities [45]. Furthermore, engaging students in debates and argumentation activities on socio-scientific issues can be an effective strategy for developing communication skills and fostering collaboration [46]. Faculty professional development programs may facilitate this transition by providing teachers with the information and resources necessary to apply collaborative learning theories, including cooperative learning, jigsaw approaches, and project-based learning. Ultimately, cultivating a culture that prioritizes and evaluates collaboration is essential for equipping students for interdisciplinary teamwork in practical settings.

3.9 Relevance to 21st-Century Skills and MBKM

This study's findings provide significant insights into the congruence between existing student competencies and the 21st-century skills framework, especially the prominent “4Cs”: Communication, Collaboration, Critical Thinking, and Creativity [47]-[49]. The observed advancement in communication skills favorably indicates the academic program's attempts to cultivate this crucial competency. Utilizing student-centered methodologies, academic presentations, and heightened participation in classroom discussions, students seem to be cultivating communication skills that align with international standards and national graduation outcomes. The standstill in collaborative skills indicates a substantial deficiency in achieving comprehensive 21st-century educational objectives. The growing significance of teamwork, interpersonal coordination, and collaborative problem-solving in academic and professional spheres creates obstacles for graduate preparedness [50]-[52]. The findings underscore the pressing necessity to reform curriculum and pedagogical approaches to incorporate significant, measurable collaborative experiences that foster the cultivation of this essential talent.

This analysis is especially pertinent in relation to Indonesia's Merdeka Belajar–Kampus Merdeka (MBKM) strategy. MBKM advocates for transformative learning experiences that are adaptable, student-focused, and grounded in practical application [53], [54]. The findings of this study advocate for systemic transformation, emphasizing the necessity of integrating collaboration as both a learning approach and a formal learning outcome. Enhancing collaborative learning via multidisciplinary projects, community service programs, and cross-campus activities can close this gap and guarantee that graduates acquire the comprehensive abilities outlined in the MBKM framework.

Based on the results of this study, it can be concluded that students' communication skills show significant development throughout their academic journey, while collaboration skills do not show significant progress. This indicates that although students can improve their communication skills through involvement in increasingly complex academic tasks, collaboration skills require a more structured teaching approach and a more in-depth learning experience. The implication of this research is that the curriculum should include more structured collaborative activities, such as group projects and problem-based discussions, to improve students' collaboration skills. More student-centered teaching and collaborative projects should be introduced to improve students' teamwork skills. Furthermore, group-based assessment and peer evaluation should be introduced to develop collaboration skills.

This study is unique in that it examines the development of communication and collaboration skills simultaneously in the context of biology education in Indonesia. Unlike many previous studies that assessed these skills separately or only in one semester, this study explores the differences in skills between three different semesters (Semesters II, IV, and VI) in one education program. Another unique feature is the use of multivariate analysis (MANOVA) to evaluate the collective impact of semester levels on both competencies

simultaneously, providing a more comprehensive picture of how academic progress affects the development of these skills. This approach also identifies stagnation in collaboration skills, which is often overlooked in similar studies, highlighting the urgent need for innovation in teaching and curriculum. One form of innovation in teaching is the use of technology to improve students' digital literacy as a skill that students must have in the early semester, so that in the final semester students can be more prominent in operational skills and the use of ICT, and when they are in the final semester students can demonstrate excellence in information literacy, collaboration, and critical thinking skills in managing and producing academic content [55].

This study has several limitations, including a) Sample limitations: This study was only conducted on students of the Biology Education Program at Tadulako University, so the results cannot be generalized to all study programs or universities in Indonesia, b) Self-Report Data: The instrument used was a self-report questionnaire, which relied on students' perceptions of their communication and collaboration skills. This could affect the objectivity of the data, as students may not be entirely accurate in assessing their own abilities, c) Research Duration: This study was only conducted over one semester for each group, which may not be sufficient to capture longer-term changes or progress in collaboration skills.

Based on the research findings and existing limitations, several recommendations for future research and educational practice are as follows: Enhancement of Collaborative Learning: The biology education curriculum should integrate more structured and in-depth collaborative learning activities. For example, the introduction of more group projects that require intensive contribution and collaboration, such as problem-based assignments and interdisciplinary simulations. Use of Diverse Evaluation Instruments: Future research should employ more diverse evaluation methods, including direct observation and peer assessments, to obtain a more objective view of students' communication and collaboration skills. Development of Advanced Communication Instruction: To ensure further development of communication in the later semesters, study programs can introduce advanced communication tasks, such as scientific debates, research presentations, and professional discussions, that challenge students' communication skills to a higher level.

4. CONCLUSION

This study concluded that there were significant differences in the development of students' communication and collaboration skills. MANOVA analysis showed that semester progression significantly impacted students' soft skills. Communication skills showed a linear trajectory from low in Semester II to moderate in Semesters IV and VI, consistent with previous research on the influence of academic experience on self-confidence and idea delivery. However, post-hoc findings revealed stagnation in Semester VI, indicating a lack of complex communicative challenges in the final semester. Conversely, collaboration skills remained low across all semesters, confirming that the ability to work in positive interdependence does not develop automatically through synchronization. This fact raises the concept of collaborative stagnation in higher education, where improved communication does not go hand in hand with collaboration. This demonstrates that the two are separate developmental pathways that require different pedagogical interventions. These findings suggest that current learning models tend to emphasize individual performance while neglecting the essence of group work, with students tending to work individually even within teams. The implication of this research is the need to implement a project-based learning model with the hope that collaboration skills can grow and develop from this learning. Thus, graduates become adaptive communicators and collaborators according to 21st-century standards and MBKM. The limitation of this research lies in the limited scope of the subject to one study program. It is recommended for future research to explore psychosocial factors that hinder collaboration through a qualitative approach or large-scale experiments to strengthen the generalizability of the findings.

ACKNOWLEDGEMENTS

The gratitude is conveyed to the Directorate General of High Education who has provided facilities. Thank you to the head of the UNTAD biology education study program, for all participants, who are available to facilitate the research process. The last, to all work relatives who helped in the research process.

AUTHOR CONTRIBUTIONS

SWS was responsible for the research design, data collection, data analysis, and manuscript preparation. NB contributed to conceptual development, SWS, NB and F, contributed to research methodology guidance, and critical review of the manuscript. All authors have read and approved the final version of the manuscript.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

REFERENCES

- [1] D. T. K. Ng, J. K. L. Leung, J. Su, R. C. W. Ng, and S. K. W. Chu, "Teachers' AI digital competencies and twenty-first century skills in the post-pandemic world," *Educational technology research and development*, vol. 71, no. 1, pp. 137–161, 2023, doi: 10.1007/s11423-023-10203-6.
- [2] K. Lu, H. H. Yang, Y. Shi, and X. Wang, "Examining the key influencing factors on college students' higher-order thinking skills in the smart classroom environment," *International Journal of Educational Technology in Higher Education*, vol. 18, no. 1, pp. 1, 2021, doi: 10.1186/s41239-020-00238-7.
- [3] L. I. González-Pérez and M. S. Ramírez-Montoya, "Components of education 4.0 in 21st century skills frameworks: Systematic review," *Sustainability*, vol. 14, no. 3, p. 1493, 2022, doi: 10.3390/su14031493.
- [4] M. Aben Ahmed, "Business English instruction: Empowering learners with the 4Cs of the 21st century," *Front Educ (Lausanne)*, vol. 7, 2022, doi: 10.3389/educ.2022.998987.
- [5] M. Khan and S. Zeb, "Academic conversation: A case to exemplify the influence of non-verbal communication on human interaction," *NUST Journal of Social Sciences and Humanities*, vol. 7, no. 1, pp. 79–98, 2021, doi: 10.51732/njssh.v7i1.68.
- [6] [6] I. Abakumova, N. Mironenkova, and E. Pronenko, "Non-verbal communication in meanings transmission," In *XIV International Scientific Conference "INTERAGROMASH 2021" Precision Agriculture and Agricultural Machinery Industry, Volume 2* (pp. 553-562). Cham: Springer International Publishing, 2022, doi: 10.1007/978-3-030-80946-1_52.
- [7] L. Badarnah, "Holistic education for a resilient future: An integrated biomimetic approach for architectural pedagogy," *Biomimetics*, vol. 10, no. 6, pp. 369, 2025, doi: 10.3390/biomimetics10060369.
- [8] M. S. Sheikh *et al.*, "Digital transformation of nephrology POCUS education—Integrating a multiagent, artificial intelligence, and human collaboration-enhanced curriculum with expert feedback," *Digit Health*, vol. 11, 2025, doi: 10.1177/20552076251328807.
- [9] Y. Aperstein, Y. Cohen, and A. Apartsin, "Generative ai-based platform for deliberate teaching practice: A review and a suggested framework," *Educ Sci (Basel)*, vol. 15, no. 4, pp. 405, 2025, doi: 10.3390/educsci15040405.
- [10] M. Giguere, "The social nature of cognition in dance: The impact of group interaction on dance education practices," *Journal of Dance Education*, vol. 21, no. 3, pp. 132–139, 2021, doi: 10.1080/15290824.2021.1928676.
- [11] E. Nolan and D. Zeidler, "Transformational learning for complex socioscientific issues," *Res Sci Educ*, vol. 55, no. 4, pp. 771–791, 2025, doi: 10.1007/s11165-025-10264-y.
- [12] T. Feraco, D. Resnati, D. Fregonese, A. Spoto, and C. Meneghetti, "An integrated model of school students' academic achievement and life satisfaction. Linking soft skills, extracurricular activities, self-regulated learning, motivation, and emotions," *European Journal of Psychology of Education*, vol. 38, no. 1, pp. 109–130, 2023, doi: 10.1007/s10212-022-00601-4.
- [13] F. Emanuel, P. Ricchiardi, D. Sanseverino, and C. Ghislieri, "Make soft skills stronger? An online enhancement platform for higher education," *International Journal of Educational Research Open*, vol. 2, pp. 100096, 2021, doi: 10.1016/j.ijedro.2021.100096.
- [14] S. I. Marin-Zapata, J. P. Román-Calderón, C. Robledo-Ardila, and M. A. Jaramillo-Serna, "Soft skills, do we know what we are talking about?," *Review of Managerial Science*, vol. 16, no. 4, pp. 969–1000, 2022, doi: 10.1007/s11846-021-00474-9.
- [15] H. Zhang, X. Cheng, and L. Cui, "Progress or stagnation: Academic assessments for sustainable education in rural China," *Sustainability*, vol. 13, no. 6, p. 3248, Mar. 2021, doi: 10.3390/su13063248.
- [16] Á. Antón-Sancho, D. Vergara, and P. Fernández-Arias, "Self-assessment of soft skills of university teachers from countries with a low level of digital competence," *Electronics (Basel)*, vol. 10, no. 20, p. 2532, 2021, doi: 10.3390/electronics10202532.
- [17] A. S. D. Martha, K. Junus, H. B. Santoso, and H. Suhartanto, "Assessing undergraduate students' e-learning competencies: A case study of higher education context in Indonesia," *Educ Sci (Basel)*, vol. 11, no. 4, pp. 189, 2021, doi: 10.3390/educsci11040189.
- [18] D. Subandowo and C. Sárdi, "Academic essay writing in an English medium instruction environment: Indonesian graduate students' experiences at Hungarian universities," *Ampersand*, vol. 11, pp. 100158, 2023, doi: 10.1016/j.amper.2023.100158.
- [19] D. F. Heriyawati and M. G. E. Romadhon, "'Can AI Be Trusted for My Thesis?' The voices of Indonesian higher education levels about ChatGPT in automated writing evaluation (AWE)," *Computer-Assisted Language Learning Electronic Journal*, vol. 26, no. 1, pp. 58–75, 2025, doi: 10.54855/callej.252614.
- [20] R. Mufanti, D. Carter, and N. England, "Outcomes-based education in Indonesian higher education: Reporting on the understanding, challenges, and support available to teachers," *Social Sciences & Humanities Open*, vol. 9, p. 100873, 2024, doi: 10.1016/j.ssaho.2024.100873.
- [21] P. Sanatbay, G. Smailova, K. Shalgynbayeva, M. Asilbekova, and A. Tauekelova, "Problem-oriented learning as a method of developing soft skills among students of pedagogical specialties," *Educ Sci (Basel)*, vol. 15, no. 7, p. 861, 2025, doi: 10.3390/educsci15070861.

- [22] P. Vaiouli, M. Theodorou, and G. Panayiotou, "Theory-guided music-based program to facilitate inclusive emotion regulation skills development in university students," In *Effective Practices for Mental Health Promotion in Education* (pp. 297-326). IGI Global Scientific Publishing, 2024, doi: 10.4018/979-8-3693-5325-7.ch012.
- [23] T. Tiahr, B. Hanus, and J. C. Porter, "Transitioning a traditional introductory information systems course to a data analytics focused course," *Decision Sciences Journal of Innovative Education*, vol. 20, no. 4, pp. 176–189, 2022, doi: 10.1111/dsji.12275.
- [24] A. Kim and Y. Su, "How implementing an AI chatbot impacts Korean as a foreign language learners' willingness to communicate in Korean," *System*, vol. 122, pp. 103256, 2024, doi: 10.1016/j.system.2024.103256.
- [25] S. González and X. Bonal, "COVID-19 school closures and cumulative disadvantage: Assessing the learning gap in formal, informal and non-formal education," *Eur J Educ*, vol. 56, no. 4, pp. 607–622, 2021, doi: 10.1111/ejed.12476.
- [26] H. Karimi and G. Farivarsadri, "Exploring the collaboration skills among architecture students: A quantitative study in North Cyprus," *Buildings*, vol. 14, no. 7, p. 1984, Jul. 2024, doi: 10.3390/buildings14071984.
- [27] E. Ribeiro, C. Farias, and I. Mesquita, "'The Game Changers': How equity-driven pedagogical scaffolding reduces participation disparities in physical education," *Educ Sci (Basel)*, vol. 14, no. 10, pp. 1077, 2024, doi: 10.3390/educsci14101077.
- [28] A. Hadyaoui and L. Cheniti-Belcadhi, "Ontology-based group assessment analytics framework for performances prediction in project-based collaborative learning," *Smart Learning Environments*, vol. 10, no. 1, pp. 43, 2023, doi: 10.1186/s40561-023-00262-w.
- [29] T. Frazier and S. L. Doyle Fosco, "Nurturing positive mental health and wellbeing in educational settings – the PRICES model," *Front Public Health*, vol. 11, Jan. 2024, doi: 10.3389/fpubh.2023.1287532.
- [30] S. Nahar, S. Suhendri, Z. Zailani, and H. Hardivizon, "Improving students' collaboration thinking skill under the implementation of the quantum teaching model," *International Journal of Instruction*, vol. 15, no. 3, pp. 451–464, 2022, doi: 10.29333/iji.2022.15325a.
- [31] S. Ghavifekr, "Collaborative learning: A key to enhance students's social interaction skills," *Malaysian Online Journal of Educational Sciences*. vol. 8, no. 3, pp. 9-21, 2020. doi: <http://files.eric.ed.gov/fulltext/EJ1271748.pdf>.
- [32] R. Williams, "The ethical implications of using generative chatbots in higher education," *Frontiers in Education*. vol. 8, 2024. doi: 10.3389/educ.2023.1331607.
- [33] K. Sonnenschein, and J. Ferguson, "Developing professional communication skills: Perceptions and reflections of domestic and international graduates," *Journal of University Teaching and Learning Practice*. vol. 17, no. 3, 2020, doi: 10.5376/1.17.3.5.
- [34] H. Donelan, and K. Kear, "Online group projects in higher education: Persistent challenges and implications for practice," *Journal of Computing in Higher Education*", vol. 36, no. 2, pp. 435, 2024, doi: 10.1007/s12528-023-09360-7.
- [35] B. Nurhayati., Jamaluddin, F.J., Daud, F., Saenab, S., Hadis, A., Hadis, N.I., Remiza, "An extraordinary duet: integration of PjBL and STEM to promote student's motivation, scientific literacy skills, and student learning outcomes," *European Journal of Education and Pedagogy*, vol. 4, no. 3, pp. 42-47, 2023. doi: 0.24018/ejedu.2023.4.3.639.
- [36] T. P. Suaco, A. D. Mangaliag, A.D., and Gadgad, M.M. "Collaborative summative assessment" means for enduring learning and attainment of 21st century skills in the online platform," *Journal of Education and Learning*, vol. 12, no.1, pp.118, 2022. doi: 10.5539/jel.v12n1p118.
- [37] J. L. A. Montano, C. Fernandez-Polvillo, T. Hassal, and J. Joyce, "Developing teamwork skills in accounting students: is communication apprehension a potential barrier?," *Revista de Contabilidad*, vol.26, no.1. pp. 97-110, 2023. doi: <https://doi.org/10.6018/rcsar.451151>.
- [38] M.Takndare, M., Nurhayati.,Adnan.,Alimuddin.,Firdaus. "Critical thinking skills of grade VII students of SMP Negeri 2 Barombong in science subjects". vol. 5, no. 2, pp. 001-007. 2024. doi: 10.47616/jamres.v5i2.530.
- [39] A. Al Yakin, Muthmainnah, S. Ganguli, L. Cardoso, and A. Asrifan, "Cybersocialization through smart digital classroom management (sdcm) as a pedagogical innovation of 'merdeka belajar kampus merdeka (mbkm)' curriculum," In *Digital Learning based Education: Transcending Physical Barriers* (pp. 39-61). Singapore: Springer Nature Singapore, 2023, doi: 10.1007/978-981-19-8967-4_3.
- [40] A. M. Amin, F. Karmila, Z. A. Laode, E. Ermin, A. Y. Akbar, and M. A. Ahmed, "The WE-ARe model's potential to enhance digital literacy of preservice biology teachers," *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 9, no. 1, pp. 36–45, 2023, doi: 10.22219/jpbi.v9i1.23061.
- [41] M. J. Kleckner and N. Butz, "Addressing undergraduate skill gaps in higher education: Revisiting communication in the major course outcomes," *Journal of Education for Business*, vol. 96, no. 7, pp. 411–423, 2021, doi: 10.1080/08832323.2020.1844119.
- [42] S. Mendo-Lázaro, B. León-del-Barco, E. Felipe-Castaño, M.-I. Polo-del-Río, and D. Iglesias-Gallego, "Cooperative team learning and the development of social skills in higher education: The variables involved," *Front Psychol*, vol. 9, 2018, doi: 10.3389/fpsyg.2018.01536.
- [43] A. B. Jamaluddin A B, Palennari M, Faisal, Bahri A. "Empowering scientific attitudes in biology students through the SIRI learning model". *Jurnal Penelitian Pendidikan IPA*. 2024. vol. 10, no. 6, pp. 3205-3211, 2024. doi: 10.29303/jppipa.v10i6.7080.
- [44] F. Faisal, B. Nurhayati, A. N. Arifin, S. N. Martin, "Challenges and strategies in teaching socioscientific issues: A Study of Indonesian pre-service biology teachers," *Asia-Pacific Science Education*. vol. 11, no. 2, pp. 398-431, 2025. doi:10.1163/23641177-bja10098.
- [45] S. J. Niu, H. Niemi, V. Harju, and L. Pehkonen, "Finnish student teachers' perceptions of their development of 21st-century competencies," *Journal of Education for Teaching*, vol. 47, no. 5, pp. 638–653, 2021, doi: 10.1080/02607476.2021.1951602.

- [46] S. Saleem, E. Dhuey, L. White, and M. Perlman, "Understanding 21st century skills needed in response to industry 4.0: Exploring scholarly insights using bibliometric analysis," *Telematics and Informatics Reports*, vol. 13, pp. 100124, 2024, doi: 10.1016/j.teler.2024.100124.
- [47] T. Valtonen *et al.*, "Learning environments preferred by university students: a shift toward informal and flexible learning environments," *Learn Environ Res*, vol. 24, no. 3, pp. 371–388, 2021, doi: 10.1007/s10984-020-09339-6.
- [48] M. Ballesteros-Sola and N. Magomedova, "Impactful social entrepreneurship education: A US-Spanish service learning collaborative online international learning (COIL) project," *The International Journal of Management Education*, vol. 21, no. 3, 100866, 2023, doi: 10.1016/j.ijme.2023.100866.
- [49] P. J. Haubrock, I. Kurtul, R. L. Macêdo, S. Mammola, A. C. S. Franco, and I. Soto, "Competency in invasion science: addressing stagnation challenges by promoting innovation and creative thinking," *Environ Manage*, vol. 74, no. 5, pp. 916–927, 2024, doi: 10.1007/s00267-024-02035-8.
- [50] A. Singun, "Unveiling the barriers to digital transformation in higher education institutions: a systematic literature review," *Discover Education*, vol. 4, no. 1, p. 37, Feb. 2025, doi: 10.1007/s44217-025-00430-9.
- [51] M. Puspitasari, "Navigating classroom challenges and curriculum changes: A qualitative study of an English Teacher's journey in the Indonesian education system," *Power and Education*, Aug. 2024, doi: 10.1177/17577438241275799.
- [52] N. R. Sonia, "Education transdisipliners: Integration interconnection approach in independent curriculum policy learning-independent campus," *Proceeding International Conference on Religion, Science, and Education*. vol. 1, pp. 169-180, 2022.
- [53] S. Wahyuni., B. Nurhayati., Faisal. "Digital literacy of biology education students: trends and differences based on semester level", vol. 7, no. 3, pp. 466-473, 2025, doi: 10.20527/bino.v7i3.22361.