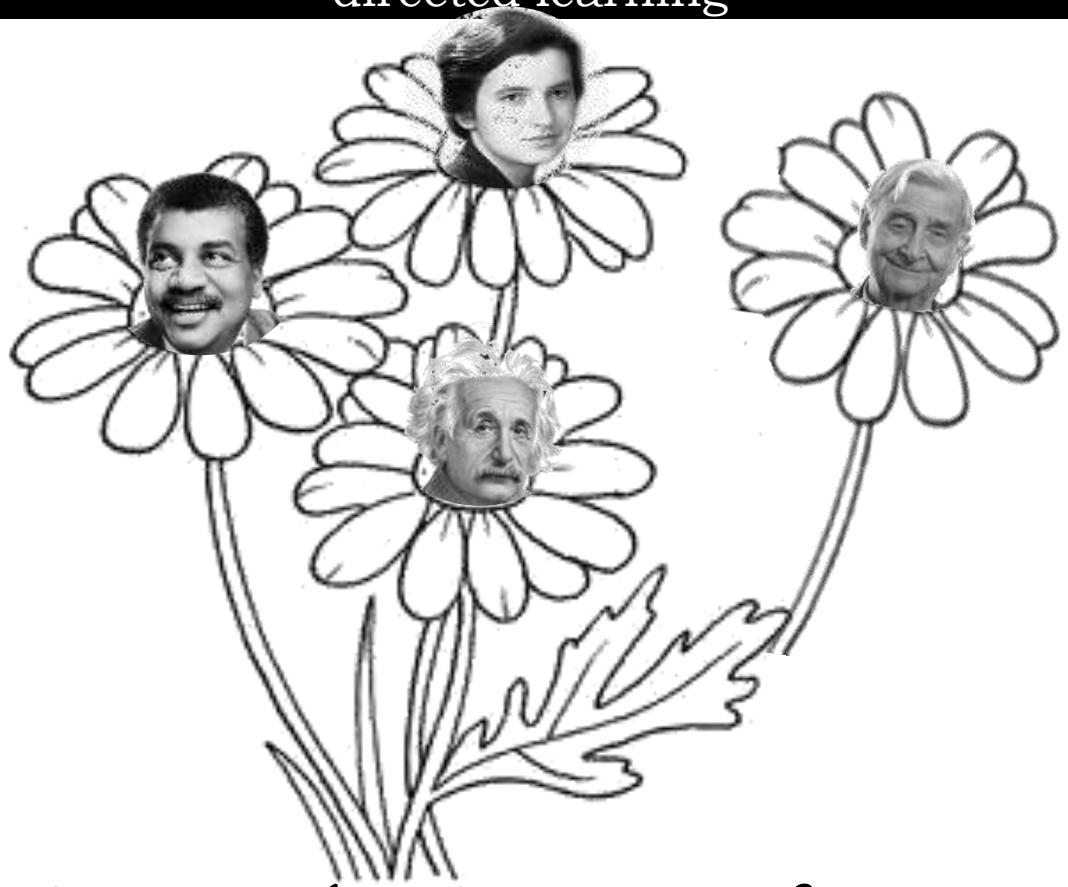
University of Wisconsin-Stevens Point

How to Grow a Scientist: Teaching pedagogies that encourage meaningful, authentic and student-directed learning



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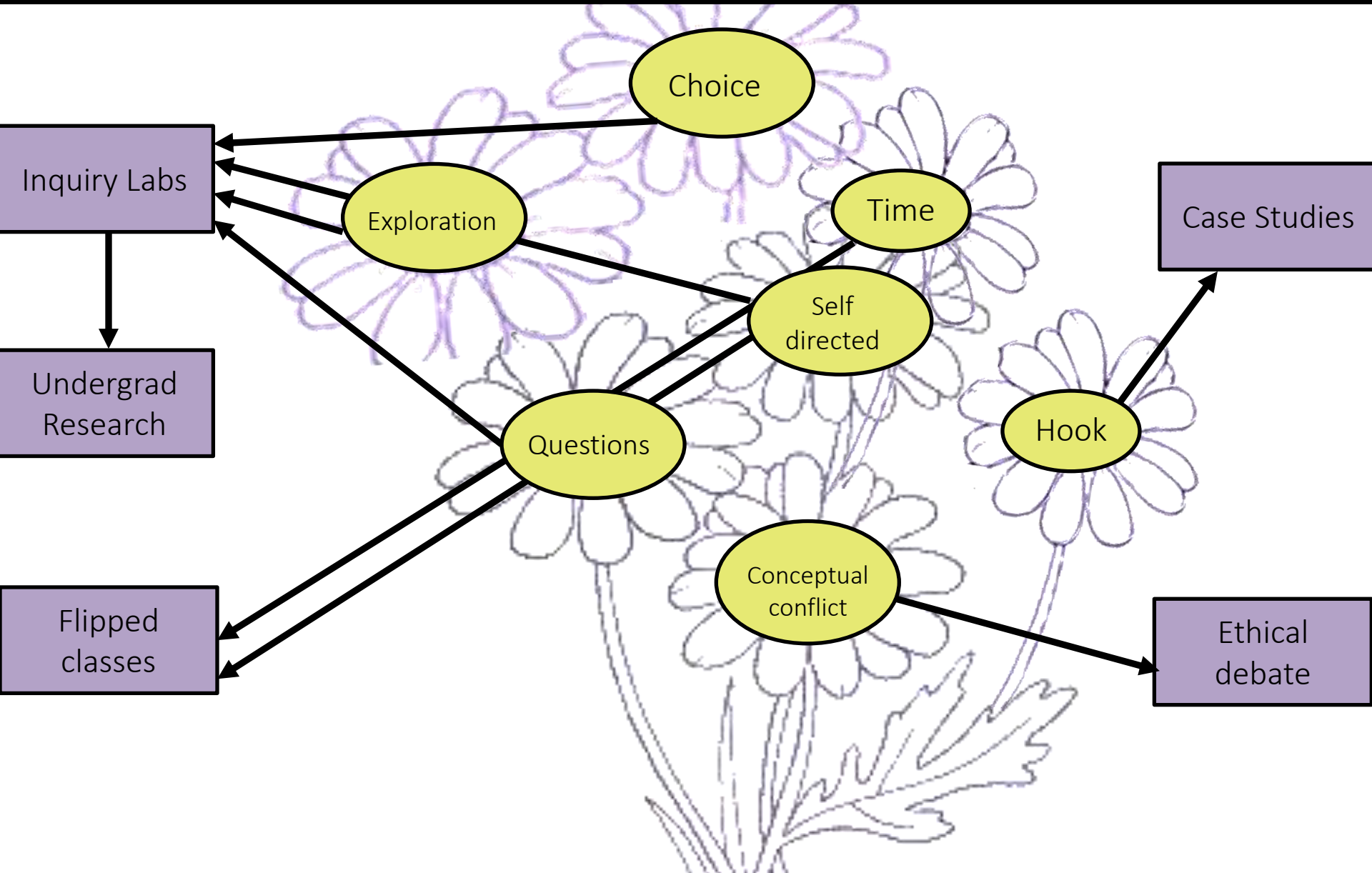
Biology Department[1], School of Education[2]

UW-Stevens Point

UW Women and Science, Fall 2015

Fostering Curiosity or How to think like a scientist



Bringing research into the classroom - Inquiry-based Biology

Inquiry-based labs

Previous lab model:

- Look and learn
- Evaluate with tests

New lab model:

- Learn by questioning, creating
- Think like scientists
- PROCESS and product

Levels of Inquiry

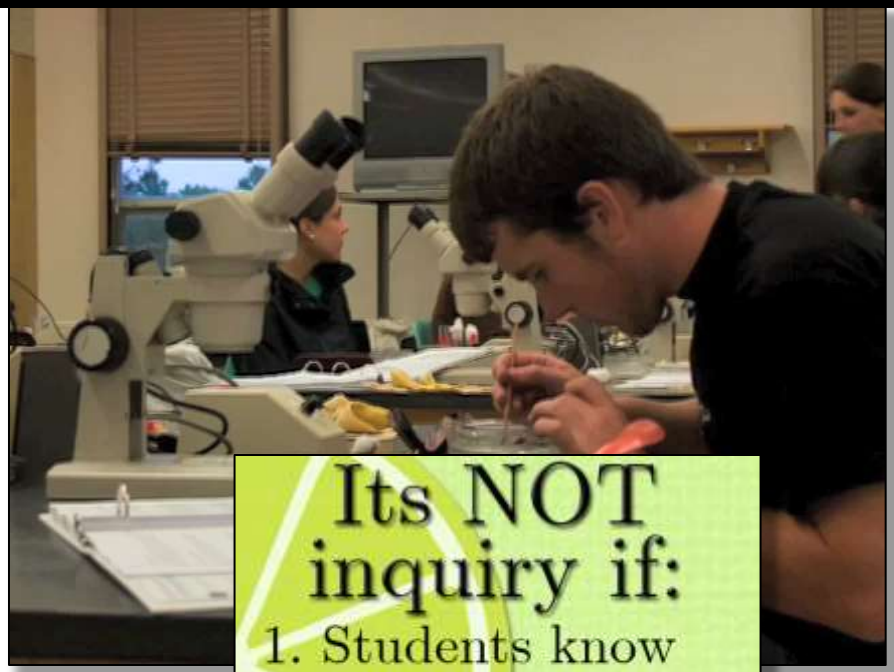
- Confirmation/Traditional Inquiry
- Structured Inquiry
- Guided Inquiry
- Open/True Inquiry

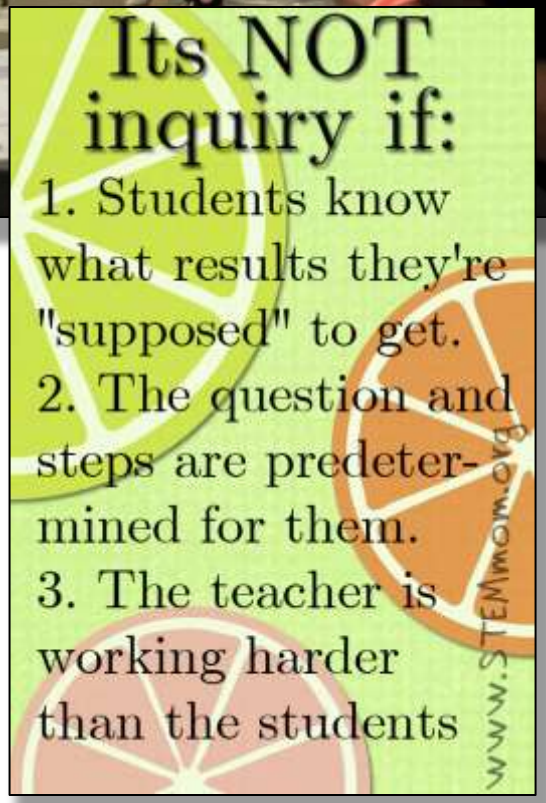
	Traditional Hands-on	Structured Inquiry	Guided Inquiry	Student Directed Inquiry	Student Research Inquiry
Topic	Teacher	Teacher	Teacher	Teacher	Teacher/Student
Question	Teacher	Teacher	Teacher	Teacher/Student	Student
Materials	Teacher	Teacher	Teacher	Student	Student
Procedures/ Design	Teacher	Teacher	Teacher/Student	Student	Student
Results/ Analysis	Teacher	Teacher/Student	Student	Student	Student
Conclusions	Teacher	Student	Student	Student	Student

From Bonnsteter Inquiry: Learning from the past with an eye on the future

Developing True Inquiry Labs

- Lab introductions
  - Describe in 5 minutes How, What and Why
- Provide guidelines for basic procedures
- Open-ended discovery
  - Outcome(s) unknown
- Students
  - ask questions
  - write hypotheses
  - design experiments,
  - evaluate/interpret data
  - defend results





Using C+E+R in Inquiry Labs

WHAT do you know?

Answers original question.
Accurate, specific and
one sentence

How do you know that?

Scientific data that supports your claim
Sufficient and relevant
Variety of sources

Claim + Evidence + Reasoning

Why does your evidence support your claim?

Explanation connecting claim to supporting evidence
Understanding of scientific principles

Adapted from E. Brunsell, edutopia

Using C+E+R in Inquiry Labs rubric

	Claim *A statement or conclusion that answers the original question/problem.*	**Evidence** *Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.*	**Reasoning** *A justification that connects the evidence to the claim. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.*
0	Does not make a claim, or makes an inaccurate claim like – "Levers do not effect work."	Does not provide evidence, or only provides inappropriate evidence or vague evidence, like "the data shows me it is true" or "It would be a lot harder to move a piano without a lever"	Does not provide reasoning, or only provides inappropriate reasoning like "levers are used in lots of ways in our lives".
1	Makes an accurate but vague or incomplete claim like – "Levers make work easier." Or "Levers do not make work easier." (It can actually depend).	Makes a general statement about how in the investigations levers sometimes made the work easier and sometimes did not make the work easier. Does not include specific data.	Repeats evidence and links it to the claim, but does not include scientific principles.
2	Makes an accurate and complete claim like – "Levers sometimes make work easier."	Provides 1 of the following 2 pieces of evidence: • Specific data (e.g. numbers) from the investigation when the lever made the work easier. • Specific data (e.g. numbers) from the investigation when the lever made the work harder.	Provides 1 of the following 2 reasoning components: • A lever can make work feel easier depending on the position of the fulcrum, effort and load. • Doing work is the ability to move an object. If it takes less force, the work feels easier.
3		Provides 2 of the following 2 pieces of evidence: • Specific data (e.g. numbers) from the investigation when the lever made the work easier. • Specific data (e.g. numbers) from the investigation when the lever made the work harder.	Provides all 2 reasoning components: • A lever can make work feel easier depending on the position of the fulcrum, effort and load. • Doing work is the ability to move an object. If it takes less force, the work feels easier.

Source: NSTA

Inquiry Labs - students understand the nature of science

1. Science is messy
2. Asking questions uncovers more questions
3. Science is creative
4. Science is not a rigid set of steps
5. Science is a never ending process

-D. Harland 2012, NSTA presentation

Ontario Inquiry Model K-12

Inquiry vs. Traditional

Higher Lecture Exam Averages		
	Traditional	Inquiry
Prelim I	83%	89%
Prelim II	73%	80%
Prelim III	76%	84%
Final Exam	74%	82%
Overall Exam grade	**76%**	**83%**

Based on Inquiry Labs, University of Maine, n=800 Bio majors
Students paired by identical SAT scores, p-value = 0.0063
Data analyzed by M. Harris Thesis, 2009, used with permission from M. Tyler

Inquiry vs. Traditional

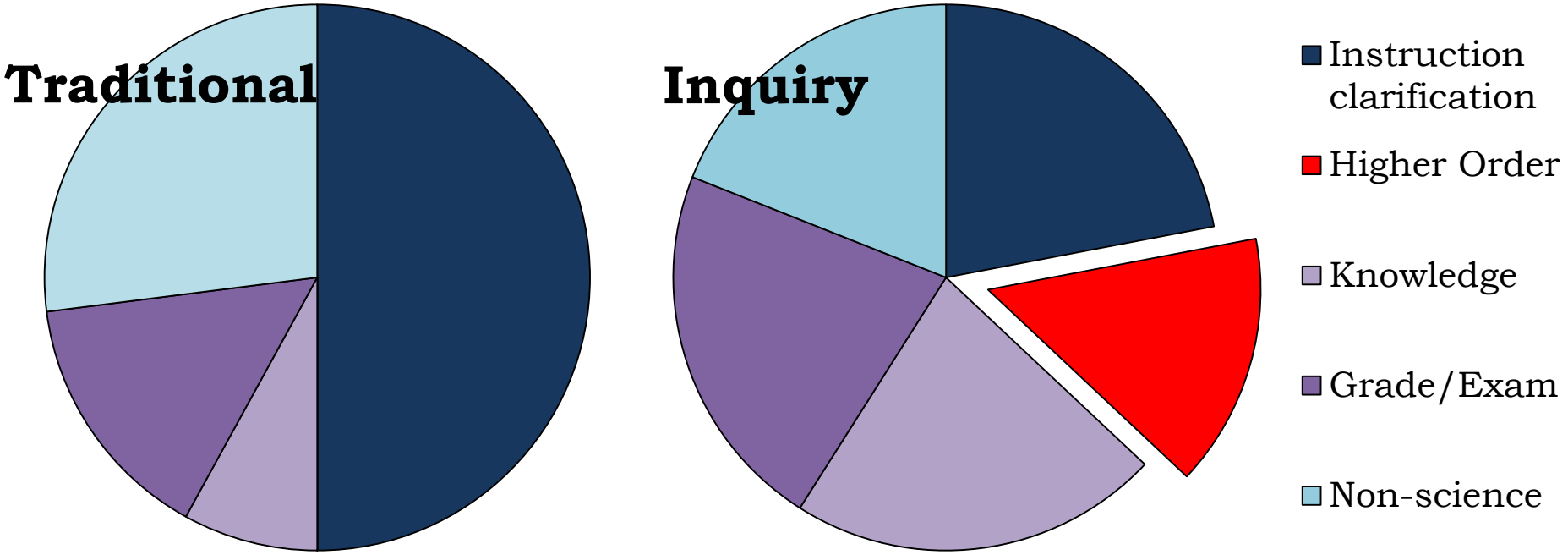


Figure 1. Based on weekly observations of Labs, University of Maine, n=800 bio majors. M. Harris Thesis, 2009, used with permission from M. Tyler

Inquiry vs. Traditional

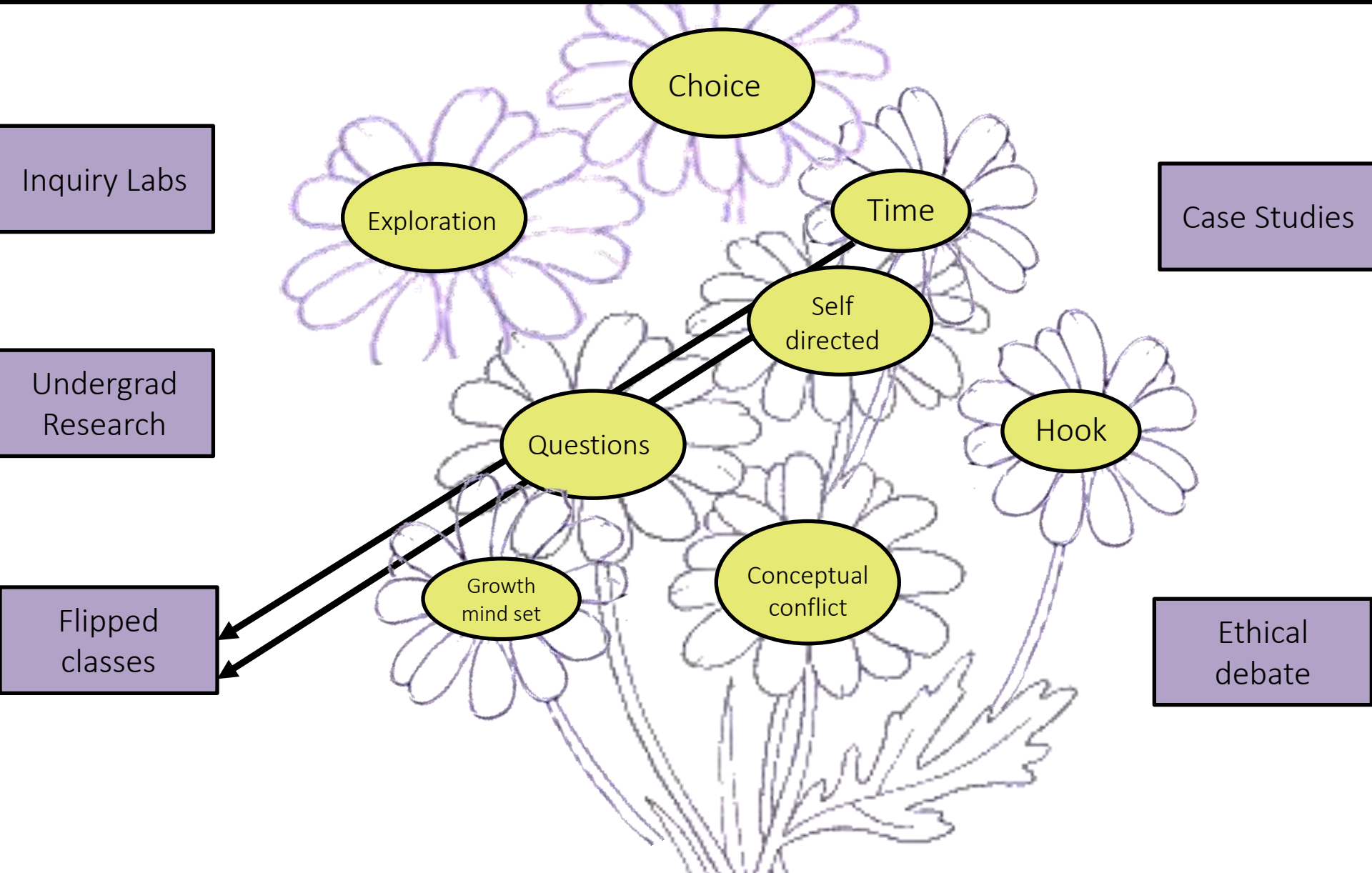
Attitude: Increased motivation and enjoyment of biology				
	Percentage		Average	
	Traditional	Inquiry	Traditional	Inquiry
Strongly disagree	8.5%	2.1%		
Disagree	23.6%	13.8%	32%	16%
Agree	47.1%	38.1%	68%	84%
Strongly agree	20.8%	46.0%		

Based on Attitudes Towards Science Inventory (ATSI) (Gogolin & Swartz, 1992); M. Harris Thesis 2009, used with permission from M. Tyler

Example labs

- Alterations to Photosynthesis
- Influence of environmental change on aquatic organisms
- Bacterial growth and restriction

Fostering Curiosity or How to think like a scientist



Flipped Classes

The Impact of Video Length on Learning in a Middle Level Science Setting

Research Questions:

1. Does the length of video segments in a flipped classroom influence student engagement, understanding and retention of content knowledge?

2. Do demographic categories differ in preference or retention when viewing different length videos in a flipped classroom?

Background

- Large scale study (6.5 million)
- Median engagement time was at most 6 minutes
- Engagement measure by
  - Watching length
  - Whether a question was answered at the end

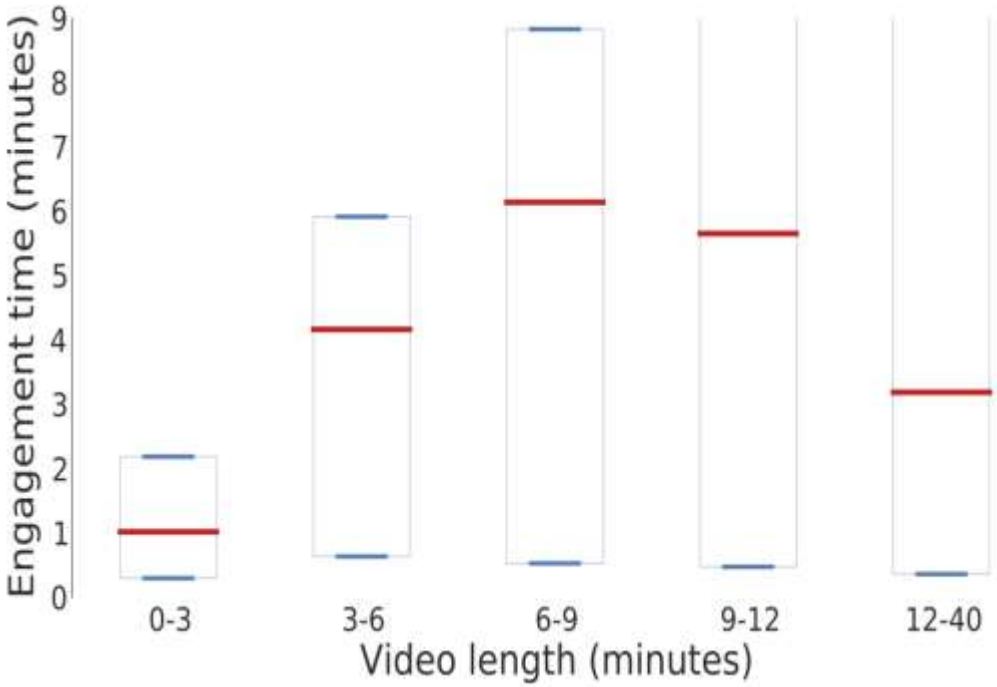
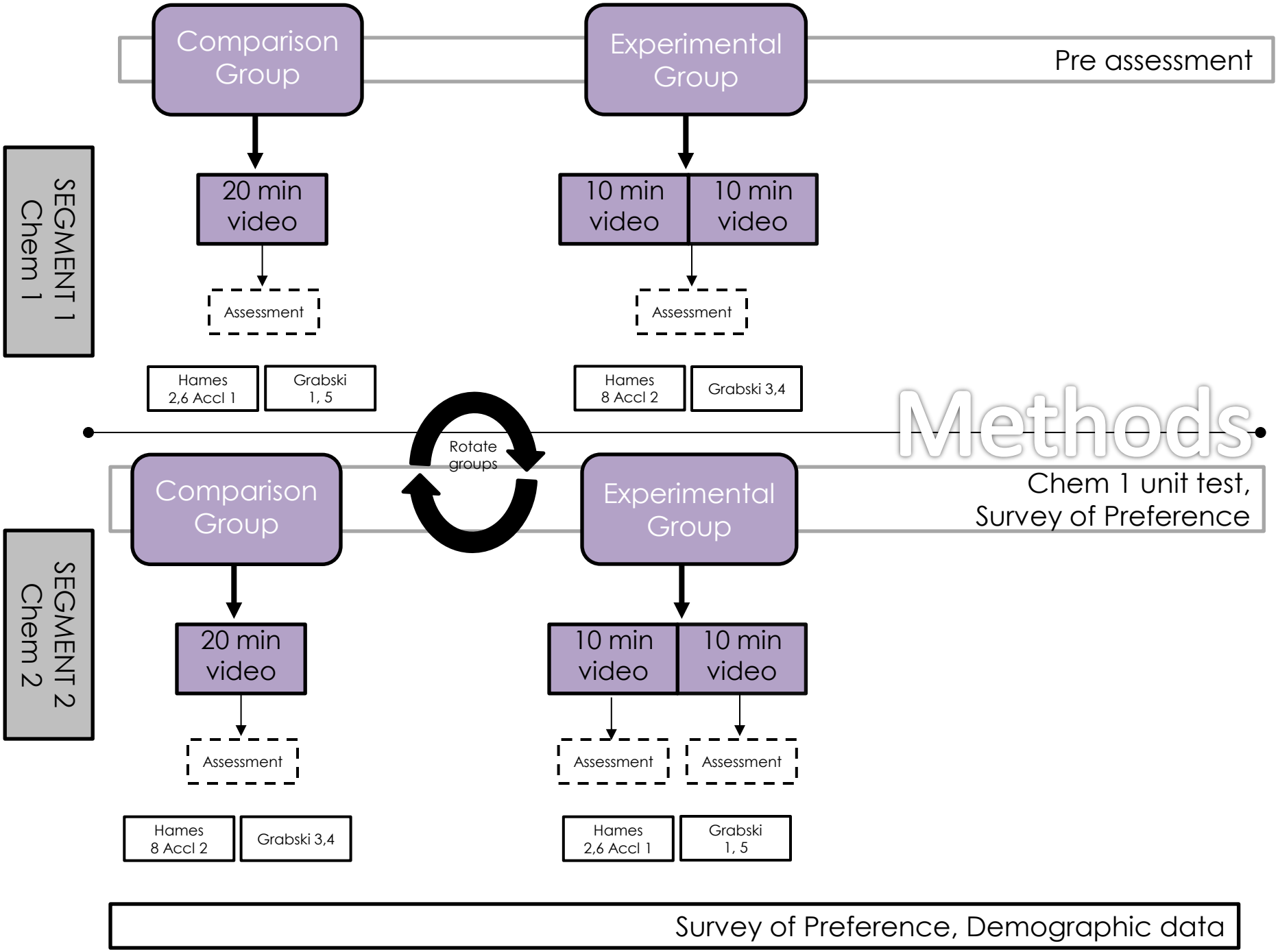


Figure 2. Boxplots of engagement times in minutes (top) and normalized to each video's length (bottom). In each box, the middle red bar is the median; the top and bottom blue bars are 25th and 75th percentiles, respectively. The median engagement time is at most 6 minutes.

Guo et al. 2014

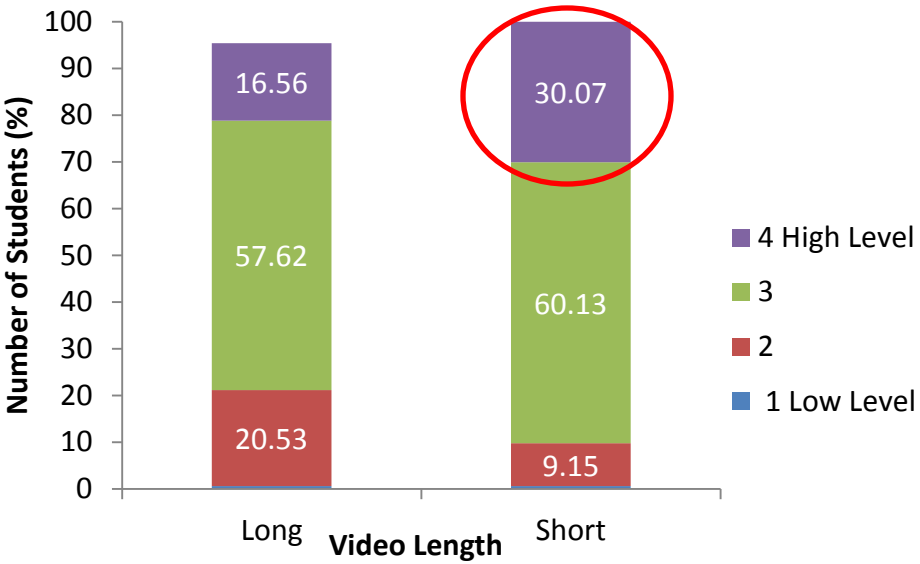
Methods


Pre assessment
Comparison Group
Experimental Group
SEGMENT 1
Chem 1
20 min video
10 min video
10 min video
Assessment
Assessment
Hames 2,6 Accl 1
Grabski 1, 5
Hames 8 Accl 2
Grabski 3,4
Rotate groups
Chem 1 unit test,
Survey of Preference
Comparison Group
Experimental Group
SEGMENT 2
Chem 2
20 min video
10 min video
10 min video
Assessment
Assessment
Assessment
Hames 8 Accl 2
Grabski 3,4
Hames 2,6 Accl 1
Grabski 1, 5
Survey of Preference, Demographic data

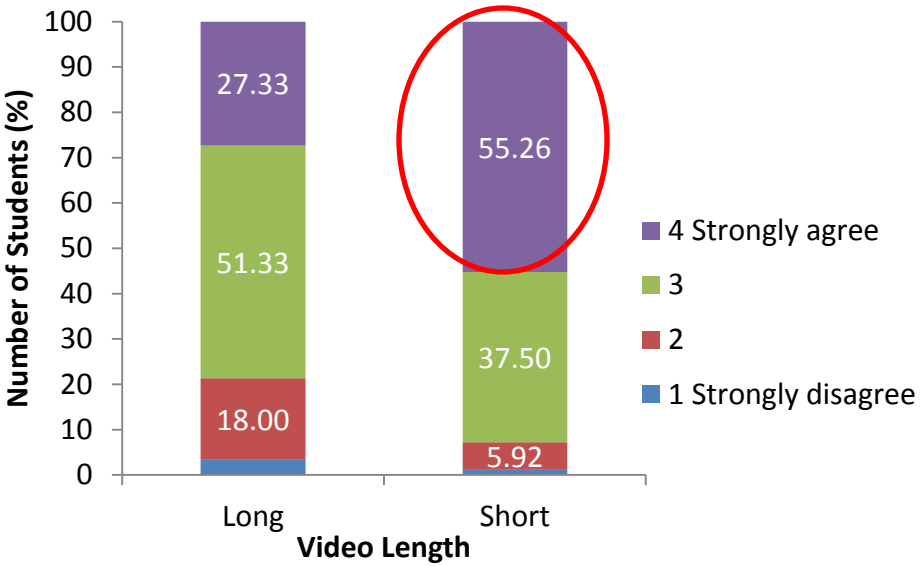
Summary of Significant Differences

- Students felt more engaged, focused, and that they retained more content during the short videos
- Multiple linear regression - factors influencing overall post test score ($p<0.05$):
  - Race
  - ADHD/ADD
  - Individualize education plan (IEP)
  - Gender and Video Length not significant
- Males scored higher in long video
- Time to watch video is negatively related to score (longer time, lower score; $p<0.0001$, linear regression)

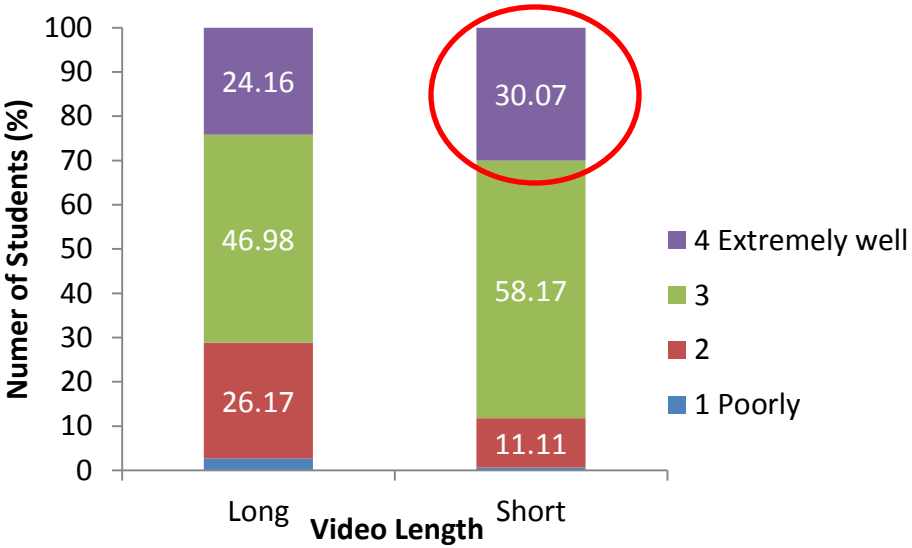
Does the length of video segments in a flipped classroom influence student engagement, focus, retention and preference?



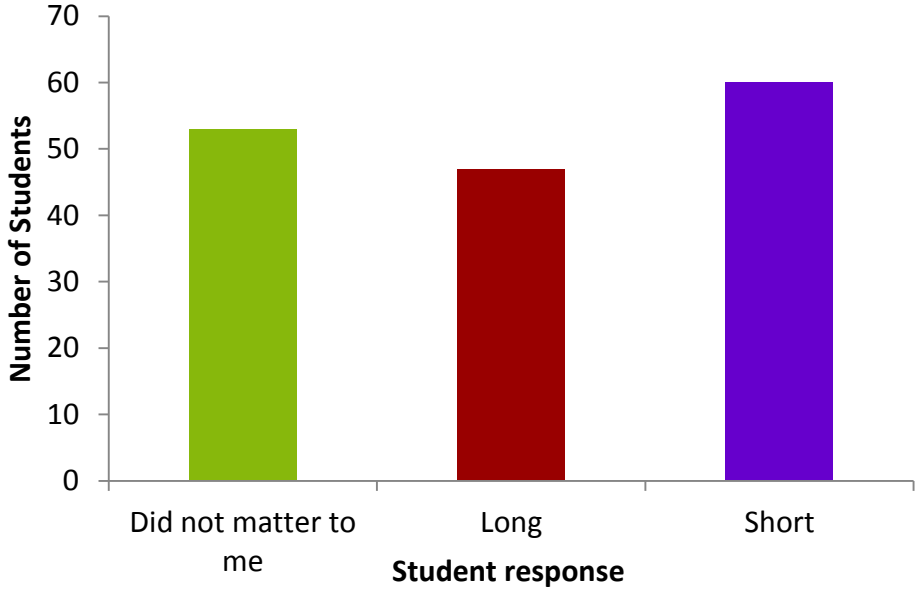
Q1: What was your level of engagement?



Q2: I was able to stay focused during the video

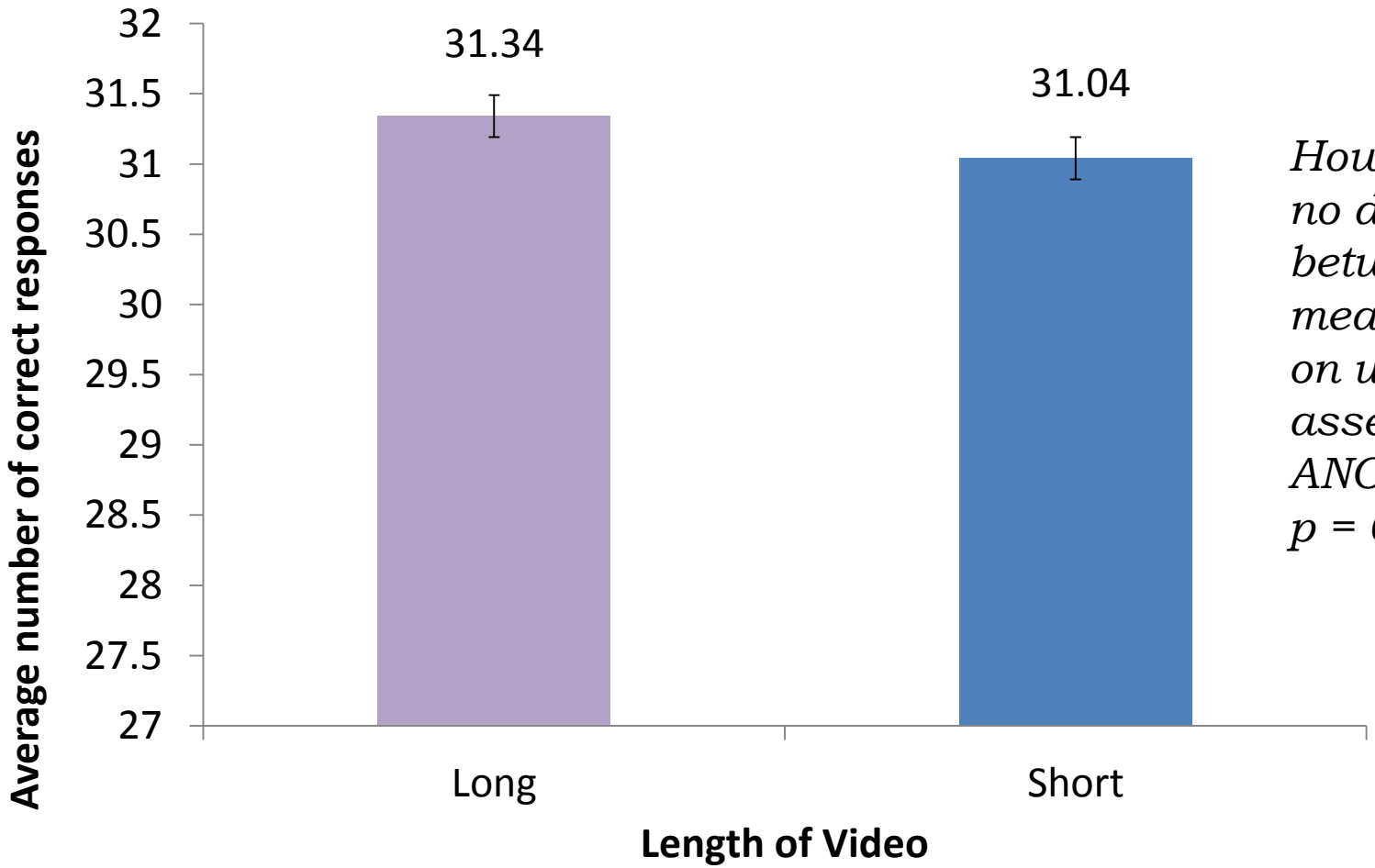


Q3: How well do you feel you retained the info?



Q4: What video format did you like better?

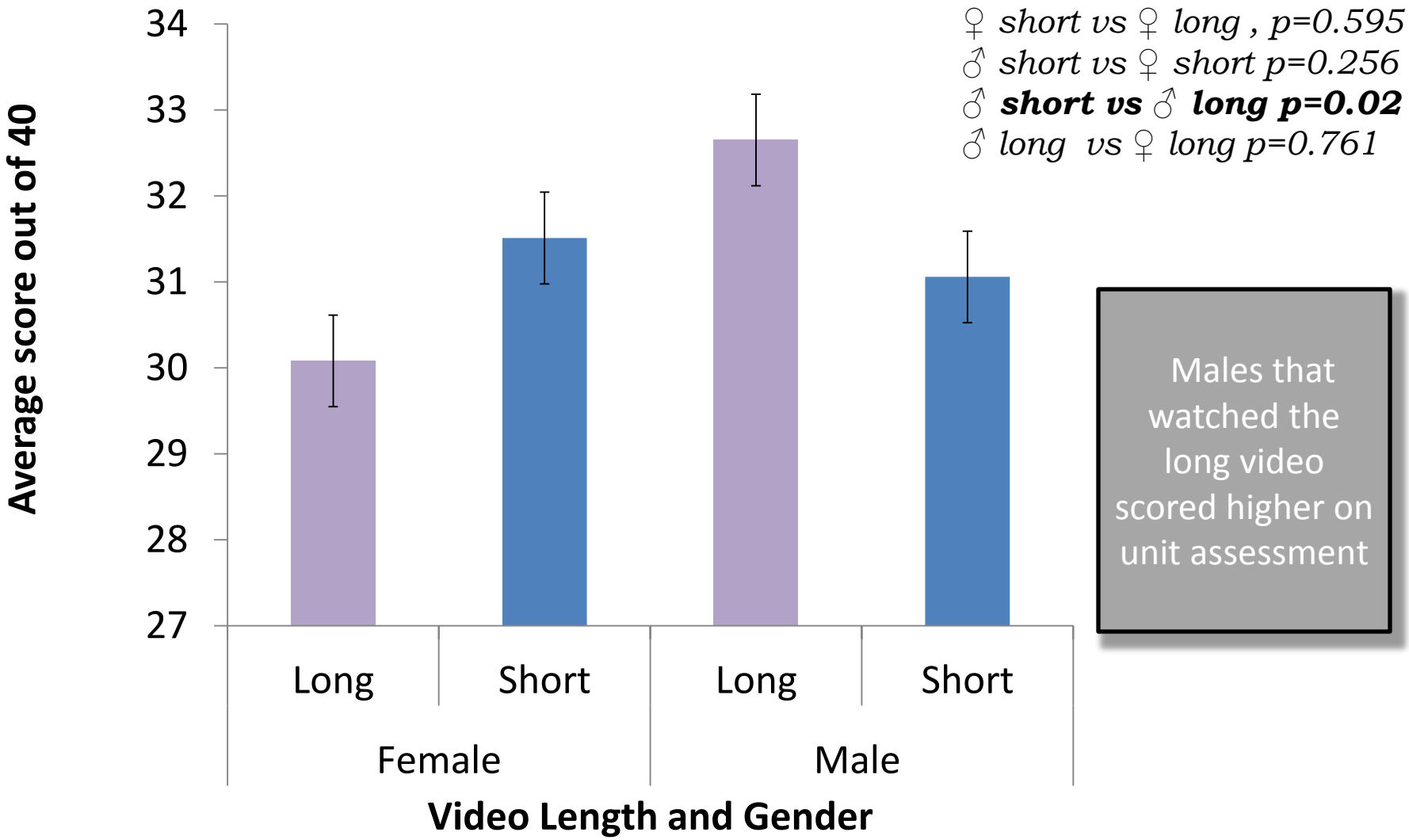
Does the length of video segments in a flipped classroom influence understanding and retention of content knowledge?



However no difference between mean scores on unit assessment ANOVA in R, $p = 0.896$

Average score on assessment based on length of video lecture for Unit I and Unit II combined.

Do test scores from different length video lectures vary with gender?



Next Steps

- Continue to collect data in middle school
  - How to make more inclusive, engaging
  - Analyze assessment data directly following the video
- Conduct parallel study in college, non-majors bio course
  - Measure ability to apply content (case study) following different length videos
  - Evaluate stereotype threat and science anxiety before and after videos and case studies

Case Studies

- Interrupted Clicker Case Studies:
  - Scientific Method – Childbed Fever
  - Biomolecules – Peanut Butter Project
  - Cellular Respiration – Death by Flea Dip
  - DNA – Vampire Case
  - Photosynthesis – Biofuels
  - Population Ecology – Mystery of missing sea lions

National Center for Case Study Teaching in Science *Good source for cases

Summary: Tips to grow scientists

1. Encourage **exploration** and **curiosity**
2. Allow for **Choice**
3. Promote **Self-directed** learning
4. Provide **Time** to apply and synthesize
5. Construct Concept **conflict**
6. Encourage **Questioning** and **testing** hypotheses
7. Show **Relevance**
8. Initiate with a **Hook**

BUT HOW?

Ethical Debates

Undergraduate research

True Inquiry Labs

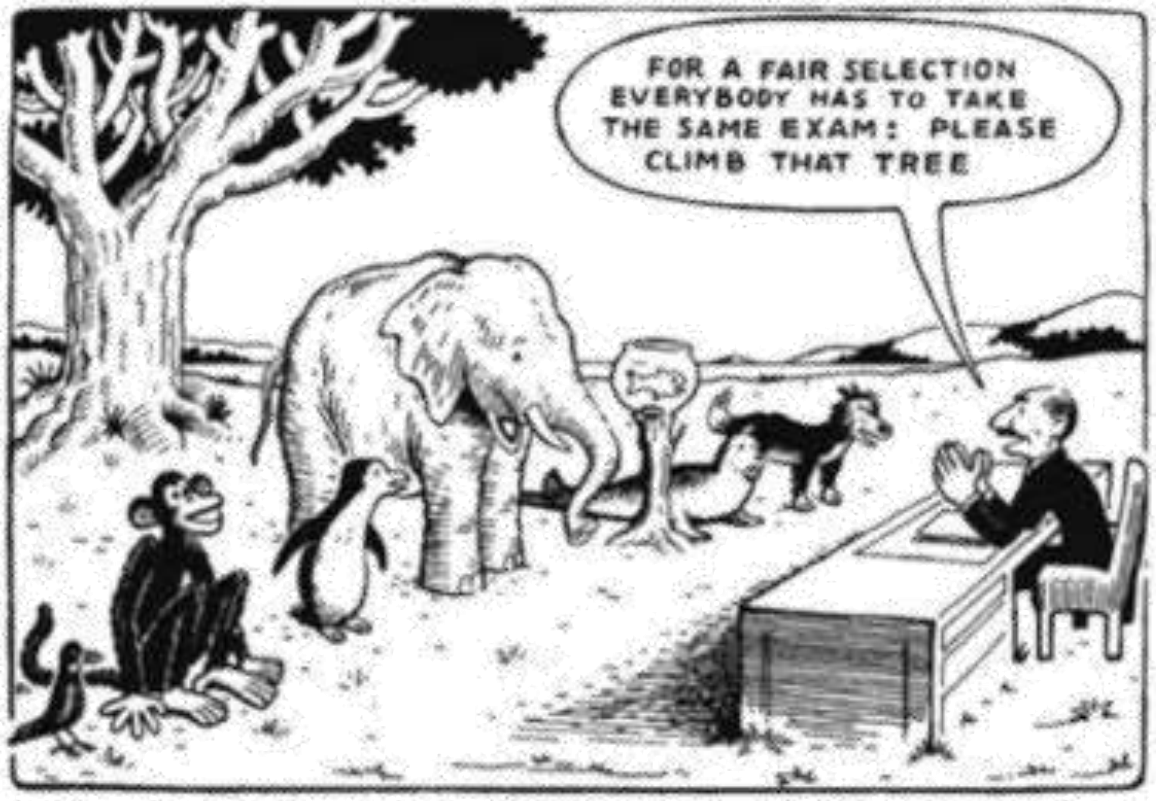
C+E+R method

Case studies

Flipped classroom

Growth mind set

Questions



"Everybody is a genius. But if you judge a fish by its ability to climb a tree, it will live its whole life believing that it is stupid."

-Albert Einstein

Thank you to our collaborators

Nancy Shefferly, Bio 101 Instructor, UWSP, Author of Bio 101 Inquiry lab manual

Dave Grabski & **Josh Hames**, PJ Jacobs Junior High School Science Teachers

Jeff Mslna, PJ Jacobs Junior High School Technology Director

Special thanks: **Mary Tyler** and **Ryan Cowan** (Univ. Maine)
Wisconsin Teaching Scholars and Fellows Program

Thank you for your time

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