Paper ID

Do Metacognitive Instruction and Repeated Reflection Improve Outcomes?

1. Introduction

Reflection - defined as thought about what one is doing - is essential to learning and professional practice, as described by several educational theories (Bishop-Clark & Dietz-Uhler, 2012; Kolb & Kolb, 2009; Schön, 1987). Kolb's Experiential Learning Theory maintains that learning occurs when "doing" is accompanied by "reflecting on one's doing" (Kolb & Kolb, 2009). Further, when students repeatedly reflect on their academic lives (i.e., learning, practices, and performance), it can enhance their metacognition, which includes the self-regulatory skills of planning, monitoring, and evaluating their learning (Schraw, 1998). Metacognition has been described as "thinking about one's thinking" and promotes lifelong learning abilities (Steiner & Foote, 2017). Unfortunately, Ambrose highlighted a lack of frequent, formal reflection and metacognition activity in the engineering curriculum (

the present research to pose weekly reflective questions to students to support their metacognitive development. Planning refers to selecting strategies and allocating resources for learning (Wengrowicz et al., 2018; Schraw, 1998). Monitoring occurs while the individual is working on the learning task (Cunningham et al., 2015; Schraw, 1998). Evaluating involves assessing one's performance and the effectiveness of the methods they used after completing the task (Cunningham et al., 2015; Schraw, 1998).

3. Methods

3.1 Study Participants

The participants in this study were junior and senior-level undergraduates taking a course in Fluid Mechanics at a large research university in the southeastern United States. These students were primarily pursuing mechanical engineering Bachelors' degree. Two cohorts of students participated in the study – 1) students completing the course in a flipped format *without* metacognitive instruction and repeated reflection during Spring 2021) students completing the course in a flipped format with metacognitive instruction and repeated reflection (i.e., experimental section) during Fall 2021. Approximately 85 students were enrolled during the Spring 2021 semester and comprised the first cohort. During Fall 2021, approximately 130 students were enrolled in the course and comprised the second cohort.

3.2 Reflective Questions

Each week, students were intentionally instructed or supported in planning, monitoring, and evaluating their problem-solving and were asked to reflect in writing about the use of these self-regulatory skills during their problem-solving. In addition, students reflected after exams. Table 1 lists the weekly reflective questions that were posed to the students, with each question being a planning (P), monitoring (M), evaluation (E), or post-exam question. The question type (i.e., P, M, or E) was alternated on a weekly basis to avoid reflection fatigue, and students were not asked to reflect during an exam week.

Table 1: Weekly Reflection Questions

Week	Reflection Question	Question Type	Kappa
1	What did I already recall or not recall about this topic from the prerequisite Thermodynamics and C-6(ic7 Tm0-14(c)4(s a)3(ncu)4(ss C(p)-6(ic f)12(ro)-6(m)ba)4(nd		

Week	Reflection Question	Question Type	Kappa
6	Will I do things differently in preparing for the next exam in Fluids based on my performance on this exam, and if so, what will I do differently?	Post Exam	0.84
7	As you work on this in-class exercise in week 7 in Fluids, are there other resources or strategies you should be using to complete the exercise more accurately or thoroughly?	Monitoring	0.73
8	What have I learned from working on the in-class exercises in Fluids since the start of the semester?	Evaluation	0.61
9	Surroundings in a classroom are believed to have effects on student learning. These include the conditions and objects that surround you. What impact, if any, are the surroundings in this Fluids classroom having on YOUR learning and comprehension? In your reflection, please include why the surroundings are impacting you in these ways.	Evaluation	0.89
11	Based on the experience of taking exam 1 in Fluid Mechanics, what did you do to prepare for exam 2?	Post Exam	0.75
12	What do you plan to do to enhance or maximize your performance on this week's (week 12's) in-class exercise in Fluid Mechanics?	Planning	0.73
13	What are you currently doing to prepare for your final exam in Fluid Mechanics? Please be honest in your response, as this question is meant to be supportive to you. Please discuss what you are doing now and not what you plan to do. If you are not doing anything, simply state as such and provide a quick explanation as a supportive note to yourself.	Monitoring	0.56
15	What are your thoughts about these weekly Canvas questions you've been answering related to the in-class exercises or exams in Fluid Mechanics?	Evaluation	0.70

The reflective responses were examined by two analysts using a content analysis and emergent coding schemes to identify the recurring themes. The analysts were engineering faculty members who conduct engineering education research (i.e., first and second authors). One of the analysts, who is highly experienced with content analysis, examined all of the responses each week and developed the coding scheme. A second analyst examined a subset (i.e., 15%) of the responses using the coding scheme. Their inter-rater reliability (IRR) based on the subset of responses was calculated using Cohen's Kappa. T2 Tm iT38.37 .s0 G[(a)4(ppa)]TJETQ5Q86.11 370.39 T

Similar final exams were administered to the two cohorts to enable comparison based on a direct assessment result. The final exam contained both multiple-choice and free-response questions. For the multiple-choice questions, although the twelve questions were not identical for the two cohorts, the concepts tested were the same, and the questions were of similar difficulty.

For the free-response questions, two of the three questions were identical across the cohorts,1oJs 458.95 626.62 Tm0 g0 G[ )]TJETQq0.00000912 0 612 792 revr342.91 626.62 Tm0 g0 0

(week 8). Exam 1 occurred during week 5, and the post-exam reflection occurred during week 6.

4.2.1 Planning

Reflection Question: *How can I do a better job on this week's (week 4's) in-class problem-solving based on my work on the in-class problems during weeks 1-3?*

The results of the content analysis for this question are shown in Table 2, in descending order of response proportion. There were eight categories in the coding scheme, as given in Table 2. The most frequently mentioned categories

Coding Category	Description	% of Responses (n=99)
	Plan solution approach	
Get help or support from peers	Get or ask for help or support from classmates, friends, or other students	10%
Ease Nervousness or Have Confidence	Try to ease one's nervousness or lack of confidence about course performance	1%

4.2.2 Monitoring

Reflection Question: *As you work on this in-class exercise in week 7 in Fluids, are there other resources or strategies you should be using to complete the exercise more accurately or thoroughly?*

In their monitoring-based reflections in week 7, the students most frequently indicated the *lecture videos*, their *peers*, and the course *notes/slides* were the resources they should be using during the in-class exercise, as shown in the upper portion of Table 3. Relative to strategies, *practice* (with problems) was the top-mentioned strategy to use, being mentioned by 40% of respondents. This proportion was similar to the proportion of students who identified *practice* as a desirable planning activity in week 4 (i.e., 42%). Of the students who mentioned this strategy in week 4, 33% of them also mentioned it in week 7 during monitoring.

Carefulness, Organization & Diligence was the third most-frequently-mentioned strategy, with 27% indicating they should be conducting themselves and their work in this way. Interestingly, this category was mentioned by a similar proportion of respondents (i.e., 34%) in the week 4 planning reflection. Of the students who mentioned this approach in week 4, only 15% of them mentioned it again in week 7 during monitoring. Was it possible the remaining students were already applying *Carefulness, Organization & Diligence*, and therefore it was not "another" strategy they should be using? In Table 3, *Independent Effort, Critical Thought, or Problem-Solving Skill* was the second most-frequently-mentioned strategy, with 31% saying they should be pursuing these types of actions. This represents an increase in the occurrence of this category from the week 4 planning reflection, where 17% of the responses were representative of this category. Similar to the planning-based reflections in week 4, the second and third most-frequent strategies in Table 3 suggest realization by the students of the importance of academic self-management for solving problems.

Table 3: Week 7 Monitoring Reflection Results

Coding Category		Description	% of Responses (n=99)
Resources	Lecture Videos	Videos assigned for pre-class learning	37%
	Peers	Fellow students, friends, or classmates	27%

Coding Category		Description	% of Responses (n=99)
	Notes or Slides	Course/topical notes or slides	21%

mentioned it again

demonstrate their problem-solving processes, which were a key component of the metacognitive instruction and weekly reflection questions. Thus, it's reasonable that there was an increase with the free-response questions versus the multiple-choice questions (necessarily).

Table 5: Exam Results Comparisons: Flip vs. Flip w Metacognitive Support

Exam Component	Adjusted Mean Percentage %	ANCOVA *p* 5
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