Effects of Self-Regulation Skills and Peer Collaboration on Laboratory Learning Satisfaction: Mediated by Laboratory Safety

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ABSTRACT-*This mediation study examined the influence of peer and self-regulation skills on laboratory learning satisfaction as mediated by laboratory safety among students at the Adventist University of the Philippines. A total of 189 students (121 females, 68 males) aged 17-44 years from the College of Dentistry, College of Health, and College of Nursing, who were enrolled in Biochemistry and General Inorganic with Organic Chemistry during the first semester of the 2024-2025 collegiate year, participated in the study. Using structural equation modeling (SEM), the research investigated both direct and indirect paths of peer collaboration and self-regulation on 'Laboratory Learning Satisfaction' through 'Laboratory Safety' as a mediator. Results revealed significant positive effects of both peer collaboration ($\beta = 0.234$, $t = 3.98$, $p < 0.001$) and self-regulation skills ($\beta = 0.487$, $t = 5.02$, $p < 0.001$) on 'laboratory safety.' Laboratory safety, in turn, significantly predicted laboratory learning satisfaction ($\beta = 0.481$, $t = 7.21$, $p < 0.001$). The mediation analysis demonstrated that laboratory safety partially mediates the effects of peer collaboration and Laboratory learning Satisfaction (indirect effect: $\beta = 0.234$, $t = 3.98$, $p < 0.001$) as well as between self-regulation skills and Laboratory learning Satisfaction (indirect effect: $\beta = 0.12$, $t= 3.36$, $p < 0.001$). The total effects showed that self-regulation skills had a stronger overall impact on laboratory learning satisfaction ($\beta = 0.619$, $t = 10.2$, $p < 0.001$) compared to peer collaboration ($\beta = 0.234$, $t = 3.98$, $p < 0.001$). These findings suggest that fostering collaborative learning environments and self-regulatory skills enhances students' laboratory safety awareness, which subsequently increases their satisfaction in laboratory courses.*

KeyWords: *Structural Equation Modeling, Peer Collaboration, Self-Regulation Skills, Laboratory Safety, Laboratory Learning Satisfaction*

I. INTRODUCTION

Laboratory courses encounter numerous challenges that affect students' learning satisfaction. Primary concerns include the lack of physical learning environments, such as limited infrastructure and insufficient resources, as well as restricted opportunities for hands-on practice due to safety regulations and limited time. In addition, the shift from traditional to online laboratory formats has posed difficulties for some students, especially in recreating the practical, experiential aspects of learning.

In the Philippines, according to Caballes 2024, many studies have emphasized the present condition of laboratories in science and the persistent difficulties faced by science educators. The scarcity of tools in science laboratories remains a widespread issue in most schools. Lanao del Sur has identified quite a sumber of problems that have toh do with laboratory facilities, including malfunctioning equipment and the absence of dedicated laboratory rooms. (Caballes et al., 2024).

Recoco. Et al. (2025) stated that laboratory activities play an important role in education, especially in science, by giving students practical, hands-on experiences that for them to be connected to real-world phenomena. Beyond having complete laboratories, the presence of qualified science teachers is needed to ensure good instruction. (Recoco et al., 2025).

Results of Harman et al. (2016) stated that students' opinion that the science laboratory is viewed as a space where experiments are illustrated for practical applications of theoretical concepts, giving them the chance to translate scientific theory into some real-world practices (Harman et al., 2016). The effectiveness of laboratory practical work is questioned by some researchers, suggesting that it may not consistently result in enough academic improvement (Wieman & Holmes, 2015).

Zimmerman (2002) stated that self-regulation skills and peer collaboration have previously been tagged as prime predictors of learning satisfaction and laboratory safety in laboratory courses (Zimmerman, 2002). In the same vein, laboratory safety itself may predict learning satisfaction significantly (Viitaharju et al., 2021). Given this relationship, laboratory safety can also serve as a mediating variable, explaining how self-regulation skills, peer collaboration, and communication influence students' satisfaction in laboratory learning environments. (Yu et al., 2023).

This study looks for the influence of self-regulation skills, peer collaboration on laboratory learning satisfaction as mediated by laboratory safety.

II. LITERATURE REVIEW

Studies of Freeman et al. (2014) indicated a positive association between laboratory learning satisfaction and academic performance. Students who are expressing greater satisfaction with their laboratory experiences tend to exhibit stronger learning outcomes, including enhanced comprehension and retention of course content. (Freeman et al., 2014)

Broadbent and Poon 2015 conducted a systematic review on the predictive value of self-regulated learning (SRL) strategies for academic achievement and satisfaction in an online higher education. Although the review's scope was not limited to laboratory contexts, its conclusions are applicable, as a significant number of the included studies pertained to STEM courses with integrated online or blended lab components (Broadbent & Poon, 2015).

An extensive meta-analysis by Moore et al. (2015) examined learning outcomes across various laboratory formats. Although it primarily emphasized academic achievement, it also integrated findings related to student attitudes and satisfaction. A central conclusion concerning satisfaction is that, on average, differences do not differ significantly between traditional hands-on labs and alternative formats such as virtual or remote labs. (Moore et al., 2015).

Laboratory safety is a serious concern for scientific employees involved in research or safety testing, for laboratory directors accountable for institutional liability, and individuals working or living near laboratory facilities. Ensuring safe laboratory operations requires a comprehensive understanding of industrial hygiene, engineering principles, and regulatory guidelines related to the handling of hazardous chemicals (Nemchin, n.d.). For more than a century, laboratory experiences have been fundamental to science education, helping students develop their scientific understanding, practical skills, and appreciation for how scientists work. (Ghayas Khan et al., 2019).

According to Yu et al. (2023), students' professional development is heavily dependent on their engagement in both classroom and laboratory activities. In laboratory environments, adherence to safety protocols and awareness are critical components of proper conduct, implying a strong link between safety behavior and the effective acquisition of professional knowledge.This study seeks to investigate and develop a comprehensive understanding of this relationship (Yu et al., 2023).

Viitaharju et al. (2021) propose that a web-based virtual environment provides an engaging and effective way to train chemical engineering students in laboratory safety. The technology facilitates integration of course content and real-time updates, and simplifies the development and revision of training materials. (Viitaharju et al., 2021).

Mendez (2023) noted three important conclusions in the study. The learning environment in the scientific lab was rated high as well, and the level of students' practices on laboratory safety is very high. Moreover, a significant relationship exists between the science laboratory learning environment and students' laboratory safety practices (Mendez, 2023).

In the experimental study of Song and Kim (2021), as of whether self-regulated learning increases as scaffolding is employed, in an experimental condition where a scaffold was provided through the conversational agent, and a control condition where the self-regulated learning information was given, but no scaffolds were provided. The results showed that the scaffolded group showed a higher degree of self-regulated learning level improvements compared with the control group. Moreover, the associations among self-regulated learning, course participation, and learning performance were assessed. (Song & Kim, 2021).

Shi et al. (2022) did a content analysis of 24 articles to examine the benefits of Self-Regulated Learning (SRL). Their findings demonstrate that SRL has an entirely positive impact on students, enhancing not only their academic performance but also their practical abilities, engagement levels, and self-efficacy. (Shi et al., 2022).

A study involving 116 college students in evolving math courses discovered that brief training in Self-Regulated Learning (SRL) substantially improved their math performance (Bol et al., 2016). Compared to a control group, students who participated in weekly SRL exercises demonstrated enhanced metacognitive abilities, including improved self-regulation and time management skills. The findings suggested that even short-term SRL training can be an effective strategy for boosting student success in challenging subjects. (Bol et al., 2016).

The author argues that while Vygotsky's theory acknowledges that both adults and capable peers can foster learning, modern research has overwhelmingly focused on the adult's role. This text deliberately shifts the focus to **peer collaboration**, asserting that it is a critical, yet under-examined, aspect of child development. (Vygotsky, the Zone of Proximal Development, and Peer Collaboration," 1990).

The study revealed that children working in groups achieved significantly better sorting performance than those working alone. However, the benefits of collaboration were not equally distributed: only lower-ability children who worked with higher-ability peers showed meaningful improvement from pre-test to post-test. (Fawcett & Garton, 2005).

This passage critiques the narrow focus of current Vygotskian research, which has largely overlooked the significant role of **peer collaboration** in learning, despite Vygotsky himself identifying "more competent peers" as key facilitators of development. (Vygotsky, the Zone of Proximal Development and Peer Collaboration," 1990).

This research investigated the effectiveness of different forms of peer collaboration in a chemistry lab, comparing them to individual learning. The findings clearly showed that any form of peer collaboration—whether general group work or structured peer tutoring—led to better immediate learning outcomes than working alone. Three months after the experiment, the peer tutoring group significantly outscored the collaborative group, suggesting that the act of explaining concepts to a peer solidifies understanding in a more durable way (Ding & Harskamp, 2011).

Investigating the key drivers of student success, this study examined how a student's personal **self-regulation skills** interact with the teaching environment to influence their **learning satisfaction**. The findings revealed a clear and direct relationship: the higher a student's capacity for **self-regulated learning**, especially when supported by a well-structured teaching context, the greater their reported **learning satisfaction** (De La Fuente et al., 2020).

In a large-scale study exploring what makes students satisfied with online learning, **online self-regulation** emerged as a critical factor. The research, involving nearly 1,700 middle school students, found that a student's ability to manage their own learning process—their **self-regulation**—had a direct and powerful influence on their overall satisfaction. Unlike motivation, which had an indirect effect, **self-regulation** played a more foundational, driving role. (The Effects of Student Motivation and Self-Regulated Learning Strategies on Students' Perceived E-Learning Outcomes and Satisfaction," 2019).

Hence, putting the main constructs together and the theoretical perspectives discussed in the literature review, Figure 1 below presents the SEM (Structural Equation Modeling) research paradigm. This graphical context unifies the latent constructs together with their dimensions under investigation and depicts their interrelatedness, offering a basis for the subsequent scrutiny.

III. MATERIALS AND METHODS

This cross-sectional study quantitatively explores the multifaceted associations between peer collaboration, self-regulation, laboratory safety, and laboratory learning satisfaction among undergraduate students. To attain this, a complete self-administered survey questionnaire is accurately designed to get relevant data on these constructs and their dimensions.

Structural Equation Modeling (SEM) is used to examine the proposed the following hypotheses:

1. **Direct Relationships:** Peer collaboration and self-regulation skills are conjectured to have an optimistic direct effect on laboratory learning satisfaction.
2. **Mediating Role of Laboratory Safety:** Laboratory safety is theorized to act as a mediating variable. In particular, peer collaboration and self-regulation are likely to improve

laboratory safety perceptions, which, in effect, lead to advanced laboratory learning satisfaction.

By explaining these relationships, this study aims to contribute valuable understandings to the optimal learning environments for laboratory-based courses. The findings will underscore the significance of fostering supportive peer interactions, promoting self-directed learning skills, and ensuring robust laboratory safety measures to enhance overall student satisfaction and learning outcomes in laboratory settings.

Population and Sampling

The respondents of this study consist of 189 students who are enrolled in Biochemistry and General Inorganic Chemistry courses at the College of Science and Technology-Adventist University of the Philippines, during the school year of the first semester of 2024-2025. Hence, the sampling method used is purposive since participants are selected based on specific characteristics or the purpose of the study. Out of 189 respondents, 121 are females, while 68 are males.

Instrumentation

This study utilizes a meticulously structured questionnaire comprising two primary sections. The first section gathers demographic information to provide context about the respondents. It includes details such as the participants' degree programs, ages, and sex, which help in characterizing the sample population. The second part is focused on exploring respondents' insights into key factors relevant to their laboratory course practices.

Peer collaboration is broken down into five important dimensions: teamwork and communication, open communication, conflict resolution, shared responsibility, and feedback and reflection. Self-regulation skills include four dimensions: goal setting, motivation and commitment, adaptability and flexibility, and time management. Laboratory Safety likewise comprises four dimensions: General Laboratory Safety, Personal Protective Equipment, Use of Equipment and Glassware, and Waste Management and Emergency Procedures. Finally, laboratory learning satisfaction is defined by four dimensions: engagement and interest, understanding and clarity, confidence in practical skills, and instructor support and feedback.

To make sure that the validity and reliability of survey forms is established, complete statistical evaluations were conducted. To establish validity, Convergent validity, Cronbach's Alpha, and Average Variance Extracted (AVE) calculations for each construct were done, signifying strong internal consistency and item convergence, as detailed in the accompanying table. Additionally, discriminant validity was also confirmed using the Fornell-Larcker Criterion, which has shown that the square root of each construct's AVE was greater than the inter-construct correlations.

Table 1: Five-point scale interpretation for study variables

Variables	1	2	3	4	5
Peer Collaboration	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Self-Regulation Skills	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Laboratory Safety	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Laboratory Learning Satisfaction	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree

Mean Scaled: 1-1.5 Strongly Disagree, 1.6-2.5 Disagree, 2.6-3.5 Undecided, 3.6-4.5Agree, 4.6-5.0 Strongly Agree

The above table shows the gauges used in the Likert scales. Higher scores indicate higher scales on peer collaborations, self-regulation skills, laboratory safety, and laboratory learning satisfaction. These scale interpretations served as a basis for the researchers in analyzing both the descriptive and statistical data and conducting the subsequent inferential analyses in this study.

Data Analysis

To ensure the measurement model, the convergent validity was evaluated using Cronbach's alpha and Average Variance Extracted (AVE). Similarly, to make sure that discriminant validity was satisfied, the Fornell-Larcker criterion was assessed.

Descriptive analyses were employed to classify respondents and gauge the levels of peer collaboration, self-regulation skills, laboratory safety, and laboratory learning satisfaction, as measured on a Likert scale from strongly disagree to strongly agree. The influence of the two independent variables on the dependent variable was examined, as well as the mediator's subsequent effect on the dependent variable using structural equation modeling. Direct, indirect, and total effects were assessed to highlight the role of the mediating variable.

IV. RESULTS AND DISCUSSION.

To look into the hypothesized relationship in the model, the study made use of Partial Least Squares Structural Equation Modeling (PLS-SEM) via SmartPLS. The analysis followed a two-stage approach: calculation of the measurement model to assess the reliability and validity and evaluation of the structural model.

The measurement model was first assessed to ensure the reliability and validity of the latent constructs: self-regulation skills, peer collaboration, laboratory safety, and laboratory learning satisfaction. Indicator reliability was confirmed, with all outer loadings exceeding the recommended threshold of 0.70. Cronbach's Alpha ranged from 0.943 to 0.962, while the Average Variance Extracted of the latent constructs was all above 0.50, indicating strong internal consistency across constructs. Hence, convergent validity was firmly established.

Table 2. Convergent and Discriminant Validity Metrics for Latent Variables

Convergent Validity			**Discriminant Validity**			
Latent Variable	Cronbach Alpha	Average Variance Extracted (AVE)	LLS	LS	PC	SR
LLS	0.962	0.84	**.917**			
LS	0.943	0.815	0.857	**.903**		
PC	0.952	0.838	0.823	0.799	**0.916**	
SRS	0.953	0.842	0.83	0.777	0.865	**.918**

Legend: LLS=Laboratory Learning Satisfaction, LS= Laboratory Safety, PC= Peer Collaboration, SR=Self-Regulation Skills

Furthermore, discriminant validity was established using the Fornell-Larcker criterion, with each construct's square root of AVE exceeding its correlation with other constructs. A table for convergent validity and discriminant validity was established above.

The structural model was then gauged to test and measure the direct and indirect effects among the constructs. Collinearity statistics revealed no multicollinearity concerns, since in the Variance Inflation Factor (VIF), no dimension had a VIP value greater than 5.

In Table 4 below, the effect sizes associated with each path in the model are presented. These effect sizes provide a clear view of the practical significance of the relationships and help to highlight which constructs exert the strongest influence on the outcome variables.

This table summarizes the effect sizes of each construct on both laboratory learning satisfaction and laboratory safety. Laboratory safety has the highest effect (.386) on laboratory learning satisfaction, while peer collaboration shows a little less but still has a distinguished influence (.177). Meanwhile, self-regulation skills significantly relate to laboratory learning satisfaction (.334) but have a comparatively meager impact (.095) on laboratory safety, for this can easily be deciphered.

Table 4. Effect Size of Constructs on Laboratory Learning Satisfaction and Laboratory Safety

Constructs	Laboratory Learning Satisfaction	Laboratory Safety
Laboratory Safety	.386	
Peer Collaboration		.177
Self-Regulation Skills	.334	.095

Results from the path analysis revealed that self-regulation skills positively impacted laboratory safety ($\beta = 0.357$, $t = 3.93$, $p < 0.001$), with a similar effect observed for peer collaboration ($\beta = 0.487$, $t = 5.02$, $p < 0.001$). Laboratory safety significantly influenced learning satisfaction ($\beta = 0.481$, $t = 7.21$, $p < 0.001$). The direct effect of self-regulation skills on learning satisfaction was also notable ($\beta = 0.447$, $t = 6.74$, $p = 0.016$). However, the effect of peer collaboration on learning satisfaction was not statistically significant ($\beta = 0.10$, $t = 1.75$, $p = 0.081$), and it was excluded from the model.

Our findings align with previous research, underscoring the importance of self-regulation skills in improving safety practices in educational settings (M. Sirazieva et al., 2018). These skills enhance time and resource management, contributing to safer laboratory environments (Zimmerman, 2002).

Johnson & Johnson (2002) highlighted that peer efforts enhance awareness and adherence to safety protocols. When students collaborate, they are more effective at identifying hazards and implementing safety measures (Keding & Nan, 2015).

Mediation analysis confirmed laboratory safety as a significant mediator ($\beta = 0.172$, $t = 3.36$, $p < 0.01$). The direct effect of self-regulation on learning satisfaction through laboratory safety was significant ($\beta = 0.447$, $t = 6.74$, $p < 0.01$), indicating partial mediation. Additionally, the mediated effect of peer collaboration via laboratory safety was significant ($\beta = 0.234$, $t = 3.98$, $p < 0.01$), suggesting full mediation.

Table 5: Influence of Peer Collaboration and Self-Regulation on Laboratory Learning Satisfaction Mediated by Laboratory Safety

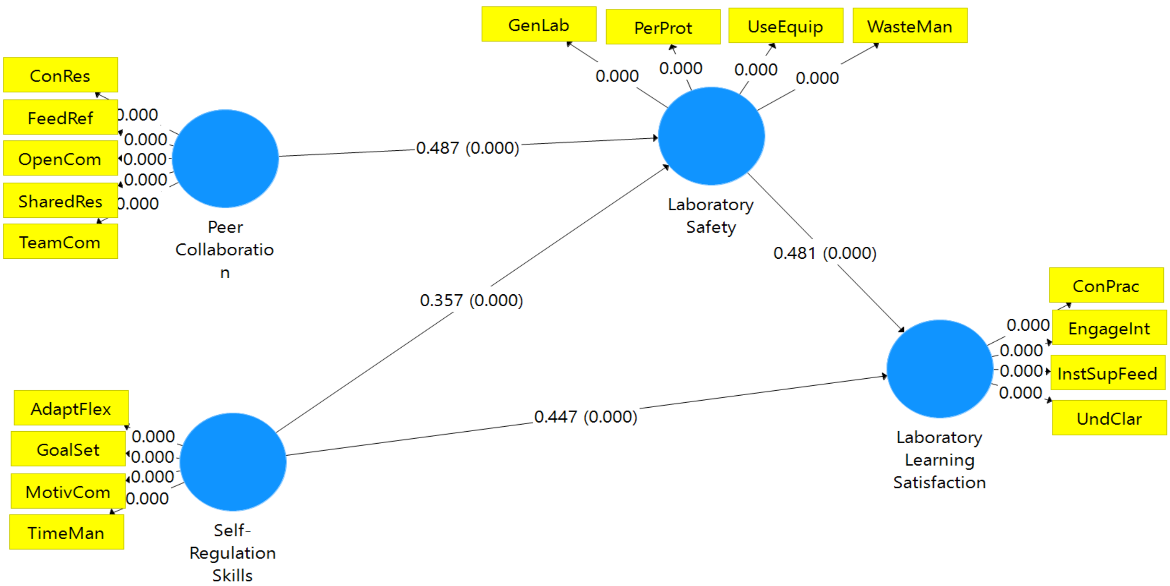
	Total Effect	Direct Effect	Indirect Effect

Path Name	Coefficient	t	p-value	Coefficient	t	p-value	Coefficient	t	p-value
PC->LS->LLS	0.234	3.98	.000	NA	NA	NA	0.234	3.98	.000
SR->LS->LLS	0.619	10.2	.000	0.447	6.74	.000	0.172	3.36	.001

Legend: PC=Peer Collaboration, LS=Laboratory Safety, LLS=Laboratory Learning Satisfaction, SR=Self-Regulation Skills.

These findings highlight the essential role of laboratory safety in linking behavioral and social competencies to laboratory learning experiences, explaining 66.7% of the variance in laboratory safety and 76.6% in learning satisfaction.

Figure 1: Structural Equation Model Illustrating Relationships Among Peer Collaboration, Self-Regulation Skills, Laboratory Safety, and Laboratory Learning Satisfaction



To get a greater picture of the effects of peer collaboration and self-regulation skills on laboratory learning satisfaction via laboratory safety, Figure 1 presents the planned structural equation model (SEM). The arrow from the independent variables, peer collaboration and self-regulation skills, to the dependent variable, laboratory Learning Satisfaction, determined the strength of the effects.

Leong Lim et al. (2020) and Eom & Ashill, 2016 also imply that self-regulated learning is a mediator of peer learning on online satisfaction (Leong Lim et al., 2020; Eom & Ashill, 2016).

The resulting model above showed that peer collaboration and self-regulation skills account for 66.7% of the variance in laboratory safety, while laboratory safety and self-regulation skills account for 76.6% of the variance in laboratory learning satisfaction. This has important implications in the field of education.

One more significant consequence of the above results suggests that devoting to safety training and peer collaboration can improve learning atmospheres, make informed decisions, and allocate resources in educational institutions. This spreads findings elaborate on the importance of self-regulated learning in laboratory situations, leading to greater knowledge and hence impacts on safety and fulfilment.

According to (M. Sirazieva et al. (2018, in their previous study they came up with a new understanding of self-regulation skills, peer collaboration, and laboratory safety in the field of education. They came out in their study that laboratory safety turned out to be a mediator. (M. Sirazieva et al., 2018). This was agreed by Zimmerman (2002), stating that self-regulation skills and peer collaboration influence learning satisfaction.

Likewise, Johnson & Johnson (2002) in their study showed the direct effect of collaborative efforts on safety compliance, but did not identify laboratory safety as a mediating variable for learning satisfaction. Hence, the above result is filling in the gap by suggesting that laboratory safety is a mediates of the influence of self-regulation skills and peer collaboration on learning satisfaction.

Viitaharju et al. (2021) and Yu et al. (2023) admit laboratory safety's significant impact on learning satisfaction; this study builds on this by providing empirical evidence of its mediating effect, presenting a more complete view of its role in educational situations. Earlier studies noted the importance of every factor; the results of this study contrast by integrating these constructs into a cohesive model, signifying their connection and uniting their influence on satisfaction.

Furthermore, while some studies like the one with Eom & Ashill, 2016 have emphasized the effect of self-regulated learning in an online environment, the findings extend these understandings to physical laboratory settings. This suggests that self-regulation is a critical fitness across varied educational situations, highlighting its adaptability (e.g., Eom & Ashill, 2016).

Conclusion

Results highlighted that students with high self-regulation skills and those who engage in peer collaboration are more likely to foster a safe laboratory environment, which subsequently improves their satisfaction with laboratory learning. The direct effect of peer collaboration on learning satisfaction is significant. This only suggests that its influence is mainly sourced through enhanced safety practices rather than directly affecting satisfaction.

These findings agree with preceding studies stressing the importance of both behavioral and social factors in active learning contexts and point to laboratory safety as a central mechanism in achieving optimal learning outcomes. Educational institutions, as well as educators, should therefore consider structured self-regulation training and collaborative safety protocols in laboratory instruction to promote both safety and satisfaction.

Authors' contributions

Edwin A. Balila served as the primary author and team leader, responsible for conceptualizing and implementing the research designs, constructing instruments, and analyzing data. Veronica C. Diaz typed the instruments, and Mormie Joseph F. Sarno digitized the research instrument utilizing Google Forms, ready for efficient data collection. Giovani P. Mercado, Myrnille Z. Galang, Viola R. Garduque, Leocadio L. Arit, and Rei Jeuz C. Del Mundo are responsible for the gathering of data.

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