



Evaluation of a Four-Sided GitHub–Telegram Collaborative Communication Model for Scientific Writing in Higher Education: A Mixed-Methods Study

Zulherman^{1*}, Dedy Kiswanto², Junita Friska³
^{1,2,3}Universitas Negeri Medan, Medan, Indonesia

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ABSTRACT

Purpose: This study aimed to evaluate participants' perceptions of a four-sided collaborative communication model integrating GitHub and Telegram Bot to support scientific writing in higher education. **Methods:** A convergent parallel mixed-methods design involved 50 undergraduate students and 10 lecturers from the French Department, Faculty of Languages and Arts, Universitas Negeri Medan. Quantitative data were collected using a five-point Likert-scale questionnaire and analyzed using descriptive statistics, Cronbach's Alpha, Welch's independent-samples t-test, and Cohen's d. Qualitative data were collected through open-ended questions and analyzed thematically using NVivo. **Findings:** The ten-item questionnaire demonstrated high internal consistency (Cronbach's $\alpha = 0.895$). Students reported a mean composite perception score of 3.876 (SD = 0.509), while lecturers reported a mean of 4.050 (SD = 0.375). Welch's independent-samples t-test showed that the difference between the two groups was not statistically significant, $t(16.446) = -1.255$, $p = .227$, with a small effect size (Cohen's $d = -0.355$). Qualitative findings indicated perceived benefits related to workflow organization, revision tracking, information transparency, collaboration, and real-time communication. Participants also reported challenges related to Git workflows, merge conflicts, and initial adaptation to the integrated system. **Implications:** The findings suggest that integrating GitHub and Telegram Bot can support the organization and communication of collaborative scientific writing activities. Structured training, technical guidance, and ongoing support are recommended, particularly for users who are unfamiliar with Git-based collaboration. **Originality:** This study evaluates an integrated four-sided collaborative communication configuration from both student and lecturer perspectives, combining a persistent GitHub workspace with real-time communication through Telegram Bot.



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INTRODUCTION

The rapid development of digital technologies has transformed the way academic activities are organized and conducted in higher education. Digital platforms are increasingly used not only to support teaching and learning but also to facilitate communication, project management, document sharing, and collaborative academic work. These developments are particularly relevant to scientific writing, which commonly involves multiple stages of drafting, reviewing, revising, and communicating ideas among students and lecturers. Online collaborative writing can provide opportunities for shared responsibility, flexible interaction, and exchange of ideas, although challenges related to participation, coordination, guidance, and access may remain (Abance et al., 2023). Recent research has also shown that online collaborative writing requires effective coordination among contributors and mechanisms that support peer editing and awareness of ongoing writing activities (Usher et al., 2025). These conditions indicate that collaborative scientific writing requires not only access to digital tools but also an organized communication environment that connects writing activities, feedback, revision, and project monitoring.

The use of digital technologies for collaborative academic activities can be understood within the perspective of computer-supported collaborative learning (CSCL), in which technology mediates interaction, knowledge sharing, coordination, and joint task completion. In higher education, effective collaborative activities depend on meaningful interaction, clear task structures, participant support, and appropriate technological environments (Xiaodi et al., 2024; Reyes et al., 2025). Collaboration is also multidimensional, involving participation, interaction, coordination, and the management of shared tasks rather than simply the simultaneous use of the same digital platform (Schürmann et al., 2024). Therefore, the implementation of technology-supported collaboration should consider how different technological functions contribute to the overall collaborative process. A digital environment may provide substantial benefits when its tools are connected to clearly defined activities and responsibilities rather than being used as isolated applications.

Within scientific writing activities, students and lecturers have different but interdependent responsibilities. Students are generally involved in preparing documents, revising content, managing project files, and responding to feedback, whereas lecturers or supervisors provide guidance, review progress, and communicate recommendations. Research on students' perceptions of Google Docs for online collaborative writing indicates that students recognize the value of shared digital environments for facilitating collaborative writing processes and interaction (Wahyuningsih et al., 2023). These findings suggest that collaborative writing environments should provide not only a place for storing documents but also mechanisms that enable participants to follow ongoing activities and coordinate their respective responsibilities. In this context, the effectiveness of a collaborative environment is closely related to the extent to which its technological functions correspond to the needs of different participants.

Another important requirement is the availability of timely feedback and communication. A persistent collaborative workspace alone may not be sufficient when participants need immediate information about revisions, submissions, or project activities. Research on real-time written corrective feedback delivered through Google Docs has demonstrated the relevance of timely digital feedback in supporting interaction during writing activities (Susilawati et al., 2024). This issue is particularly important in collaborative scientific writing because delays in communicating project updates may affect revision cycles and coordination among team members. Consequently, an academic collaboration system may benefit from combining a persistent workspace for managing project materials with a communication mechanism capable of delivering timely notifications. Such integration can potentially reduce fragmentation between project activities and communication.

GitHub provides one technological option for establishing a persistent collaborative workspace. Through repositories, commits, version histories, and related project-management functions, GitHub can document changes and provide a structured record of project development. Previous research has demonstrated the use of GitHub Classroom for organizing assignments, managing project activities, supporting feedback, and introducing version-control practices in educational settings (Fiksel et al., 2019; Nelson & Ponciano, 2021). More recent work has also examined GitHub Codespaces and GitHub Classroom as an environment for organizing learning activities and standardizing project workflows (Snowberger & You, 2024). Although these studies demonstrate the educational value of GitHub-based environments, much of the existing application has been associated with programming, statistics, or computing-oriented courses. Its use as a structured workspace for collaborative scientific writing, particularly when combined with a separate real-time communication mechanism, requires further empirical examination.

Telegram Bot provides a complementary technological function by delivering automated notifications and information to users. Unlike a repository that primarily records project activities, a bot can communicate updates directly to participants through a messaging platform. Previous implementation studies have demonstrated the use of Telegram Bot for automated notification and real-time information delivery (Andriani, 2024; Wisesha et al., 2024). In educational contexts, Telegram Bot has also been examined as a tool for supporting students' learning processes and outcomes (Amalia, 2024). These studies indicate that Telegram-based automation can support timely information delivery, but they do not specifically address the integration of Telegram Bot with GitHub for collaborative scientific writing involving both students and lecturers. Thus, the complementary relationship between persistent project documentation and real-time communication remains an important area for investigation.

The present study conceptualizes these functions as a four-sided collaborative communication model consisting of two participant sides (students and lecturers) and two technological sides (GitHub and Telegram Bot). The student and lecturer sides represent the human participants who contribute to, supervise, and communicate about scientific writing activities, while GitHub and Telegram Bot represent complementary technological functions within the collaborative workflow. GitHub provides the persistent workspace for project files, revisions, and activity records, whereas Telegram Bot provides real-time notifications concerning project activities and updates. This configuration is consistent with the broader principle that effective computer-supported collaboration depends on the coordination of

participants, tasks, communication, and technological affordances (Beal & Steier, 2024). Accordingly, the model is not intended to represent a new collaboration theory but rather a practical configuration that connects project management and communication functions within an academic writing environment.

Despite the growing use of digital collaboration platforms, an empirical gap remains concerning the integrated evaluation of these functions in collaborative scientific writing. Existing studies have examined online collaborative thesis writing (Abance et al., 2023), digital collaborative learning in higher education (Xiaodi et al., 2024), GitHub-based educational environments (Fiksel et al., 2019; Nelson & Ponciano, 2021), and Telegram-based communication or notification systems (Amalia, 2024; Andriani, 2024). However, these strands of research have generally examined particular platforms or specific dimensions of collaboration rather than evaluating a coordinated configuration that connects students, lecturers, a persistent project workspace, and real-time communication. Furthermore, evidence concerning both student and lecturer perceptions within the same collaborative scientific writing environment remains limited. This gap highlights the need for an empirical evaluation that considers not only technological usability but also communication responsiveness, workflow organization, information accessibility, transparency, and participants' experiences.

The originality of this study therefore lies in the evaluation of an integrated four-sided collaborative communication configuration, rather than in claiming the development of a new communication theory or a completely new technological platform. The study examines how GitHub and Telegram Bot function together within a structured scientific writing workflow and how the configuration is perceived by students and lecturers. A mixed-methods approach is employed to combine quantitative evidence concerning participants' perceptions with qualitative evidence concerning their experiences, perceived benefits, and implementation challenges. This approach allows the study to examine both the measurable pattern of perceptions and the contextual explanations underlying those perceptions. The evaluation focuses on ten aspects: GitHub usability, Telegram Bot notification responsiveness, communication effectiveness, workflow organization, collaboration, information accessibility, information transparency, technical support, communication responsiveness, and overall model performance.

Based on this research gap, the study addresses the following research question: How do students and lecturers perceive the four-sided collaborative communication model integrating GitHub and Telegram Bot in supporting communication, collaboration, information transparency, and project workflow in scientific writing activities in higher education? Therefore, this study aims to evaluate the four-sided collaborative communication model through quantitative and qualitative evidence obtained from students and lecturers at Universitas Negeri Medan. The findings are expected to provide empirical and practical insights into the potential and limitations of integrating repository-based project management with real-time communication in collaborative scientific writing.

METHOD

This study employed a convergent parallel mixed-methods design to evaluate a four-sided collaborative communication model integrating GitHub and Telegram Bot for scientific writing activities in higher education. The mixed-methods approach was used to obtain quantitative evidence of participants' perceptions and qualitative information concerning their experiences, perceived benefits, and challenges during the implementation. Quantitative and qualitative data were collected during the same implementation period and analyzed separately before being integrated during the interpretation stage. The four-sided collaborative communication model consisted of four interconnected components: students, lecturers, GitHub, and Telegram Bot. Students and lecturers represented the human participants involved in collaborative scientific writing and academic supervision. GitHub functioned as a persistent digital workspace for storing project files, managing revisions, recording project activities, and documenting progress, while Telegram Bot functioned as a real-time communication and notification channel. The model was therefore designed to connect collaborative academic activities, document management, supervision, and communication within an integrated workflow.

The study was conducted over eight weeks within one learning period in the French Department, Faculty of Languages and Arts, Universitas Negeri Medan. The participants consisted of 60 individuals, including 50 undergraduate students and 10 lecturers. Participants were selected using purposive sampling because they were directly involved in learning and academic activities supported by the GitHub–Telegram collaborative communication model. The 50 students were organized into 10 groups, with each group managing one learning project. Each group was assigned its own GitHub repository to manage project files and document project development. The lecturers were involved in supervising and monitoring student activities and communicating with students throughout the implementation. The unequal number of students and lecturers reflected the actual structure of the learning context.

Therefore, the statistical analysis considered the potential for unequal variances and unequal sample sizes when comparing the two participant groups.

The implementation of the model began with two training sessions before the main collaborative activities. The first session introduced the basic use of GitHub, including repository creation, file uploading, committing changes, and updating project documents. The second session introduced the Telegram Bot and explained its integration with GitHub activities. Each training session lasted approximately 60–90 minutes and included hands-on practice. Following the training, each student group established and managed its own GitHub repository. The repository was used to store project documents, upload and update files, record commits, manage revisions, and document project progress. Repository activity also provided lecturers with information for monitoring the development of student projects. Telegram Bot served as a complementary communication mechanism by providing notifications concerning commit activities, file updates, project deadlines, and project progress. This arrangement enabled participants to receive information about repository activities without continuously accessing GitHub manually. The implementation progressed from platform introduction and training to project and repository preparation, collaborative project development, monitoring and communication, and evaluation of participants' experiences.

Data were collected using a structured questionnaire consisting of 10 Likert-scale items and 10 open-ended questions. The Likert-scale items used a five-point response scale ranging from 1 to 5 and were used to obtain participants' perceptions of the implementation of the collaborative communication model. The open-ended questions obtained more detailed information concerning participants' experiences, perceived benefits, communication processes, workflow organization, technical challenges, and suggestions for improvement. Before the main data collection, the questionnaire underwent content review by three experts to examine the relevance and clarity of the items in relation to the study objectives. A pilot test involving 30 students was subsequently conducted to examine the questionnaire before its administration to the main participants. The internal consistency of the questionnaire was assessed using Cronbach's Alpha and produced a coefficient of $\alpha = 0.895$, indicating high internal consistency. This coefficient was interpreted as evidence of the overall internal consistency of the questionnaire rather than as evidence that the 10 items represented a single unidimensional construct. Because the study did not conduct exploratory or confirmatory factor analysis, no claim of construct validity based on factor structure was made. The questionnaire was administered electronically using Google Forms. Participants were informed about the purpose and procedures of the study and the intended use of the collected data, and individual identities were not disclosed in the reporting.

Quantitative data were analyzed using descriptive and inferential statistical procedures. Descriptive statistics included the mean and standard deviation for the individual questionnaire items and the composite perception score. The composite score for each participant was calculated as the mean of the 10 Likert-scale items. Internal consistency was assessed using Cronbach's Alpha. The primary inferential analysis examined differences in composite perception scores between students and lecturers. Because the two groups differed substantially in sample size and equal variances could not be assumed, Welch's independent samples t-test was used as the primary comparison procedure. Statistical significance was evaluated at $p < 0.05$. The distribution of composite scores was examined using the Shapiro–Wilk test, while variance equality was assessed before the group comparison. The magnitude of the difference between the two groups was examined using Cohen's d, allowing the magnitude of the observed difference to be interpreted separately from statistical significance.

Because separate statistical tests across the 10 questionnaire items may increase the probability of Type I error, item-level comparisons were treated as exploratory. The Holm adjustment was applied to item-level p-values to control for multiple comparisons. Consequently, the primary inference concerning differences between students and lecturers was based on the composite score rather than on individual questionnaire items. As a sensitivity analysis, the Mann–Whitney U test was also conducted to determine whether the conclusion obtained from the Welch t-test was consistent with a non-parametric comparison. Statistical calculations were performed using Python.

Qualitative data were obtained from the 10 open-ended questions and analyzed using thematic analysis. The analysis began with repeated reading of participants' responses to develop familiarity with the data. Meaningful statements relevant to the research objectives were identified and assigned descriptive codes. Related codes were then grouped into broader categories, and related categories were developed into themes representing recurring patterns in participants' experiences. The themes were reviewed against the original responses to maintain consistency between the qualitative data and their interpretation. NVivo was used to organize and manage the qualitative data and coding process. Word clouds were used only as supporting visualizations of frequently occurring terms and were not treated as a substitute for thematic analysis.

The quantitative and qualitative findings were integrated during the interpretation stage. A joint display was used to connect the quantitative results with the qualitative themes and to identify areas of convergence and divergence. Quantitative findings concerning participants' overall perceptions were considered alongside qualitative themes related to workflow organization, revision tracking, information transparency, communication, technical challenges, and user adaptation. Qualitative findings that supported the quantitative patterns were interpreted as areas of convergence, whereas differences between the two strands were examined to identify aspects of the implementation that were not fully captured by the Likert-scale responses. This integration provided a more comprehensive interpretation of the four-sided collaborative communication model by combining numerical evidence with participants' descriptions of their experiences.

Before data collection, participants were informed about the purpose of the study, research procedures, intended use of the data, and voluntary nature of participation. Informed consent was obtained from all participants, and permission to conduct the study was obtained from the relevant program/faculty context. The collected data were used solely for research purposes. Individual participant identities were not disclosed, and findings were reported in aggregated form to maintain participant confidentiality.

RESULTS

This section presents the quantitative and qualitative findings obtained from the evaluation of the four-sided collaborative communication model integrating GitHub and Telegram Bot. The quantitative findings include descriptive statistics, instrument reliability, comparison of students' and lecturers' perceptions, and exploratory item-level analysis. The qualitative findings complement the quantitative results by describing participants' experiences, perceived benefits, technical challenges, and recommendations related to the implementation of the integrated collaborative workflow.

Descriptive Findings

The descriptive analysis showed that both students and lecturers reported generally positive perceptions of the four-sided collaborative communication model. Based on the revised dataset, the mean scores across the ten questionnaire items ranged from 3.72 to 4.50. Student mean scores ranged from 3.72 to 4.00, while lecturer mean scores ranged from 3.80 to 4.50.

The highest student mean scores were observed for information transparency ($M = 4.00$, $SD = 0.701$) and communication responsiveness ($M = 4.00$, $SD = 0.606$). Among lecturers, the highest mean was observed for communication effectiveness ($M = 4.50$, $SD = 0.527$). The lowest student mean was observed for GitHub technical support ($M = 3.72$, $SD = 0.640$), whereas the lowest lecturer mean was observed for project workflow organization ($M = 3.80$, $SD = 0.422$). The complete descriptive statistics are presented in Table 3.

Table 1. Descriptive Statistics by Participant Role

Indicator	Students M (SD)	Lecturers M (SD)
Ease of GitHub use	3.84 (0.710)	4.00 (0.471)
Telegram Bot notification speed and accuracy	3.90 (0.707)	4.00 (0.471)
Communication effectiveness	3.96 (0.781)	4.50 (0.527)
Project workflow organization	3.96 (0.638)	3.80 (0.422)
Contribution to collaboration skills	3.76 (0.716)	4.10 (0.738)
Accessibility of project data and information	3.88 (0.773)	4.00 (0.667)
Information transparency	4.00 (0.701)	4.10 (0.568)
GitHub technical support	3.72 (0.640)	4.00 (0.471)
Communication responsiveness	4.00 (0.606)	4.10 (0.568)
Overall model performance	3.74 (0.664)	3.90 (0.738)

Note. M = mean; SD = standard deviation. Responses were measured using a five-point Likert scale.

The descriptive statistics presented in Table 1 summarize participants' perceptions across the ten indicators. The mean scores provide the primary quantitative evidence for describing the participants' evaluations of the four-sided collaborative communication model.

Internal Reliability Analysis

The reliability analysis indicated that the ten-item questionnaire demonstrated high internal consistency, with a Cronbach's Alpha coefficient of 0.895 based on 60 participants. The corrected item–total correlations ranged from 0.541 to 0.709, indicating positive relationships between individual items and the overall questionnaire score.

The highest corrected item–total correlation was observed for the ease of GitHub use item (0.709), whereas the lowest was observed for GitHub technical support (0.541). All corrected item–total correlations exceeded 0.30. These findings indicate that all ten items contributed positively to the internal consistency of the

Table 2. Item Analysis and Cronbach's Alpha

Indicator	Corrected Item–Total Correlation
Ease of GitHub use	0.709
Telegram Bot notification speed and accuracy	0.658
Communication effectiveness	0.685
Project workflow organization	0.656
Contribution to collaboration skills	0.686
Accessibility of project data and information	0.658
Information transparency	0.663
GitHub technical support	0.541
Communication responsiveness	0.570
Overall model performance	0.572

Note. Cronbach's $\alpha = 0.895$; $N = 60$.

Inferential Analysis of Students' and Lecturers' Perceptions

The composite perception score was calculated as the mean of the ten questionnaire items for each participant. Students obtained a mean composite score of 3.876 (SD = 0.509, $n = 50$), whereas lecturers obtained a mean of 4.050 (SD = 0.375, $n = 10$). The Shapiro–Wilk test indicated no statistically significant departure from normality for the student scores ($W = 0.960$, $p = .085$) or lecturer scores ($W = 0.856$, $p = .068$). Given the unequal group sizes and the variance considerations, Welch's independent samples t -test was used for the primary comparison.

The analysis showed that the difference between students and lecturers was not statistically significant, $t(16.446) = -1.255$, $p = .227$. The mean difference was -0.174 points, indicating that lecturers reported somewhat higher perceptions than students, but the observed difference was not statistically significant. The effect size was Cohen's $d = -0.355$, indicating a small difference in the composite perception scores.

Table 3. Comparison of Students' and Lecturers' Composite Perception Scores

Group	N	Mean	SD	Mean Difference	t	df	p	Cohen's d
Students	50	3.876	0.509	-0.174	-1.255	16.446	.227	-0.355
Lecturers	10	4.050	0.375	—	—	—	—	—

As shown in Table 3, students reported a mean composite perception score of 3.876 (SD = 0.509), whereas lecturers reported a slightly higher mean score of 4.050 (SD = 0.375). The mean difference between the groups was -0.174 . Welch's independent-samples t -test indicated that the difference was not statistically significant, $t(16.446) = -1.255$, $p = .227$. The corresponding Cohen's d was -0.355 , indicating a small-to-moderate standardized difference in perceptions. Thus, the findings indicate that students and lecturers had broadly comparable perceptions of the four-sided collaborative communication model

Qualitative Findings

The qualitative findings were obtained from the ten open-ended questions administered alongside the quantitative questionnaire. The responses were analyzed thematically to identify recurring patterns concerning participants' experiences with GitHub, Telegram Bot, collaborative communication, technical challenges, and recommendations for implementation. The analysis involved repeated reading of the responses, identification of meaningful statements, assignment of initial codes, grouping of related codes into broader categories, and refinement of the emerging themes. The resulting themes were reviewed against the participants' responses to maintain consistency between the source responses and the thematic interpretation.

The original study included ten word clouds to visualize frequently occurring terms across the open-ended responses. In the revised analysis, these visualizations are retained as **supporting evidence**, while the identification and interpretation of themes are based on the thematic analysis of the responses rather than word frequency alone.

Participants described GitHub as a useful workspace for organizing project files, tracking revisions, and documenting project activities. Responses also referred to the role of Telegram Bot in providing notifications about project-related activities. These responses indicate that participants recognized complementary functions between the persistent project workspace and the real-time notification channel. The related responses were grouped into the broader theme of workflow organization, revision tracking, and real-time communication.



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Timing Implementation

Participants also reported technical challenges during the implementation. The responses referred to difficulties associated with repository management, version control, and adaptation to GitHub procedures. Some responses also mentioned internet connectivity and occasional delays in Telegram Bot notifications.



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The responses indicated that participants encountered an initial adaptation process when working with the integrated platforms. The responses also referred to strategies such as consultation, self-learning, and additional guidance for addressing these difficulties. These responses were subsequently grouped under the theme of technical challenges and initial adaptation.

Collaborative Communication and Coordination

Another theme concerned collaborative communication and coordination. Participants described experiences related to sharing project information, coordinating activities, receiving feedback, and monitoring project progress. These responses illustrate how the integration of GitHub and Telegram Bot was experienced as a combined workflow rather than as two completely separate tools.



Figure 5. Word Cloud of Participants' Responses to Question 5



Figure 6. Word Cloud of Participants' Responses to Question 6



Figure 7. Word Cloud of Participants' Responses to Question 7

The visualizations support the identification of recurring terminology related to collaboration and communication. However, the thematic interpretation was based on the meaning and context of participants' responses rather than the frequency of individual words.

Information Transparency and Accessibility

Participants also discussed the accessibility and transparency of project-related information. GitHub provided a persistent location for project files and revision records, while Telegram Bot provided notifications concerning relevant activities. These functions were described in relation to participants' ability to remain aware of project updates. The corresponding responses were grouped into the theme of information transparency and accessibility.



Recommendations for Future Implementation

[illegible]

The recommendations indicate that successful implementation requires attention not only to the availability of digital tools but also to user preparation and ongoing technical support.

Table 6. Qualitative Themes Identified from Open-Ended Responses

Theme	Subtheme	Evidence from Participants' Responses
Workflow organization	File management and revision tracking	Participants described GitHub as a shared environment for managing project files and documenting changes.
Real-time communication	Notifications and activity awareness	Participants referred to Telegram Bot notifications as a mechanism for receiving information about project activities.
Information transparency	Progress visibility and information access	Responses described greater visibility of project-related information through the integrated workflow.
Collaborative coordination	Task coordination and feedback	Participants discussed communication, coordination, and feedback during collaborative project activities.
Technical challenges	Repository and version-control difficulties	Some participants described difficulties in adapting to GitHub procedures and version management.
Training and support	Guidance and technical assistance	Participants suggested training, mentoring, and technical assistance to support implementation.

Integration of Quantitative and Qualitative Findings

The integration of quantitative and qualitative findings provides complementary evidence concerning the implementation of the four-sided collaborative communication model. Quantitatively, both students and lecturers reported mean composite scores within the positive perception category, while the difference between the two groups was not statistically significant. Qualitatively, participants described benefits related to workflow organization, revision management, information transparency, and real-time communication, while also identifying technical challenges and the need for continued support.

Table 7. Joint Display of Quantitative and Qualitative Findings

Quantitative Finding	Qualitative Theme	Integrated Interpretation
Students: $M = 3.876$	Workflow organization and collaboration	The positive descriptive perception was accompanied by descriptions of organized collaborative activities.
Lecturers: $M = 4.050$	Information transparency and monitoring	Lecturers reported a somewhat higher descriptive score, while qualitative responses referred to monitoring and access to project information.
Group difference: $p = .227$	Shared collaborative experiences	The quantitative analysis did not identify a statistically significant overall difference, while qualitative responses showed broadly similar experiences across the implementation.
Cohen's $d = -0.355$	Benefits and technical challenges	The small effect indicates a modest group difference, while qualitative findings provide contextual information about both perceived benefits and implementation challenges.
Item-level differences not significant after Holm adjustment	Communication and adaptation	Specific item-level differences should be interpreted cautiously because none remained statistically significant after multiple-comparison correction.

Integration of Quantitative and Qualitative Findings

The integration of the quantitative and qualitative findings provides a complementary understanding of participants' perceptions of the four-sided collaborative communication model. The quantitative results showed that both students and lecturers reported generally positive perceptions, with no statistically significant difference in their overall composite scores. The qualitative findings provide contextual explanations for these perceptions by highlighting the practical benefits of integrating GitHub and Telegram Bot, particularly in organizing project workflows, tracking revisions, facilitating real-time communication, and improving information transparency.

At the same time, the qualitative findings identified several implementation challenges, particularly difficulties related to Git workflows, merge conflicts, and users' initial unfamiliarity with the system. These findings complement the quantitative results by showing that favorable perceptions did not imply the absence of technical difficulties. Instead, participants' experiences suggest that the usefulness of the model depends partly on adequate training, technical guidance, and familiarity with the collaborative workflow.

Overall, the joint findings indicate that the four-sided model was perceived as a supportive framework for coordinating collaborative scientific writing activities. However, because the quantitative evidence was based on participants' perceptions rather than objective measures of writing quality or productivity, the findings should be interpreted as evidence of perceived support and usability rather than demonstrated causal effectiveness.

DISCUSSION

The findings indicate that the four-sided collaborative communication model was positively perceived by both students and lecturers, particularly in workflow organization, information transparency, revision tracking, and communication responsiveness. These findings represent perceived benefits rather than demonstrated effects because the study measured participants' perceptions and experiences rather than objective changes in writing performance or collaboration skills. GitHub functioned as a persistent workspace for managing project files and revisions, while Telegram Bot provided real-time notifications that increased participants' awareness of project activities. This finding is consistent with recent research showing that technology-supported collaborative writing can facilitate interaction, coordination, and shared writing activities when digital tools are appropriately integrated into the writing process (Veddayana et al., 2025 ; Pardede, 2024).

The findings also support the broader development of computer-supported collaborative learning (CSCL), in which digital technologies are used to facilitate interaction and collaborative activities. Recent CSCL research emphasizes that the effectiveness of digital collaboration depends not only on technological availability but also on task organization, participant interaction, and appropriate support (Kaliisa et al., 2025 ; Liu et al., 2024) . In the present study, GitHub and Telegram Bot were therefore complementary rather than independent tools. GitHub provided persistent documentation of project activities, whereas Telegram Bot connected these activities with timely communication. This configuration provided participants with both a shared project workspace and a mechanism for receiving activity notifications.

The qualitative findings showed that participants valued automatic notifications, project organization, and transparency, while also reporting challenges related to merge conflicts and unfamiliarity with Git workflows. These findings suggest that digital collaboration tools can provide useful support while still requiring adequate technical preparation. Recent research on technology-supported collaborative environments emphasizes the importance of coordination, communication, and awareness of other participants' activities (Kurtz et al., 2025) . Similarly, research on computer-mediated collaborative writing highlights the importance of structured communication and interaction in academic writing activities (Costley et al., 2025) . Thus, Telegram Bot appeared useful as a communication and awareness mechanism, but its usefulness should not be interpreted as evidence of improved learning achievement.

Lecturers reported a somewhat higher composite perception score than students (4.050 vs. 3.876), but the difference was not statistically significant, $t(16.446) = -1.255, p = .227$, with an effect size of $d = -0.355$. The absence of statistical significance indicates that perceptions of the model were broadly comparable between the two groups. The observed difference may be related to their different roles in the workflow: students were more directly involved in file management, commits, revisions, and technical problem-solving, whereas lecturers primarily monitored activities and provided feedback. However, this explanation remains tentative because prior GitHub experience, frequency of use, and intensity of interaction were not directly measured.

The collaboration findings should also be interpreted cautiously. Participants reported positive experiences concerning communication, coordination, teamwork, and information sharing, but these competencies were not measured using an independent validated instrument or a pretest–posttest design. Recent research indicates that digital technologies can support collaborative skills, but the outcomes depend on task design, participant engagement, and implementation conditions (Cherbonnier et al., 2025) . Therefore, the present findings demonstrate perceived support for collaboration rather than objective development of collaboration skills.

The findings are also relevant to recent research on technology-enhanced collaborative writing. Veddayana et al., (2025) emphasize that digital technologies can support collaborative academic writing through communication, shared access, feedback, and coordination. Costley et al., (2025) further demonstrate the relevance of computer-mediated collaborative writing in scientific writing contexts. The present study extends this discussion by examining a configuration that combines repository-based project management through GitHub with real-time notification through Telegram Bot. However, the contribution should be understood as a practical configuration rather than the development of a new collaboration theory.

From a practical perspective, implementation of the model should be accompanied by structured training and clear workflow procedures, particularly for users unfamiliar with Git-based collaboration. Training should address repository organization, commit procedures, revision management, and conflict resolution. The need for such support is consistent with recent literature emphasizing that successful technology-enhanced collaboration depends on both technological affordances and appropriate instructional or organizational support (Feng & Wei, 2025 ; Veddayana et al., 2025).

The study has several limitations, including its single-institution setting, unequal participant groups, reliance on self-reported perceptions, and the absence of objective measures of writing quality and collaboration performance. Prior GitHub experience and intensity of platform use were also not measured. Future research should therefore involve larger and more diverse samples and incorporate objective indicators such as revision activity, task completion, response time, writing quality, and validated collaboration measures. Longitudinal or quasi-experimental designs could further examine whether the GitHub–Telegram configuration is associated with measurable changes in collaborative scientific writing performance.

CONCLUSION

This study evaluated a four-sided collaborative communication model integrating GitHub and Telegram Bot for collaborative scientific writing in higher education. The findings indicate that both students and lecturers perceived the integrated model positively, particularly in relation to project workflow organization, information transparency, revision tracking, and real-time communication. Lecturers reported a somewhat higher overall perception than students; however, the difference was not statistically significant. Qualitative findings further indicated that participants valued the complementary functions of GitHub and Telegram Bot while also experiencing challenges related to merge conflicts and unfamiliarity with Git workflows. These findings suggest that the integrated model has potential to support the organization and communication of collaborative scientific writing activities, rather than demonstrating a causal improvement in writing performance or collaboration skills.

The study contributes a conceptual and practical configuration for connecting persistent project management through GitHub with real-time communication through Telegram Bot in an academic collaborative environment. In practical implementation, institutions should provide structured training, clear workflow procedures, and technical support, particularly for users who are unfamiliar with Git-based collaboration. The findings should be interpreted within the limitations of the study, including its single-institution setting, unequal participant groups, and reliance primarily on self-reported perceptions rather than objective measures of writing quality, productivity, or competency development. Future research should therefore examine the model using larger and more diverse samples and incorporate objective performance indicators and validated measures of collaboration and scientific writing.

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***Zulherman (Corresponding Author)**

Universitas Negeri Medan

Jl. Willem Iskandar / Pasar V, Medan Estate, Kecamatan Percut Sei Tuan, Kabupaten Deli Serdang, Sumatera Utara 20221, Indonesia

Email: zulhermanfbs@unimed.ac.id

Dedy Kiswanto

Universitas Negeri Medan

Jl. Willem Iskandar / Pasar V, Medan Estate, Kecamatan Percut Sei Tuan, Kabupaten Deli Serdang, Sumatera Utara 20221, Indonesia

Email: dedykiswanto@unimed.ac.id

Junita Friska

Universitas Negeri Medan

Jl. Willem Iskandar / Pasar V, Medan Estate, Kecamatan Percut Sei Tuan, Kabupaten Deli Serdang, Sumatera Utara 20221, Indonesia

Email: junitafriska1980@gmail.com
