

Helping Students to Metacognitively Read Scientific Literature With Talking to the Text

Heather G. McGray^{1†}, Ella Tour^{2†}, and Tin Ki Tsang^{3†*}

¹Life Sciences, San Diego City College

²School of Biological Sciences, University of California, San Diego

³Department of Biology, University of San Diego

[†]All authors contributed equally; names in alphabetical order.

Abstract

Reading primary scientific literature enhances students' understanding of material, increases their self-efficacy, and critical thinking skills. However, scientific articles often present multiple challenges to the students, the first among them is the unfamiliar nature of scientific texts: their high information density, formal language, and abundance of scientific jargon. In this lesson, students are taught the Talking to the Text method to metacognitively read scientific texts. The Talking to the Text method, which is part of the Reading Apprenticeship approach, enables students to have a metacognitive conversation with a scientific text, annotating it with their own questions, connections to previous knowledge, predictions, and drawings. The method is introduced through instructor's modeling, individual practice, peer interactions, and class discussions. The collaborative approach of this lesson normalizes the struggles that students face when reading complex scientific texts. We have successfully used the Talking to the Text method in an introductory biology course with diverse students who often do not have experience in reading dense scientific texts. We find that this method promotes inclusion and holds students accountable to address what they do not understand in the text. In a survey, half of the students indicated that they were still using the method at the end of the semester. Students commented that the method improved their understanding of concepts, built their metacognitive skills, and helped them connect new information with what they already know. We believe that this method can be valuable for all students who are starting to read complex scientific texts.

Citation: McGray HG, Tour E, Tsang TK. 2023. Helping Students to Metacognitively Read Scientific Literature With Talking to the Text. CourseSource 10. <https://doi.org/10.24918/cs.2023.28>

Editor: Justin Shaffer, Colorado School of Mines

Received: 8/4/2022; **Accepted:** 4/12/2023; **Published:** 8/31/2023

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Conflict of Interest and Funding Statement: This work is supported by the Biology Education Intersegmental Collaborative's (BEIC) NSF RCN-UBE grant 1920315. The NSF RCN-UBE grant was awarded to Kristine Callis-Duehl, Stanley Lo, Brian Sato, and Tara Giblin. None of the authors have a financial, personal, or professional conflict of interest related to this work.

*Correspondence to: Tin Ki Tsang: 5998 Alcalá Park, San Diego, CA, 92110; ttsang@sandiego.edu

Learning Goals

Students will:

- ◊ develop the ability to metacognitively read scientific texts.

Learning Objectives

Students will be able to:

- ◊ read dense scientific texts.
- ◊ extract critical information from scientific texts.
- ◊ annotate scientific texts to make explicit their metacognitive thinking while reading.

INTRODUCTION

Reading Scientific Texts

What makes reading scientific articles and other data-rich scientific texts so difficult for our students? Part of this difficulty lies in the high informational content, the abundance of discipline-specific jargon, and the scientific writing style that differs from expository language typical in recreational reading or more informal online texts (1–3). To support better reading comprehension and enhanced critical thinking, instructors should consider teaching students how to “read for understanding” in their discipline. By teaching our students discipline-specific reading skills early in the course, instructors can help students better use scientific texts (scientific articles and scientific textbooks) for independent learning. The objective

of this lesson is to provide students with a metacognitive tool to support independent reading of discipline-specific texts.

In order to achieve this objective, we adopted one of the methods used in the Reading Apprenticeship® approach (4), specifically the “Talking to the Text” method (5). In Talking to the Text, students conduct a metacognitive conversation with the text they are reading by annotating the text with their questions and making connections to their existing knowledge. Talking to the Text engages the students in three dimensions of learning—cognitive, personal, and social—to support students' discipline-specific knowledge building (5). Our lesson first engages the cognitive domain: students acknowledge and engage with their own thoughts while reading and then make this thinking visible through annotations. The personal

dimension is also engaged because students bring their background knowledge and interests to their reading, while building confidence as a scientific reader. Finally, students engage in the social dimension of learning as they share their thinking with peers and the instructor, getting feedback and deciphering the meaning of the text together (5).

We believe that the Talking to the Text method helps bridge a gap that the existing approaches to reading scientific texts do not address: training students to read actively and metacognitively. The existing literature on how to read scientific articles contains multiple approaches to reading the entire article (e.g., 6–13) or how to tackle specific parts of an article: for example, the “Figure Facts” template guides students through their analysis of figures and tables (14). Others describe approaches to scientific articles used by expert scientists (15, 16), or elucidate the differences between students and scientists in reading scientific articles (17, 18). However, most of these resources do not offer approaches aimed to help students with the initial challenges of reading scientific articles by developing a different, more active, and metacognitive type of reading.

The three approaches that tackle some of the initial challenges in reading scientific texts are the teaching strategy described by van Lacum and colleagues (8), the C.R.E.A.T.E. method (6, 7), and the Collaborative Annotation Project (CAP) (13). van Lacum and colleagues (8) used the cognitive apprenticeship model to help students use authors’ rhetorical moves to identify the structure of the argument that the authors are making. The Talking to the Text method described in this lesson, however, focuses on the more fundamental process of reading, helping students to develop metacognitive, active reading strategies. Similar to the Talking to the Text method, the C.R.E.A.T.E. method (6, 7) and the CAP method (13) make use of annotations. For example, in the C.R.E.A.T.E. method students are asked to draw and annotate the procedures described in the Materials and Methods sections of a paper. While also incorporating drawings, the Talking to the Text method uses annotations in additional ways. In their annotations, students are encouraged to articulate their own understanding of the text, their questions, and their predictions. Moreover, the Talking to the Text method can be used to annotate and draw visualizations of any section of an article to clarify the meaning of its text. For instance, we can use this approach to visualize a cellular process described in the Introduction section of an article. In the CAP method (13), students in a class work together to annotate assigned scientific articles; these annotations contain summaries of figures, questions, links to helpful online resources, or comments on other student’s annotations. While this collaborative process of reading an article is valuable, our method aims to help students to develop their own effective way to engage with scientific texts through annotations. Thus, we believe that the method described in this lesson can be especially useful to students who are beginning their journey in reading complex scientific texts.

Intended Audience

All students beginning to learn how to read complex scientific texts can benefit from increased metacognition during the reading process. We believe that this method is

suitable for diverse undergraduate students, ranging from non-science majors to science majors.

Required Learning Time

Two class sessions, 50 minutes each, to introduce the method. Students practice outside of class throughout the semester.

Prerequisite Student Knowledge

No prior knowledge or skills for reading scientific texts is needed.

Prerequisite Teacher Knowledge

To teach this lesson, the instructor needs to be familiar with the Talking to the Text method. We highly recommend watching our [modeling video](#) to familiarize yourself with the method. We also recommend practicing Talking to the Text out loud before modeling it in the classroom. Instructors should be able to display or project real-time notetaking to a class using a tool such as a document camera. Lastly, we suggest that instructors review common note-taking methods (e.g., Cornell Note-Taking System, SQ3R method) to prepare for the in-class discussion about the differences between those methods and the Talking to the Text method.

SCIENTIFIC TEACHING THEMES

Active Learning

Active learning is incorporated into this module in the following ways:

- The reading process is changed from passive to active by using the Talking to the Text method.
- Students engage in multiple peer discussions—an active learning method that has been demonstrated to improve conceptual understanding (19).
- Students reflect on the effectiveness of their own and Talking to the Text reading strategies and share their observations with a partner, thus practicing metacognition—an important component of active learning (20).
- Whole-class discussion about the challenges of reading scientific texts normalizes these challenges and allows students to learn from each other’s strategies of reading scientific texts.

Assessment

At multiple times throughout the semester, students are asked to read and annotate complex scientific texts. Their annotations are submitted electronically as part of the course homework. Because annotations can be highly personalized (they are someone’s personal thoughts and notes), we do not assess the quality of annotations with grades. Instead, to support continual improvement of the annotation technique, we provide feedback either by addressing common annotation challenges in class or individually, using a rubric (Supporting File S1). Both types of feedback address the quality of students’ annotations along several parameters. However, we discourage the use of a prescriptive method (trying to check all the boxes), or the use of the rubric as a summative assessment or for “points.” Some annotations should include all elements, others may not need to. Some students make meaning better through pictures and others through equations or writing.

Key concepts from the reading are also assessed in quizzes and exams, typically using multiple choice and short answer questions.

Students self-evaluate the effectiveness of their pre-existing method of reading scientific texts and the Talking to the Text method in two surveys, one administered shortly after the method is introduced and the other administered at the end of the semester (Supporting File S2).

Inclusive Teaching

The lesson described here promotes inclusion in several ways:

- It normalizes the struggles of reading challenging texts by having the instructor demonstrate the method using a text outside of their area of expertise, and students discussing the challenges they experience in pairs and as a class. This relieves the pressure to “be perfect” and to “know everything” about the text. The collaborative nature of this lesson aims to foster an environment in which students feel safe to acknowledge their challenges and to get support (21).
- It empowers students to use their own knowledge, cultural background, and lived experience to make their own, individual meaning of the text. Students learn to follow up and find answers to their questions about the text, promoting their sense of self-efficacy and belonging in science (22).
- The multiple ways in which the Talking to the Text method is demonstrated (instructor’s modeling, working in pairs, class discussions, independent work) aim to reach students with diverse learning preferences.
- The Talking to the Text method empowers students to reflect upon and develop their own way to make meaning of the text through annotations. In alignment with a principle of the Universal Design for Learning (UDL) (23), students can express their understanding of the text through a variety of ways, such as drawings, using their primary language in their annotations, or symbols that hold meaning for the student.

LESSON PLAN

Lesson Overview

We provide instructions for the introduction of the Talking to the Text method: two days of in-class practice followed by out-of-class assignments (Table 1).

Materials

- A scientific article or textbook reading that can be used for sessions 1–2. This text often includes a scientific figure or a graph (Supporting File S3).
- Course readings that can be used for out-of-class practice throughout the semester.
- A method to broadcast instructor’s note taking to a projector or live digital feed (e.g., a document camera or a tablet with note-taking capabilities).

We encourage instructors to use paragraphs from the scientific texts that they would typically assign as course readings. In selecting the text, instructors should be mindful

of the amount of the background knowledge needed to understand the text: the text should include concepts, ideas, experiments, or data analysis that are challenging to the students, but that can be dealt with some support from the peers and the instructor.

Class Session 1: Introduction of the Method

The goal of the initial activity is to have students reflect on what works and what does not work about their own method of reading scientific texts (Supporting File S4). First, students are asked to identify their current reading method by imagining themselves reading a science textbook or a scientific article (see Supporting File S4 for specific prompt). Importantly, to elicit an honest response, students are encouraged not to judge themselves. Students are then asked to use their current approach to read a brief (one paragraph to one page long) scientific text that is new to them. We recommend that instructors choose the assigned reading based on its relevance to course content. If the student’s reading approach includes note taking, they are encouraged to do so. After students complete this task, they are asked to reflect on and write about what worked and what did not work using their approach to understand this text. Next, students are asked to share their reflection with a partner; this sharing can be followed by a whole-class discussion that helps elucidate common challenges. These challenges typically include: understanding scientific jargon, connecting concepts in the text to students’ previous knowledge, understanding and interpreting visualizations of data, comprehending experimental procedures, and feeling frustrated with their own lack of understanding (i.e., the text is “too hard”).

Having established the need for some modification in students’ current reading method, the instructor models the Talking to the Text method. To do this in a way that is close to students’ experience, the instructor selects text (typically one paragraph long) from a scientific article from outside of the instructor’s area of expertise. The instructor reads the text/paragraph out loud while simultaneously verbalizing their thinking about the text and making annotations to record their thoughts (see our [Modeling Video](#) and Supporting File S5). It is important to emphasize that the Talking to the Text method is actively engaging in conversation about what you are reading and literally write or “talk through” the ideas within the text as you read.

The following are examples of what the instructor would do while modeling Talking to the Text:

- Acknowledge when context clues give you information (e.g., “The font is bigger and bold and at the top of the page, so I think that is the title of the article”).
- Don’t skip things you don’t understand. State that you don’t understand it and write a “?” or a note to yourself to return to this.
- Write a brief summary next to the things you understand.
- Underline vocabulary words or words you need to look up. Define them in your own words.
- Make predictions and write them down.
- Visualize things by drawing pictures of them.
- Rewrite in your own words.

- Use arrows to make connections between things.
- Identify big picture ideas.

After the instructor's demonstration of Talking to the Text, students are asked to read the same text they read in the beginning of this lesson, while applying the Talking to the Text method (Supporting File S4). After completing this activity, students again are asked to think metacognitively and reflect on the benefits and challenges in understanding the text while using the Talking to the Text method. Next, students are asked to share their reflection with a partner; this sharing can be followed by a whole-class discussion that helps elucidate common challenges.

Some questions that can help promote metacognition in this discussion are:

- "How did you know when you had difficulty understanding something? What did you do when you didn't understand?"
- "Why did you say that?"
- "What was especially interesting for you?"
- "Did anyone else have a similar problem?"

Class Session 1: Homework

The instructor assigns course reading for homework. The reading should take 30 minutes to 1 hour to complete. Students are asked to submit their Talking to the Text annotations on the reading before class. This assignment prepares students for the activity in the next class period, acclimates students to completing active reading before class, and provides the instructor time to review students' annotations. Based on a review of the submissions, instructors can alter the session 2 lesson plan to include a class discussion of improvements or modifications. We consider this a formative feedback stage and do not assign scores to the student annotations. Alternately, instructors could provide written feedback to individual students with a formative rubric (Supporting File S1).

Class Session 2: Partner Practice

The goal of session 2 is to get additional practice with the Talking to the Text method while the students both give and receive peer feedback. One of the more challenging, but very useful, methods in Talking to the Text is to draw out concepts or experiments to help visualize them. Instructors can select the assigned reading for session 2 such that students can specifically practice the "draw it out" method. Readings that include experimental design or procedures are particularly well suited for this purpose.

Session 2 starts with a class discussion of the benefits and challenges the students experienced while completing the homework. Based on the instructor's review of the homework, the instructor then provides feedback to the class on how to improve their reading approaches. The instructor should explicitly highlight specific elements of the method that need improvement. Typically, these elements include making predictions, drawing it out, and identifying big picture ideas. We often need to encourage students to move away from underlining and highlighting to writing down their thinking in the annotations.

Next, students are assigned partners and asked to apply the Talking to the Text method to read in pairs (Supporting File S6). Each student is assigned around 1–2 paragraphs of course material for their reading. The first partner practices Talking to the Text out loud, while the second partner makes the annotations based on what the first partner is saying. This activity makes a student's thinking visible to the partner. We find that students often ask their partner to explain or rephrase their thinking. This communication helps both students to make meaning from and to better communicate their thinking about the text.

After the first partner reaches the end of the assigned reading, the second partner is asked to share what they noticed about the first partner's thinking. Here are some sample instructor prompts to facilitate student discussions:

- What was interesting about what your partner did?
- Was there a pattern to your partner's approach?
- Did your partner overcome any challenges while reading?

After the discussion, the partners switch roles. Once both partners have completed the activity, we initiate a class discussion. Students share the parts of Talking to the Text that are the most beneficial to them (Supporting File S6).

Additional Activity: Practice Drawing It Out (Optional)

After the second partner has finished their section, students are asked to work with their partner to draw out the experimental method (if one is described in the reading) (Supporting File S6). Students typically find this challenging, and you may need to guide them on how to start. For example, you may suggest the diagram they draw should look like a flow chart, or that students should draw differences between the experimental treatments. Ask students to share their drawings on the board and have the class discuss the strengths of each drawing. During this time, we do not critique students' drawing, because the goal of this activity is to use each drawing's strengths to come to a collective idea of what a high-quality drawing may look like.

Class Session 2: Homework

The goal of the homework is to give students an additional opportunity to practice the Talking to the Text method and receive feedback. The instructor assigns course reading for homework. Students are asked to submit their Talking to the Text annotations on the reading before class. Instructors should provide written feedback on each student's notes to encourage deeper thinking and meaning making.

We recommend that instructors assign course readings for independent practice at least the first couple weeks of class. Students complete Talking to the Text and submit their annotations to receive instructor feedback. This will support the development of high quality Talking to the Text annotations and promote active preparation for class discussion. For example, in our classrooms, students submitted their annotations weekly to receive credit for class preparation and to get instructor feedback throughout the semester (Supporting File S1).

TEACHING DISCUSSION

Instructor's Reflections on Lesson Outcome

This method was implemented over multiple semesters of an Introductory Major's Biology course at a Hispanic Serving Community College, with a highly diverse student population (66% URM, 32% first-generation to college students). The instructor (HM) noted the following benefits of Talking to the Text method:

- Promotes inclusion in STEM by teaching students an approach that leverages their strengths and knowledge
- Empowers students to actively engage in reading and making meaning
- Requires students to address what they don't understand in the text (as opposed to ignoring it)
- Builds students' metacognitive skills
- Normalizes the challenges of reading in STEM
- Provides a starting place for students to improve their STEM reading skills

Students' Reactions to the Lesson

In a survey administered right after the method was demonstrated, close to three quarters of the students said they were planning to use this method when reading in this course. When a similar question was asked in the survey administered at the end of the semester, half of the students said they were still using the method or parts of the method in their reading.

We noted several themes in students' reflections about the effectiveness of Talking to the Text:

- Led to better conceptual understanding
- Improved metacognitive skills: e.g., realization of what they don't understand in the text
- Helped relate new ideas to the information they already know
- Flexibility of the method: students modified the Talking to the Text method to suit their needs

Students also noted a few challenges they experienced with Talking to the Text:

- More time consuming than their pre-existing method of reading
- Not helpful when the text is very challenging
- Discomfort in using Talking to the Text on their own, without a partner
- Preference for or attachment to, their own pre-existing method of reading texts

Adaptations

This lesson has been used successfully by one of the authors (HM) in an in-person Introductory Major's Biology course at a community college with a class size of around 24 students. Another author (TKT) successfully adapted this method to an online synchronous version of the same course, using Zoom breakout rooms for peer activities. We believe that this method can also be implemented in larger classrooms, provided that the instructional team can review the student annotations and provide feedback (individually or to the whole class) in a timely manner. We envision that Talking to the Text can also be implemented in a hybrid format, where the instructor's

demonstration of the method and the students' initial annotations are done as a homework activity. Afterwards, the peer activities, whole-class discussion, and instructor's feedback should happen synchronously. We do not believe that Talking to the Text can be effectively introduced in an asynchronous environment, because students need to share their thinking process with their peers and receive feedback in real time.

If the instructor had limited time in the classroom, the first activity in Class Session 1 can be assigned as a pre-class assignment in which students are asked to read an assigned text with their current reading strategies. The instructor can also ask students to write about the benefits and drawbacks of their reading strategies in the pre-class assignment. The Class Session 1 lesson can be used to teach the content of the course by asking students to read a section of a relevant scientific text (e.g., scientific article, textbook, government report).

Talking to the Text is a method used in the Reading Apprenticeship approach that is designed to be applicable to texts in any discipline. Therefore, this is a skill that can benefit students in other courses and throughout their lives.

SUPPORTING MATERIALS

- S1. Talking to the Text – Feedback Rubric
- S2. Talking to the Text – Survey Questions
- S3. Talking to the Text – Suggested Readings
- S4. Talking to the Text – Class Session 1 Slides
- S5. Talking to the Text – Annotated Text Example
- S6. Talking to the Text – Class Session 2 Slides

ACKNOWLEDGMENTS

We thank Stu Matz for contributing to the conception and the early development of the project. We are grateful for the mentorship and advice that we have received from Kristy Daniel. This work is supported by the Biology Education Intersegmental Collaborative's (BEIC) NSF RCN-UBE grant 1920315. The NSF RCN-UBE grant was awarded to Kristine Callis-Duehl, Stanley Lo, Brian Sato, and Tara Giblin.

Table 1. Lesson timeline. The lesson takes two 50-minute class sessions and outside of class time for student preparation and homework. Suggestions for adaptations are noted in the Teaching Discussion section.

Activity	Description	Estimated Time	Notes
Student Preparation for Class			
Download the textbook or scientific paper	Ask students to download the textbook or scientific paper.	5 minutes	This step is optional if the instructor is providing the reading as a handout in the classroom.
Class Session 1 (50 minutes)			
Student reflection on their reading techniques	Guide students to reflect on their current reading techniques to a piece of text, then apply the approach to read ~1–2 paragraphs of the assigned text.	5 minutes	Lecture slides with notes are in Supporting File S1. Alternatively, this can be assigned as homework to be completed before class.
Partner discussion about approaches	Assign each student a partner, and have them discuss the strengths and challenges of their approaches in understanding what they read.	5 minutes	Lecture slides with notes are in Supporting File S1.
Class discussion about approaches	Lead a class discussion to get students feedback on techniques that do or do not benefit reading for understanding.	5 minutes	Lecture slides with notes are in Supporting File S1. Common student responses are indicated in the notes section of the slides.
Introduce Talking to the Text	Instructor introduces and models Talking to the Text with annotations. Instructors should display annotations to the class in real time using a document camera or other display method.	10 minutes	Lecture slides with notes are in Supporting File S1. Video example of this approach is here . Example of an annotated scientific article is in Supporting File S2. Instructors should choose an example paper that they have a hard time understanding to best simulate the student's experience.
Students practice Talking to the Text	Students practice Talking to the Text method, re-reading the ~1–2 paragraphs of the assigned text.	10 minutes	Lecture slides with notes are in Supporting File S1.
Student reflection	Students reflect on the benefits and challenges of using Talking to the Text to read for understanding.	5 minutes	Lecture slides with notes are in Supporting File S1.
Class discussion	Instructor leads class discussion on the successes and challenges of using Talking to the Text.	10 minutes	Lecture slides with notes are in Supporting File S1. Common student responses are indicated in the notes section of the slides.
Independent Student Homework (after Class Session 1)			
Apply Talking to the Text to assigned reading	Have students complete a reading using Talking to the Text. Students submit their annotations/notes, and the instructor provides feedback before the second Class Session.	1–2 hours depending on the length of assigned reading	Suggested rubric in Supporting File S3.

Activity	Description	Estimated Time	Notes
Class Session 2 (25–50 minutes)			
Class discussion about independent practice	Instructor leads a class discussion to get students feedback on techniques that do or do not benefit reading for understanding	5 minutes	Lecture slides with notes are in Supporting File S4.
Students practice Talking to the Text in pairs	Students practice Talking to the Text approach in pairs	20 minutes (10 minutes per student)	Lecture slides with notes are in Supporting File S4.
Draw it out practice (optional)	Students work to develop a diagram to visualize an experimental method or other aspect of the assigned reading	25 minutes	Lecture slides with notes are in Supporting File S4.
Independent Student Homework (as many times as needed after Class Session 2)			
Apply Talking to the Text to assigned readings	Have students upload their Talking to the Text annotations on assigned readings. Instructor provides feedback before the next class period.	1 hour	It is beneficial for students to practice Talking to the Text repeatedly throughout the semester. Asking students to submit their annotations regularly holds them accountable and allows the instructor to provide continuous feedback. The annotations are graded based on completion instead of the quality of the annotations. Suggested rubric in Supporting File S3.

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