Metacognition Modules: A Scaffolded Series of Online Assignments Designed to Improve Students’ Study Skills†

Jean A. Cardinale* and Bethany C. Johnson
Alfred University, Alfred, NY 14802

Many first-year biology students begin college with high aspirations but limited skills in terms of those needed for their success. Teachers are increasingly focused on students’ lack of metacognitive awareness combined with students’ inability to self-regulate learning behaviors. To address this need, we have designed a series of out-of-class assignments to provide explicit instruction on memory and learning. Our metacognition modules consist of six video assignments with reflective journaling prompts, allowing students to explore the relationship between the learning cycle, neuroplasticity, memory function, expert and novice thinking, and effective study strategies. By setting lessons on improving study behavior within a biological context, we help students grasp the reasons for changing their behavior based on an understanding of biological functions and their application to learning. Students who complete these scaffolded journaling assignments show a shift toward a growth mindset and a consistent ability to evaluate the efficacy of their own study behaviors. In this article, we discuss the modules and student assignments, as well as provide in depth support for faculty who wish to adopt the modules for their own courses.

INTRODUCTION

Teachers frequently tell students to use particular high-impact studying strategies, but first-year students tend to rely on their well-learned high school strategies, which are ineffective for many college-level courses. Researchers are investigating whether students who understand how learning works choose to implement strategies based on that understanding (1–3). Undeniably, self-regulated learning, metacognition, and specific study behaviors that promote deep processing are important skills for academic success (4, 5). However, students need to be taught these principles and skills explicitly (6–11) because they are not intuitive (12) and trial-and-error learning is potentially too slow to achieve success in the span of a semester. We have therefore designed a metacognitive intervention that will help students overcome the temptation to rely on their habitual, ineffective strategies.

The aim of our intervention is to present metacognition by using psychological language contextualized within a biological system, beginning with the connection between brain plasticity and learning, and tying that to memory. We have found that this physical context resonates with our students—and is an innovative approach to teaching metacognition. Our intervention involves multimedia modules delivered online outside of class, paired with scaffolded reflective writing assignments. Students complete journal assignments that require them to assimilate the module content with course content and their personal behaviors. We also incorporate Dr. Stephen Chew’s video series (http://www.samford.edu/departments/academic-success-center/how-to-study) along with our original videos to accentuate the value of and biological rationale behind specific studying behaviors. The sequence of assignments builds understanding incrementally, which promotes and models the advantages of retesting, spacing, and elaboration in our original intervention (7).

Intended audience

These metacognition modules are designed for first-year first-semester introductory biology students but would be beneficial for first-year students in any subject.

Prerequisite student knowledge

No prior student knowledge is required.

Learning time

The six modules are designed as out-of-class assignments and distributed across the semester. The first five assignments consist of a 10- to 15-minute instructional video and written reflection prompt, while the sixth is solely a written reflection assignment. The first module should be assigned a few weeks into the semester, to give students...
a chance to experience collegiate level challenges before beginning the scaffolded reflection. Because the modules are not directly linked to course content, they may be assigned in order at various intervals throughout the semester to accommodate other course time constraints.

Learning objectives

Upon completion of the full set of six metacognition modules, students will:

1. Display evidence of a growth mindset
2. Demonstrate an ability to self evaluate learning behaviors and choose effective study behaviors

Learning objectives are also provided for each individual assignment:

Module 1:

1.1 Students will begin developing self-awareness by identifying and evaluating their own beliefs about learning.
1.2 Students will begin developing self-awareness by identifying and evaluating their own behaviors that impact their learning.

Module 2:

2.1 Students will be able to connect information presented in the video to their own behaviors.
2.1.1 Students will be able to explain how their own behaviors facilitate or undermine their learning.
2.1.2 Students will be able to explain how their own behaviors may lead to false confidence in their learning of the material.
2.2 Students will be able to articulate their understanding of the complete learning cycle by applying it to a new personal academic example.

Module 3:

3.1 Students will be able to summarize the relationship between learning and neuroplasticity.
3.2 Students will be able to identify behaviors that promote neural connections.

Module 4:

4.1 Students will be able to identify that the process of connecting information by meaning is the same as the physical process of neural connection.
4.2 Students will be able to integrate the concepts of elaboration and rehearsal with the learning cycle and neuroplasticity.
4.3 Students will be able to distinguish between behaviors that promote meaningful connections within memory and those that do not.

Module 5:

5.1 Students will be able to accurately explain how their own behavior will promote elaboration.
5.2 Students will be able to accurately explain how their own behavior will promote automaticity.
5.3 Students will be able to accurately explain how their own behavior will promote overlearning.

Module 6:

6.1 Students will be able to demonstrate an understanding of the connection between their learning outcomes and behaviors under their control.
6.2 Students will explain how active strategic study behaviors will allow them to achieve learning goals.

PROCEDURE

Materials and student instructions

This series of assignments, comprised of online video tutorials and reflective journaling prompts, is designed to link information about how the brain functions to information about how memory and learning work. The videos (Table 1) and writing prompts (Table 2) are presented in sequence and scaffolded to allow students the opportunity to build knowledge from module to module while critically evaluating their own behavior and beliefs about learning. For ease of assignment, we have also included ready-to-cut-and-paste modules in the supplemental materials (Appendix 1).

For each module, students watch the tutorial video first, then reflect on and respond to the journal prompt. Students can access the links to the online video tutorials and prompts for the reflective written responses through e-mail or on their learning management system (LMS), or receive the video URLs and writing prompts on paper as a handout in class. Students will need access to the internet to view the videos. Students can submit the journals electronically through a plagiarism checking service such as TurnItIn.com, upload them to the LMS, or hand the assignments in on paper.

Faculty instructions

We created three tutorial videos for this assignment and used them along with videos from an existing sequence of online, open-access instructional videos (http://www.samford.edu/departments/academic-success-center/how-to-study). Summaries of the videos and the rationale for the writing prompts are included below, along with a summary of typical student responses. Teachers can include a short description
of the modules and their instructions in the syllabus. We suggest: “During the course, you will be given six short written assignments that you will submit as journal entries. Journal entries are expected to be at least 250 words, but no more than 400 or 500 words (~1 page double spaced) and are due on our course LMS. The focus of the journal will be you and what allows you to succeed in our course.”

Faculty should wait to distribute the instructions for the first module until a few weeks into the semester, so that students have had a chance to experience collegiate-level

TABLE 1.
Metacognition module video details.

<table>
<thead>
<tr>
<th>Module</th>
<th>Video Title</th>
<th>URL</th>
<th>Length</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Beliefs That Make You Fail… Or Succeed</td>
<td><a href="https://www.youtube.com/watch?v=RH95h36NChI&amp;list=PL85708E6EA236E3DB&amp;index=2">https://www.youtube.com/watch?v=RH95h36NChI&amp;list=PL85708E6EA236E3DB&amp;index=2</a></td>
<td>6:54</td>
<td>a</td>
</tr>
<tr>
<td>1</td>
<td>What Students Should Understand About How People Learn</td>
<td><a href="https://www.youtube.com/watch?v=9O7y7XEC66M&amp;index=3&amp;list=PL85708E6EA236E3DB">https://www.youtube.com/watch?v=9O7y7XEC66M&amp;index=3&amp;list=PL85708E6EA236E3DB</a></td>
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<td>a</td>
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<tr>
<td>2</td>
<td>The Biology of Learning, Part 1: The Learning Cycle and the Sensory Brain</td>
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<td>8:01</td>
<td>This work</td>
</tr>
<tr>
<td>3</td>
<td>The Biology of Learning, Part 2: Neuroplasticity</td>
<td><a href="https://vimeo.com/138256403/ca63c1e290">https://vimeo.com/138256403/ca63c1e290</a></td>
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<td>This work</td>
</tr>
<tr>
<td>4</td>
<td>The Biology of Learning, Part 3: Memory and Learning</td>
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<td>5</td>
<td>Cognitive Principles for Optimizing Learning</td>
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<td>a</td>
</tr>
<tr>
<td>5</td>
<td>Putting the Principles for Optimizing Learning into Practice</td>
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</table>


TABLE 2.
Metacognition module writing prompts.

<table>
<thead>
<tr>
<th>Metacognition Module #</th>
<th>Writing Prompt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Write a response after watching the videos, considering the following questions: What are your beliefs about how you learn? What was your initial answer to the question, “What is the most important factor in successful learning?” and what was your reaction to Dr. Chew's answer? Consider the study behaviors that Dr. Chew described – do you do any of these? Do you think you should change any of your study behaviors, based on what you have learned from these videos?</td>
</tr>
<tr>
<td>2</td>
<td>Consider what you learned in the video and think about how it relates to your personal experience. First, think of a situation where you learned something very well. Then, think of a situation where you thought you knew something well, but then found out you didn’t. Use your new knowledge of the learning cycle and sensory brain to explain each of those situations. What lessons can you apply that will help you succeed in this and other college courses?</td>
</tr>
<tr>
<td>3</td>
<td>In your own words, describe what neuroplasticity is, and why you should know about it as a student. Consider your study habits – what behaviors are you doing that help you to develop useful neural connections? What behaviors could you incorporate to promote useful neural connections?</td>
</tr>
<tr>
<td>4</td>
<td>Describe how the information you learned from the first two videos is related to the information presented in this video, and how you might use all of this information to your advantage to become an expert thinker. Are there behavioral changes you can make to take advantage of what we know about the brain, memory, and learning?</td>
</tr>
<tr>
<td>5</td>
<td>What in-class and out-of-class behaviors can you personally do to promote elaboration, automaticity and overlearning? For each behavior, explain why it would work based on what you learned in the biology of learning and the memory videos.</td>
</tr>
<tr>
<td>6</td>
<td>Over the course of the semester you've had the opportunity to watch videos on learning from a variety of perspectives, and may be were able to use some of the information to improve your own study behaviors. Whether you're new to college, or new to Biology, starting a new course of study can be especially challenging. Please reflect on your abilities to handle the challenge of this course and other science courses you may be enrolled in. Have your study behaviors changed over the course of the semester? Whether yes or no, please explain why or how.</td>
</tr>
</tbody>
</table>
courses for a while. The modules are sequential, and should be distributed one at a time so that students have enough time to focus on each assignment. The first five modules should be assigned during the first half of the semester, and we suggest weekly intervals. The sixth module should be reserved for nearer the end of the semester.

Module 1

- **Video assignment.** “Beliefs that make you fail... or succeed” and “What students should understand about how people learn” (http://www.samford.edu/departments/academic-success-center/how-to-study). These videos address beliefs and misconceptions about learning that students bring with them from high school. Students often have a hard time developing study methods needed for collegiate level class work, and rely instead on superficial study methods that were sufficient for success in high school.

- **The writing prompt and typical student responses.** Students reflect on what they believe about learning (how knowledge is gained), and begin the process of self-examination of their behaviors (what they do and think) in the context of what they learned from the video tutorial. Many students will reveal important background information about their past study habits; frequently, students report doing very little in high school, and may believe that success in a particular field depends on innate ability and/or intrinsic understanding. As instructors, we believe these insights are incredibly important; these beliefs of innate ability are often tied to the students’ sense of identity and are one of the driving factors of resistance to change in study behavior (unpublished results). Interventions must be sensitive to this link.

- **Notes from assessment.** In our assessment of this module, it was important to consider only statements that explicitly addressed the prompt, rather than reading into the students responses. We recognize that this approach had the potential to underrepresent students’ ability, especially those who may be weaker writers, but it results in a more accurate analysis.

Module 2

- **Video assignment.** “The Biology of Learning, Part 1: The Learning Cycle and the Sensory Brain” (this work). In this video, we describe the connection between the sensory brain (sensory input, processing of sensory information, and action) and the learning cycle (concrete experience, reflective observation, synthesis/evaluation, active testing) through the use of an easy-to-understand example that illustrates the full learning cycle.

- **The writing prompt and typical student responses.** Students are asked to pull from their own experiences: to reflect on something they learned well, reflect on something they thought they knew but actually did not, and to apply knowledge of the learning cycle to future academic experience. We hope that students are able to come away with two key points: that there is an iterative cycle to learning that necessitates active participation, and that this cycle is grounded in physical brain processes. Most students do understand these concepts in the context of past success, but have a harder time seeing the breakdown of the learning cycle when discussing false confidence (Fig. 1).

Module 3

- **Video assignment.** “The Biology of Learning, Part 2: Neuroplasticity” (this work). In our second video, we explain neuroplasticity and describe how active thought processes stimulate neurons to establish larger neural networks through dendritic connections. The concept of repeated stimulation over days, interspersed with time for anabolic growth, is highlighted by using the readily accessible analogy of muscle building in a weekend versus over a period of time. The brain is described as a physiological structure to help students understand that learning is a physical process, and that their thought processes influence physical neural connections in regions activated by what they are thinking about.

- **The writing prompt and typical student responses.** The writing prompt for this module focuses on two key ideas. First, students should understand the phenomenon of neuroplasticity and accept that they can influence their ability to make connections between what they know and what they are learning. This understanding is necessary when beginning the shift to a growth mindset. Second, students should begin to accept the idea that distributed studying in shorter sessions over a period of days or weeks is preferable to massed studying (i.e., “cramming”). The analogy of muscle building is a particularly powerful analogy for helping students to understand this concept. Some students limit their discussion to points raised in the video on the benefits of exercise and sleep. These students, in particular, would benefit from feedback following evaluation. Their responses indicate that they are on the continuum of shifting to an understanding of learning as a physical neural process, but are too focused on the fitness factor. They would benefit from feedback that reinforces the need for repeated and spaced study.
Module 4

- **Video assignment.** “The Biology of Learning, Part 3: Memory and Learning” (this work). This video provides a succinct summary of the relationship between working memory and long-term memory, schemas, and how elaboration and rehearsal allow individuals to shift from novice to expert thinkers. The video utilizes two highly accessible analogies. First, students can readily visualize moving files between a desktop (short term memory) and file cabinet (long term memory), to illustrate key differences in memory function. We then build on that understanding as they learn about schemas and explicit, declarative, semantic, and episodic memory. Their understanding of novice and expert thinking is enabled through a sports analogy: a soccer game where the players are either young children (novices) or professional athletes (experts).

- **The writing prompt and typical student responses.** The writing prompt asks students to connect the information presented in the previous two videos on the biology of learning to this video on memory. First, we want students to understand that rehearsal is analogous to the iterative process of the learning cycle, which is grounded in physical neural processing of information. Second, we hope they realize that the development of schemas and progress towards being an expert thinker rely on neuroplasticity and the growth of physical neural connections. In general, students elaborated on rehearsal and repetition and how these are necessary for forming memory, but had a harder time describing the link to physical neural processes.

Module 5

- **Video assignment.** “Cognitive principles for optimizing learning” and “Putting the principles for optimizing learning into practice” (http://www.samford.edu/departments/academic-success-center/how-to-study). In these videos, Chew first introduces levels of processing, and then contrasts studying behaviors that promote deep processing versus shallow processing.

- **The writing prompt and typical student responses.** The purpose of the writing prompt for this module is for students to begin to identify strategies they can incorporate into their own routines. Students readily make the connection that elaboration requires effort and conscious reflection on previous knowledge, but fewer link that to Kolb’s learning cycle, introduced in Module 2. Likewise, students tend to understand the role of repetition in the development of automaticity and its relationship to overlearning, but fewer make the connection to neural growth.

Module 6

- **This module does not include a video assignment.**

- **The writing prompt and typical student responses.** The final writing prompt asks students to self-evaluate and rationalize why they may or may not have made changes to their study strategies across their science courses. We are not looking for an exhaustive list, but rather to have students justify their choice of particular study behaviors.
As part of the justification, we expect that students will use the language of the videos in describing why they choose particular behaviors. Most students can describe learning from a growth mindset perspective—that is, they do not focus on external factors such as the style of textbook, teacher, or situations affecting their learning. The students recognize that their actions directly affect their learning. Students still have a harder time, however, verbalizing why they select different study behavior using the language from the videos. Our impression is that with greater feedback on earlier modules, and/or class discussions, this language will be more prevalent in the later journal reflections.

- **Notes from assessment.** In assessing students’ justification of their own study behaviors (module learning objective 6.2), we were careful to consider only explicitly stated justifications, and did not assume implicit understanding from student responses. As with Module 1, we feel this resulted in a possible underestimation of student learning in this area but a more accurate analysis.

### Suggestions for determining student learning

Assessment and grading may be completed several ways, depending on the instructor’s goals for these assignments. The most low-stakes approach to evaluation would be to assign a nominal grade for completion of the assignment. The grading rubric provided (Appendix 2) emphasizes the structure of the written assignment, while deemphasizing the quality of the content of their reflection. Faculty who wish to assess learning objectives for each of the journal assignments may use the provided assessment rubric (Appendix 3), or may merge the assessment rubric with the grading rubric to evaluate both module learning objectives and assignment compliance.

### Sample data

We have included representative student assignments in the supplemental material (Appendix 5).

### Safety issues

None.

### DISCUSSION

#### Field testing

The metacognition modules were used in their current configuration in three different sections of BIOL 150 Biological Foundations at Alfred University, a one-semester four-hour non-lab student-centered course focused on the Vision and Change Core concepts (Evolution; Structure and Function of all living things; Information Flow, Storage and Exchange; Energy and Matter Transformations; and Systems) (13). The present configuration of videos and prompts was developed over the preceding two-year period, and pilot testing was done using students enrolled during first-semester introductory biology courses at two campuses (Alfred University and Rochester Institute of Technology), as well as students enrolled in online versions of BIOL 150 over winter and summer terms at Alfred University. Data presented in this work are specific to the current iteration of the modules.

### Evidence of student learning

The majority of students completing each metacognition module approached or achieved competence on individual module learning objectives. Student achievement of learning objectives for each of the metacognition modules was evaluated using the assessment rubrics (Appendix 3) separately from grading the assignments for the course. Each researcher independently read approximately 70% of completed journals, resulting in approximately 40% of the journals being read by both researchers (intrarater reliability analysis is provided in Appendix 4). Module learning objectives (MLOs) corresponded directly with assessment rubric criteria, except for MLOs 2.1 and 4.1, which were each broken down into two criteria that were assessed independently. For journals that were read by both researchers, analysis was done using the average of the two ratings for each MLO. A composite score for each journal assignment was calculated as the mean of all the objectives assessed for that assignment. Scores could range from 0 (Unacceptable) to 3 (Acceptable Competence). MLOs were typically rated with a zero if the student did not address the prompt, and higher scores therefore indicate that students responded to some extent to the prompt (see assessment rubric in Appendix 3). A repeated-measures analysis of covariance (ANCOVA) revealed no significant differences between the composite scores for the six journals, while controlling for students’ SAT-math score and their GPA across all their classes for the intervention semester, \( F(5, 155) = 0.335, \) ns. In general, the majority of students were rated as having approached or achieved competence on all but one of the individual module objectives (Fig. 1), with at least two-thirds or more of students obtaining some level of competence in their composite score (Table 3.) We interpreted this as evidence of learning in related but separate, sequential lessons, as opposed to expecting to see increasingly higher scores across the six journals as if we were measuring the same construct repeatedly.

Metacognition modules improve students’ growth mindsets. Overall, we originally designed the metacognition modules to address issues we observed with our first-year students, specifically their strong misconceptions about the nature of learning and the effort...
required in the learning process. The modules themselves are scaffolded to link lessons on metacognition and study behavior with biological mechanisms of brain plasticity and memory, using physical processes with which students are already familiar as an analogy. This approach, which can provoke cognitive dissonance between perceived ability and physical (biological) reality, allows students to identify behaviors that they should adopt without challenging their self-identity as successful students. One way to investigate the impact of the intervention holistically across the semester is to compare the students' ability to correctly evaluate whether their original beliefs about learning facilitate or undermine their learning (represented by scores for MLO 1.1) with their ability to articulate how learning is a result of their own behavior (MLO 6.1), meaning they demonstrate a growth mindset. A repeated-measures analysis of covariance (ANCOVA) revealed a marginally significant improvement between students' scores on MLO 1.1 and their scores on MLO 6.1, while controlling for their SAT-math score and their GPA across all their classes for the intervention semester, F(1, 49) = 3.68, p < 0.06, partial $\eta^2 = 0.07$, which is a small effect size. Students were initially less competent at evaluating the impact of their beliefs on their learning (MLO 1.1 M = 1.69, standard deviation [SD] = 1.14) than they were at articulating a growth mindset at the end of the semester (MLO 6.1 M = 2.14, SD = 0.67).

### Table 3. Composite score for each module based on the average of all criteria.

<table>
<thead>
<tr>
<th>Module</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62</td>
<td>2.02</td>
<td>0.78</td>
</tr>
<tr>
<td>2</td>
<td>63</td>
<td>1.90</td>
<td>0.84</td>
</tr>
<tr>
<td>3</td>
<td>55</td>
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</tr>
<tr>
<td>4</td>
<td>60</td>
<td>1.78</td>
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</tr>
<tr>
<td>5</td>
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<td>1.90</td>
<td>0.97</td>
</tr>
<tr>
<td>6</td>
<td>57</td>
<td>2.02</td>
<td>0.72</td>
</tr>
</tbody>
</table>

N = number of completed journal assignments; M = mean composite score; SD = standard deviation.

Metacognition modules and student self-evaluation promote adoption of effective study behaviors. In addition to improving growth mindsets, we also designed the metacognition modules to help students improve their ability to self-evaluate their own learning behaviors. We did not observe a significant increase in composite scores between Module 1 and Module 6, suggesting that students were able to evaluate their own behavior to some degree over the course of the modules. In hindsight, this is not surprising. Students wrote Journal 1 after watching Chew's videos, which do an excellent job of highlighting and elaborating on several common ineffective study behaviors. Students were able to correlate Chew's examples easily to their own habits. We examined what study behaviors students reported needing to change in Journal 1, and compared it with what they reported changing in Journal 6 (Table 4). In Journal 1, most students declared that they only needed to eliminate distractions in order to do better in college. By Journal 6, students reported making an average of 2.4 behavior modifications to their study routines, and the range and sophistication of the responses reflect their greater understanding of effective study habits. For example, one-third of the students articulated their understanding that they should connect new information to prior knowledge, rather than memorize isolated facts. Furthermore, almost half of the students adopted better time management practices, recognizing that it allowed them to spend more time studying and take advantage of spacing as a study technique.

### Possible modifications

The metacognition modules were administered without instructor feedback during the pertinent semester to allow us to see the impact of the modules alone, independent of the impact of different section instructors’ styles and frequency of feedback on the students’ progress. While the modules themselves affected students’ mindset and self-evaluation of their study behavior, we feel strongly that instructor feedback, either free response or by merging grading and assessment rubrics to expand criteria related to reflection content, can only have a positive effect on student performance. Because students seem to have similar and predictable difficulty with various aspects of the assignments, an instructor could compose feedback in advance to deploy as needed to individual students, rather than writing separate statements for every student. This strategy would make using this intervention feasible even in large classes.

In his set of instructional videos, Chew presents a fifth video, “I Blew the Exam, Now What?” (http://www.samford.edu/departments/academic-success-center/how-to-study). While we did not incorporate this video in our module set, it is a good accompaniment to our modules. This video could be used in combination with post-exam reflections or exam wrap-up assignments, and could be assigned between Modules 5 and 6 to take advantage of both previous scaffolded instruction and inclusion in the final reflection.

Because students enrolled in our introductory biology course are often co-enrolled in first-semester writing classes, we did not include instruction on how to write reflective journal entries, other than providing the grading rubric prior to due dates. Depending on student writing experience and/or co-enrollments, faculty may wish to provide additional instruction on how to approach prompts and to organize a personal essay. There are a number of appropriate web resources that provide instruction in lieu of writing instructions from scratch.

The word count requirement was included in our assignment based on early iterations during module development. In the future, we are considering removing the word count...
requirement, and evaluating the journal assignments on the expanded assessment rubric. We feel that some students were too focused on length and prepared incomplete reflections as a result. Elimination of the word count and a greater focus on content may lead to a greater impact of the individual assignments.

SUPPLEMENTAL MATERIALS

Appendix 1: Module assignments
Appendix 2: Grading rubric
Appendix 3: Assessment rubric
Appendix 4 Interrater reliability data
Appendix 5: Sample student work, Journal assignments 1–6

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REFERENCES