Students' Metacognitive Regulation Strategies in Written Reflections within Third-Year Introductory Environmental Engineering Course

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Abstract

Lifelong learning plays an important role in achieving success in one's professional life. Engaging students in metacognition assists in the development of their lifelong learning abilities. Instructors can integrate reflection activities in their courses to provide multiple opportunities to students for metacognitive engagement. During reflection, students regulate their cognition by engaging themselves in three dimensions of metacognition: Planning, Monitoring, and Evaluating. Reflection is a complex process, and it takes time to reach the level of critical reflection. The purpose of the study was to investigate the change in students' level of engagement in three dimensions of metacognition when reflecting on the third and tenth-week assignments of the environmental engineering course. Data collection took place in the Fall of 2023 at a large Midwest University. Students' responses to the assigned reflection prompts for each dimension were coded for their level of engagement in each element of the three dimensions using a revised prior coding scheme. Results showed that for both assignments, students' responses were mainly at the vague level for all elements of the three dimensions, indicating students' superficial engagement in the reflection activity. Recommendations for instructors are provided to improve students' understanding of the reflection activity and their level of engagement in the three dimensions of metacognition.

I. Introduction

Environmental engineers work on natural systems to find solutions for human needs. Significant changes occurring in the environment raise the need for environmental engineers to be well-equipped with skills such as critical thinking and lifelong learning. The United Nations [1] presented 17 Sustainable Development Goals (SDGs) with the overarching objective of enhancing human life by focusing on improving health, education, equality, and economic growth, along with preserving oceans and forests. The National Academies Press [2] identified that out of the 17 SDGs, 10 SDGs are associated with the field of Environmental Engineering and highlighted the most critical challenges of the 21st century that need to be addressed by environmental engineers. Recognizing the important role of environmental engineers in resolving future challenges and preparing students for future challenges, Daigger et al. [3] emphasized the need for transforming environmental engineering and science education and practice, where one emphasis is on developing lifelong learning abilities in students.

Lifelong learning skills support an individual's career growth and assist in achieving personal goals [4] as they require individuals to have a capacity for self-direction and metacognitive awareness [5]. Specifically, five lifelong learning skills are: goal setting, self-direction and self-evaluation, information seeking, application of knowledge, and adaptation of learning strategies to different conditions [6]. Metacognitive engagement plays a crucial role in developing lifelong learning skills [7]. Metacognition enhances an individual's awareness of their learning process, which assists in the judgment of their performance and influences their learning choices [8].

Individuals can be metacognitively engaged through the use of activities such as think-aloud, concept mapping, and reflection.

In engineering classrooms, reflection activities are commonly implemented to promote students' metacognitive engagement [9] and to aid students in acquiring the characteristics of "expert" problem solvers [10]. Students can be engaged in reflection in different ways, such as blogging, talking, writing letters, formal essays, etc. Reflection assists in the development of metacognitive skills [11], which strengthens learners' knowledge and control of their learning process with the use of three metacognitive strategies: Planning, Monitoring, and Evaluating [12].

Previous works have shown that students do not engage fully in the three metacognitive strategies during reflection [13], and students achieved low levels within each strategy during reflection on course content [14]. Hence, there is a need for an in-depth exploration of students' use of each metacognitive dimension during reflection.

The present qualitative work is part of a larger study designed to develop engineering students' abilities to employ metacognitive strategies through written reflection activities and to prepare them for lifelong learning. The purpose of this work was to identify students' use of elements that comprise each metacognitive regulation strategy while responding to their weekly reflection assignments in an environmental engineering course. Knowledge of students' level of use of metacognitive regulation strategies could help instructors design instructional strategies to assist students to overcome the challenges associated with reflection writing and to elevate students' level of engagement in these strategies.

II. Theoretical Framework:

Metacognition in general, is defined as "thinking about thinking." In literature, numerous other definitions of metacognition have appeared [15], [16]. Early on, Flavell [17] defined metacognition as "*knowledge and cognition about cognitive phenomenon*" (p. 906). Schraw and Moshman [18] explained that metacognition consists of two parts: metacognitive knowledge, i.e., knowledge of one's own cognition, and regulation component, which refers to controlling one's own thinking and learning. Fernandez-Duque et al. [19] related metacognition to executive functions which is related to cognitive flexibility, inhibitory control, and working memory. The present work focuses on regulation of the cognition component of metacognition described by Schraw and Moshman [18], which consists of three strategies: Planning, Monitoring, and Evaluation. The Planning strategy is described as selecting relevant strategies and resources that affect performance. Monitoring involves individuals' awareness of their comprehension and performance on a task, and Evaluation refers to the assessment or judgment of their work or performance.

Students can engage in metacognitive regulation through reflection activities; the process is highly cognitive [20]. The term reflection became popular in the educational context due to Dewey's [21] work on the importance of training students to have reflective thoughts, where the term reflective thoughts was defined as "*active, persistent and careful consideration of any belief or supposed form of knowledge in the light of grounds that support it*" (p. 6). Schön [22] presented reflection as an important skill in a professional context and introduced the terms *reflection-in-action* and *reflection-on-action* to differentiate reflection that happens during an activity and after an activity, respectively. Reflection is a complex and time-consuming process

[23], and to develop reflective skills, one needs to engage in reflective writing. The stages of development of reflective writing range from pure descriptive writing (lowest level) to reflective writing (highest level), where reflective writing entails metacognitive engagement [24].

The present work uses periodic reflection assignments as a tool to develop students' reflective abilities and metacognitive skills by engaging them in each of the metacognitive regulation strategies, i.e., Planning, Monitoring, and Evaluation.

III. Literature Review

Reflection improves students' learning of the content and results in higher performance on assessments. Menekse [25] showed that the students enrolled in a sophomore industrial engineering course using the Reflection Informed Learning and Instruction (RILI) model scored higher marks on examinations than those in the control group. Similarly, an empirical study conducted by Rahman et al. [26] in a civil engineering course showed that students who attended lectures and wrote reflective papers performed better on a subsequent test in comparison to students who only attended lectures. In both above-mentioned studies, students were only asked to write about their difficulties related to that day's lecture content and what they had learned. Neither study asked students to include their plans to overcome those difficulties. Yet, these studies still demonstrated that even these short reflections improved their content learning.

During the reflection process, engineering students struggle for various reasons. In a graduate-level course with a flipped classroom setting, Zarestky et al. [27] found that students struggled to express their own thought processes early in the semester, thought their ability improved as the course progressed. In a software engineering distance learning course, Pedrosa et al. [28] qualitatively analyzed students' perceptions of the integration of self-reflection activities in the course and found that students mainly expressed concern over time management. Both of the above-mentioned studies analyzed students' written reflection, whereas McCord and Matusovich [29] coded engineering students' conversations during problem-solving assignments and found that students needed support in goal setting, evaluation, and judgment of reasonableness. The above-mentioned studies only reported students' challenges and did not investigate students' level of engagement in different dimensions of metacognition.

Previous studies [13], [14], [30] have focused on identifying students' level of engagement in the three metacognitive strategies (i.e., Planning, Monitoring, and Evaluating) as they reflected in a process engineering course. It was found that, in general, students' written reflection responses were at the lowest metacognitive levels. These studies only identified students' levels of engagement in each metacognitive strategy, which does not provide sufficient information to uncover the nature of students' responses. To get further insight into students' use of metacognitive dimensions, exploring their engagement in the different aspects of each strategy could provide instructional insights.

IV. Research Question

The study aimed to address the research question:
What were the students' levels of engagement in the elements of the three metacognitive regulation strategies while reflecting on their third- and tenth-week course assignments?

V. Methods

A. Setting and Participants

The study was conducted in an introduction to environmental engineering course offered by a civil and environmental engineering department in Fall 2023 at an R1 university. The participants in the study were sophomore, junior, and senior undergraduate students. A total of 22 students were enrolled in the class and 20 consented to participate in the study. The class consisted of 68% males and 32% females. The course met twice per week for 75 minutes over the course of 16 weeks.

The objective of the course was to develop students' understanding of environmental engineering topics and develop their professional skills. The course aimed to familiarize students with a broad range of environmental engineering topics and improve their understanding of key concepts in environmental engineering. Topics covered in the course included material balance, water quality, air quality, solid waste management, risk assessment and treatment systems for water, air, and solid waste. Students were expected to complete assigned reading before participating in a mini-lecture and in-class problem solving. To facilitate students' professional development, activities such as team projects, peer evaluation, and reflection activities were integrated in the course. The final course grade was based on five elements: weekly homework, two team projects, two midterms, a final comprehensive examination, and course engagement and participation. Among all graded components, team projects carried the greatest weight. Students were encouraged to complete their homework in groups, but each student individually submitted their homework.

Reflection was integrated into the course through the homework assignments. Upon completion of weekly homework assignments, students were first asked to self-grade their homework based on a provided answer key before responding to three open-ended reflection prompts. There was no set word limit for responses to the open-ended reflection prompts. The three prompts asked students to reflect on a challenge they experienced in relation to the current week's assignment (Monitoring), describe actions they took to address that challenge (Evaluating), and devise a plan with goals and actions to overcome the challenge (Planning). Unlike the other two dimensions, in the Planning dimension, students were provided with two prompts. The first prompt (Planning) asked for their plan to overcome the learning difficulty, and if the difficulty was resolved, then students were asked to respond to the second prompt (Planning-Transfer) and discuss the use of their learning strategy that was used to resolve their existing learning difficulty in future applications. Students were expected to respond to only one of the Planning dimension prompts at a time.

The three prompts were worded as follows:

What is one difficulty you are (or were) most concerned about? Be specific. Include a description of how you know (or knew) you are (or were) having this difficulty. (Monitoring)

How have you tried to overcome this difficulty? Include a description of how your approaches have been successful or unsuccessful and what you learned. (Evaluating)

What is your plan to further address this difficulty? Include an explanation of why you believe your plan will help. (Planning)

OR

If you were successful in addressing this difficulty, discuss how you might use these approaches to address future difficulties. (Planning-Transfer)

To raise students' awareness of the expectations for reflective writing, at the beginning of the semester, the instructor explained the reflection activities to the students and had them watch several videos about metacognition from skillful learning videos [31]. Students were given specific information about the segments they needed to watch in the videos. The instructor provided sample responses for each prompt to familiarize students with what is expected from them when responding to each of the three reflection prompts. Additionally, the teaching assistant (TA) provided detailed feedback on students' responses for each prompt. Early in the semester, the instructor trained the TA on assessing students' reflection responses and writing feedback. The feedback given to students was personalized, highlighting what was lacking or needing further explanation.

B. Data Collection

Data included students' reflection responses to assignments from the third and tenth week of the semester. These two assignments were selected to gain insights into students' level of engagement in the different elements of the metacognitive regulation strategies at an early and later stage of the semester.

Students' responses to the three opened reflection responses for the third- and tenth-week reflection assignments were downloaded from Canvas and saved in an Excel file. Students who did not give permission to use their data for the study were removed from the Excel file, and students' names were replaced with research IDs to maintain confidentiality of the participants.

C. Data Analysis

A coding scheme consisting of three dimensions representing the three metacognitive regulation strategies (i.e., Planning, Monitoring and Evaluating) was used to analyze students' reflection responses on their third- and tenth-week assignments. The coding scheme was based on *a priori* coding scheme developed by Ku and Ho [32], which consisted of the three dimensions and only two levels (i.e., low and high). The present work has three levels (none, vague, sufficiently detailed) for each dimension as shown in Table 1.

For the present coding scheme, each dimension was broken down into elements which provide further insights into students' engagement in the metacognitive regulation strategies. Elements associated with each dimension are shown in Table 1. Each element of the dimensions has three levels: none, vague, and sufficiently detailed. Level "none" indicates the absence of the element in a student's response. Level "vague" indicates superficial information was provided by the student, and level "sufficiently detailed" indicates the highest level of student engagement with the strategy. Monitoring dimension includes a description of students' difficulty (*difficulty*), circumstances under which it occurred (*experience*), how students identify that there is a problem

(*identification*), and how this difficulty relates to learning expectation (*standard*). Evaluating dimension includes description of action taken by student (*action*), assessment of those actions (*assessment*) and consideration of whether the results change or confirms their beliefs about their approach to learning (*change/confirmation*). For Planning dimension, elements related to the first prompt (Planning) includes a description of personal goals for learning outcome(*goal*), actions to achieve that goal (steps), and justification for the steps (*justification*). The elements related to the second prompt of the Planning dimension (Planning-Transfer) includes a description of how learning may be used in other contexts or in the future (*transfer*).

Student responses were coded for the presence of each element of each dimension and for the level of each element. For each dimension, the text corresponding to a particular element was first color coded and then assigned a level. For example, the response shown below is students' response to the second open ended reflection prompt (Evaluating) from tenth week assignment:

I have since tried to overcome this difficulty by getting through the assignment and seeking help from me peers when I was stumped. I had a couple questions from my peers on what exactly I was supposed to graph. so thankfully was able to clear up these questions with quick simple answers in class.

In the first and second sentences of the response, the student described the action taken (actions), i.e., getting through the assignment and seeking help from peers. The student only mentioned the names of actions and did not describe the details of the actions, such as what part of the assignment was referred to and what specific questions were asked from peers. Therefore, the element *action* was marked vague. In the third sentence of the response, the student assessed the action of asking for help from peers (*assessment*) to resolve the difficulty. In this sentence, the student explicitly mentioned that the action of asking for help from peers helped to resolve the difficulty, but the student did not provide evidence for the claim made, hence marked vague level of assessment. The above response lacks the third element of Evaluating dimension, i.e., *change/confirmation*.

Table 1. Description of Elements of Metacognitive Strategies

Dimensions	**Elements**	**Description**	**Levels**
Monitoring	Difficulty	Identify a learning concern	None; Vague; Sufficiently Detailed;
	Experience	Experience in which learning concern arose	
	Identification	How learning concern was identified	
	Standard	Reference to learning expectation/other standard	
Evaluating	Action	Action taken/not taken to address learning concern	
	Assessment	Assess action taken to improve learning	
	Change/ Confirmation	Change in/confirmation of one's thinking (about learning strategy or learning concern) as a result	
Planning	Goals	Description of clear goal	
	Steps	Articulate action(s) to be taken	
	Justification	Explain/Justifies choices made to move forward	
OR			
Planning-Transfer	Transfer	Description of application of learning strategy/ skill/content to future	

VI. Results

The levels of students' engagement in the three metacognitive regulation strategies are presented in the order of the reflection prompts: Monitoring, Evaluation and Planning. Comparisons are made between their engagement in their reflections on the third- and tenth-week assignments as shown in Figures 1-3.

For Monitoring (Figure 1), in general, students remained at a vague level for all four elements (difficulty, experience, identification and standards) for both assignments. However, during the tenth week assignment, there is slight increase in number of vague responses across all elements. The majority of students were able to describe a difficulty in their content learning. However, the level of detail provided by students in the *difficulty* element was predominantly vague for both assignments, indicating a lack of specificity in describing their learning challenges. Similarly, students' engagement in the *experience* element was predominantly at a vague level for both assignments, lacking details on the description of their experience in which learning concern (difficulty) arose. Regarding the *identification* element, a greater number of students attempted to explain how they identified their learning difficulty for the third-week assignment as compared to the tenth-week assignment, but their description was limited to a vague level. Further, the majority of students failed to provide sufficient details to describe how they identified their learning concern (difficulty) in their third and tenth-week reflection. For both assignments, only a few students referred to *standards* in their responses, and these few only mentioned the name of the standard without establishing a connection to their learning difficulty.

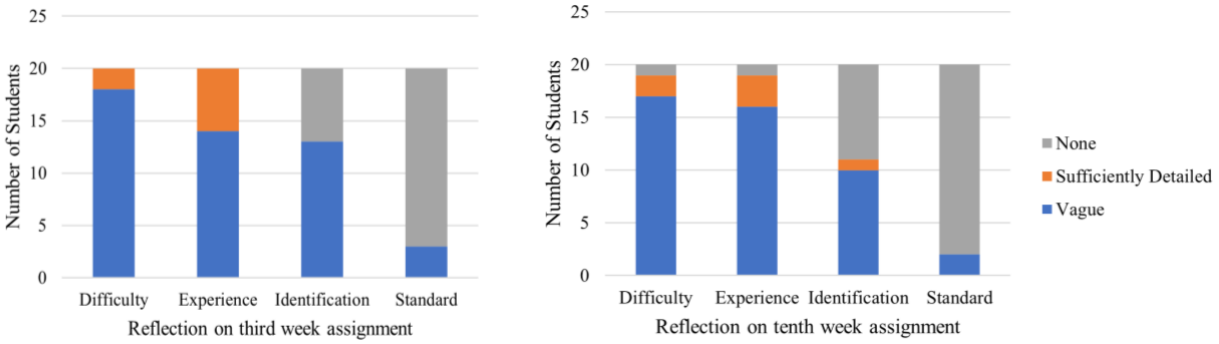

Figure 1: Students' level for each Monitoring dimension element during reflection

For the Evaluating dimension (Figure 2), overall students' responses were limited to vague levels in their third-and tenth-week reflections. However, the tenth-week assignment includes a few "sufficiently detailed" responses for action and assessment element. For the *action* element, all students named the action they took to address their learning concern in third-week assignment but did not provide a detailed explanation of their actions. Similarly, for the *assessment* element, in general, students only mentioned whether the actions they took worked for them or not; they did not provide details on why their actions worked or not worked. Hence, their descriptions were vague. For the third element *change/confirmation*, a greater number of students expressed *change/confirmation* in their thinking regarding learning during third-week assignment in comparison to the tenth-week assignment. However, responses for *change/confirmation* in the thinking element were vague because responses were based on students' beliefs, and they did not include reasons for this change.

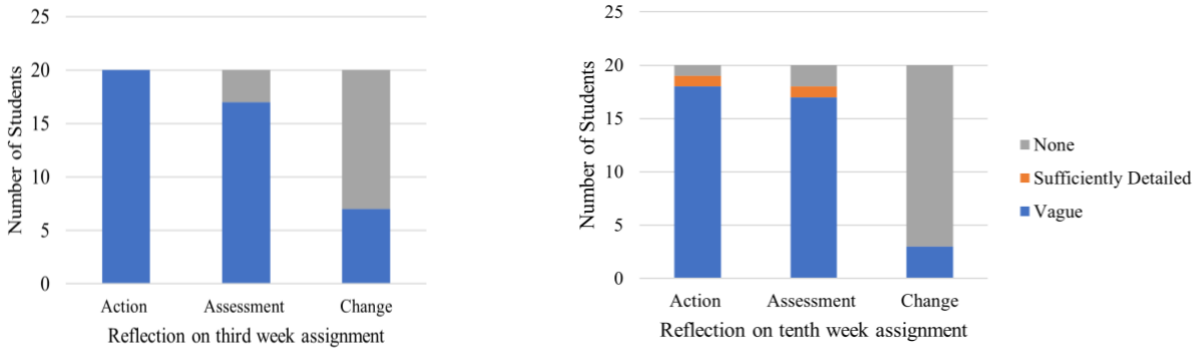

Figure 2: Students' level for each Evaluating dimension element during reflection

Students' engagement in the different elements of Planning dimensions is shown in Figure 3. For the third-week assignment, 18 students responded to the first prompt (Planning) and two students responded to the second prompt (Planning-Transfer). Meaning, 18 students were still having their indicated difficulty and needed to further plan for improvement, and two students had resolved their difficulty. For the tenth-week assignment, four students answered both prompts, indicating that they still had their difficulty but optionally responded to the transfer prompt as well.

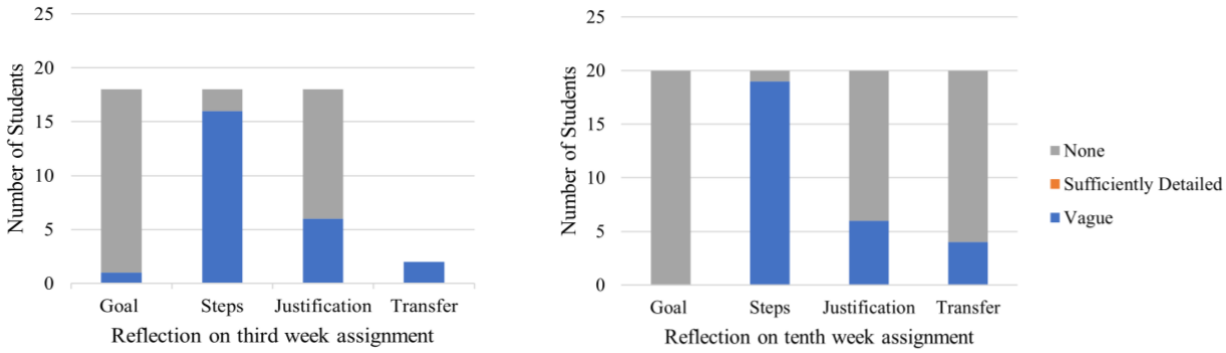

Figure 3: Students' level for each Planning dimension element during reflection

Overall, for both reflection assignments, students' responses for the first Planning reflection prompt lacked sufficiently detailed explanations for all three elements (goal, steps, and justification) of the dimension. For both assignments, students did not provide a *goal* for their plan, while most students mentioned steps to further address their learning concerns. For both assignments, students only named the steps they planned to take; they did not provide specifics about these steps. Almost the same number of students in both assignments provided *justification* for their actions, which again lacked details, limiting their engagement level to vague. For the third-week assignment, two students chose to respond only to the second reflection prompt (Planning-Transfer), whereas the remaining 18 students responded to only the Planning prompt. On the contrary, in the tenth-week assignment, none of the students responded solely to the Planning-Transfer prompt, while four students responded to both the Planning and Planning-Transfer prompts. However, in both assignments, students' responses for the *transfer* element lacked details.

VII. Discussion

The purpose of the study was to gain insight into students' level of use of elements of three metacognitive regulation strategies while reflecting on their learning associated with the third- and tenth-week assignments. First, an overall discussion of the findings will be conducted before delving into each dimension and associated elements before providing recommendations for instructors interested in incorporating reflection in the classroom.

From the results, it is evident that across all elements of the three metacognitive dimensions, students' level of detail is predominately vague, if it was present at all, due to the limited use of evidence during the reflection process. This means that students' engagement was limited to only naming the difficulty, actions taken, or steps planned, which shares characteristics of descriptive writing [33], which involves only the reporting of events. This result is consistent with Dyment and O'Connell's [34] work that examined the level of students' reflection in higher education and found that the quality of the majority of students' reflection writing is below the defined criterion of good reflective writing based on different models (e.g. Blooms taxonomy, Boud's framework, and others). Defining the concept of "reflective thought," Dewey [21] emphasized the inclusion of evidence in reflective writing. Therefore, the very first step towards improving the level of engagement of engineering students in the reflection process is to emphasize the inclusion of evidence in their reflection responses.

The vague level of detail provided by students suggests their limited engagement in critical thinking during reflection writing. This means that students did not provide evidence for their responses. This interpretation is further supported by Halpern's [35] description of critical thinking i.e., "*purposeful, reasoned and goal-directed*" (p. 15). Also, Rüütmann [36] explained that the process of critical thinking involves asking higher level questions such as *what if? Why do you think so?*; questions students in this study appear not to be asking themselves. Another reason for students' consistent engagement at the vague level for both assignments could be engineering students' attitude towards writing, which limits their responses to only naming their difficulties, actions, or steps without providing detailed explanations and reasoning. This finding seems consistent with the findings of Daly and Shamo's [37] work which found that people working in science and engineering do not consider writing to be a major part of the discipline.

In the third-week reflection responses, one student's comment explicitly raised the question of the purpose of integrating reflection writing into the course, the comment is: "*Why do we do a reflection and a self assessment? It seems really redundant. I am answering with almost the same answers I was during my self-assessment.*" In the tenth-week assignment, students used sentences such as "*Like I said in the previous question*", "*Like I previously stated*" in their responses to successive prompts. These statements seem to indicate that students do not understand the difference between the prompts. From these statements, it might also be inferred that, despite the instructor's effort to familiarize students with the structure of the reflection activity and its importance in their learning process early in the semester, students assigned low task value to the reflection activity. This result is consistent with the findings of Bae and Kwon [38]. They investigated the various factors that influence students' use of metacognitive skills during learning and revealed that how students perceive the task value of the metacognitive activity influences their metacognitive engagement in the task.

***Monitoring*:** Overall, among the four elements of monitoring for both assignments, while mentioning their difficulty, students only mentioned names of their difficulties and vaguely described the details (includes experience and evidence elements) for the difficulty. Acknowledging the possibility of students' assignment of low task value to reflection and subsequent resistance to writing, this finding might indicate that students are not able to explicitly describe what they know and what they do not know and may indicates their low monitoring ability [39]. These possible indications should be disturbing when past research has considered monitoring highly relevant in an individual's learning process [40] and found a mediating role of monitoring in relationship to creative mindset and divergent thinking [41]. Additionally, an increase in the number of vague responses during the tenth week assignment indicates that students forgot the early semester instruction. This can be explained with the lower task value students assigned to reflection activity which influences their metacognitive engagement and their effort for the task [42].

***Evaluating*:** Results of students' engagement in all three elements of the Evaluating dimension indicate a need for instructor discussion on students' vague level of engagement in all three elements (action, assessment and change/conformation). Despite providing a guiding reflection prompt, feedback on each reflection response by the teaching assistant, and learning materials, the students' engagement level remained at "vague" in third- and tenth-week reflection assignment. This finding may be explained by the work of Lew and Schmidt [43] that shows that for self-assessment, students showed fear of judgement, where they believed that it could influence their instructor's perception towards them and their final grades. Also, only providing name of actions, yes/no response in assessment and mentioning change based on belief indicates that students do not understand that they need to go deeper provide evidence for their claims. Perhaps this might be due to students' limited understanding of what evidence is. This finding is supported by Du and List's [44] work, where students' written arguments lacked the use of evidence.

***Planning*:** For both assignments, among all four elements of the planning dimension, students' engagement is least for the goal element, indicating either students' limited understanding of the importance of goal setting in their learning process and not understanding the difference between a goal, as desired outcome, and steps, as a means of obtaining the goal. Despite providing relevant material (videos and sample reflection responses) to assist students in the formation of SMART goals students did not engage in goal formation, instead they only included planned steps. This could be explained by the findings of Bae and Kwon [38], according to which students' perception of task values directs their level of metacognitive engagement in the task. On the third-week assignment, the one student who did state a goal provided a performance goal, "*My goal is to know about every reactor in depth (why they are used, how they work, what equations are associated with them)*." Students with Performance goals aim to achieve the end result, whereas students with learning goals focus on achieving competence by identifying strategies to attain the desired result [45], [46]. During the third week of reflection, the lack of goals in students' reflections indicates the need to train engineering students for a growth mindset [47] so that they can develop learning goals.

Recommendations for Instructors:

Based on the findings of this work, below are the recommendations for instructors to integrate reflection in the classroom and to improve students' metacognitive engagement in a reflection activity.

Raising the task value of reflection activity. According to expectancy-value theory [48], students' value belief for a task influences their level of engagement in the task. Instructors can elevate the task value of reflection activity in the course in following ways:

- *Emphasizing the importance of metacognitive engagement in student careers*: Research studies have shown that metacognitive skills assist students in improving their learning and performance [49], [50] and play a crucial role in gaining employment [51]. Instructors should include data from research studies to inform students early in the semester of the critical role of metacognition in their success at college and in the workplace.
- *Weightage of reflection activity*: Instructors can elevate the task value of the reflection activities by increasing the weight of the reflection activity in the course final grade and aligning the activity with the course objectives [52].
- *Importance of writing in engineering*: In general, engineering students tend to focus more on calculation and technical content rather than writing [53]. Instructors should emphasize and make students aware of the importance of writing in the learning process [54]. Sometimes, students struggle with writing due to a lack of knowledge of writing strategies; as a result, they consider writing more challenging than calculations [55]. In such a scenario, instructors can provide brief introductions to writing models, for example, Hayes & Flower model [56] to students to provide them with a strategy for their writing.

Instruction on expectation for each metacognitive activity. Instructors should explicitly communicate their expectations regarding students' level of engagement in each dimension (Planning, Monitoring, and Evaluating) and corresponding elements. To do so, instructors can provide sample responses for each dimension, highlighting the difference between responses of low and high-level metacognitive engagement. The use of examples has been shown to influence students' motivation and self-efficacy and help students understand what the expected response should look like [57].

To enhance students' overall level of metacognitive engagement in all dimensions, instructors should direct students to provide evidence for their claims [21], which also improves students' critical thinking skills [58]. For example, the student's response, *"My approach was successful,"* should be followed up with evidence stating *why/why not*.

Instructors should also guide students to improve their level of engagement in specific elements of each dimension. For the Planning dimension, instructors should familiarize students with the framework of setting goals that are specific, measurable, achievable, relevant, and time-bound (SMART), which can also contribute to students' success in the course [59]. For the Monitoring dimension, instructors could provide students with a detailed list of course learning objectives with proficiency indicators to assess their learning of the content. Such transparency about intended learning allows students to better identify the gaps in their learning.

Periodic iteration of ideas of reflection and metacognitive engagement in the classroom: Instructors should explicitly explain the reflection activity, its purpose in the course, and the

three dimensions of metacognition along with their elements early in the semester, before the first reflection assignment [52]. During the semester, instructors should repeatedly discuss the idea of reflection and metacognition because reflection is complex, and instructors' continuous guidance is required to improve students' engagement [60]. During these discussions, instructors should adopt verbal immediacy behaviors (e.g., smiling, eye contact) to encourage students to be more motivated and engaged [61] in reflection activities. Instructors should also address the common struggles that students have while responding to reflection prompts in the classroom.

Support for students. Instructors should extend their support to students allowing students to discuss their struggles and challenges of reflection writing during office hours. Additionally, instructors should provide detailed personalized feedback on students' reflection writings, highlighting the difference between their work and the expected response to enhance students' motivation [62] to engage in higher levels of metacognition dimensions.

VIII. Conclusion

Students' level of engagement in each of the of the metacognitive regulation strategies (i.e., Planning, Monitoring and Evaluating) while reflecting on third- and tenth-week assignments in a third-year environment engineering course were analyzed. Results showed that for both assignments, most responses were at vague level for all elements of the three dimensions. Only a few responses were at the level of sufficiently detailed. Results indicate almost no improvement in students' metacognitive engagement on the assignment in the tenth week as compared to that in the third week. Overall, ongoing instruction and guidance on reflection and implementation of instructional strategies to improve students' metacognition is necessary to prepare students as critical thinkers and lifelong learners. In the future, we aim to improve instructors' understanding and gather insights into students' level of engagement in different elements of metacognitive strategies. Therefore, future work will compare students' metacognitive engagement in reflection, considering various factors such as gender, age, demographics, and year in the program (first-year, sophomore, junior, or senior).

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