Improving Scientific Literacy through a Structured Primary Literature Project

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Abstract: Emphasizing scientific literacy in the core science curriculum promotes informed students within a liberal arts education. In our Introduction to Biology course, which enrolls predominantly humanities majors in their final science course of their academic careers, we designed a project to advance these analytical processes through the deliberate dissection of primary literature. This project, completed over the course of one semester, includes both a written analysis and an oral presentation of a primary scientific article of the students' choosing. The students are guided through this iterative process from article selection to the completion of products. Within this work we detailed the objectives and created complementary tools to stimulate the progression of higher order cognitive skills and assist faculty in assessing the interpretations of applied biological concepts. Surveys from faculty and students suggest that this project and its supporting materials are useful to improve scientific literacy and improve critical thinking skills. Whether the audience is non-STEM majors or scientific minded persons, this project can be utilized to enhance critical analysis skills. Overall, we found this student-led group activity allowed for exploration of the scientific process outside of the classroom environment, which facilitated a more hands-on approach to developing increased scientific literacy in undergraduate students.

Key words: scientific literacy; metacognitive progression; scientific communication; primary literature analysis

INTRODUCTION

Increasing scientific literacy is an important goal in undergraduate science courses (Gormally et al., 2012). Rather than memorizing facts and information, applying knowledge through critical analysis stimulates higher-order cognitive skills (Zoller, 1993). These skills reinforce course objectives and support the assessment of a deeper conceptual understanding. It is this understanding that can be applied in a larger context for students to exercise metacognitive skills when examining scientific literature. Biological courses can cultivate informed decision makers by practicing skills in scientific interpretation and communication (McPhearson et al., 2008).

Critical thinking requires students to move beyond consumption of knowledge and into the analysis, evaluation, and synthesis of ideas. Faculty can foster these skills when training students to evaluate and discriminate the components of primary literature. Some have approached this goal by achieving information literacy in biology (Porter et al., 2010) by analyzing published data and discoveries from one particular laboratory over a period of years (Hoskins et al., 2007). Others have integrated a cell biology laboratory project with a literature analysis (Woodham et al., 2016) or drawn conclusions from figures in a specifically assigned paper (Round & Campbell, 2013). These and others have demonstrated that upper-level biology courses benefit from the incorporation of primary literature module threads (Sato et al., 2014) or discipline specific article dissection (Kovarik, 2016). While this concept of literature analysis is not entirely new (Gillen, 2007), our study concentrates on the deliberate progression of critical thinking skills (reading, evaluation, and synthesis) and strategic communication in a topic which may be otherwise unfamiliar to students. Previous work mentions the general gap of comprehensive tools to assess these guided development strategies to enhance higher cognitive learning (Crowe et al., 2008). Studies have examined this process in biology major courses (Varela et al., 2005), but few have implemented this universally in a predominately non-science majors population. We sought to address this gap in an introductory biology course, an audience of primarily humanities majors, by designing a semester-long project to deliberately dissect primary scientific literature and communicate findings in oral and written forms.

Table 1. Assessment mechanisms of taxonomy progression. Students advance their analytical skills through specific actions during this project. [Select actions modified from Bloom's-based Learning Activities for Students (Crowe et al., 2008).]

Goal: Cultivate critical thinkers who can solve ill-defined problems	
Cognitive Progression	**Key Action**
Knowledge/Comprehension	• Identify & define key terms • Describe background and experimental design in own words
Application/Analysis	• Create flowchart or diagram to summarize a key experimental method • Assess effectiveness/appropriateness of statistical methods and analytical tools used
Synthesis	• Generate a new hypothesis or propose additional experiment
Evaluation	• Prepare a written & verbal assessment of the article analysis

We exposed students to primary literature through a highly-structured analysis on an article of their choosing. The objectives of this small group project, accounting for 11% of the total course grade, were detailed in hand-outs and grading rubrics provided to all students (Appendix 1) at the beginning of the course. Students were to summarize and identify the purpose of the study, outline a key method to examine, and evaluate the experimental design. This assessment of higher order thinking skills, in a step-wise manner to maintain student engagement, can further scientific comprehension and application. With the goal of improving strategic communication, this capstone project concluded with an oral presentation, geared towards improving applied scientific literacy.

MATERIALS & METHODS

Development of the Project & Guidelines

As the American Association for the Advancement of Science describes, the scientific competencies of applying the process of science and effective communications should be practiced in a variety of oral and written methods as "a standard part of undergraduate biology education" (Brewer & Smith, 2011). Embedding contemporary research articles into a biology course is one such mechanism to develop these competencies. Our program goal is to cultivate critical thinkers who can solve ill-defined problems. Problem solving requires an initial factual foundation, the ability to design an experimental strategy, and assessing whether the approach was appropriate to address the research question (Sensibaugh et al., 2017). Thus, we used published research as a means to practice the scientific process.

We approached enhancing metacognitive skills by building on the Blooming Biology Tool (Crowe et al., 2008), which describes this progression from describing or summarizing concepts in lower-order cognitive skills to higher-order interpretations of data. Students began by examining the relative merit of the selected study by analyzing whether the experimental design was a suitable test for validating the hypothesis. Through the deliberate guided progression from knowledge to the synthesis and evaluation of materials, we desired to establish a mechanism to practice critical thinking skills. Table 1 illustrates this progression beginning with the initial description of the experiment in students' own words. Students were encouraged to relate course knowledge to experimental descriptions, conditions, or variables encountered in the classroom. The generation of a concept map or chart focused on one key method required synthesis and using higher-level cognitive skills. Additionally, directed comments on the statistical models encouraged inter-disciplinary STEM applications. Finally, the synthesis of the chosen study and the generation of a novel hypothesis and follow-on experiment moves students from consumers to producers of knowledge. Each of these activities are included within this project to guide the cognitive progression of scientific literacy. As further described in Appendix 1, the assessment of student progression and performance is prescribed in both narrative form and a rubric, available to all students and faculty during the first class. The second objective was to communicate this analysis in written form. Through this product, faculty can identify significant misconceptions that students have on topics or improper interpretations or conclusions from a particular experiment. In partnership with our Writing Center, faculty can also identify students who struggle with written communication and provide additional resources early within the student's academic progression to address shortfalls. The final goal was for students to present scientific data to their peers during in-class presentations at the end of the course. Thus, students could apply their course knowledge using the selected study as a vehicle to summarize, dissect, and critique or propose further lines of investigation. Together, these goals sought to advance scientific communication and literacy.

Study population and classroom implementation

In an undergraduate biology course for non-majors, students often have little experience in reading primary scientific literature. The majority of our students (n = 550) were first or second year humanities majors enrolled in a one-semester undergraduate biology course over the period of one academic year. Prior to the study, exemption was granted by USMA IRB CLS17-001. Students were randomly divided between fifteen sections each semester consisting of 16-21 students. Nine faculty were allocated to teach the course, six senior doctoral faculty with more than five years of experience, and three junior faculty with masters' degrees and less than five years of experience. Senior faculty taught one to two sections per semester while junior faculty instructed three to four sections.

Over the course of the semester consisting of 40 lessons and 8 laboratories, students were required to select and analyze one primary literature article in a topic of their choosing. Faculty familiarized students with the project during the first lesson by providing detailed handouts and grading rubrics (Appendix 1), standardizing the expectations and assessment over the course of the semester. The project was divided into four portions: 1) article selection; 2) written analysis; 3) slide submission; and 4) oral presentations.

Assessment

1) Assessment: group designation and article selection

Groups were self-designated on sign-up sheets, available within Appendix 1 (Enclosure 1). Students worked in groups of two to three with their initial task to select a primary literature article. While the article topic was not prescribed, article selection was accomplished early in the semester to verify primary sourcing as well as the feasibility for the target audience. Students were encouraged to choose a topic of interest; written in a manner they were able to understand and interpret.

A common issue for our cadets, 78 of 550 students, was difficulty identifying primary literature. Instructors stressed examples of primary literature in class and shared tips on searching the library databases. While article selection was a low stakes event, a ten-point allocation, it was useful for faculty to both confirm that the article was primary research and that it was to a level of which non-science majors would be able to interpret. Five points (of the 10) were designated for providing a copy to the instructor for review by the designated time with the remaining five points for the article being from primary literature. Once instructors confirmed the selection of a primary article the groups were directed to proceed with their analysis over the course of the semester.

2) Assessment: written analysis

Students had the first half of the course to read and reflect on their chosen article in preparation of their written submission. Instructors used the rubric (Appendix 1, Enclosure 2) to assess student analysis and interpretations. In an iterative fashion, these comments and rubrics were returned to students to incorporate in the preparation of a slide packet for oral presentations at the end of the course. The writing assignment was challenging as most students had not previously assessed primary literature and even fewer had communicated scientific findings in written form. Faculty assessment was facilitated by rubric criteria considering the level of insight and thoroughness of their effort. The written analysis was divided into sections worth 125 of the total 220 project points. Students were specifically directed to address the article organization, hypothesis, references, introduction, and study design. An in-depth analysis of one key method and materials allowed groups to explore the findings, statistics, and the biological relevance of the results. Importantly, students examined the interpretation and potential bias or issues within the study as they generated a novel hypothesis and experiment to continue the work. A memorandum with instructions for each of these sections assisted students in viewing the article in a scientific context (Appendix 1). Enclosures within this appendix further specify the content and grading of each category specified within the instructional memorandum. For example, in summarizing the article abstract, students were tasked to describe the article in common terms as if they were speaking to nonscientists. When identifying the hypothesis, students referenced course material in an effort to tie classroom instruction to their project. As the materials and methods section can be unfamiliar to non-science majors, students selected one key method and created a flowchart describing this method.

Keeping the focus on the scientific question, students dissected the study design, results, and discussion sections. We were interested in the "how" and included specific questions and guidance to avoid students simply paraphrasing the corresponding sections. For example, in the results section, students identified a key figure and explored the statistical tests performed by the authors and the main findings. They could apply their mathematics coursework and determine if the tests were appropriate. Within the discussion section, groups considered the coherency of the author's story, how easily they were able to interpret results, if they felt the study supported author's claims, identified new questions that emerged, and made suggestions on how to address those questions in future experiments.

3) Assessment: slides

The slide assessment was subdivided into slide submission and instructor assessment, specified within Appendix 1, Enclosure 3. Five points were specified for the timely upload of slides. Fifty points were allocated for the quality and content of the slides themselves. Students were assessed not only on the overall design and appearance but also in how they summarized their article analysis findings. Groups consolidated their ideas on the scientific

	Select Article	Written Analysis	Oral Presentation	Slide Upload	Slide Assessment
Max Points	**10**	**125**	**30**	**5**	**50**
Average (pts)	9.2 (+/- 1.3)	113.3 (+/- 9.3)	27.5 (+/- 1.5)	5.0 (+/- 0.1)	46.7 (+/- 2.0)
Average %	92.4%	90.7%	91.6%	99.1%	93.3%

Table 2. Student performance on the five specific graded portions of the project. Average scores for each portion are shown (+/- standard deviation of the average) along with the average percentage for that event. (n=183 groups totalling 550 students over the course of two semesters).

design and approach as they described the hypothesis, experimental methods, and results. Finally, groups proposed a future experiment and novel hypothesis for the respective field.

4) Assessment: oral presentations

Presentations received a maximum of thirty points with criteria focused on the clarity of their talk, overall bearing, and the incorporation of figures. Specifically, the focus was to communicate findings by integrating their ideas and figures with seamless transitions between members of the group. The final criterion was whether students adhered to the established time limits.

Collection of data

Data collection on student performance for each category of the project was extracted from the Academy Management System (AMS) database, an internal Academy grading system (West Point, 2017). Instructors separately entered scores for the article selection and verification of primary literature (10 points); written analysis (125 points); slide upload (5 points); slide assessment (50 points); and oral presentation (30 points). Results are shown in Table 2. All students within the same group received the same scores. Similarly, student responses to end-of-course feedback survey questions (Table 4) were anonymously collected within AMS. Data regarding the strength of agreement to question prompts was automatically compiled from all responses.

The instructor assessment of this project was through faculty surveys on a scale of 1 to 5, with five being the most effective. This survey focused on whether students were able to distinguish primary literature and apply the scientific method before and after the project (Table 3). Additionally, faculty were asked to describe the usefulness of the provided rubrics and instructions and whether this project was effective at improving literacy and critical thinking skills.

RESULTS

Within our study, students who followed the guidance and assessment metrics scored very well (Table 2). Students that lost points did so mainly for not clearly answering questions or omitting answers entirely. Points were also deducted for misinterpreting data. Instructors assessed and returned feedback on the written submissions (90.7% +/- 7) to the groups (n=183) prior to their presentations. Improved adherence to rubrics evidenced an increase in the average scores for the slide assessment (93.3% +/- 6) and for oral presentations (91.6% +/- 2) compared to the written submissions. With a variety of topics covered, oral presentations stressed the importance of conveying

Table 3. Instructor assessment of Article Analysis Project. Faculty were surveyed on a scale of 1 to 5 for their responses to questions indicated. (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5= strongly agree). Average scores are reflected (+/- sd, n=7).

Students were able to:	Prior to Project	After Project
Distinguish primary literature	2.5 (+/-0.5)	4.0 (0)
Apply the scientific method	2.2 (+/-0.2)	4.0 (0)
Project Design		
Students self-selecting topic was useful		5.0 (0)
Grading rubrics were useful for assessment		5.0 (0)
Instructions were sufficient for students		4.5 (+/-0.5)
Project is effective in improving scientific literacy		4.5 (+/-0.5)
Project is effective in improving critical thinking skills		4.5 (+/-0.2)

Table 4. End of course feedback. Students were surveyed at the end of the course as to their thoughts on learning attributable to their instruction (n=279 students).

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
This instructor encouraged students to be responsible for their own learning.	151	115	12	1	0
This instructor used effective techniques for learning, both in- and out-of-class assignments.	129	120	21	7	2
In this course, my critical thinking ability increased.	94	109	55	17	4
After taking this course, I can apply multiple disciplines to solve ill-defined problems.	115	126	32	6	0

scientific findings in an understandable manner to increase awareness (thus scientific literacy) for the subject at hand. The slide decks were also assessed on timely upload to our server (99% +/- 1). The presentation was limited to ten minutes and the audience was able to ask the group questions at the conclusion. The ability of students to answer questions was considered in the student's final presentation grade.

A secondary mechanism to assess improvement in scientific literacy was through course-end feedback. Faculty surveys suggest that the ability to distinguish primary literature and apply the scientific method increased following project completion (Table 3). While the faculty survey is limited to our internal cohort, it would be of interest to see how similar institutions apply this project and assess the usefulness of provided informational tools and rubrics. Faculty that penalized cadets for not adhering to published project guidelines or submitting secondary items provided the baseline for the pre-project ability to distinguish primary literature. Preliminary faculty feedback suggests that this project is an effective approach to improve scientific literacy and critical thinking skills. Additionally, in free-response text, instructors noted that students who chose topics that interested them or selected articles written in a manner they could interpret were more enthusiastic and appeared more comfortable answering questions during their oral presentations. Students (Table 4) were surveyed on their improvements in learning throughout the course and their ability to solve complex, ill-defined problems. While the faculty feedback directly relates to the project, it is possible that student gains or motivation are due to unrelated aspects of the course.
on learning attributable to their instruction (n=279 students).

DISCUSSION

Reports have suggested that biology curriculums need to promote critical thinking using primary literature (Tabor & Jakobsson, 2004 and Varela et al., 2005). Building on preliminary coursework, this guided approach provides the framework for students to apply preliminary coursework in a biological topic of their choosing, following the scientific process from the original question to conclusions. With careful consideration of the methods employed, as well as any bias or statistical implications, students become informed readers rather than passive consumers of knowledge.

We found this student-led group activity allowed for exploration of the scientific process outside of the classroom environment, which facilitated a more hands-on approach to developing increased scientific literacy. Moreover, this project encouraged the progression from lower- to higher-order cognitive skills. In the future, we plan to incorporate this into our advanced biology courses for STEM majors and suggest that it can be adopted by courses desiring to improve analytical skills and promote scientific literacy.

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NOTE TO EDITOR

The work was reviewed and approved as exempt under IRB USMA DCLS 17-001. The views contained within are those of the authors and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the US government.

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SUPPLEMENTAL MATERIAL
APPENDIX 1. Analysis of Primary Literature Instructions with Grading Rubric

Memorandum of Instruction for Improving Scientific Literacy through a Structured Project
Subject: Primary Literature Project Guidelines for Introduction to Biology

1. Scientists publish and distribute their experimental findings and conclusions from original experiments in primary research. Authors describe how their research is relevant to the scientific community and propose future experiments. These articles undergo a peer review process, where editors and other scientists evaluate the soundness of the experimental design and interpretations along with relevance and novelty within the field. In contrast, secondary literature or sources are items that summarize primary literature through review articles and meta-analyses. Secondary sources can include magazines, textbooks, or websites. While these may be trusted sources, they do not meet the criteria for primary literature.

2. Review articles (secondary literature) are a great place to begin research and often summarize several aspects of primary literature, presenting them in one location. One must, however, take this analysis and go to the referenced primary source(s) before formal conclusions can be drawn, based on experimental data.

3. This is a group project, no more than three students per group. Each student within the group will receive the same grade for all submissions. This project is subdivided into four objectives: 1) Identify formal groups. 2) Select one primary research article and provide a copy to your Instructor via SharePoint. 3) Perform an analysis and prepare written products further described below. 4) Prepare and present your analysis to the class.
Students are encouraged to choose a topic that interests them and an article written in a manner you are able to understand and interpret. To determine your topic of interest, it is useful to scan the table of contents of journals such as Cell or Nature. Following topic selection, there are several databases to begin searching for relevant articles. While not all inclusive, databases such as PubMed (www.ncbi.nlm.nih.gov) or Science Direct (sciencedirect.com) allows one to query journals which offer free access to recently published articles. The specificity of search terms will increase the targeted return of relevant articles. For example, someone interested in fungi could enter "white nose fungus in bats" as opposed to "animal fungus". Ideally, specific search criteria will yield several articles to further interrogate. Access to some primary articles require coordination through library resources. Allow adequate search time or seek freely available articles for the project.

4. The grading rubrics are available as enclosures. These identify the assessment criteria for the article analysis and slides for the in-class presentations.

5. Each group will examine a primary article on a biological topic of their choosing and prepare a written commentary, according to the following specifications. Points will be assessed, as indicated below in parenthesis, and according to the grading rubric located at Enclosure 2. In addition, five points will be assigned for overall format and aesthetics and five points for appropriate citations (internal and works cited). The use of passive voice, misspellings, and grammatical errors will result in additional point deductions in the sections in which they appear.

A. *Title & Abstract. (5 points) Read the abstract and summarize the main idea and purpose of the paper using your own words in 2-3 sentences. Use common terms as if you were talking to a family member or friend.*
B. *Problem Statement/Hypothesis. (5 points) Referring to Lesson 1, describe whether this was discovery science or hypothesis-driven science. In your own words, identify the hypothesis. State the problem and question within the field this work attempts to address/answer. Be specific as articles often seek to examine one small aspect of a very large field.*
C. *Reference Section. (5 points) Examine the reference section of the article. Are the author(s) citing their own previous work(s) or current work of other scientists? Are there any disclosed or perceived conflict(s) of interest?*
D. *Introduction. (10 points) This is where background information is presented for those who may be unfamiliar with the area. In no more than one paragraph, summarize the key background information regarding the topic.*
E. *Terms. (5 points) Within the Introduction, identify and define five key terms that are used. These terms should be vital to understanding the paper and your analysis.*

F. *Overall Study Design. (15 points) 1) How did the researchers attempt to answer their research question/evaluate their hypothesis? Provide an overview of the experimental/study design keeping in mind the research question. 2) What controls were used and why?*
G. *Material & Methods. (20 points) The Materials & Methods section describes how the authors performed the research so others may replicate the same experiments. Considering the overall study design, select one key method from the paper and create an ORIGINAL (i.e. your own) flowchart or diagram that describes the key method. Include as much detail as necessary. This should clearly explain what was done and how. A reader should be able to understand your flowchart and explanation without referencing the paper. Include any conditions (time, temperature, etc.) and reagents (concentrations, chemicals, subjects) so that you could take this into the lab/field and repeat the experiment using your flowchart or diagram.*
H. *Results. (15 points) The Results section presents experimental data. To fully evaluate scientific claims, the results section is the most important for discerning validity of claims. Identify the most critical table or figure presented within the paper for further analysis. Specify which figure is being analyzed and answer the following questions: A) What is the main finding from the data? B) How large is the population size (n)? C) Is there a statistically significant difference (focus on the p–value) in the treatment versus control group? Keep in mind there may not be a treatment and/or control group. D) What statistical test was performed and what is the likelihood of a false positive or false negative result? Keep in mind not all experiments will include this information. E) Explain how the results are biologically relevant to the problem statement or hypothesis.*
I. *Discussion. (35 points) The Discussion section is the authors' mechanism to convey their findings and interpretations. They also discuss the significance of their finding and propose additional studies. Within this section, A) Do the authors present a coherent story? Why or why not? B) How do you, as the reader, interpret the results? Are they aligned with the authors? C) Have they presented sufficient evidence to support their claims? D) Do they identify areas of potential weakness in their experimental design? If so, what are the weaknesses? If not, what do you think are weaknesses? E) Describe how this article is novel in either content or experimental approach and how it is important to the scientific field. F) What new questions emerge from the results of this experiment? Include your questions and any the authors bring up. G) In your own words, describe one future experiment or line of inquiry that the authors (or you) could take on this topic.*

6. Scientific literacy is not only in written form but involves critical analysis and oral presentation. As such, each group will prepare a 9-11 minute summary of their respective article. Groups will present their data to the class using PowerPoint. Presentations will be assessed on format, content, and delivery.

7. Grades will be assessed for each main objective during the semester. The total points (220) are allocated as follows:

Group selection	0 points	Lesson 6
Provide copy of primary article	10 points	Lesson 7
Article Analysis	125 points	Lesson 25
Submit Slides to Instructor **due NLT 0600 Lesson 39	5 points	Lesson 39
Slide Assessment	50 points	Lesson 39
Presentation Assessment	30 points	Lesson 39/40

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XXXXXXXXXXX
Course Director

Encl
1-Group Sign-up Sheet
2-Article & Analysis Rubric
3-Grading Rubric Slides & Presentations

Encl 1- Group Sign-up Sheet

Primary Article Group Analysis Sign-up Sheet

Section _______

Identify formal group (LSN6)

Group #1	Names	*
Group #2	Names	*
Group #3	Names	*
Group #4	Names	*
Group #5	Names	*
Group #6	Names	*

*Denotes group leader. Leader is responsible for submitting items to instructor and coordination.

Encl 2- Article & Analysis Rubric

	Max Point		Criteria	Assessed Points	Total/notes
Group & Article Selection	**10**				
		5	Provide copy of article that group will analyze		
		5	Article is from primary literature		
Article Analysis	**125**				
		5	**Overall design and appearance:** 0—disorganized & difficult to follow 1-2—adequate organization, somewhat difficult to follow 3-4—organization and images aid understanding 5—professional appearance with text greatly increasing understanding of topic		
		5	**Appropriate citations (internal and works cited):** 0—no references presented 1-2—limited references using somewhat consistent formatting but missing two or more internal citations 3-4—several well-presented references in consistent format but missing one to two internal citations 5—fully referenced		
		5	**A: Describe abstract in common terms:** 0—no abstract discussion 1—topic is not introduced in general terms 2—description present but unclear 3—relevant background provided 4—clear understanding of topic with some synthesis 5—excellent background provided		
		5	**B: Hypothesis** 2—correctly specify discovery or hypothesis-based approach 3—identify problem statement/hypothesis		
		5	**C: Analyze reference section for completeness/conflict of interest:** 0—analysis not included 1—only states no conflict of interest 2—only mentions reference section 4—examines 1-2 references 5—full consideration of references and analysis of conflicts of interest		
		10	**D: Summarize introduction of topic:** 0—no introduction 2—topic is not introduced in general terms 4—description present but unclear 6—relevant background provided 8—clear understanding of topic with some synthesis 10—excellent introduction provided		
		5	**E: Identify and define five key terms**: 1—for each term and definition		
		15	**F: Study design:** (8) Overview of experimental/study design 0—no discussion of experimental design 2—briefly mentions study design without any description 4—discussion present but not clear or informative with two misinterpretations		

		6—clear understanding of design with some synthesis or slight misinterpretations 8—excellent description of study design with clear understanding and interpretation (4) Analyze controls used 0—not discussed 2—mention controls but not discussed 4—correctly identifies and discuss controls (3) Why those control are important 1—simply states that controls are important 2—relates controls to the particular type of experiment 3—correctly relates controls to the particular type of experiment and states why that particular control was selected		
	20	**G: Materials & Methods:** (5) Thoroughness of flowchart 0—flowchart not included 2—flowchart included but missing two or more key components from study 4—flowchart clearly labeled, concise design 5—chart is clearly labeled, concise design, contains legend (5) Ability to use flowchart at bench 0—unclear 2—three or more mistakes or missing items 3—two or more mistakes or missing items 4—chart clear but missing one item 5—chart is concise and easily translated to lab use (5) Clearly describe what was done 0—unclear 1—does not use common verbiage 2—confusing wording or excessive grammatical errors 3—clear wording but two or more grammatical errors 4—clear with one grammatical error 5—clear with correct grammar (5) Clearly state conditions 0—no reference to experimental conditions 1—conditions mentioned but not correlated within flowchart 2—conditions have two or more errors or missing one key component 3—conditions have two or more errors 4—conditions mentioned 5—conditions clearly described and discussed within diagram ***Note, direct copying of the Materials and Methods paragraphs will results on a zero on this portion (20 points).*		

	15	**H: Results from a particular figure** (5) Identify the main finding 0—no identification 1—state finding without discussion 3—state finding with sufficient discussion 5—findings clearly and concisely stated (2) Sample size 0—does not discuss sample size 2—clearly states sample size (3) Statistical significance 0—does not discuss statistical significance 2—states statistical significance of finding 3—relates significance to original hypothesis (2) Statistical test and false positive/negative 1—identifies the type of test used 1—discuss the potential for false positive or false negative results (3) Biological relevance of results 0—no relation of results to hypothesis 1—states results are relevant without context 2—relevance mentioned but in general terms 3—results related to original hypothesis		
	35	**I: Discussion:** (5) Coherent story 2—states the article was coherent 3—explains why the article was/was not clear 5—excellent discussion of the flow, content, and results of study (5) Interpretation of results 2—references results only 4—results and their interpretations are discussed 5—coherent mention of how authors interpreted and applied their results to hypothesis (5) Sufficient evidence 2—states sufficient evidence was presented 4—relates strength of evidence to conclusion 5—synthesizes evidence to describe whether sufficient results convince the reader (5) Weakness in experiments 2—states no weakness in experiments 4—identifies one potential issue with experiments (design or conduct) 5—identifies two or more potential issues with experimental design or conduct (5) Novelty of article 1—states experimental design is novel 3—minimally identifies why article is novel 5—relates why article is novel compared to other published studies (5) New questions		

		1—restates question from paper 3—generate your own research question 5—restates question from paper and generates own novel research question (5) Future experiment 2—identify one future experiment 3—identify one experiment and hypothesis 5—identify one experiment, hypothesis, and resources necessary to complete experiment		

Encl 3 Grading Rubric Slides & Presentations

	Max Points		Criteria	Assessed Points	Total/notes
Slides	**5**				
		5	Digitally submitted via SharePoint NLT 0600 Lesson 39 [all or nothing]		
Slides (Instructor Assessment)	**50**				
		10	**Overall design and appearance:** 0—disorganized & difficult to follow 2—illegible portions on slides 4—adequate organization, somewhat difficult to follow 6—organization and images aid understanding 8—slides flow with complete titles and labels 10—professional appearance with text greatly increasing understanding of topic		
		5	**Citations (internal and works cited):** 0—no references presented 1—missing works cited 2—somewhat consistent formatting but missing two or more internal citations 3-4—several well-presented references in consistent format but missing one to two internal citations 5—fully referenced		
		5	**Introduce topic and background:** 0—no introduction 1—introduction is not concise 3—description present but unclear 5—clear understanding of relevant information presented		
		5	**State problem statement/hypothesis** 2—correctly specify discovery or hypothesis-based approach 3—identify problem statement/hypothesis [points are all or nothing]		
		5	**Describe the overall experiment/paper** 2—mention goal of paper 4—mention goal of paper, relevant background provided 5—clear goals, background, & results		
		10	**Methods** (4) Focus on one key method 2—include figure from paper 4—include figure from paper and designed flowchart (4) Describe how/what was done from one key method 2—minimal description of what was done 4—description conveyed in succinct manner (2) Controls and comparison/treatment group within key figure 1—identify control(s) 2—clearly identify control(s) and experimental group(s)		

		5	**Discuss results of this overall experiment** 1—summarize one conclusion 3—summarize findings and conclusion 5—summarize findings and mention novelty of results		
		5	**Discuss how overall findings relate to original problem statement/hypothesis and future inquiry** 2—relate findings to hypothesis 3—include future experiment(s) 5—include future experiment and pose a novel hypothesis		
Presentations (Instructor Assess)	**30**				
		10	**Quality of oral presentation (clear, concise, avoid speech filler)** 2—excessive speech fillers 4—minimally effective at conveying information 6—message somewhat clear but trouble answering questions 8—clear, concise, with one to two errors 10—confident, concise, effective		
		5	**Overall bearing/demeanor** 1—one or more member disengaged 3—sufficient posture and bearing 5—excellent bearing and demeanor		
		5	**Use of appropriate figures** 0—includes memes or inappropriate figures 1—displays figures but does not refer to them 3—casually refers to figures 5—fully integrates slides into presentation		
		5	**Flow of data among group** 2—obviously not rehearsed 4—smooth transition with one awkward pause 5—seamless transitions		
		5	**Time requirement** 2—exceeds prescribed time 5—within time limits		