# Effects of a cancer model organism course on student self-efficacy and attitudes about science


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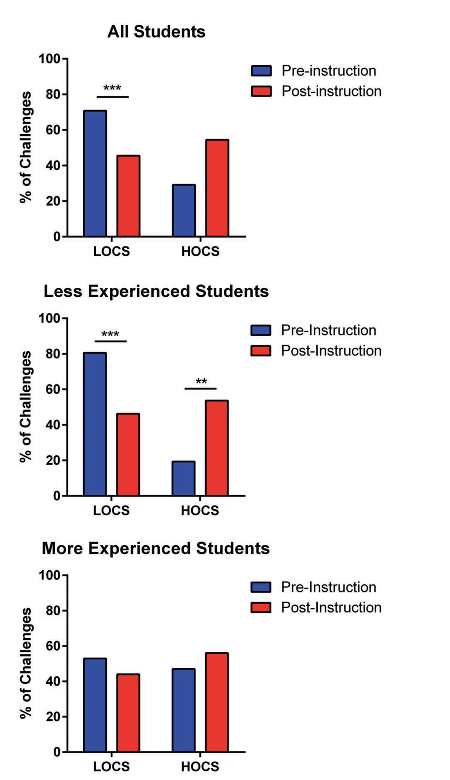
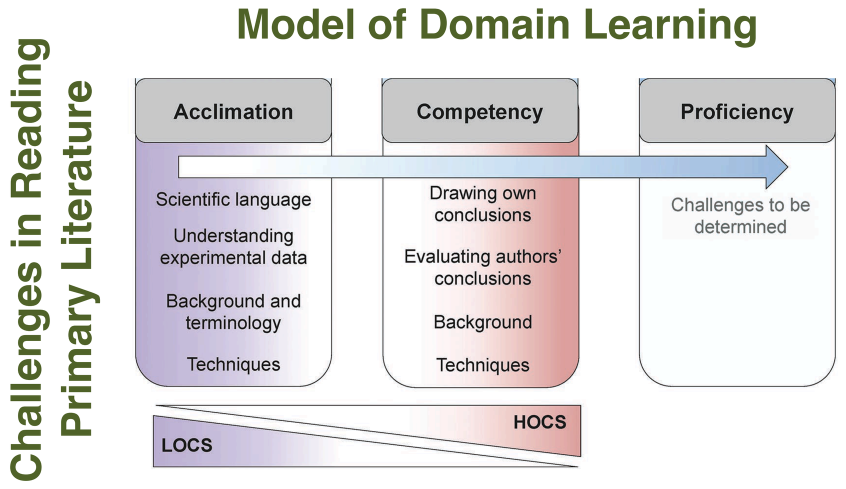
## Abstract


Incorporating primary literature into undergraduate science curriculum is a common goal among biology educators. Implementation of journal articles as part of existing core courses or as stand-alone courses, such as those using the CREATE method, are becoming the norm particularly in biology courses. Recent research has focused on paper selection, research topics, structured reading methodology, and student perceptions and outcomes. One unique aspect of biomedical research, which has not, to my knowledge, been directly addressed, is the use of model organisms. Biomedical research utilizes a variety of common model organisms with unique strengths and weaknesses that make them well-suited for specific approaches and research questions. Here, I describe the novel design of an upper-level undergraduate elective course that uses cancer as a paradigm to explore the use of model organisms in primary literature. Cancer hallmarks (proliferation, genomic instability, apoptosis evasion, and metastasis) were used as course units. Both teacher- and student-selected data from journal articles was used to explore a variety of model organisms. These data were used to discuss the benefits and limitations of each model system in the context of the research. Instructional emphasis was placed on data analysis, data interpretation, and experimental design and methodology. A structured analysis rubric was utilized to facilitate student engagement with the primary literature and data. As a final project, students incorporated their knowledge of cancer model organisms by developing an experimental design to test a hypothesis developed throughout the course. Here we present our findings from a pre- and post-course survey and assessment involving students' attitudes, self-rated abilities and epistemological beliefs.


## Background

### Students' perceived challenges with reading primary literature change with increased exposure




Adapted from Lie, Abdullah et. al. 2018

Figure 1: Previous published work demonstrated that aspects of primary literature that students' self-reported as difficult shifted from the beginning of a Master's course dedicated to critically analyzing journal articles. (Left) Lower order cognitive skills (LOCS) and higher order cognitive skills (HOCS) of difficulties identified by students pre- and post-intervention. (Right) Model of domain learning as a framework for understanding challenges in reading primary literature.

## BER Question and Hypothesis

**Does repetitive data analysis of journal article figures promote increases in science process skills?**

*Using repetitive, structured analysis of primary literature articles will increase students' ability:*

- *to design follow-up experiments*
- *to self-assess their abilities*

## Student Learning Objectives

### SCIENCE PROCESS SKILLS

Students should be able:

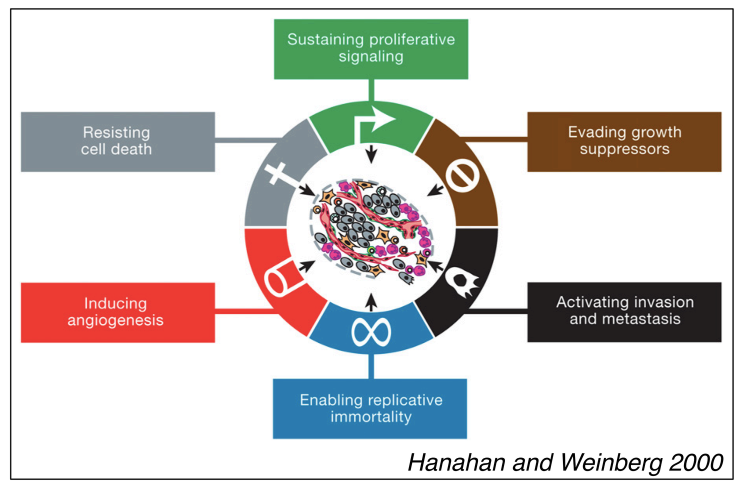
- To understand the scientific process
- To conduct a literature search
- To identify scientific questions and hypotheses
- To critically analyze primary literature data
- To identify controls and experimental variables
- To understand a variety of experimental techniques
- To design a follow-up experiment

### COMMUNICATION SKILLS

Students should be able:

- To write about science effectively
- To communicate science orally
- To design and present a scientific poster
- To provide feedback on experimental designs
- To use peer review experimental design

## Course Design




*Hanahan and Weinberg 2000*

Model Organisms of Cancer Research

- Upper-level undergraduate elective
- Master's student elective
- 1 semester course
- Twice weekly for 75 minutes

Demographics

- Southern Historically Black University
- 14 students (11 seniors, 3 MS students)
- All Biology Majors

5 Units

- Model Organisms
- Oncogenes/Tumor Suppressors
- Genomic Instability
- Invasion/Metastasis
- Tumor Microenvironment

Cancer Gene Poster Project

- Phylogenetic tree
- Literature review
- 2 pieces of background data from FAs
- Experimental question
- Experimental design

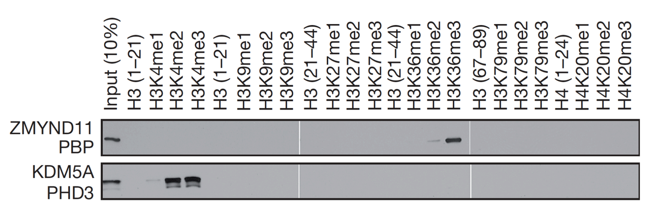
### Semester Schedule

| UNIT 1 | | | UNIT 2 | | | UNIT 3 | | | UNIT 4 | | | UNIT 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 | | P2 | P3 | | P4 | P5 | | P6 | P7 | | P8 | P9 | | P10 |
| FA1 | FA2 | FA3 | FA4 | FA5 | FA6 | FA7 | FA8 | FA9 | FA10 | FA11 | FA12 | FA13 | FA14 | FA15 |
| Q1 Phylogenetic Tree | | | Q2 First Half Literature Review | | | Q3 Question/ Hypothesis | | | Q4 Professor Meeting | | | Q5 Poster Presentation | | |

P = Paper Selection (odd numbers chosen by Professor and discussed as a class, even chosen by students aligning with their Cancer Gene Project)
FA = Figure Analysis Worksheet on selected papers for that unit
Q = Quiz on model organism, data type discussed in class

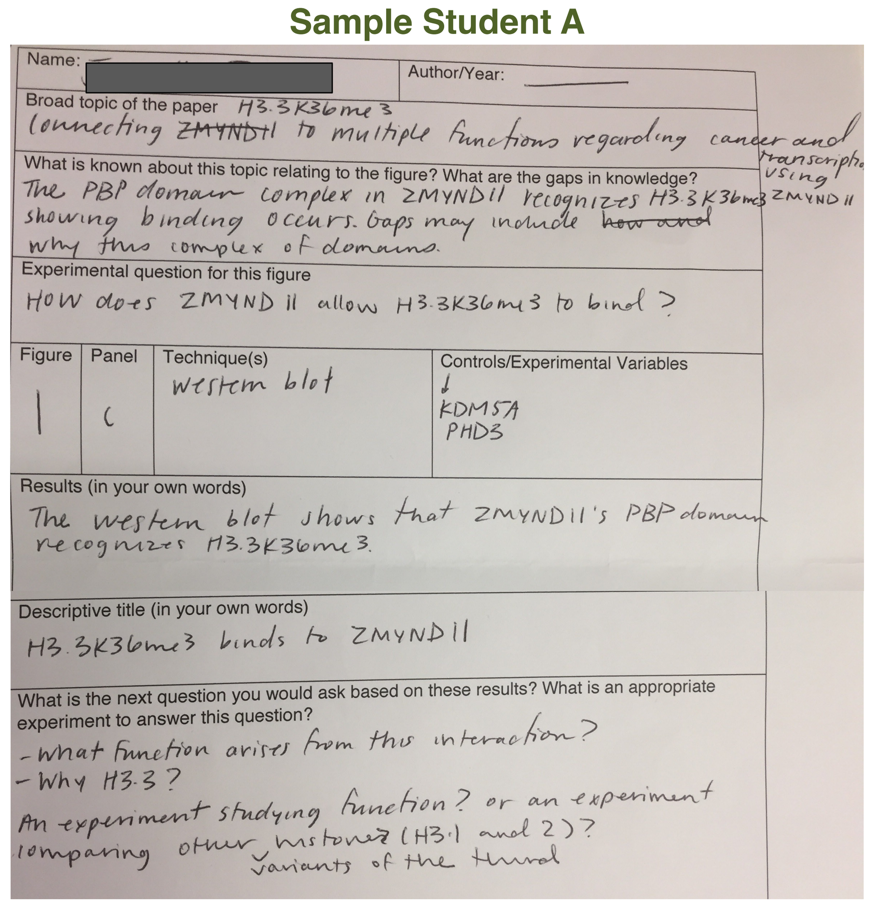
### Example Figure Analysis Worksheet

**Sample Figure Panel**




Western blot analysis of histone peptide pull-downs with GST-ZMYND11 PBP and the indicated biotinylated peptides. KDM5A is included as a positive control for the assay. (Wen et. al. 2014)

**Sample Student A**



Name: [redacted]
Author/Year:

Broad topic of the paper H3.3K36me3 (connecting ~~ZMYND11~~ to multiple functions regarding cancer and transcription using ZMYND11

What is known about this topic relating to the figure? What are the gaps in knowledge?
The PBP domain complex in ZMYND11 recognizes H3.3K36me3 showing binding occurs. Gaps may include ~~how and~~ why this complex of domains.

Experimental question for this figure
How does ZMYND11 allow H3.3K36me3 to bind?

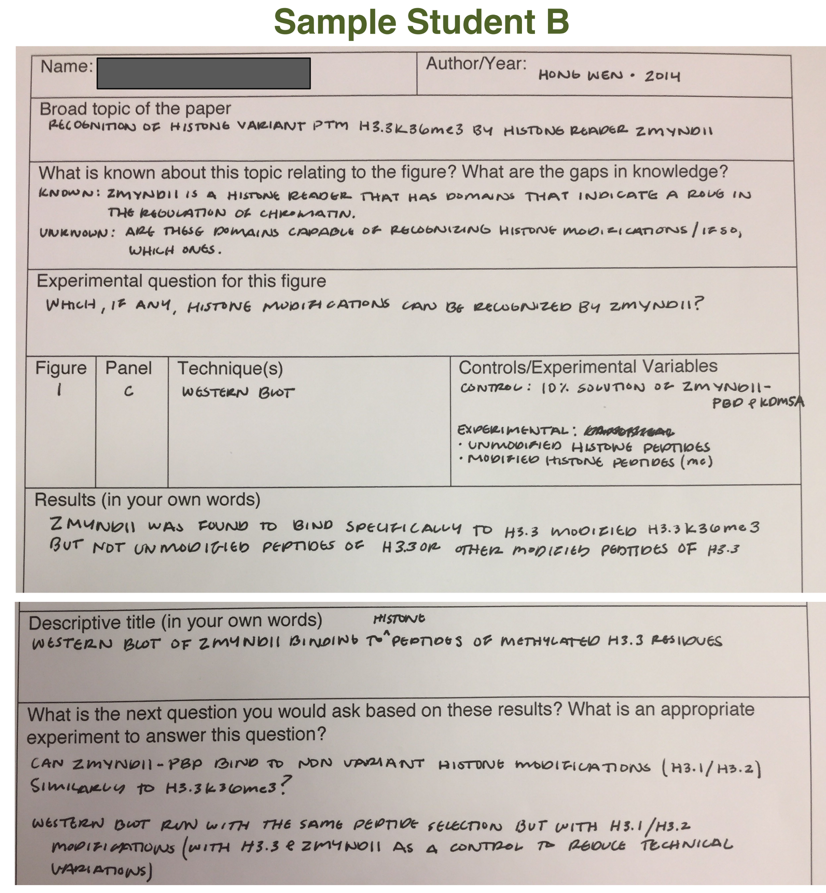
| Figure | Panel | Technique(s) | Controls/Experimental Variables |
|---|---|---|---|
| 1 | C | western blot | KDM5A PHD3 |

Results (in your own words)
The western blot shows that ZMYND11's PBP domain recognizes H3.3K36me3.

Descriptive title (in your own words)
H3.3K36me3 binds to ZMYND11

What is the next question you would ask based on these results? What is an appropriate experiment to answer this question?
- what function arises from this interaction?
- Why H3.3?
An experiment studying function? or an experiment comparing other histones (H3.1 and 2)? variants of the third

**Sample Student B**



Name: [redacted]
Author/Year: HONG WEN • 2014

Broad topic of the paper
RECOGNITION OF HISTONE VARIANT PTM H3.3K36me3 BY HISTONE READER ZMYND11

What is known about this topic relating to the figure? What are the gaps in knowledge?
KNOWN: ZMYND11 IS A HISTONE READER THAT HAS DOMAINS THAT INDICATE A ROLE IN THE REGULATION OF CHROMATIN.
UNKNOWN: ARE THESE DOMAINS CAPABLE OF RECOGNIZING HISTONE MODIFICATIONS / IF SO, WHICH ONES.

Experimental question for this figure
WHICH, IF ANY, HISTONE MODIFICATIONS CAN BE RECOGNIZED BY ZMYND11?

| Figure | Panel | Technique(s) | Controls/Experimental Variables |
|---|---|---|---|
| 1 | C | WESTERN BLOT | CONTROL: 10% SOLUTION OF ZMYND11-PBD & KDM5A; EXPERIMENTAL: · UNMODIFIED HISTONE PEPTIDES · MODIFIED HISTONE PEPTIDES (me) |

Results (in your own words)
ZMYND11 WAS FOUND TO BIND SPECIFICALLY TO H3.3 MODIFIED H3.3K36me3 BUT NOT UNMODIFIED PEPTIDES OF H3.3 OR OTHER MODIFIED PEPTIDES OF H3.3

Descriptive title (in your own words)
WESTERN BLOT OF ZMYND11 BINDING TO HISTONE PEPTIDES OF METHYLATED H3.3 RESIDUES

What is the next question you would ask based on these results? What is an appropriate experiment to answer this question?
CAN ZMYND11-PBP BIND TO NON VARIANT HISTONE MODIFICATIONS (H3.1/H3.2) SIMILARLY TO H3.3K36me3?
WESTERN BLOT RUN WITH THE SAME PEPTIDE SELECTION BUT WITH H3.1/H3.2 MODIFICATIONS (WITH H3.3 & ZMYND11 AS A CONTROL TO REDUCE TECHNICAL VARIATIONS)

*FA Adapted from Round et. al. 2013 and Angra and Gardner 2018*

## Assessment

### *Science Process Skills Assessment Tools*

**Rubric for Experimental Design (RED)**

**Assess selection of FA Worksheets**

- Teacher-selected
- Student-selected
- Quizzes

Ongoing Analysis

**Assess Experimental Design (ED)**

**Assess Student Peer Reviews of ED**

**Areas of Difficulty**

- Variable property of an experimental subject
- Manipulation of variables
- Measurement of outcome
- Accounting for variability
- Scope of inference of findings

*Dasgupta et. al. 2014*

**Biological Experimental Design Concept Inventory (BEDCI)**

**Pre/Post-course assessment**

- Controls
- Hypotheses
- Biological Variation
- Accuracy
- Extraneous Factors
- Independent Sampling
- Random Sampling
- Purpose of Experiments

*Deane et. al. 2014*

### *Pre- and Post-course Survey*

**CREATE Survey Themes**

- Decoding Primary Literature
- Interpreting Data
- Active Reading
- Visualization
- Thinking Like a Scientist
- Research in Context

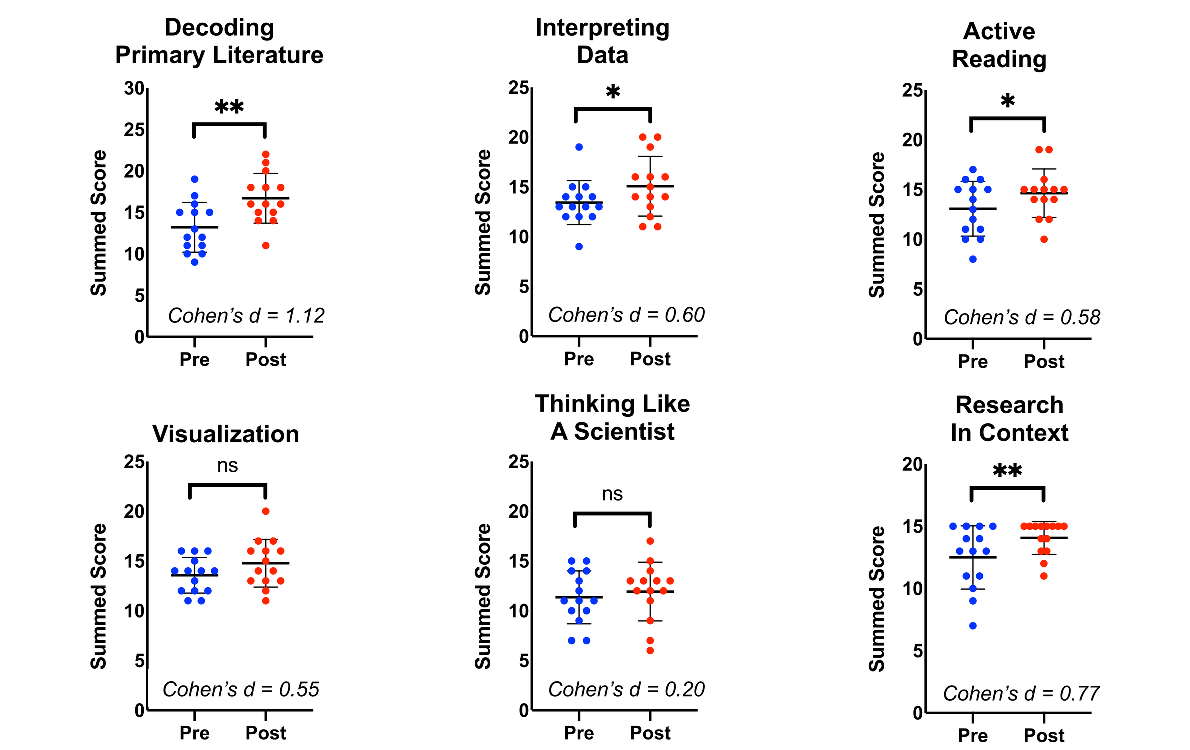
**Epistemological beliefs**

- Knowledge is Certain
- Creativity
- Sense of Scientists
- Sense of Motives
- Known Outcomes
- Collaboration

*Hoskins et. al. 2011*

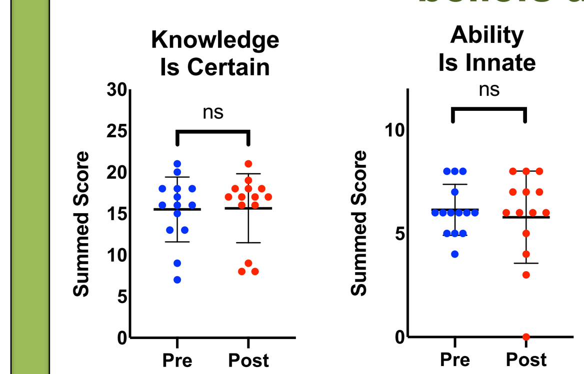
## Survey Results

### Students demonstrated self-efficacy gains in decoding primary literature, interpreting data, active reading, and research in context

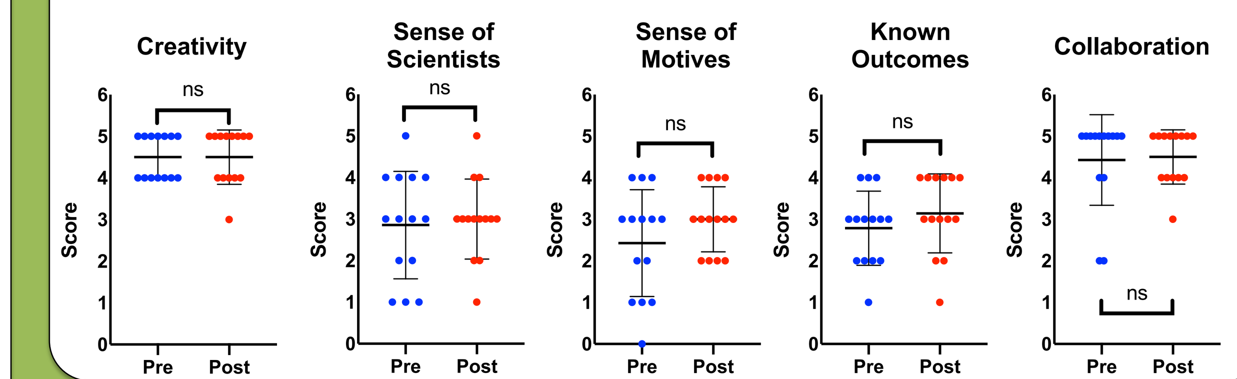



Students responded to pre- and post- survey questions based on a Likert scale, and questions were binned into 6 factored categories as previously described (Hoskins et. al. 2011). Statistical significance was calculated using paired *t*-tests (p<0.05 = *, p <0.01 = **) and magnitude of effect was estimated using *Cohen's d*. n = 14 pre- and post-survey pairs.

### Students showed no changes in epistemological beliefs about science




*(Left)* Students responded to pre- and post- survey questions based on a Likert scale, and questions were binned into 2 categories as previously described (Hoskins et. al. 2011). *(Below)* Single questions were asked about each of the epistemological beliefs. None of these were significant, however, these may be limited by either single responses or ceiling effects. Statistical significance was calculated using paired *t*-tests. n = 14 pre- and post-survey pairs.




## Future Directions

- Use the RED to assess the experimental designs
- Subset students to test whether certain populations of students shown more benefit than others
- Devise a strategy to incorporate this into larger class sizes
- Expand study into larger cohorts
- Explore differences in lower- vs upper-level courses

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