

## **Promoting Metacognitive Awareness in a First-Year Learning Strategies Course for Cohorted General Engineering Students**

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First Year Programs Division

## **Abstract**

This complete research paper builds on our ASEE 2018 paper “Work in Progress: Strategic, Translational Retention Initiatives to Promote Engineering Success” [1], which describes a pilot program, the General Engineering Learning Community (GELC), started in Fall 2017 to leverage existing university resources to support successful course and program outcomes for students entering general engineering with insufficient calculus preparation. The program was continued in Fall 2018 and remains in progress. One component of the program is a learning strategies course focused on skills relevant to success in the students’ three cohorted STEM courses: introductory engineering, general chemistry, and the first semester of an extended, year-long calculus course.

Entangled Learning [2] provides the pedagogical framework for the learning strategies course. The pedagogy is an action-based metacognitive framework for individual and collective self-directed learning. The active processes of Entangled Learning, “design,” “learn,” “apply,” and “know,” are informed by cycles of documenting, self-regulating, critically reflecting, integrating, and collaborating. Course activities and assignments scaffold learning through these actions. Most of the assignments are learning journal activities for which students identify a developmental behavior. Students identify a resource that will inform their decisions on changing their behavior or conceptual understanding, engage with and document their activity, evaluate their results, and derive meaning for themselves as STEM students. Learning journals address self-regulation, time and energy management, self and wellness, learning strategies, and exam wrappers. Additionally, students work collaboratively to apply their developing skills to learn the content in the cohorted courses.

The Entangled Learning framework aligns with the Skillful Learning series on metacognition as presented by Cunningham, Matusovich, and Blackowski in their 2018 ASEE pre-conference workshop “The impact of metacognitive instruction on students’ conceptions of learning and their self-monitoring behaviors” [3]. Their videos and classroom resources elaborate on metacognition as knowledge of cognition (persons, tasks, strategies) and regulation of cognition (planning, monitoring, controlling, evaluating). With permission, we included their Skillful Learning video modules in our learning strategies course and used selected supplemental resources in instruction.

This paper will explain the course design with Entangled Learning as the underlying pedagogy and the use of the Skillful Learning metacognitive instruction resources developed by

Cunningham, Matusovich, and Blackowski. We will present an analysis of first-year general engineering students' ability to engage in practices to promote metacognitive awareness. Analysis of quantitative and qualitative data will inform a discussion of the effectiveness of our use of the Cunningham, Matusovich, and Blackowski materials with our first-semester freshmen. This data will also be used to explore students' ability to demonstrate metacognitive awareness and engagement within the Entangled Learning framework.

## **Introduction**

Initiated in 2017 as a pilot, the General Engineering Learning Community (GELC) at Clemson University supports first-year students in general engineering whose calculus skills are insufficient to enter Calculus I in their first semester. The primary goal of the program is to achieve rates of graduation in engineering majors commensurate to those for students who enroll in Calculus I in their first semester. Additional goals are to equip the students with skills for academic success, build a learning community, and provide mentoring. Most of the students in the program enter with characteristics that place them at risk for graduating [1]. Students in the program enroll in a yearlong sequence that reviews precalculus concepts and covers Calculus I content at a slower rate. Students in the program are cohorted into sections of general engineering and calculus courses as well as a version of a university success skills course.

The university success skills course carries two credit hours and meets twice weekly for 75 minutes. The university success skills course focuses on self-directed and collaborative learning with emphasis on reflective practice. Course content includes metacognitive skill development. Learning outcomes include engaging in habits for academic success (e.g. time management, sleep, exercise, nutrition), effective learning strategies (e.g. organizing information graphically, using the textbook, following the study cycle, extending test preparation across five days), and habits of mind for success (e.g. grit, mindfulness, positivity, growth mindset). The course includes periodic assignments to practice the skills and culminates in a portfolio.

This paper is an overview of the course and our integration of the Skillful Learning series about metacognition [3]. We conducted a mixed-methods analysis on a survey of student responses to the videos. The research questions we sought to answer were:

1. What were the first-semester freshmen able to understand about metacognition from the Skillful Learning series, which was designed for more advanced students?
2. What impact did the Skillful Learning series have on student learning?

## **Metacognitive content and Entangled Learning**

Entangled Learning [1] (Figure 1) shapes the pedagogy of the course. As a framework for learning, Entangled Learning (EL) promotes learner-designed activities for self-directed learning

and application through personal practices to deepen and improve the quality of the learning. While learners pursue individual learning, they also collaborate with others in a community of practice [4] to pursue practice-based group activities. Learning is synthesized into knowledge as individuals engage in contemplative inquiry to reflect upon or visualize what they know [5]. Demonstrating the practices of self-regulation, reflection, integration, and collaboration provides evidence of having gained skills for deep learning [6]. Engaging in these practices becomes a learning process that is documented in the multimedia product that is an ePortfolio [7]. Documenting the practices in an ePortfolio that is subsequently shared with others, permits feedback on and validation of claims of learning and meaning making [6].

While EL functions as a framework to support self-directed learning, it can also function as a pedagogy to support learner-centered instruction. Teachers shift roles from instructing to mentoring and coaching as they guide students in pursuing the students' own learning goals within broader course outcomes. The pedagogy supports metacognitive awareness on multiple levels. Students think broadly to identify their own goals, actions, and criteria for evaluation as they progress through their learning design. Activity-based or assignment-based metacognition occurs as students plan actions in personal or group-based practices, do the actions, check to evaluate effectiveness, and act to maintain quality or adjust for improvement before repeating the quality improvement cycle [8]. Students document in their ePortfolios their progress in developing the skills for deep learning. These skills represent metacognitive processes related to assessing the task and developing knowledge of self through evaluating one's personal skills and deficits, developing a plan through which to apply strategies and pay attention to their effectiveness, reflecting on the outcome, and designing a new plan to increase effectiveness [9]. Through promoting metacognitive awareness, teachers can urge students to develop a toolkit of practices to support their learning in any domain. Encouraging students to document their toolkit in their ePortfolio, along with narrating the story of their learning, can be a powerful tool for program assessment [10].

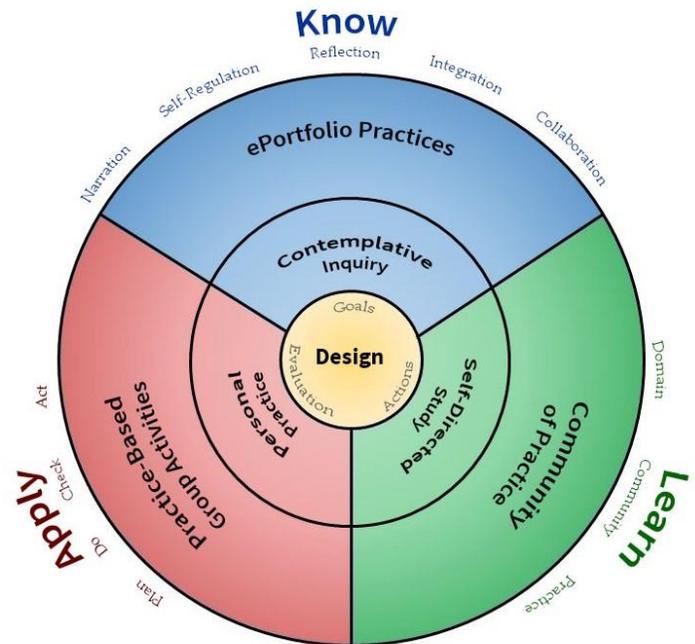


Figure 1. Entangled Learning Framework

## Metacognitive content and use of Skillful Learning series

Metacognition at its essence is a “process of thinking about thinking” [3] that involves learners engaging “in a variety of processes to monitor and control their learning” [9]. While Entangled Learning implicitly builds metacognitive processes into student learning through the pedagogical approach to the course, videos from the Skillful Learning Project ([skillful-learning.org](http://skillful-learning.org)) incorporate metacognition into the course explicitly. Cunningham and his colleagues developed a metacognition framework through research and interventions in their own courses. They shared their videos for our use in the course. Each video explains aspects of their metacognition framework, which is divided into two components (see Figure 2): knowledge of cognition and regulation of cognition [3]. The videos, designed for advanced students in engineering majors, use clever animations to present the information visually. “Joe” and “Sue” are hypothetical students who exemplify archetypal challenges experienced by students. “Joe” portrays a fixed mindset towards learning and lacks effective learning strategies. “Sue” has a growth mindset but lacks efficient practices for learning. We showed videos 1 and 2 (“What is metacognition and why should I care?” and “Knowing about thinking”) in the third week of the course. At midterm in week seven, we showed video 3 (“Reflecting on our thinking”). One section showed a portion of video 5 (“Optimizing our thinking”) in week twelve. We showed video 6 (“Thinking back and thinking ahead”) on the last day of the 15-week course.

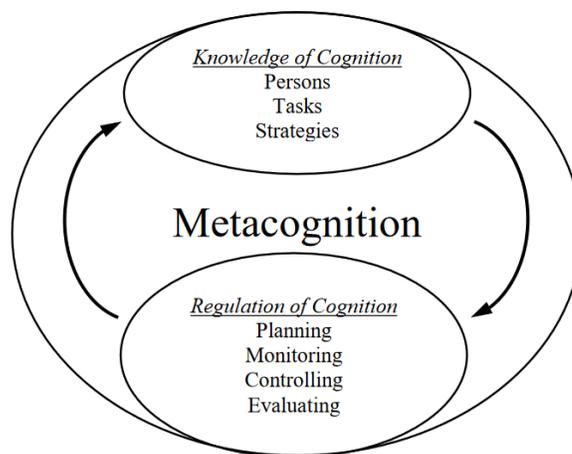


Figure 2. Skillful Learning Model of Metacognition

Supplemental resources were available to support use of the videos in class. We used only one of these resources but developed for ourselves analogous or simplified versions of other resources that were available. The level of detail in a number of their resources called for more depth of thinking and experience than we believed the first-semester freshmen could attempt meaningfully. The resource we used most substantively was the GAMES survey by Svincki, reproduced in the workbook that accompanies the video series [3]. We used the skills and strategies from the survey as the basis for a card sorting activity for students to identify the behaviors they use in their own learning. Early in the semester, students identified and wrote a reflection on their main study behaviors. Late in the semester, students mapped the study behaviors onto the EL model to see how the behaviors could be implemented within that framework. Two sections also included the survey as a supplemental component of our extended exam wrapper [11], using the survey as a diagnostic and planning tool for study behaviors.

## Methods and results

We used a mixed-methods approach to examine results of an assessment of learning from the videos. After viewing the final video, students in all four sections (n=81) were administered a multiple choice and open-ended question survey (Appendix A) to gauge their knowledge of metacognitive processes and to elicit their comments on ways they believed the videos impacted their understanding of thinking and learning during the semester.

Students' responses to the open-ended prompt to define "metacognition" were varied in detail, but most made reference to some aspect of awareness, monitoring, and/or control of thinking. For example:

- "Metacognition is the awareness and understanding of one's own thought processes."
- "Metacognition is, in the simplest terms, thinking about your thinking. Using metacognition is to reflect on yourself and evaluate what you know."
- "I would define "metacognition" as the process of analyzing one's own thoughts and modifying their thinking and learning processes to be able to learn more effectively."
- "Metacognition is thinking about thinking. It is the way that your brain processes and stores information for you to later use. Metacognition helps to take control of learning and puts knowledge into practice."

Seven multiple choice questions assessed students' comprehension of terms and their ability to translate certain terms to learning practices (Table 1). Two of the answer sets were designed to check whether students understood the difference in terminology between the metacognition videos and the EL model.

Question	% Correct	% Incorrect EL terms
2. What are the two main parts of the metacognition model?	54% (n=44)	
3. What components are considered knowledge of cognition?	26% (n=21)	52% (n=42)
4. What processes are involved in regulation of cognition?	59% (n=48)	26% (n=21)
5. What are the three big-picture strategies for studying promoted in the videos?	65% (n=53)	
6. Which of the following is an example of rehearsing?	69% (n=56)	
7. Which of the following is an example of organizing?	95% (n=77)	
8. Which of the following is an example of elaborating?	90% (n=73)	

Question 9 of the survey asked students to discuss how they related to the “Joe” and “Sue” characters. Nearly every student was able to relate to either or both of the characters. As one student reported, “It was nice relating to the characters in the video because I realize that I am not the only person struggling with being a skillful and effective learner because they would not use these examples if other people di [*sic.*] not have these problems as well. I understood all of the concepts and have applied most of them to my study habits in order to become a skillful learner.” Student responses indicate that not only do students relate to the characters, but they are able to articulate how they relate as well as how the example was helpful to them, revealing a deep level of metacognitive awareness.

The open-ended Question 10 “Comment on ways the videos impacted your understanding of thinking and learning” provided insight to the effectiveness of incorporating the videos. Comments were analyzed using thematic coding and grouped into emergent categories. Comments that addressed multiple topics were divided for purposes of coding. The greatest number of comments related to strategies for learning (n=23) and self-awareness (n=21). No other category had more than 12 comments.

Strategies for learning: Students commented that the videos aided their understanding of strategies to use for learning, either to identify strategies that they could use, or to help them evaluate why their strategies were ineffective. One student said, “This video, using Joe and Sue as examples, has helped me a lot. It has addressed the problems of each character that I can relate to. Throughout the video series, I have seen what they did to change there [*sic.*] habits to do better in school. Some of those tips I now know and can apply them to my own experiences.” Another student said, “I used the videos and tried to apply the things that were discussed to my own life. When [Cunningham] discusses solutions that Joe and Sue should do I wrote them down and referred back to them when I found myself in those same struggles. I applied his solutions and they helped me greatly.” The videos helped students understand ways they could improve their learning in the future: “The videos helped me to learn exactly what I was doing wrong with my learning over the semester, and even though I may not be able to go back and fix what happened, I will be able to correct my mistakes for next semester and set myself up for success in the future.”

While about half of the students discussed learning strategies in general terms, the other half who commented on strategies were able to relate more specific information about what they learned. For example, “The video made me realize that there is more than one way to learn, whether it is by rehearsing, organizing, or elaborating. I used to think that the only way to learn was to memorize, and I was not aware that there was a better way to learn and actually understand.” One student referred to processes for regulating cognition, saying, “I learned that I need to put more thinking, organizing, evaluating, and planning into my work before I start it to better

prepare myself to learn the material. I learned that I learn best in certain subjects by myself while other subjects that require collaboration are easier to learn with a group of people. I mainly learned I need to apply all these learning strategies to be the most successful student I can be.” Other students referred to specific study practices such as note taking, using the textbook, working practice problems, planning an overall approach to problem-solving, taking breaks, and getting sufficient sleep.

Self-awareness: Knowledge of self is one of the areas of knowledge of cognition addressed in the videos. Our students reported impact upon their own self-awareness. Several mentioned an increase in understanding the importance of developing a growth mindset: “I need to have a growth mindset. I am able to get better. I need to learn how to use different learning strategies when other are not working for me. One strategy isn’t good for every single class.” Some students realized that they became more aware of what strategies they were using and that they would self-evaluate and choose strategies to become more effective. Students reported becoming more aware and intentional about their choices of learning strategies: “Also the video made me more aware of my thinking and how I process information. I should consciously reflect on how I am processing information.” Several students reported increased awareness of their state of mind or flaws in their thinking: “[The videos] made me realize that I need to be more aware of the state I am in when I am trying to study. I am only able to study effectively if I am in a certain mental state and the video made me realize what I need to do in order to get myself into that state.” Also, “This video reinforces my conclusion that I need to stop trying to convince myself that I am effectively learning when I am not. They used the term ‘illusion of comprehension’ to describe this. It’s helpful to know that this happens to other people too because it makes me feel like I can overcome it.”

Learning: Some students differentiated between strategies and learning as a general concept. Students mentioned specific strategies, but they also discussed learning as a separate concept that is more expansive than studying. Learning requires effort: “These videos helped me understand that learning is so much more than doing practice problems and reading over notes. It takes time, and constant reinforcement, in order for topics to stick. Learning requires a lot of effort and attention, and it is on the individual to understand everything.”

Normalizing: Several students mentioned that the videos were helpful in showing that they are not alone in how they are feeling about learning. They could identify with the challenges that “Joe” and “Sue” faced. The videos also gave students hope and reassurance that they could improve: “[The videos] made me realize that I was going through similar struggles to [Joe and Sue] and that working hard in the right way can have a positive influence.”

Metacognitive control: Several students referred specifically to the concept of metacognitive control, stating that the videos made them aware of learning processes as well as the fact that

they have control over those processes: “The videos have approached thinking and learning as something that we can control. We can control our thoughts, but if we change them we can change our learning. If we start to think ahead instead of in the moment, or think about what we don’t know instead of what we do know, we can progress and learn new things. It is important to think about the best way to learn something.” A few students found the videos to have an impact by helping them understand what metacognition is and how to understand or use it for themselves: “The videos helped me to understand the meaning and importance of metacognition. When you step back and evaluate your learning, it is significantly easier to improve it. I have learned that with thinking and learning, there is not one set path, and what works for one person might not necessarily work for another.”

Habits: A few students related their habits to concepts in the videos. Some mentioned time management and study habits as things they know they need to manage better for more effective learning. One student wrote at length about having developed poor study habits in high school, which now require effort to break to effectively meet the rigor of college learning.

## **Discussion**

### *Knowledge of metacognition as a concept*

Results of the survey on the Skillful Learning videos reveal that students developed a general understanding of metacognition. Some definitions provided in response to the open-ended short answer Question 1 “How do you define ‘metacognition’?” indicated that most students grasped some aspect of the concept, such as awareness of or control of one’s thinking.

While most students understood the overall definition of metacognition, only 54-65% of the students could correctly identify metacognitive processes and concepts (Questions 2-5) that were discussed in the videos and presented repeatedly through graphics. Particularly interesting is that students confused EL processes of designing, learning, doing, and knowing with the metacognitive process of planning, monitoring, controlling, and evaluating (Question 4). The EL concepts were presented on different days from the metacognition videos and with different presentation methods (e.g. PowerPoint presentation and worksheets for mapping their learning practices). That students mis-identified the EL action clusters for the correct answer for regulation of cognition suggests that students perceive EL to have significant metacognitive procedural content, and that gains in metacognitive awareness may be attributed to both the EL pedagogy and to the specific content and integration of the videos into the course. Indeed, in response to Question 1, one student connected metacognition and EL: “Metacognition is what is considered to be the best way of learning and thinking through problems. It seems that it is another way of saying entangled learning, but I am not sure.”

Although students had difficulty identifying terminology related to metacognition (and EL), they were more easily able to match the metacognitive strategies of organization, rehearsal, and elaboration to known learning strategies (Questions 6-8). Surprisingly, matching rehearsal with “working practice problems” was more challenging than correctly matching organization and elaboration with the correct strategies, especially since many, if not all, students repeatedly reported working practice problems as one of their main study strategies. Students who incorrectly answered the question were most likely to say that the organizational strategy of creating a KWL chart (indicating what one **k**nows, **w**ants to know, and has **l**earned in a study session) is an example of rehearsal.

### *Impact on metacognitive awareness*

Having the “Joe” and “Sue” archetypes was helpful for illustrating effective learning strategies. Not only were students able to relate to the characters and the metacognitive concepts, but they felt supported by knowing their felt experience is shared by others. The characters made the concepts real to our students. Some student responses indicate that not only do students relate to the characters, but also they are able to articulate how they relate as well as give an example of how the “Joe” and “Sue” illustrations were helpful to them. This level of explanation reveals a deeper level of metacognitive awareness, according to the rubric proposed by Cunningham, Matusovich, and Blackowski [3]. For example:

I think I relate more to Joe than Sue. For example Sue spent way too much time going over notes, I spend too little. Joe spends extended periods of time doing work instead of in short bursts, just as I do. This method is extremely effective in getting assignments completed, however, quality often lacks and mental health also suffers a bit because of extended periods of working which results in less sleep that causes both Joe and I to perform [*sic.*] less than we could have been performing with a full night's rest.

In addition to the content of the students’ comments reflecting metacognitive awareness, the types of comments students made reflect the two main components of metacognition: knowledge of cognition (knowledge of self, knowledge of strategies, and knowledge of task requirements) and regulation of cognition (planning, monitoring, controlling, and evaluating). In response to the question asking students to name the impact on their learning from watching the videos, students’ comments predominantly related to knowledge of cognition (naming specific strategies for learning, self-awareness, and normalizing) and regulation of cognition (using strategies for learning, metacognitive control, and habits).

### *Limitations*

Design of the course and design of the data gathering did not isolate EL concepts from the Skillful Learning videos. Indeed, the EL components of incorporating the plan-do-check-act quality improvement model [8] and of integrating monitoring, evaluating, and reflecting into the regular assignments reinforced metacognitive processes.

The Skillful Learning series was designed for use with advanced undergraduate students. The students in this study were first-semester freshmen. Aspects of the examples and the level of discourse may have created a challenge for the less mature students' understanding.

### **Conclusion**

The interplay of Entangled Learning as a pedagogy for implicitly scaffolding metacognitive development with use of the Skillful Learning videos for explicitly illustrating metacognitive processes created a rich environment for impacting students' metacognitive awareness. Students were able to relate to the archetypal "Joe" and "Sue" examples and to adjust their habits and learning practices in relation to the experiences of the illustrations. The videos were successful in communicating what "metacognition" is and ways students can adopt metacognitive learning practices for greater efficiency and effectiveness of their learning. The pedagogy designed around EL gave students multiple opportunities to apply these new learning strategies of their choice, evaluate effectiveness and create a plan for more successful application, and reflect on what their findings mean to them as learners.

Further analysis of student responses is necessary to evaluate the level of metacognitive processing depth that our students were able to illustrate through the combination of EL as a pedagogy and interaction with the Skillful Learning videos. An additional area of research would be to determine the effect of Entangled Learning alone on the metacognitive awareness of students. Another area of future work may be to develop a clear rubric that can be used to classify or evaluate levels of metacognitive awareness. Cunningham, Matusovich, and Blackowski propose such a rubric [3]. Clearer examples or more specific evaluative criteria would strengthen the rubric. Fadel, Bialik, and Trilling [12] classify articulation of metacognitive processes into three levels: verbalization of information that is explicit, verbalization of information that is tacit, and verbalization of explanations of tacit information. Combining the two frameworks may provide enhanced clarity.

Entangled Learning is a promising model for scaffolding a pedagogy that supports student development of metacognitive awareness. We found the Skillful Learning series effective in providing accessible examples to students to promote their awareness and improvement of effective learning strategies.

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## Appendix A - Metacognition Video Survey (correct answers in bold)

1. How do you define “metacognition?” (short answer response)
2. What are the two main parts of the metacognition model?
  - a. **Knowledge of cognition and Regulation of cognition**
  - b. Knowledge of cognition and Designing for learning
  - c. Designing for learning and Regulation of cognition
  - d. Designing for learning and Reflecting on knowledge
3. What components are considered knowledge of cognition?
  - a. Knowledge of your learning style preferences, your personality type, and your engineering learning inventory
  - b. Knowledge of the processes of designing, learning, doing, and knowing [EL terms]
  - c. **Knowledge of your strengths, requirements of the task, and strategies to address the task**
  - d. Knowledge of your own strengths, the strengths of your team, and the strengths of the instructor
4. What processes are involved in regulation of cognition?
  - a. Managing time, Sleeping, Eating, Exercising
  - b. **Planning, Monitoring, Controlling, Evaluating**
  - c. Designing, Learning, Doing, Knowing [EL terms]
  - d. Taking notes, Reading textbook, Explaining in your own words, Teaching others
5. What are the three big-picture strategies for studying promoted in the video?
  - a. **Rehearsing, Elaborating, Organizing**
  - b. Taking notes, Reading textbook, Explaining in your own words
  - c. Identifying concepts, Drawing diagrams, Making concept maps
  - d. Identifying actions related to learning, doing, and knowing
6. Which of the following is an example of rehearsing?
  - a. Creating a KWL chart (What I know, want to know, and learned)
  - b. Drawing a concept map
  - c. Listing learning outcomes to study
  - d. **Working practice problems**
7. Which of the following is an example of organizing?
  - a. **Making a list of learning outcomes to study**
  - b. Working practice problems

- c. Explaining concepts in your own words
  - d. Reading your textbook
8. Which of the following is an example of elaborating?
- a. Working practice problems
  - b. Taking notes from the textbook
  - c. Taking a practice quiz
  - d. Explaining concepts in your own words**
9. The videos used examples of Joe and Sue to show two students' experiences with metacognitive thinking and learning. Discuss how the Joe and Sue examples related to your own experiences as a student. (short answer response)
10. Comment on ways the videos impacted your understanding of thinking and learning. (short answer response)
11. Comment on your overall experience with the videos. For instance, discuss how much you felt that you were able to connect with and absorb the information, whether you understood the concepts, if the information was relatable to your experience, if the examples and graphics were helpful, etc. (short answer response)