Analyzing Interplay of Metacognition, Cognitive Presence, and Course Performance in MOOCs and Master Course Forums

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***Abstract*—The significance of metacognitive processes in online learning cannot be overemphasized. This study delves into the application of metacognitive processes as manifested in the active participation of online students within discussion forums. It aims to unravel the correlation between the utilization of metacognition, cognitive presence, and overall course performance, scrutinizing these dynamics across distinct courses and diverse online settings. Employing a robust methodology, we harness data from online discussion forums in both a Massive Open Online Course (MOOC) and an online master's program. Through a priori coding technique, we meticulously analyzed a substantial dataset comprising over a thousand forum entries. The study findings indicate that students generally utilize metacognition through active discussion and the application of learning strategies, as well as monitoring and evaluating their effectiveness. Specifically, MOOC students engage in almost all processes of metacognition, while online master's students focus on debugging and monitoring. Notably, a significant positive correlation exists between MOOC students' cognitive presence levels and various metacognitive processes, underscoring the pivotal role of metacognition in developing higher-order thinking and inquiry skills. Furthermore, course performance shows a positive association with metacognitive processes across both courses. These findings have implications for designing effective online discussions in MOOCs and online graduate courses, fostering metacognition and critical thinking, and enhancing learning performance.**

Keywords— metacognitive processes, cognitive presence, online graduate education; massive open online courses, course performance; community of inquiry

I. INTRODUCTION

Online educational programs, such as certificates and master's degrees, are increasingly popular among lifelong learners, including working adults and non-traditional students. Despite the advanced technologies available, online students face challenges like limited face-to-face interaction, technical issues, and the need for self-directed learning. Effective metacognitive processes can help manage these challenges, enhancing engagement and performance in online learning [1-4]. Metacognition refers to the awareness and regulation of one's own cognitive processes, often described as "thinking about thinking" [5, 6]. It involves two main components: knowledge of cognition, understanding one's own learning processes, strategies, and abilities, and regulation of cognition, the ability to plan, monitor, and evaluate one's cognitive activities and strategies [7]. These processes enable students to identify knowledge gaps, plan actions, and seek help when needed [8, 9].

Improving online courses requires understanding shared learning environments and strategies that develop students' metacognitive processes, which involve monitoring and regulating cognitive processes. The Community of Inquiry (CoI) framework [10, 11] provides a structure for fostering productive online communities by integrating instructional, social, and cognitive processes. There are three presences in the CoI framework. Cognitive presence (CP) is crucial as it represents the extent to which learners can construct meaning through critical thinking, reflection, and active engagement with the content, laying the foundation for deep learning. Social presence comes into play, emphasizing the importance of learners' ability to project themselves socially and emotionally, creating a sense of community and connection in the online environment. Teaching Presence is essential as it involves the instructor's role in designing, facilitating, and directing the learning experience, ensuring that the environment remains structured, supportive, and conducive to effective learning. When these three elements work together seamlessly, they create a robust online learning community where students are engaged, learning is meaningful, and everyone feels connected and supported [10, 11]. Recent studies revealed that metacognitive processes are a critical part of the CoI framework, supporting various forms of regulation, including self-regulation, shared regulation, and co-regulation [12, 13]. Moreover, metacognition is crucial for deep, meaningful learning and plays a central role in CP within the CoI framework [12].

Although understanding metacognition in learning is essential, examining metacognitive processes in online learning is challenging. Previous studies have employed verbal or written cues in online learning communities to capture metacognitive engagement [14, 15]. These studies have shown that analyzing discussion forum data can reveal metacognitive processes [14, 16]. To overcome challenges in online learning environments, students often interact with peers and instructors through discussion forums. These forums facilitate reflection and idea exchange due to their accessibility and delayed response time [17, 18]. In Massive Open Online Courses (MOOCs), these forums are crucial communication channels for group knowledge construction and individual cognitive processing [19-22]. The level of participation and quality of discussions correlate with cognitive engagement and learning achievements [23]. Additionally, metacognitive processes are evident in these interactions, reflecting awareness and regulation of learning [12]. However, more research is needed on how metacognition is nurtured in socially situated online learning environments [24].

Building on previous efforts, this study investigates how students employ metacognitive processes in online discussion forums across different instructional settings. It examines the

association between metacognitive processes, cognitive presence (CP), and students' overall course performance.

In online learning settings, students' perceived metacognition has been shown to have close relationships with their CP. For example, Akyol and Garrison [14] assessed students' metacognitive knowledge and skills in an online graduate course. Their study findings indicated that metacognition "is properly placed at the intersection of teaching and cognitive presence" (p. 189) through questioning, feedback, and direction. Similarly, Sadaf, Kim and Olesova [25] found that both self-regulation and co-regulation, the two main dimensions of metacognition in online learning communities, had positive and significant correlations with CP in an online case-based instruction course. The case-based instruction is designed to facilitate critical thinking by engaging students in discussing authentic cases with their peers to analyze and solve complex real-life problems.

Research indicates that metacognitive support enhances online students' academic achievement. For example, metacognitive activities in asynchronous courses improve interaction quality and academic performance [26]. The impact of metacognition in online learning was guided by the framework that views the concept of metacognitive regulation as consisting of two components, including metacognitive monitoring, also referred to as metacognitive calibration, and metacognitive control or self-regulation [27, 28]. Zhao and Ye [28] revealed that higher levels of accuracy in judging one's own knowledge in certain learning domains (i.e., metacognitive calibration) positively predicted online students' performances on assignments, which subsequently led to higher exam grades. In other words, a higher accuracy in calibration indicates a higher level of ability to monitor learning outcomes in a learning situation where students engage with self-regulated assignments.

A. Research Scope of the Present Study

Our study contributes to the literature by addressing three research gaps that emerged in the recent trend of studying metacognition in online learning settings.

The initial gap in understanding centers around the expression of metacognition within online discussions, especially in asynchronous settings commonly utilized to support teaching, learning, and collaborative activities in online education. Akyol and Garrison [14] sought to create and validate a metacognition construct assessing three dimensions of metacognition. However, their validation was confined to a single online graduate course, underscoring the need for additional research and data. Subsequent work by Garrison and Akyol [13] acknowledged the "fuzziness" surrounding metacognition's executive functioning, suggesting refinement for a better grasp of learning in collaborative communities. Our study seeks to build on these endeavors by further validating metacognition using Schraw and Dennison [7] framework across two distinct online course environments to comprehensively explore its manifestation in different online learning contexts, specifically a MOOC and a traditional online master's course.

Recent studies [9, 29, 30] have presented emerging evidence supporting the importance of promoting metacognitive learning strategies in enhancing academic outcomes for MOOC learners. These strategies encompass goal setting, planning, monitoring, and regulating learning activities in MOOCs, such as generating questions during video lectures to maintain focus [30]. Despite this, there remains a scarcity of research examining how metacognition manifests and influences academic achievement differently in the more accessible and affordable MOOC learning environments compared to traditional online courses. Additionally, there is a gap in understanding how students' use of metacognitive processes varies based on their subject domain or class level (e.g., introductory undergraduate-level versus advanced graduate-level). Specifically, our study delves into the nuanced deployment of metacognitive processes among students enrolled in an introductory computing MOOC and those in a high-stakes online graduate course in artificial intelligence.

The second research gap revolves around the connection between metacognition and CP. While the CoI framework provides a theoretical foundation that suggests a relationship between these two constructs, to the best of our knowledge, only one empirical study [31] has been conducted to uncover concrete evidence supporting this association. However, the limited number of studies addressing this topic indicates the need for further research and additional data. In our study, we aimed to statistically examine the correlation between students' metacognition and cognitive presence in the MOOC and for-credit online master's course discussion forums.

The third research gap relates to the limited understanding of the correlation between students' success in online classes and metacognition. Although Huang, Valdiviejas and Bosch [24] provided valuable insights by analyzing students' metacognitive confidence in relation to success, their study did not delve into the intricacies of the interplay between the various processes of metacognition and how they align with students' academic performance. This leaves a significant research gap that our study sought to address. Therefore, this study investigated the correlation between metacognition and course grades in both MOOC and graduate-level online courses.

Overall, we sought the following research questions:

1) How does metacognition manifest within the dynamics of online learning discussions across two diverse online learning environments, a) MOOC and b) online master's course?

2) How is metacognition correlated with cognitive presence within the context of a) MOOC and b) online master's course?

3) How is metacognition correlated with course performance within the context of a) MOOC and b) online master's course?

II. METHODS

A. Data Sources

This study analyzed discussion forum data from two different courses, CS1301 and CS6601. The CS1301 is an introductory undergraduate-level computer programming course offered by a technology-focused public university in the US, which is available free of charge on the edX MOOC platform. Although no prior knowledge of programming is required, basic arithmetic and high school-level algebra are desirable. The course is low-stakes, and thousands of students typically enroll each semester.

On the other hand, CS6601 is a graduate course in artificial intelligence and a fundamental component of the Online Master's in Computer Science program offered by the same university that provided the MOOC course. It is a high-stakes for-credit course with only 796 students enrolled in Spring 2020 and features a notably smaller class size compared to CS1301. The CS6601 demands a solid foundation in college-level mathematical concepts, as well as proficiency in computer programming and algorithms. The course is meticulously structured to integrate extensive readings, assignments, and independent study.

The CS1301 data were collected during the Fall 2017 and Fall 2018 semesters. Using a stratified random sampling technique, the research team selected 521 comments contributed by 201 distinct contributors, including an instructor and a TA.

The CS6601 dataset included randomly selected 500 posts that were written by 87 distinct contributors and associated with two particular assignments, generating significant engagement in online discussions. Although participation in the discussion forum was not mandatory and did not contribute to the final grading in both courses, students enrolled in CS6601 were encouraged to utilize the Piazza platform by posting their questions prior to scheduling office hours appointments.

B. *Procedures and Measures*

We used quantitative content analysis, a common method in studies of computer-mediated communications and learning [32-34], to create categories and frequency counts based on a pre-established coding scheme for metacognition. Instances of metacognitive processes in discussion forum transcripts were identified using the metacognitive coding scheme by Schraw and Dennison [7], influenced by prior studies (e.g., Akyol and Garrison [14]) which noted vagueness in the executive functioning dimension of metacognition. This framework divides metacognition into two elements: knowledge about cognition and regulation of cognition. Regulation of cognition includes planning, applying information/process management strategies, monitoring, debugging, and evaluation.

Each message served as a unit of analysis. Researchers assigned one, multiple, or zero metacognition indicators to each message. Two authors independently practiced coding a small portion of the data, identifying metacognitive processes such as knowledge of cognition, planning, application of information/process management strategies, monitoring, debugging, and evaluation. They then resolved disagreements through discussion. Student research assistants, trained by experienced co-authors, coded the data, which was reviewed and verified by the lead researcher for accuracy.

Student course performance was assessed through final course grades. The CP in discussion forums was coded using Garrison et al.'s [10] CP scheme, covering four phases: triggering events, exploration of ideas, integration of ideas, and resolution of problems/issues [35]. Comments on logistics or social topics were coded as non-CP (phase 0). Higher CP phases indicate deeper levels of inquiry or critical thinking.

C. *Data Analyses*

Metacognitive processes and CP phases were tallied, and descriptive and correlation analyses were conducted to examine the relationships between metacognition, final grades, and CP.

III. Results

A. *Metacognition in MOOC and Master's Course Discussion Forums*

Metacognitive engagement varied between courses. In the MOOC, metacognitive processes were evenly distributed, with a focus on information management and monitoring, suggesting active student involvement in problem-solving strategies and peer verification (Fig 1).

In the Master's course, debugging and monitoring were prominent, indicating students sought help with difficulties and reflected on their learning processes (Fig 2). Planning was the least discussed process in both courses, suggesting a lack of focus on setting and adjusting learning goals.

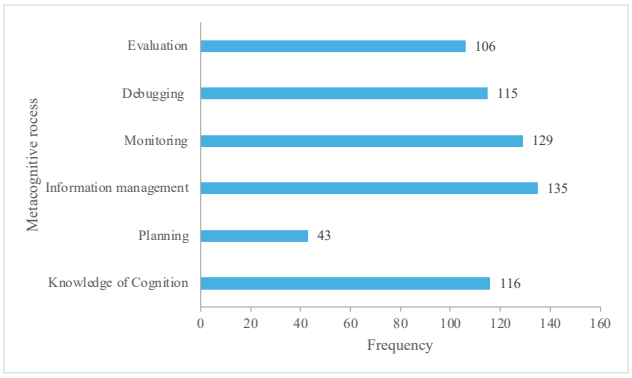

Fig 1 Distribution of metacognitive processes in CS1301

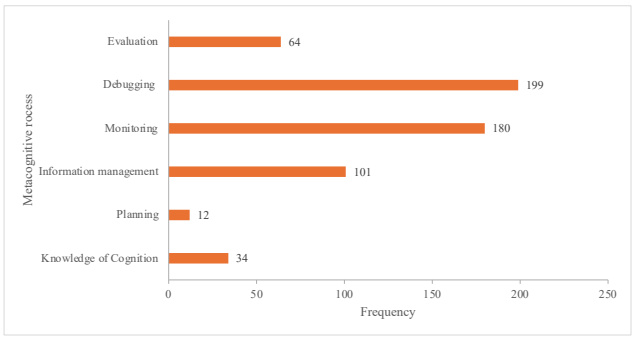

Fig 2 Distribution of metacognitive processes in CS6601

B. *Interplay Between Metacognition and CP in MOOC and Master's Course*

The distribution of CP phases showed more non-CP comments in the Master's course (61%) than in the MOOC (32%). MOOC students showed a higher frequency of phase 4 (resolution of problems) comments compared to Master's students, indicating a greater inclination to seek solution confirmations (Fig 3).

Nonparametric correlation analyses (Table I) revealed significant correlations between CP phases and most metacognitive processes in the MOOC, except for planning, which was negatively correlated. In the Master's course, only monitoring showed a significant positive correlation with CP phases, highlighting its role in advanced problem-solving.

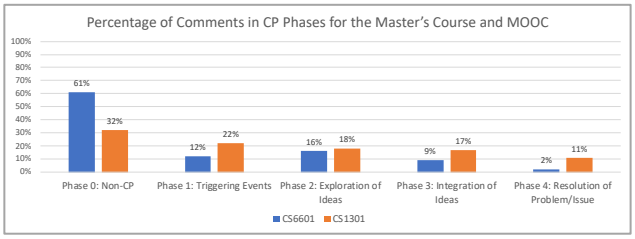

Fig 3 Distribution of CP in CS6601and CS1301

TABLE I. KENDALL'S COEFFICIENT OF RANK CORRELATION BETWEEN METACOGNITIVE PROCESSES AND CP IN THE TWO COURSES

	CP Phases	
	CS1301 (MOOC)	*CS6601 (Master's course)*
Knowledge of Cognition	.18**	.02
Planning	-.27**	.03
Information Management	.34**	.09
Monitoring	.19**	.15**
Debugging	.15**	.08
Evaluation	.16**	.05

** Correlation is significant at the 0.01 level

C. *Relationship Between Metacognition and Course Performance in MOOC and Master's Course*

The relationship between metacognition and course performance was examined with Pearson correlation in two different course settings, and the results of the analysis from the MOOC course were presented in Table II. Information management and evaluation were significantly correlated with MOOC students' course performance, indicating that students who shared more inputs related to information management and evaluation achieved higher course performance.

TABLE II. PEARSON CORRELATION BETWEEN METACOGNITIVE PROCESSES AND AVERAGE GRADES IN CS1301

	1	*2*	*3*	*4*	*5*	*6*	*7*
1. Average Grade	--						
2. Knowledge of Cognition	.17						
3. Planning	-.07	.01					
4. Information Management	.20*	.91**	.01				
5. Monitoring	.17	.60**	-.10	.66**			
6. Debugging	.18	.87	.07	.88**	.72**		
7. Evaluation	.22*	.46	-.00	.56**	.55**	.59**	--

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Considering the performance of online graduate students, the results in Table III demonstrated a significant positive but low association with knowledge of cognition while indicating a negative and low correlation with planning. This finding highlighted that online graduate students who engaged in discussions related to knowledge of cognition, such as their skills, intellectual resources, and abilities, were more likely to achieve higher course performance. On the other hand, the negative correlation between planning and course performance suggested that online graduate students who focused on inputs related to planning and goal setting were more prone to receive lower grades.

TABLE III. PEARSON CORRELATION BETWEEN METACOGNITIVE PROCESSES AND AVERAGE GRADES IN CS6601

	1	*2*	*3*	*4*	*5*	*6*	*7*
1. Average Grade							
2. Knowledge of Cognition	.25*						
3. Planning	-.27*	.13					
4. Information Management	.04	.35**	.34**				
5. Monitoring	-.02	.09	.06	.45**			
6. Debugging	.03	.27*	.06	.56**	.48**		
7. Evaluation	.01	.23*	.17	.55**	.43**	.47**	

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

IV. DISCUSSION

The primary objective of this study was to investigate metacognitive processes within online discussion forums and understand how metacognition correlates with CP and course performance in MOOCs and online master's courses. While the focus was not on comparing these courses, the observed metacognitive patterns suggest the need for diverse course design approaches.

Initially, the study examined how metacognitive processes manifested in online discussion forums. Findings indicated different patterns: MOOC students showed a more even distribution across all metacognitive processes, with information management and monitoring being the most prominent. In contrast, master's students focused more on debugging and monitoring, with planning and knowledge of cognition being less apparent.

The differences can be attributed to various factors. MOOC students, typically self-paced learners [9], are more proactive in engaging in metacognitive activities, such as finding strategies for task completion and monitoring progress. The critical role of discussion forums in information management for MOOC students highlights the need for guidance on implementing learning strategies and diagnosing challenges. Online graduate students benefit from online learning communities to enhance metacognition, with a stronger focus on debugging and monitoring. This could be due to the higher instructor presence and structured programs, leading to reliance on formal guidance and less interaction in discussion forums.

The nature of the forums also plays a role. MOOC forums, characterized by openness and informality, may foster a comfortable environment for sharing thoughts and experiences, facilitating metacognition. Conversely, the formal nature of master's courses might cause restraint in engaging openly. Increasing social presence and strengthening community bonds could mitigate this restraint [12, 36].

Regarding the relation between metacognition and CP, both courses showed varying degrees of correlation. MOOC students' engagement in metacognitive processes increased with higher CP phases, except for planning. . The observed negative correlation between planning and CP aligns with prior research findings [14] in light of the understanding that cognitive processes linked to planning tend to occur during the initial stages of inquiry. In contrast, master's students showed a positive correlation between monitoring and CP phases, indicating a growing inclination to monitor strategy implementation as they approach problem resolution.

Overall, MOOC students actively use metacognition in problem-solving and seek peer input, while master's students

seek more input and feedback in advanced CP phases due to structured course frameworks and solid foundational understanding. The study also found a positive correlation between metacognition and course performance in both course types, with specific metacognitive processes varying by course setting. MOOC students' course performance correlated strongly with information management and evaluation, while master's students' performance correlated with knowledge of cognition. This suggested that online graduate students who had a strong understanding of their own learning process and how they learn best were more likely to achieve higher course performance. Given the prior research findings [37, 38], the negative correlation between planning and course performance in master's courses was an interesting finding. One possible explanation for this finding is that online graduate students who focus too much on planning and goal setting may become overly anxious or stressed, which can negatively impact their learning. Nevertheless, additional research is required to gain a deeper understanding of the factors influencing the planning process of metacognition and its impact on course performance. Additional research is needed to understand the factors influencing the planning process of metacognition and its impact on course performance.

Based on the current research findings, educators can design course activities that explicitly incorporate metacognitive processes, such as self-assessment quizzes or reflection prompts, with a particular focus on underutilized areas like planning. This approach can be especially beneficial in MOOC environments, where students are typically more self-directed and may need additional guidance in structuring their learning strategies. Additionally, the study highlights that different online courses (e.g., MOOCs vs. Master's courses) may require distinct approaches to fostering metacognition. For instance, in a MOOC, offering modular, self-paced metacognitive scaffolding tools, such as personalized feedback or adaptive learning paths, could be highly effective. Conversely, in structured graduate courses, integrating metacognitive prompts at critical points in the course (e.g., before exams or major assignments) may help students better plan and monitor their learning.

V. Limitations

This study provides valuable insights into the relationships among metacognition, CP, and online course performance but has several limitations. Firstly, it focuses on specific MOOCs and Master's courses, which may limit the generalizability of the findings as different courses could yield varying outcomes. Secondly, characteristics such as instructor involvement and assignment types impact student engagement in metacognitive processes, complicating direct comparisons between the courses. Lastly, the study identifies correlations but does not establish causation, meaning other unobserved factors could influence the observed relationships.

VI. Conclusion

Our study sheds light on the complex dynamics of online education, highlighting how students engage with metacognition and its connection to CP and overall course performance in MOOCs and online master's courses. The diverse patterns of metacognitive engagement emphasize the need for tailored pedagogical approaches that match each course's unique characteristics. By addressing the specific needs of students in these contexts, educators can refine teaching strategies to integrate cognitive and metacognitive processes, ultimately improving learning outcomes.

Future studies could explore interventions to enhance metacognition, examine the role of teaching and social presence in mediating metacognitive utilization, and investigate how the identified patterns manifest in other online learning environments. As online education evolves, prioritizing metacognitive processes as a core aspect of effective learning could enhance the quality of online education and equip learners with essential lifelong skills for success.

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