

Formal teacher professional development and academic performance of 'O' level students in core 'O' level science subjects in selected secondary schools in Central Uganda: a cross-sectional study

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Abstract

Background:

This study examined the effect of formal teacher professional development (TPD) on the academic performance of 'O' Level students in the compulsory core science subjects (physics, chemistry, and biology) in selected secondary schools in Central Uganda.

Methodology:

Utilizing a sequential explanatory mixed-methods design, the research gathered data from 547 respondents, comprising 213 science teachers and 334 'O' Level students. Data collection relied on a triangulated approach including researcher- and self-administered questionnaires, semi-structured key informant interviews, and documentary reviews of inspection and academic records. The research instruments demonstrated high scientific rigor, achieving a Content Validity Index of 0.891 and an overall Cronbach's alpha coefficient of 0.908.

Results:

Quantitative analysis using Pearson correlation revealed a positive yet weak and statistically significant link between formal TPD and student academic performance ($r = .188$, $p = .006$). Descriptive data indicated high teacher collaboration on pedagogical techniques within schools ($M = 4.61$, $SD = 0.593$) and a strong commitment to applying new methods in the classroom ($M = 4.75$, $SD = 0.515$). Nevertheless, the weak correlation suggests that participation in training alone does not guarantee high academic achievement. The transformative impact of formal TPD depends heavily on post-training factors, such as ongoing peer collaboration focused on content, active classroom implementation, systematic school monitoring ($M = 4.48$, $SD = 0.731$), and constructive administrative feedback ($M = 4.41$, $SD = 0.776$).

Conclusion:

The study emphasizes that educational stakeholders should shift from one-time, compliance-based training to fostering ongoing, school-embedded learning communities complemented by strong follow-up systems.

Recommendation:

Educational stakeholders should prioritize continuous, school-based teacher professional development rather than relying on occasional training workshops.

Keywords: Formal Teacher Professional Development, Academic Performance, Core Science Subjects.

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Introduction

The effective teaching of core science subjects (Physics, Chemistry, and Biology) along with other STEM fields remains a matter of concern on the African continent, where leading institutions have raised concerns about the inability to fill STEM jobs due to exam-oriented instructional practices rather than the practical application of skills to solve real-life problems (Global Partnership for Education, 2018). Within the Ugandan context, a Uganda National Examinations Board (UNEB) report revealed that 40% of Senior Four candidates who sit national examinations annually fail the core subjects of Mathematics and sciences (UNEB, 2015). This performance deficit has persisted over time, with 50% of candidates failing to achieve a minimum pass of 8 in core science subjects (UNEB Report, 2021).

During specific sittings, such as the 2019 exams, nearly half of the candidates returned a failing grade in Physics and Chemistry papers (Odong, 2020, cited in Kisekka, Issa, & Naggayi, 2020). Despite government initiatives to make core science subjects compulsory (Omoding, 2022), construct laboratories, and distribute thousands of science equipment kits (Kyagaba et al., 2013; Kabunga et al., 2016; Wetaya, 2020), student outcomes remain low. This persistent underperformance is directly attributed to the quality of instruction, as studies have revealed that many science teachers lack flexibility, adaptability, and the necessary pedagogical skills to nurture productive student learning (Wadero, 2020; Rukundo & Bashaija, 2022).

While tertiary teacher training programs equip trainees with initial skills, maintaining a high-quality science teacher

workforce demands meaningful, ongoing professional development to support educators throughout their careers (NSTA, 2006). In Uganda, although statistics indicate that 67% of secondary school teachers possess the minimum required qualifications, they still require continued professional development to enhance their teaching capacities (MoES, 2007b). To address these needs, the Ugandan government and JICA established the Secondary Science and Mathematics Teachers (SESEMAT) program in 2005 to retrain in-service educators, promote teamwork, and facilitate a shift from teacher-centered to learner-centered instructional practices (Komakech & Osuu, 2014; Kaweesi et al., 2022). However, many teachers continue to experience professional development as episodic, superficial, and disconnected from their actual classroom practices. Consequently, this study investigates the impact of formal and informal teacher professional development on the academic performance of 'O' Level science students in selected secondary schools in Central Uganda. By examining factors such as the type of professional development received and teacher participation, this research seeks to address the gap in long-term quantitative studies tracking instructional changes and student outcomes over time (International School of Uganda, 2024). This article therefore was to examine the effect of formal teacher professional development on the academic performance of 'O' Level students in core 'O' Level science subjects in selected secondary schools in Central Uganda.

Methodology

Study Design

This study utilized a sequential explanatory mixed-methods research design. The quantitative phase was conducted first to gather statistical data regarding teacher professional development practices and student academic outcomes. The subsequent qualitative phase built upon these statistical findings through key informant interviews and documentary reviews to explore administrative mechanisms and pedagogical experiences in depth.

Study Setting

The research was conducted across selected Ordinary Level ('O' Level) Universal Secondary Education (USE) schools in Central Uganda, covering urban, peri-urban, and rural districts such as Kampala, Wakiso, Mukono, and Mpigi. Primary field data collection took place in 2023, supplemented by a retrospective documentary review of national examination and inspection records spanning 2009 to 2022.

Study Population

The study population comprised 1,077 educational stakeholders drawn from Universal Secondary Education

(USE) secondary schools in Central Uganda. From this population, a total of 602 participants were included in the study, consisting of 547 respondents ($n = 547$) in the quantitative component and 55 key informants ($N = 55$) in the qualitative component. The quantitative sample included 213 core science teachers (Physics, Chemistry, and Biology) and 334 O Level students (Senior Two to Senior Four), while the qualitative participants comprised 49 Headteachers and 6 District Education Officers (DEOs).

Participant Selection Methods and Procedure

A combination of probability and non-probability sampling techniques was implemented. Sampling was conducted using both probability and non-probability techniques. Simple random sampling was employed to select core science teachers and O' Level students, ensuring equitable representation across public and private, single-sex and co-educational, as well as day, boarding, and mixed day-and-boarding schools. Students were selected from Senior Two to Senior Four classes. In addition, purposive sampling was used to select Headteachers and District Education Officers (DEOs) because of their administrative responsibilities, oversight roles, and specialized knowledge relevant to education policy and school management.

Inclusion & Exclusion Criteria: Included were active 'O' Level science teachers (physics, chemistry, biology), S2–S4 students exposed to lower secondary science assessment cycles, active Headteachers of selected USE schools, and serving DEOs. Excluded were non-science teachers, Senior One students, and non-USE or out-of-region schools.

Sample Size Determination

The quantitative sample size was determined using Yamane's (1967) formula at a 95% confidence level and a 3% margin of error:

$$n = \frac{N}{1 + N(e)^2} n$$

$$= \frac{1,077}{1 + 1,077(0.03)^2} \text{ is approximately } \approx 547$$

Accordingly, a quantitative sample of 547 respondents was obtained. In addition, 55 key informants (49 Headteachers and 6 DEOs) were purposively included in the qualitative component, yielding a total study sample of 602 participants.

Study Variables

The Independent Variable of the study was formal practices for TPD, operationalized through: networking between Schools, Collaboration by teachers on teaching, Forums such as seminars and workshops, Teacher experience, and in-service courses. The Dependent Variable of the study was Academic Performance of 'O' Level Students in Core Science Subjects (Physics, Chemistry, Biology), measured via continuous assessment scores, mid/end-of-term exams,

and UCE national examination results. The Moderating Variable of the was School resource allocation, laboratory consumables, infrastructure, curriculum alignment, and student psychosocial attitudes.

Bias

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Potential sources of bias were minimized through several measures. Selection bias was reduced by employing simple random sampling when selecting teachers and students, thereby enhancing the representativeness of the sample. Social desirability and reporting bias were mitigated by assuring participants of confidentiality, using alphanumeric identification codes, and presenting official university introduction letters to clarify the academic purpose of the study. Measurement bias was addressed through pre-testing of research instruments and expert review of all study tools prior to data collection. Furthermore, methodological triangulation was employed by cross-validating findings from questionnaires, interviews, and documentary evidence to improve the credibility and reliability of the results.

Data Collection Tools and Procedure

Data were collected using multiple instruments to capture both quantitative and qualitative evidence. Structured questionnaires employing a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) were administered to teachers and students, while semi-structured key informant interview guides were used to obtain insights from Headteachers and District Education Officers (DEOs). A document review checklist was used to extract secondary data from UNEB UCE examination summaries (2009–2022), school inspection reports, and departmental mark sheets. To ensure the quality of the instruments, content

validity was established through expert review, yielding a Content Validity Index (CVI) of 0.891, while reliability was confirmed using Cronbach's alpha, with an overall coefficient of 0.908 and subscale values ranging from 0.677 to 0.837.

Data Analysis

Quantitative data were cleaned and analyzed using SPSS version 27, with descriptive statistics (frequencies, percentages, means, and standard deviations) used to summarize respondents' characteristics and study variables. Pearson correlation and linear regression analyses were conducted to examine the relationship between professional development practices and student performance at a significance level of $p < 0.05$. Qualitative data from interviews and open-ended responses were transcribed, coded, and analyzed thematically using MAXQDA 12 to provide contextual explanations and enrich the quantitative findings.

Ethical Considerations

Ethical clearance was formally granted by the Clarke International University Research Ethics Committee (CIUREC). Official institutional permission was secured from Nkumba University. Voluntary written informed consent was obtained from all respondents prior to data collection, anonymity was preserved using alphanumeric codes, and confidentiality was maintained throughout.

Data Presentation, Analysis and Presentation

Findings from the study revealed the following demographic data and the descriptives as shown below:

Table 1: Demographic Data

Characteristic	Category/Statistic	Frequency (n)	Percentage (%)
Teachers (N = 213)			
Gender	Male	166	77.9
	Female	47	22.1
Marital status	Married	120	56.3
	Single	81	38.0
	Divorced	8	3.8
	Widowed	4	1.9
Education level	Diploma	102	47.9
	Bachelor's degree	107	50.2
	Postgraduate qualification	4	1.9
Teacher status	Subject teacher only	157	73.7
	Subject and class teacher	56	26.3
School status	Day school	27	12.7
	Boarding school	28	13.1
	Day and boarding school	158	74.2
Type of school	Public single	12	5.6
	Public mixed	50	23.5
	Private single	14	6.6
	Private mixed	137	64.3
Age (years)	Mean $\pm$ SD	31.69 $\pm$ 7.37	Range: 21–57
Teaching experience (years)	Mean $\pm$ SD	4.15 $\pm$ 3.17	Range: 1–16
Students (N = 334)			
Age (years)	Mean $\pm$ SD	17.92 $\pm$ 1.84	Range: 14–22
Class level	Median	Senior Four	Range: S2–S4

Source: Primary Data (2023)

The study involved 213 teachers and 334 students. Among the teachers, the majority were male (77.9%), while females constituted 22.1% of the sample. More than half of the teachers were married (56.3%), followed by single respondents (38.0%). Regarding educational qualifications, nearly equal proportions held bachelor's degrees (50.2%) and diplomas (47.9%), with only 1.9% possessing postgraduate qualifications. Most respondents were subject teachers only (73.7%), while 26.3% performed both subject teaching and class teaching roles. The teachers had a relatively young profile, with a mean age of 31.69 years (SD = 7.37) and an average teaching experience of 4.15 years (SD = 3.17), suggesting that a substantial proportion of the participants were in the early stages of their teaching careers. Regarding the school characteristics, most teachers were drawn from day and boarding schools (74.2%) and private mixed schools (64.3%), while smaller proportions came from public mixed, private single, and public single schools. Among the student respondents, the mean age was 17.92 years (SD = 1.84), ranging from 14 to 22 years, with the majority being in the upper secondary classes, particularly Senior Four. Overall, the demographic profile indicates that the study captured perspectives from relatively young and

early-career teachers working predominantly in private mixed and day-and-boarding school settings, alongside students mainly within the typical age range for O-Level secondary education.

The findings concerning descriptive results on formal Teacher Professional Development and Academic Performance are shown below:

The study involved 213 teachers and 334 students. Among the teachers, the majority were male (77.9%), while females constituted 22.1% of the sample. More than half of the teachers were married (56.3%), followed by single respondents (38.0%). Regarding educational qualifications, nearly equal proportions held bachelor's degrees (50.2%) and diplomas (47.9%), with only 1.9% possessing postgraduate qualifications. Most respondents were subject teachers only (73.7%), while 26.3% performed both subject teaching and class teaching roles. The teachers had a relatively young profile, with a mean age of 31.69 years (SD = 7.37) and an average teaching experience of 4.15 years (SD = 3.17), suggesting that a substantial proportion of the participants were in the early stages of their teaching careers. Regarding the school characteristics, most teachers were drawn from day and boarding schools (74.2%) and private

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Descriptive Results on Formal Teacher Professional Development and Academic Performance

Table 2: Descriptive Statistics on Formal Teacher Professional Development

	STATEMENT	SD	D	N	A	SA	Mean	SD
		%	%	%	%	%		
1	My school regularly participates in networking events for science teachers with other secondary schools to share teaching methods, skills, and techniques.	3.8	-	10.	36.6	49.3	4.28	.928
2	My school ensures collaboration between/among teachers within the school on teaching messages, skills, and techniques.	-	-	5.6	27.7	66.7	4.61	.593
3	My school ensures collaboration between/among teachers within the school on content focus and content coherence.	-	1.9	9.9	27.2	61	4.47	.750
4	My school regularly organizes seminars/conferences stroke symposium on teaching methods, skills, and techniques.	-	5	2.3	26.8	48.4	4.21	.873
5	I put into practice the methods, skills, and techniques I learnt from collaborations, seminars/conferences/symposia.	-	-	3.8	17.8	78.4	4.75	.515
6	My score monitors whether I implement the message, skills, and techniques I obtain as part of my professional development.	-	-	14.1	23.9	62	4.48	.731
7	My school gives me periodic feedback on my implementation of the teaching methods, skills, and techniques.	-	1.9	12.2	28.6	57.3	4.41	.776
8	My school encourages/motivates me to improve the application of methods, skills, and techniques.	1.9	4.2	3.8	20.7	69.5	4.52	.899

Source: Primary Data (2023)

When asked about networking events for science teachers, the participants reported a relatively high mean score ($M = 4.28$, $SD = 0.928$), indicating that their schools regularly participate in networking events with other secondary schools to share teaching methods, skills, and techniques. This suggests that collaboration and knowledge exchange among teachers are valued in these schools. The low standard deviation indicates that there is relatively less variability among the responses. This implies that the emphasis on networking events can facilitate the dissemination of effective teaching practices, allowing teachers to learn from each other and potentially improve their instructional approaches. It suggests that fostering a network of teachers can positively impact professional development and, subsequently, the academic performance of students.

Concerning the collaboration among teachers within the school, the participants reported a high mean score for collaboration on teaching methods, skills, and techniques within their school ($M = 4.61$, $SD = 0.593$). The low standard deviation suggests that there is relatively consistent

collaboration among teachers within these schools. This implies that the high mean score indicates that collaboration among teachers within the same school is encouraged and practiced. Such collaboration can lead to a collective effort in improving teaching practices, sharing resources, and aligning instructional approaches. It has the potential to enhance teaching quality and contribute to better academic performance among students.

When asked about collaboration on Content Focus and Coherence, participants reported a high mean score for collaboration on content focus and coherence within their school ($M = 4.47$, $SD = 0.750$). The standard deviation suggests that there is some variability in the extent of collaboration among schools. This implies that the high mean score indicates that collaboration among teachers within schools is also focused on content-related aspects, ensuring that teaching approaches align with the curriculum and maintain coherence. This collaboration can help maintain consistency in content delivery and promote a unified educational experience for students.

On organizing Seminars/Conferences/Symposia, participants reported a relatively high mean score ($M=4.21$, $SD=0.873$), indicating that their schools regularly organize seminars, conferences, or symposia on teaching methods, skills, and techniques. The standard deviation suggests that the extent of such events may vary among schools. This thus implies that the high mean score suggests that the schools prioritize professional development opportunities by organizing seminars, conferences, or symposia. These events can provide teachers with exposure to new ideas, research, and pedagogical approaches, enhancing their teaching practices and potentially impacting student academic performance.

On the item of implementation of Learned Methods, Skills, and Techniques, respondents reported a high mean score ($M=4.75$, $SD=0.515$), indicating that they actively apply the methods, skills, and techniques they have learned through collaboration and professional development activities. The low standard deviation suggests a relatively consistent implementation. This implies that the high mean score suggests that teachers are motivated to implement the knowledge and skills gained through professional development activities into their teaching practice. This indicates a positive attitude towards adopting innovative approaches and implementing evidence-based strategies in the classroom, which can potentially lead to improved academic performance.

For monitoring and feedback, participants reported a high mean score ($M=4.48$, $SD=0.731$), indicating that their schools monitor the implementation of teaching methods, skills, and techniques learned through professional development. The standard deviation suggests some variability in the monitoring practices. This therefore implies that the high mean score suggests that schools value

monitoring and providing feedback to teachers regarding the implementation of learned methods, skills, and techniques. Monitoring and feedback mechanisms allow schools to assess the effectiveness of professional development initiatives and provide targeted support to teachers. It facilitates continuous improvement and helps teachers align their instructional practices with the desired outcomes.

With regard to analysing encouragement and motivation for improvement, interviewees reported a relatively high mean score ($M=4.52$, $SD=0.899$), indicating that their schools encourage and motivate them to enhance the application of the methods, skills, and techniques learned through professional development. The standard deviation suggests some variability in the level of encouragement and motivation among schools. This implies that the high mean score suggests that schools recognize the importance of motivating and supporting teachers in their professional growth. By fostering a positive and supportive environment, schools can empower teachers to further improve their teaching practices and contribute to better academic performance.

In conclusion, the analysis reveals a positive picture regarding the effects of formal teacher professional development on the academic performance of 'O' Level students in the selected secondary schools in Central Uganda. The high mean scores across various dimensions of professional development indicate a strong emphasis on collaboration, knowledge sharing, and implementation of learned techniques. The low standard deviations in several areas suggest relative consistency within schools. These findings show the potential of well-structured professional development initiatives to positively impact teaching practices and, consequently, enhance student academic performance.

Correlation analysis on Formal Professional Development and Academic Performance

Table 3: Correlations Between Formal Professional Development and Academic Performance

		Formal Professional Development	Academic performance
Formal Development	Pearson Correlation	1	.188**
	Sig. (2-tailed)		.006
	N	213	213
Academic performance	Pearson Correlation	.188**	1
	Sig. (2-tailed)	.006	
	N	213	213

** . Correlation is significant at the 0.01 level (2-tailed).

Source: Primary Data (2023)

The Pearson correlation analysis was conducted to determine the relationship between formal professional development and academic performance. The results in Table 6.2 indicate a positive correlation coefficient ($r = 0.188$) between formal professional development and academic performance. The associated p-value ($p = 0.006$)

is less than the 0.01 level of significance, indicating that the relationship is statistically significant.

The positive correlation suggests that increases in formal professional development are associated with slight improvements in academic performance. However, the magnitude of the correlation coefficient (0.188) indicates

that the relationship is weak. This implies that although formal professional development contributes to academic performance, its influence is relatively limited and not strong enough to be considered a major determinant on its own.

Page | 7 Discussion of Findings

The results showed that formal teacher professional development was widely practiced in the selected secondary schools in Central Uganda, as evidenced by high average scores for the implementation of learned methods and techniques ($M = 4.75$, $SD = 0.515$), teacher collaboration ($M = 4.61$, $SD = 0.593$), monitoring of implementation ($M = 4.48$, $SD = 0.731$), and encouragement to enhance professional practices ($M = 4.52$, $SD = 0.899$). These findings suggest that professional development involves more than just attending training; it also includes collaboration, application, monitoring, and feedback. The results align with Visscher et al. (2025), who reported a positive overall effect of teacher professional development on student achievement, especially when programs incorporate effective teacher-learning principles. Similarly, Lynch et al. (2025) found that professional development in mathematics and science improved teachers' knowledge and instructional practices, which were linked to better student outcomes. Therefore, the high levels of professional learning observed in this study create a supportive environment for enhancing science teaching and potentially boosting students' academic performance.

The correlation analysis established a positive and statistically significant relationship between formal teacher professional development and students' academic performance ($r = .188$, $p = .006$, $N = 213$). Although the relationship was weak, the significant result indicates that increased formal professional development was associated with better academic performance among O-Level students. This finding agrees with Visscher et al. (2025), who reported positive effects of professional development on student achievement, while noting considerable variation across programmes. It also supports Lynch et al. (2025), who found that professional development influences student achievement partly through improvements in teachers' knowledge and classroom instruction. In Uganda, Mwesigye et al. (2024) similarly found a significant positive relationship between professional development and science teacher effectiveness ($r = .473$, $p < .01$). The weaker relationship in the present study suggests, however, that formal TPD is only one of several factors influencing academic performance and that its effects may depend on teacher effectiveness, school leadership, learning resources and student-related factors.

The findings further demonstrate that participation in professional development alone does not guarantee improved student achievement. Kirsten et al. (2023), using TIMSS data from 2003–2019, found a small negative

average effect of the professional development typically received by mathematics and science teachers on student achievement. This contrasts with the positive relationship found in the present study but reinforces the importance of TPD quality and implementation. The high scores for application of acquired methods ($M = 4.75$) and monitoring and feedback ($M = 4.48$) may help explain the positive relationship observed in the selected schools. Consistent with Mwesigye et al. (2024), who identified inadequate planning, limited funding, and insufficient teacher involvement as challenges to professional development in Uganda, the findings suggest that TPD is most likely to benefit students when teachers are supported to apply new knowledge and receive continuous monitoring and feedback. Therefore, schools should strengthen formal professional development alongside collaboration, follow-up support, monitoring, feedback, and practical classroom application.

Conclusion

In conclusion, the study offers valuable insights into formal teacher professional development practices in selected secondary schools in Central Uganda. While collaboration among teachers, the use of learned teaching methods, monitoring, and administrative feedback were generally well established, there were variations in the consistency of professional learning and follow-up support. Consequently, ongoing classroom application, peer collaboration, regular monitoring, constructive feedback, and continuous school-based professional learning are crucial for turning formal TPD into meaningful improvements in student outcomes.

Generalisability

The findings can be cautiously generalized to secondary schools in Central Uganda and other similar settings. The study offers valuable insights from 547 teachers and 'O' Level students in various urban, peri-urban, and rural schools. Nevertheless, applying these results to areas outside Central Uganda should account for differences in school types, resources, teacher traits, and student demographics. Consequently, additional broad and longitudinal research is suggested to determine whether these findings are applicable to other regions and educational environments.

Limitations

The study targeted specific secondary schools in Central Uganda, which may limit the generalizability of the results to other regions. Its cross-sectional approach collected data at one time point, preventing analysis of changes in professional development and academic performance over time. The teacher sample was predominantly male and early in their careers, potentially limiting the diversity of teacher profiles represented. Moreover, as data relied on self-reports, biases like reporting inaccuracies or social

desirability may have influenced the findings, despite efforts to minimize such biases.

Recommendations

Educational stakeholders should prioritize continuous, school-based teacher professional development rather than relying on occasional training workshops. Schools need to foster peer collaboration, encourage the application of learned methods in the classroom, and promote content-specific professional learning. To support this, administrators should implement systematic monitoring, provide constructive feedback, and motivate teachers to ensure consistent use of professional development practices.

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List of Abbreviations

CIUREC: Clarke International University Research Ethics Committee

CVI: Content Validity Index

JICA: Japan International Cooperation Agency

MaxQDA: Maximum Qualitative Data Analysis Software

MoES: Ministry of Education and Sports

SESEMAT: Secondary Science and Mathematics Teachers Program

SPSS: Statistical Package for the Social Sciences

STEM: Science, Technology, Engineering, and Mathematics

TPD: Teacher Professional Development

UNEB: Uganda National Examinations Board

Source of funding

Not Applicable.

Conflict of interest

None

Data availability

The data underlying this study contain potentially identifiable participant information and cannot be publicly shared due to ethical restrictions and participant confidentiality agreements. Anonymized data may be made available by the corresponding author upon reasonable request and subject to approval by the relevant ethics committees.

Author contributions:

EOO: Conceptualization, Methodology, Data collection, Investigation, Writing-original draft.

JBS: Supervision, Validation, Writing- review and editing.

JPK: Data curation, Visualization, Supervision, Project administration.

All authors: Approved the final version of the manuscript and agreed to be accountable for the work.

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