Continuing to Promote Metacognitive Awareness in a First-Year Learning Strategies Course

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Abstract

This **complete, evidence-based practice paper** builds upon our previous work [1] in developing a learning strategies course for first-year engineering students in a cohort who enter the university underprepared for success in Calculus I. Revisions to the course include improvements in scaffolding metacognitive development and engaging students in professional practices to develop learning capacity and career competency. All members of the cohort are co-enrolled in STEM courses that are prerequisites for changing into their engineering major of choice. Additionally, the students are enrolled in a 2-credit learning strategies course focused on the development of personal and professional strategies relevant to academic success.

The pedagogical model for the learning strategies course is Entangled Learning [2], which proposes an iterative cycle of activity in four areas that supports individual and collaborative self-directed learning and metacognitive processing. The model emphasizes reflection, evaluation, and integration while individuals design their learning, engage with resources to support individual study or learning in a community of practice [3], develop practices or projects to integrate conceptual into applied knowledge with an iterative cycle of quality improvement [4], and engage in practices to increase awareness of and synthesize learning. Having completed one course through the cycle, learners synthesize and enhance awareness of their knowledge through curating their learning narrative in an ePortfolio [5].

After evaluating student and instructor feedback over the past two years, the course was streamlined and added a scaffolded approach to developing student metacognition and engagement in professional practices for the Fall 2019 iteration. Assignments involved students in peer sharing for content delivery [6] and simplified but extended learning journals which emphasized evaluation and reflection. In-class study group time was structured after industry practices, such as after-action reviews [7], [8] and meeting facilitation, for the processes of planning and evaluating the group's learning. Greater integration was achieved with the Skillful Learning model of metacognition throughout the course and journal activities [1], [9]. A program goal is to engage students with resources provided by the Clemson University Academic Success Center, so participation in peer-assisted learning, tutoring, and evening coaching hours became a required component of the course.

This paper outlines the revisions to the course design, and presents an analysis of first-year engineering students' ability to engage in professional practices to promote metacognitive awareness. Analysis of culminating reflection essays from Fall 2019 and comparison of results from Fall 2018 will inform a discussion of the effectiveness of our approach.

Introduction and program context

This **complete, evidence-based practice paper** explores the impact of curricular redesign on indicators of students' metacognitive ability. Students in the General Engineering Learning Community typically have backgrounds and high school experiences that have not prepared them

with social capital or with academic experiences conducive to success as self-directed learners at the collegiate level [10]. Metacognition refers to reflective processes by which learners become aware of and control their thinking [11], [12]. To become self-directed learners, students must develop the capability to assess what is asked of them by tasks, evaluate their knowledge and ability relative to the task, plan an approach using an appropriate strategy, and monitor their progress while making adjustments as needed [13]. Thus developing metacognitive ability is crucial for academic success. This paper will present the context for the learning strategies course, describe recent changes, and present data that suggests the changes have strengthened students' metacognitive awareness.

The learning community includes students on two curricular tracks. In one track, students enroll in a year-long Calculus I sequence and complete Calculus II over the summer or during the following fall semester. The second track, the Boyd Scholars, enroll in an applied mathematics course designed to introduce students to mathematical thinking for engineers. The students then enroll in Calculus I in the spring semester and Calculus II during the summer. The engineering course sequence is slowed for Boyd Scholars, with the two semesters of courses extended to three and completed during the summer.

Students in both tracks enroll in a two-credit hour learning strategies course in the fall semester [1]. This course is designed to facilitate students in becoming stronger STEM students. Students learn strategies that they apply to their own personal success as well as to their academic success in the mathematics, chemistry, and Engineering courses in which they are co-enrolled.

Pedagogical model

The pedagogical model that informs the learning strategies course is Entangled Learning [2], a process model for self-directed learning (see Figure 1). The model presents an iterative cycle of activity in four areas that supports individual and collaborative self-directed learning. Documentation of metacognitive processes is built into the model.

First, learners reflect on and document their values, purpose, and meaning for learning in a particular domain. Learners also document their baseline knowledge and skills by starting a learning portfolio. The initial stage of the portfolio includes the learner's questions and topics for exploration. From here, individuals create their learning design by identifying their goals for learning, how they will evaluate whether they met their learning goals, and what activities they will undertake to achieve their learning goals. "Self-direction" sometimes refers to students' ability to independently complete tasks assigned by others. In this model, "self-direction" means that learners are agents in designing their own learning experiences. As described by Ponton [14],

> Self-direction implies enlisting the self-regulatory processes of identifying discrepancies between current and desired states, planning learning activities with relevant resources to bridge this gap, monitoring progress to assess achievement, and providing corrective feedback to the learning activity; that is, the "directing" aspects of the learning activity. This is not an imposed or selected environment as much as it is one created by the individual. (p. 70)

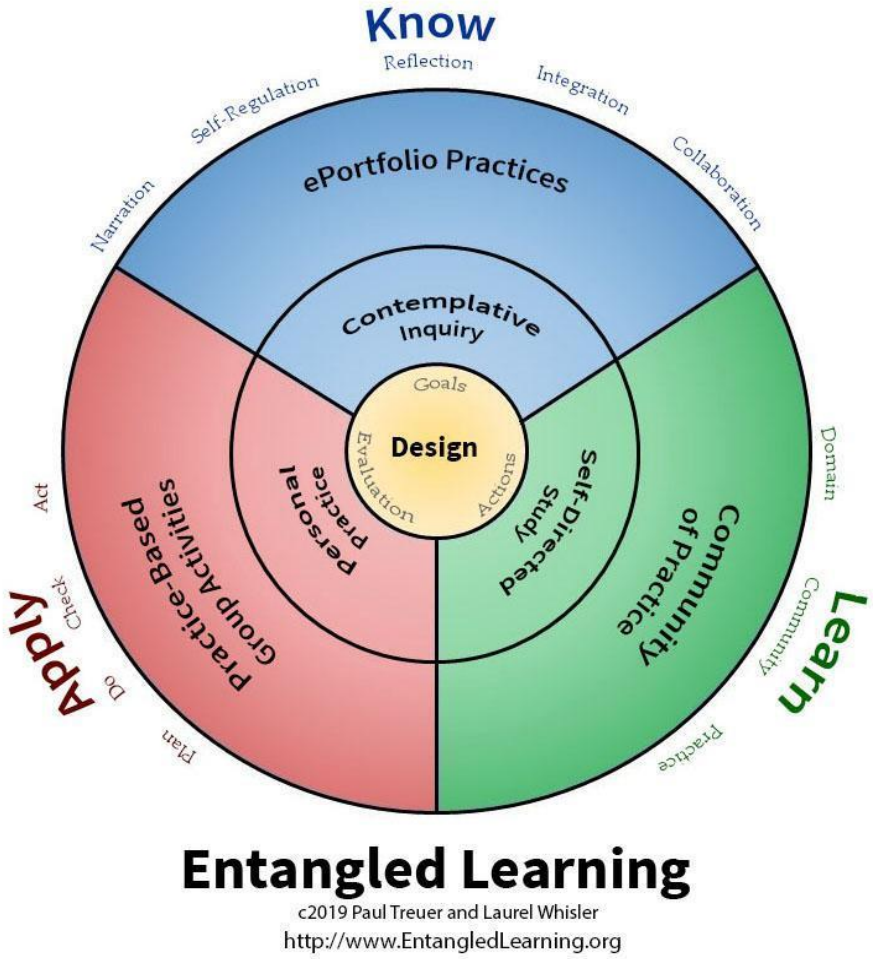

Figure 1. Entangled Learning Model

With a design in place, learners engage in individual and collaborative learning through participation in a community of practice [3]. The community consists of peers in the learning strategies course who are co-enrolled in other STEM courses. Thus learning strategies modeled in this course influence students' approach in their other courses, and the learning strategies course becomes an environment for social cognitive learning [14]. The fourth area is to apply learning in personal and group practices with an iterative cycle of quality improvement [4]. In this cycle, individuals identify their plan for accomplishing a project related to the learning or develop habitual practices to support their learning. After engaging with the project or practices, the individuals check or evaluate their effectiveness and determine appropriate actions to improve or maintain their current effectiveness.

Learners reflect on and become aware of what they are learning through periods of contemplation and reflection. During reflection, learners are encouraged to envision the object of their learning from multiple perspectives to gain increased awareness of the learning, gaps in understanding, and connections with other concepts. Having completed one course through the cycle, learners synthesize and enhance awareness of their knowledge through curating their

learning narrative in the ePortfolio [5] they began at the initiation of their learning. By documenting their story, self-regulation, critical reflection, integration, and responses to feedback from collaborators, individuals become aware of deeper learning. As a pedagogy, the model outlines a process for instructors to use when shaping the course so that assignments move students through the cycle. For students, the model presents a structure useful for scaffolding their independent learning and is a model that can be applied in future learning.

Course design

The course has two lenses. One is inward, with focus on gaining personal skills for wellness and self-regulation. The outward-facing lens focuses on developing professional skills and integrating with the co-enrolled STEM courses. We define "professional skills" as learning strategies, since the students' current professional activity is becoming stronger STEM students, and professional practices are used in industry.

With the goal of modifying the learning strategies course to better support metacognitive development and engage students in building their learning capacity, student and instructor feedback over the past two years was evaluated. As a result, the course was redesigned to have a more streamlined and scaffolded approach to developing student metacognition and engagement in professional practices for the Fall 2019 iteration. Included in this restructuring are several core activities and assignments: peer sharing presentations, journals, practice-based group activity sessions, Skillful Learning materials, and course support resources. We discuss each of these practices in greater depth below.

An intentional, evidence-based approach to students' selection of learning and wellness strategies for peer sharing presentations was implemented. Peer sharing of learning strategies conveyed course content quickly without need for instructor lectures, while simultaneously allowing students to engage actively in their learning [6]. In each of the four peer sharing presentation rounds throughout the semester, students were exposed to a number of academic or professional strategies for success.

The journal assignments were restructured and simplified to put more emphasis on evaluating the learning process and engaging in reflective practice. Throughout the semester, students created short-term academic and wellness goals in alignment with their long-term goals and professional purpose. The journals acted as a space for students to record their goals, document their use of strategies in support of the goals, and reflect on their progress.

In-class study group time, or practice-based group activity (PBGA) time, was given increased structure to aid students in planning and evaluating their group's learning. Professional practices used in industry, such as meeting agendas, the use of team member roles, and after-action reviews [7], [8], were incorporated into the PBGA experience.

Greater integration was achieved with the Skillful Learning model of metacognition throughout the course in class discussions and structured reflections [1], [9], [15]. The concepts and characters discussed in the metacognitive video series were referenced frequently throughout the semester.

A program goal is to engage students with resources provided by the Clemson Academic Success Center, so participation in peer-assisted learning, tutoring, and evening coaching hours is a required component of the course. Undergraduate peers serve as academic coaches, embedded in the course. They provide assistance during in-class activities and share their experiences as a near peer. The coaches also facilitate evening sessions twice weekly. One session is for less-structured collaborative learning. The second session offers practice quizzes, an evidence-based learning strategy to improve retention [11].

Research Question

In our second year of using the Skillful Learning videos on metacognition coupled with revisions to course assignments and activities, we ask whether a change is noticeable in indicators of students' metacognitive awareness.

Methods

Data were taken from the Fall 2018 and Fall 2019 final portfolio assignments, which included similar writing prompts (Appendix A and B) that requested students to review their learning journey over the semester and discuss their challenges and successes. The Fall 2018 assignment asked students to write a minimum of three paragraphs telling the story of their challenges and triumphs during the semester. A separate prompt asked students to identify their most successful learning and self-regulation strategies. The Fall 2019 assignment included two prompts for the students: narrate their learning journey for challenges and successes as modeled in the Skillful Learning video series [15] and identify two learning strategies and one self-regulation strategy that were helpful.

A sample of student reflections was selected for analysis. One author was the only instructor to teach at least one section of the course in both years. We chose students from her sections for data analysis, removing the instructor variable as a potential factor from the results. Another author reviewed the assignments and scored student responses according to a rubric, which will be discussed in more detail. Twenty students from her Fall 2018 section submitted reflections and consented to participate in research. Sixty-six students who consented from her two sections in Fall 2019 submitted reflections. A random sample of 10 reflections each from Fall 2018 and Fall 2019 were selected for scoring.

Reflections were scored using the metacognitive indicator rubric developed by Cunningham and his colleagues [12]. The rubric categorizes responses as low, medium, or high, with the following category descriptions:

- "Low" responses are characterized as "disconnected from question OR vague strategy with no or weak evidence." Examples include vague strategies, such as "getting work done on time," "always finishing homework," and "studying." Missing or weak evidence includes responses with phrases such as "it helps me learn," or "due to my high standards."

- "Medium" responses name a strategy with "weak evidence, but attempt is made." Examples of named strategies include "I schedule my time," or "I make lists of what I have to get done." Weak evidence includes subjective criteria, such as "I feel that I am on top of my work," "I am more efficient with my time," or "I know how long things take."

- "High" responses name a clear strategy with information about how the strategy was implemented. Such responses include "I offer incentives for when I complete my work" or "I schedule my study/homework time in my planner." Evidence is clear and concrete, demonstrable, or objective. Such criteria include performance measures, such as "I timed myself so I know I am getting faster" or "I am more organized, I can find what I need in minutes."

We scored "low" responses with a value of 1, "medium" responses with a value of 3, and "high" responses with a value of 5. We considered a response to be a statement about knowledge of self, knowledge of task, knowledge of strategy, or regulation of cognition (planning, monitoring, controlling, or evaluating). Statements that began with "I learned that…" would be considered a response. Implicit "I learned that…" statements were also considered. Statements that identified requirements of tasks or described strategies used to achieve certain academic or self-regulatory purposes were also considered responses.

The metacognitive indicator value derived from the rubric is the primary measure used in our study to determine the relative metacognitive awareness of students in our samples. Since the prompt for each year's sample varied, we determined that focusing on the metacognitive content of the responses would create the most valid point of comparison. For each reflection, responses were given a score based on the metacognitive indicator rubric. The scores were summed and divided by the number of responses identified for that student.

Results

Values derived from scoring student responses from the narrative reflection prompts with the metacognitive indicator rubric are shown in Table 1. The range of mean scores, based on the metacognitive indicator rubric, ranged in the Fall 2018 sample from a low of 3.17 to a high of 5.00. The Fall 2019 sample extended from a low of 3.72 to a high of 5.00. Students in the Fall 2018 sample scored a mean of 3.83. The students in the Fall 2019 sample had a mean score of 4.29 using the same rubric. This difference is significant at an alpha level of 0.05, with $p=0.017$. The median for the Fall 2019 sample is 0.8 points higher than for the Fall 2018 sample.

Table 1. Sample Data and Metacognitive Indicator Rubric Scores

	Fall 2018 Sample				Fall 2019 Sample		
	Responses	Score	Mean		Responses	Score	Mean
Reflection 1	3	11	3.67	Reflection A	6	28	4.67
Reflection 2	9	45	5.00	Reflection B	6	26	4.33
Reflection 3	8	32	4.00	Reflection C	7	33	4.71
Reflection 4	4	14	3.50	Reflection D	10	46	4.60
Reflection 5	3	11	3.67	Reflection E	11	41	3.72
Reflection 6	12	38	3.17	Reflection F	8	34	4.25
Reflection 7	6	22	3.67	Reflection G	10	38	3.80
Reflection 8	5	19	3.80	Reflection H	12	48	4.00
Reflection 9	5	21	4.20	Reflection I	6	30	5.00
Reflection 10	8	28	3.50	Reflection J	6	28	4.67
Total	63	241		Total	82	352	
Mean			3.83	Mean			4.29
Median			3.67	Median			4.47

Discussion

It is important to note that while a significant difference exists between the Fall 2018 and Fall 2019 cohort samples, there is no conclusive evidence to definitively attribute specific factors directly to the improvement. We can, however, suggest ways course changes in Fall 2019 may factor into the difference that was observed.

Learning journals in Fall 2018 were too numerous and did not have iteration built in. The six learning journals were conceived as two-week discrete experiences. They did not allow for extensive time on task for improving one's practice through iterative attempts at evaluating and improving one's approach. The Fall 2019 learning journal was conceived as a semester-long activity with only three strategies being added incrementally by the end of the semester. The journal assignment was developmental in focusing on one strategy, giving students the opportunity to develop competence with it before adding another strategy. Checkpoints with writing prompts that align with the EL plan-do-check-act cycle for quality improvement [4] were built into the semester assignments to promote iterative attention. This cycle aligns closely with

the concept of regulation of cognition (plan, monitor, control, evaluate) that is featured in the Skillful Learning video series [15].

Writing the assignment prompt with explicit connection to the Skillful Learning video series may have triggered a cognitive schema that the students were able to emulate in their Fall 2019 reflections. That schema may have provided a model that students used as a framework for articulating what they learned and how they learned it. The Fall 2018 prompt was general, so although the students in Fall 2018 saw the same videos used in the same way in the course, the prompt's lack of explicit connection with the model from the video may have meant that the students didn't make a connection with the schema as a model for writing. This is to say, writing a better, more-focused prompt may have been a contributing factor in students' being able to write a better, more-detailed response.

An in-class reflection question near the end of the semester provided students an opportunity to practice constructing their narrative (see Appendix C). No such opportunity was given to Fall 2018 students. Although formative feedback on the reflection responses was minimal (eg. "provide more detail in your responses"), the opportunity to create the response may have helped students understand how to be more articulate with their final reflection.

Three examples illustrate the relative gains in metacognitive indicators from Fall 2018 to Fall 2019 cohorts. First, a student in each sample expressed knowledge of self related to motivation. The Fall 2018 student wrote:

> This semester has taught me a lot. To begin my intended major was not what my heart really wanted. My classes were a lot harder than I expected which caused me to be stressed and miserable a lot. I felt like I had no motivation toward school because I was in the wrong major for me which cause [*sic*.] my grades to suffer.

The Fall 2019 student wrote:

> He also had one awful friend named the procrastination monkey. The procrastination monkey always wanted to have fun and do no work while the rational side of myself told me to do work, but he always listened to the fun monkey, so he felt that this is also a big part as to why his exam and quiz grades were not what he wanted them to be. He would spend lots of his time having too much fun rather than studying and making sure the information that he needs to know is begin [*sic*.] committed to long term memory. He thought this was like high school where he could study the night before the quiz and still do fine. So, Guillermo[1] … suffered a 64 on his first quiz and was very concerned.

Comparing the two examples illustrates that the student from the Fall 2019 sample could articulate in greater detail the motivational challenge, naming it specifically as procrastination. Whereas the Fall 2018 student stated a lack of motivation and the fact that grades suffered, the Fall 2019 student identified specific examples of negative impacts from procrastination and provided more concrete documentation of the effect by reporting a specific grade.

Representative examples of time management also illustrate differences in metacognitive indicators. The Fall 2018 student wrote only in vague terms: "I have found ways to do my work in a timely manner. I have also surprisingly been organized, as I have only missed a couple of

[1] A pseudonym is used to protect confidentiality. Many Fall 2019 students wrote in third person to tell their story, modeling their narrative on the third-person illustration provided in the Skillful Learning videos.

small assignments here and there." This student offered no strategies. In contrast, the student from Fall 2019 provided multiple specific strategies.

> His first task was to start really working on his personal goal of having good time management. He tried multiple things throughout the month, including using a planner, sticky notes, even writing notes on his arm to help remind him, but then he stumbled on to a method that worked for him. He started to use Canvas's … calendar and then would write a schedule based around the assignments due and when they were due.

Finally, two students in each cohort illustrate differences in quality and detail of articulating their use of learning strategies. The student's description from Fall 2018 names strategies but with little detail about implementation.

> I learned quickly that I wasn't going to be able to coast by with just what I remembered hearing in class. This was rough for me because not only did I not study beforehand, I didn't even know how to study. One of the first things that I started to do was thoroughly re-read my notes that I took in class. This helped at first but definitely not my best option. I then learned that the best way for me to study, especially in STEM classes, was to work practice problems. This allowed me to become familiar with the concepts and how the [*sic.*] interacted.

In contrast, a student from the Fall 2019 cohort wrote specific details of how they worked practice problems with a robust technique that reveals insightful knowledge of task and articulate explanation of the technique's effectiveness.

> I have also found a new technique that I kind of came up with. I call it writing steps. See my brain is used to pattern matching because that is how high school is set up, but I am trying to figure out how to move away from that. This is the first step. I will do a problem on my own and then write down the steps of that problem. This is useful because when looking at problems I am teaching myself to first, find the identity of the problem. It's basically figuring out what the problem is asking of me. Then I follow the steps in completing the problem. This way I have a checklist in my mind that lets me know what I need to make sure I have.

Limitations

One limitation is the assignments and writing prompts from Fall 2018 to Fall 2019 were slightly different. Fall 2018 specified a three-five paragraph minimum, while the Fall 2019 prompt made no reference to minimum or maximum length. The Fall 2018 prompt was a general "tell your story" directive, while the Fall 2019 prompt directed a narration based on a model which demonstrated metacognitive awareness. The Fall 2018 assignment had another section of prompts for learning and self-regulation strategies separate from the narrative. For Fall 2019, both prompts for strategies and narrative were integrated into the same assignment.

A second limitation is the metacognitive indicator rubric was designed to assess responses to specific questions in another setting. The questions appear to have been more tightly focused on a single aspect of metacognition. Using the rubric with a broader narrative sample may have introduced opportunities for error in distinguishing the number of responses per item in the sample and for consistently assigning a score, particularly as some of the "knowledge of self" responses related to strategies students realize they were not using effectively.

A single researcher scored the responses; thus our study did not have the benefit of a more robust review of the data or the benefit of inter-rater reliability.

Conclusion and Implications for Future Research

We propose that a course environment that focuses on increasing metacognitive awareness through self-directed learning in individual and collaborative settings may positively impact students' self-efficacy. As students focus on attaining goals that are important to them, in settings where the challenge is not beyond their capability, in a social setting that supports persistence, students' self-efficacy should be enhanced [16]. This is an area ripe for future research. Particularly for students who enter the engineering major underprepared for success in Calculus, it is important to create an environment with support systems and challenge so learners can pursue competency-development that directly supports their perceived learning needs. Reinforcing video presentations of metacognitive concepts with a pedagogy and course design that involves students in learning about themselves, disciplinary content within the domain, and cycles of design, control, reflection, and evaluation of their learning creates a rich environment for development of self-efficacy, which is necessary for academic success.

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Appendix A: Fall 2018 Final Narrative Prompt

Purpose: The purpose of the final portfolio is to give you an opportunity to reflect critically upon and to document your progress towards becoming an effective STEM student and to become aware of what more you can learn and develop as you continue next semester. This activity will also give the instructors and the ASC important evidence for how well the course design helped you achieve the learning outcomes listed in the syllabus.

Your portfolio should be engaging and convincing. It is a look back and a celebration of what you have learned and done this semester. You are welcome to submit the portfolio as a PDF document, but you can make it an Adobe SPARC page, ask a friend to video you, or create a website if you would like - Be creative! Play!

While compiling this portfolio, keep the CU 1010 course meta-question in mind: **How did I progress towards becoming a successful STEM student?**

Part 3: Narration - After you have completed everything else in your final portfolio, write a minimum of three paragraphs (or 5 minutes of audio/video/screencast) in which you tell the story of your challenges and triumphs as a learner this semester. Introduce us to what you want people to know about your experience that your grades don't reflect. **What defines or illustrates how you see yourself as a learner and what you have achieved?** Be real. Be honest. Write or speak as if you were talking with a grandparent, a close friend, or a trusted mentor.

Appendix B: Fall 2019 Final Reflection Prompt

During the semester, we watched the Skillful Learning videos, which told the story of Joe and Sue's experiences of becoming more effective learners. Joe and Sue faced challenges in regulating their personal and professional habits and in developing effective approaches to studying through adopting techniques for metacognitive awareness and for organizing, rehearsing, and elaborating. We learned what Joe and Sue tried that was successful and what still needs more attention for the future,

Become the narrator for your own story. Tell your experience in the same way that Dr. Cunningham narrated the Joe and Sue stories.

Your grade will be based on the quality of your reflection - how richly you explain your learning experiences - not on whether you were always effective.

Your narration must include two main parts:

1. Describe and give examples of **two significant** personal and / or professional **challenges or successes** you experienced this semester. Discuss what you have **discovered about yourself as an individual and as a learner** that you will carry forward. Explain how these experiences influenced your **habit of mind [resilience, grit, growth mindset].**

- *What's "significant?" The outcome was especially important or meaningful, you felt like you made progress in being a stronger student by greatly improving your grades in a course, etc. Consider experiences that took several weeks to work out.*
- *Examples: living on your own for the first time, attempting to overcome negative self-talk, rebounding from failure, rebounding from being over-confident, learning challenging course content, developing study skills you didn't use in high school*

2. Identify the following things you attempted this semester. Explain why you thought the strategy might be effective when you chose them. Discuss whether the strategies worked and why they did or didn't work. How did you measure your success? What challenges did you have in implementing your strategy?

At least one self-regulation strategy [personal habits or behaviors]
At least two learning strategies.

Appendix C: Daily Reflection 11

Today we watched the Skillful Learning video titled "Thinking Back and Thinking Ahead".

Earlier in the semester, you identified if you related more to Joe or Sue; refer to this Daily Reflection to review your responses.

How have the changes in behavior and use of metacognitive strategies that you implemented throughout the semester been similar to what Joe or Sue have done? How have they been different?

Use specific examples of Joe and Sue's behaviors mentioned in the video, and of your own behaviors, to support your response.