

# FLOW VIS AND BEYOND: THE POWER OF AESTHETICS IN ENGINEERING EDUCATION

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# Outline

- Course Contexts:
    - Flow Visualization
    - Perception of Design/ Aesthetics in Design
  - Research Design
  - Assessments
    - Perception Surveys
    - Visual Expertise Study
  - Conclusion
- 




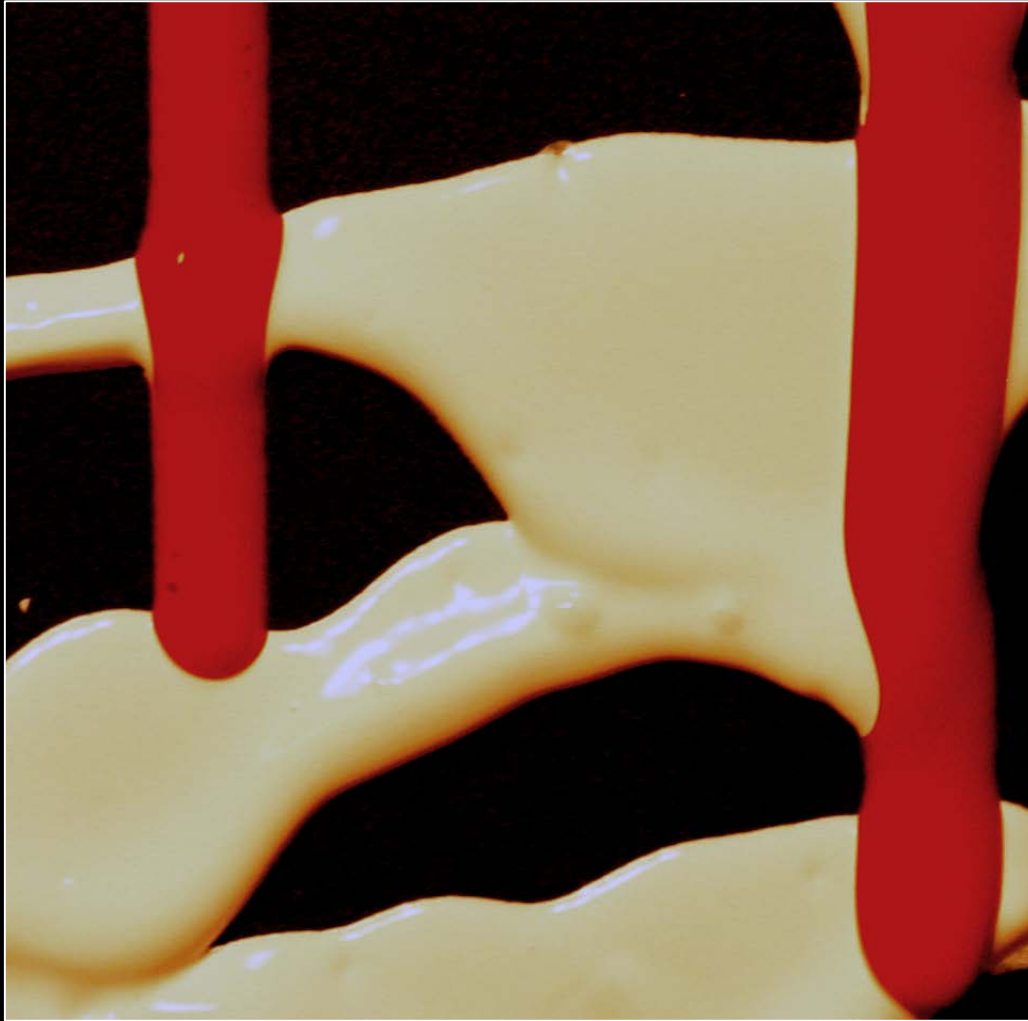
# Flow Visualization

- Making the physics of fluids visible
  - Techniques include adding dyes, particles, and using the index of refraction
- 



A falling  
stream of  
water acts as  
a lens,  
distorting  
shadows  
behind.  
Jessica Lucia  
2010





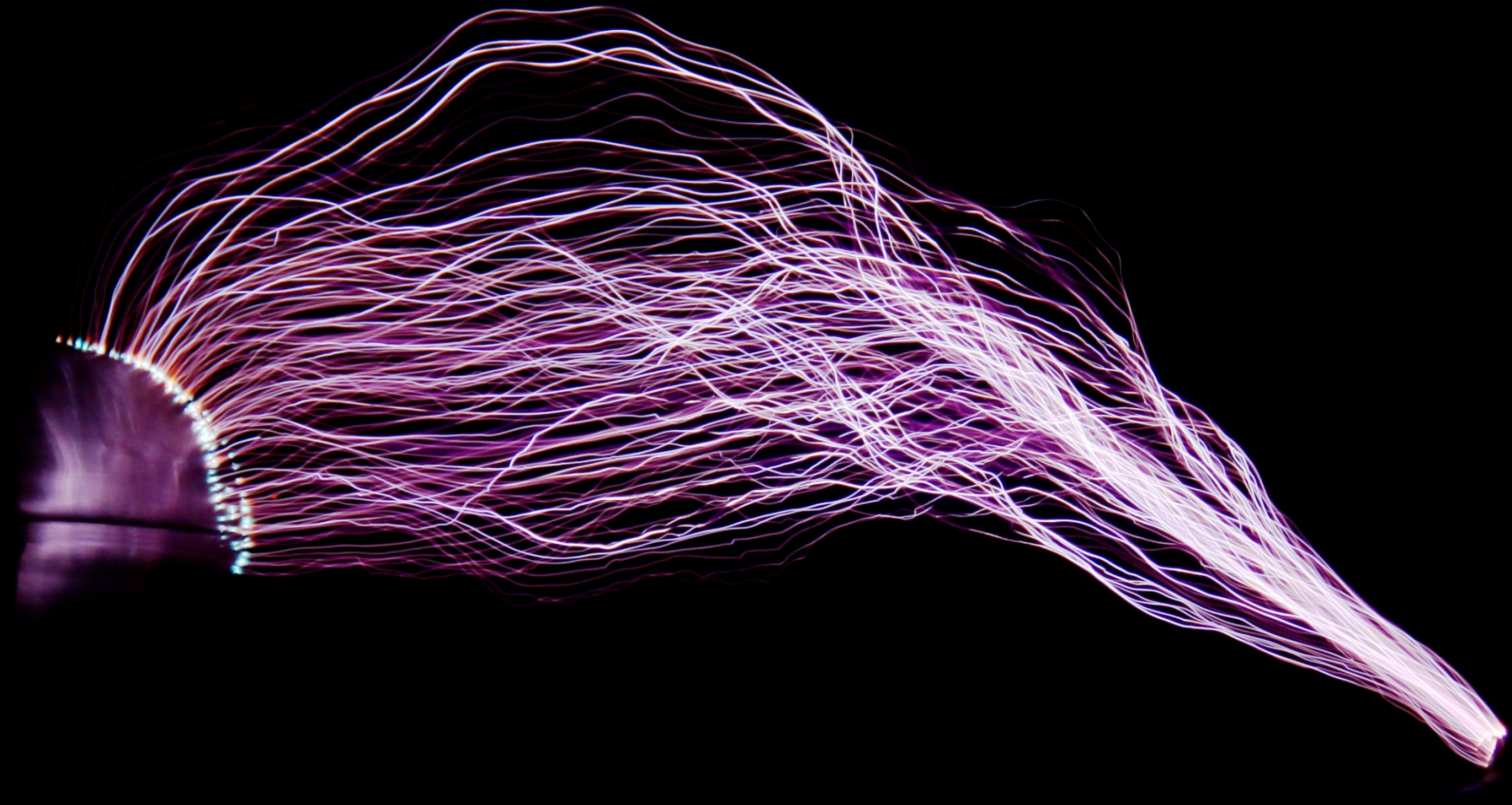
Thin red paint drips over thick white paint. Eric Stahl 2010

“Water Talks.” Droplet splashes rebound into Worthington jets.

Chris Bonhila 2009



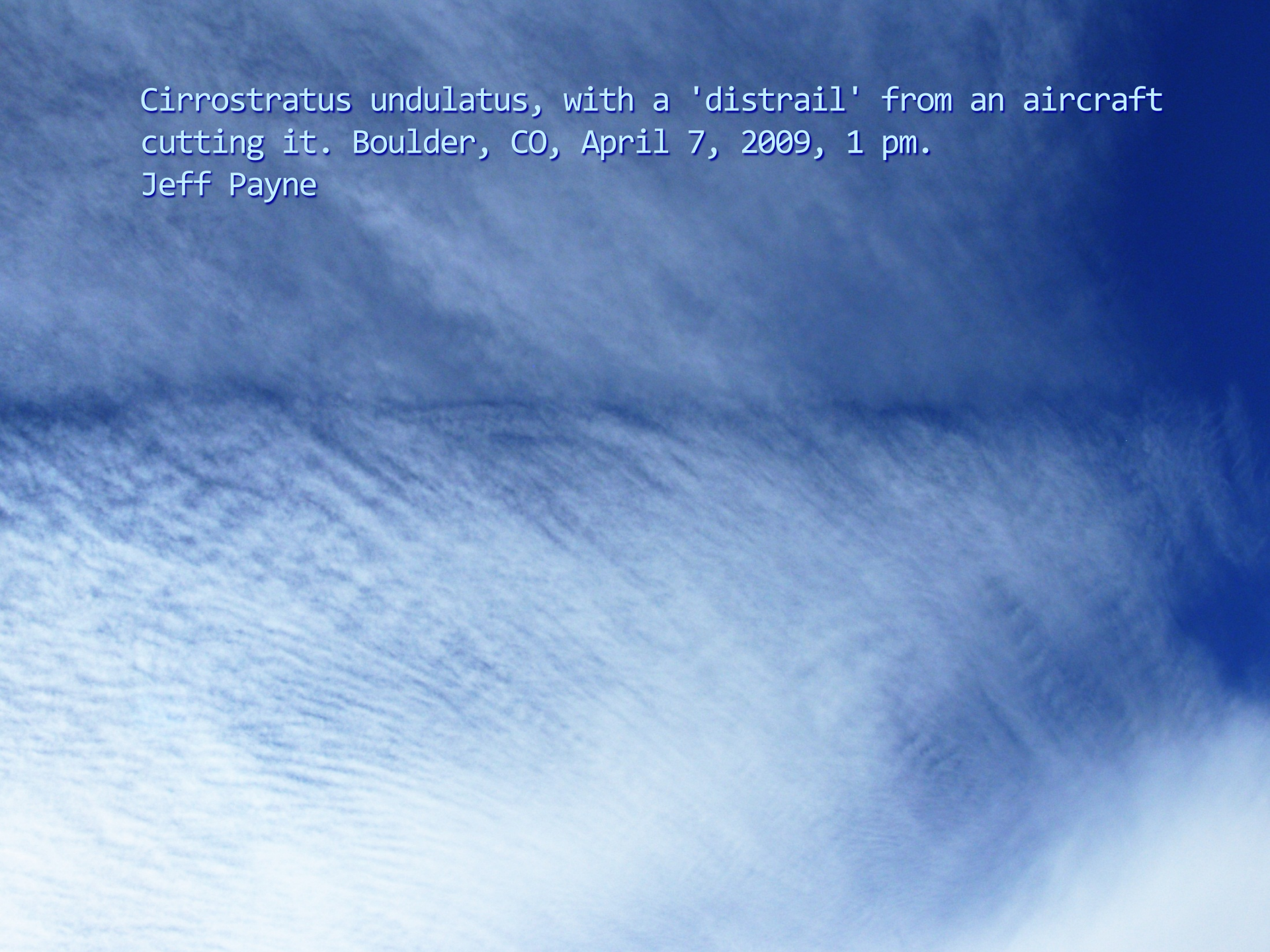
A Tesla coil creates plasma arcing through air  
Mark Reusser, Larissa Rhodes, William Murray, Brian Hancz




Streamwise vorticity in an altocumulus lenticularis, created by  
a stable atmosphere and good wind shear.  
Corey Davis 2009




Cirrostratus undulatus, with a 'distrail' from an aircraft  
cutting it. Boulder, CO, April 7, 2009, 1 pm.  
Jeff Payne






# Flow Visualization

## Course Structure

- Teams of mixed students (20 – 50 total)
    - 1/3 graduate, 2/3 undergrad
    - 1/3 arts, 2/3 engineering (scheduling: administrative challenge)
  - Lecture (2 - 3 hrs/wk) Laboratory (0 - 3 hrs/wk)
  - 6 assignments:
    - 1 individual, using small scale, at home flows
    - 3 team, some apparatus available
    - 2 individual cloud images
  - Students choose physics and visualization techniques
  - Detailed reports with scaled expectations
- 




# Course Content

- Photographic techniques (6 lectures)
    - Optics, exposure, resolution, composition, digital technology
  - Flow Visualization Techniques (6)
  - Fluid phenomena (3 - 6)
    - Survey, scaling, cloud physics, vorticity
  - Critiques (5 - 10)
  - Art aspects; aesthetics, impact of technology on art (guest lectures)
- 



# Unique Aspects

- First Flow Visualization course
  - Art students are expected to be scientists
    - Document, experiment
  - Engineering students are expected to be artists
    - Create expressive images with impact and intent
  - Grading on contribution quantity
  - Motivation via publication and critiques
- 



# Students Develop Experiments

- Initially, students are encouraged to work with simple flows at home
- Everyday, household fluids, often edible
- Environmentally benign
- Some unusual\* physics are revealed
- Drawback: exact properties are unknown
  - Food coloring, WD-40

\*To me.



# Anecdotal Impact of FV

- High FCQs, large waitlists
  - FV (Flow Vis) alumni write me with recent examples, web links etc.
  - FM (Fluid Mechanics MCEN 3021, required) never write.
  - Students cited important aspects:
    - Emphasis on aesthetics vs. utility
    - Students choose fluid physics to study/ Freedom from constrained assignments
    - Creativity is expected
    - Photography context
  - “I see fluids everywhere now”
-



# Perception of Design

## Similarities to FV

- Students photograph design examples
- Emphasis on photography
- Freedom in subject matter
- Pervasive topic
- Visual assignment, in-class critique, short report, posted.
- Non-competitive, generous grades

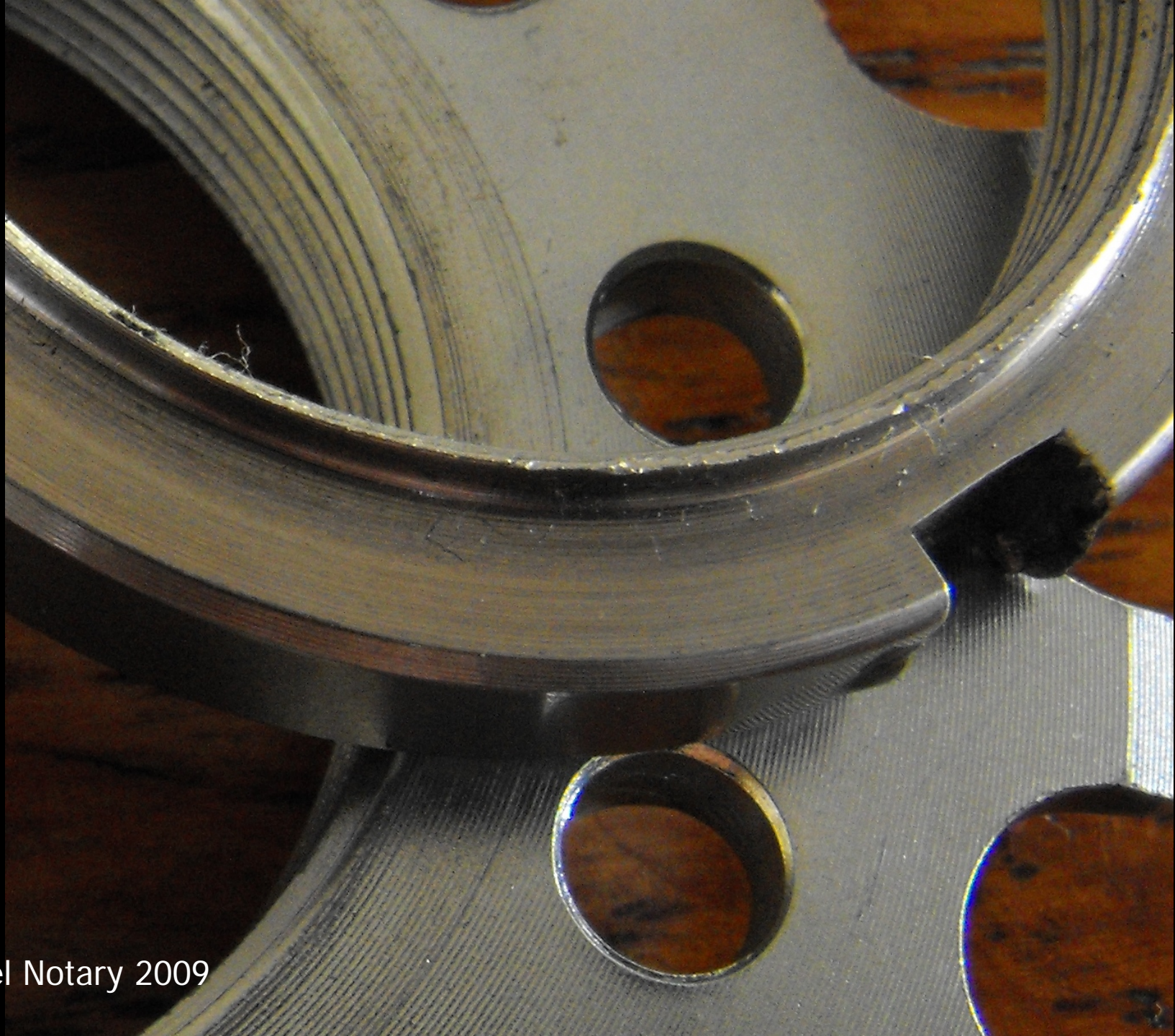
## Differences from FV

- 1 credit vs. 3 for FV
- ME undergrads only, vs. mixed grad and undergrad, engineers and photo/video students
- Photographs of existing objects



Rosie Steinhaus  
2010








Chris Moore 2009

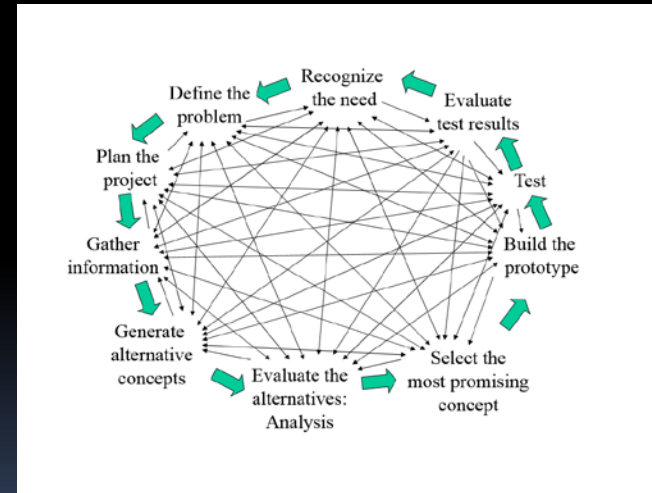


# Perception of Design

- Many images of sports equipment and automobiles
  - Surveys indicated no shift in affect/attitude.
- 
- No “eye opening”, transformative experience. So?
- 

# Discipline Based Education Research (DBER)

- Use iterative principles of science, engineering and design (my disciplines) to improve teaching and learning.
  - Stop guessing, get data
  - Read the literature
  - Make a plan
  - Revise and repeat



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# Research Questions


- Overarching, 10 year goal:

How does increasing visual perception of engineering topics improve educational outcomes?

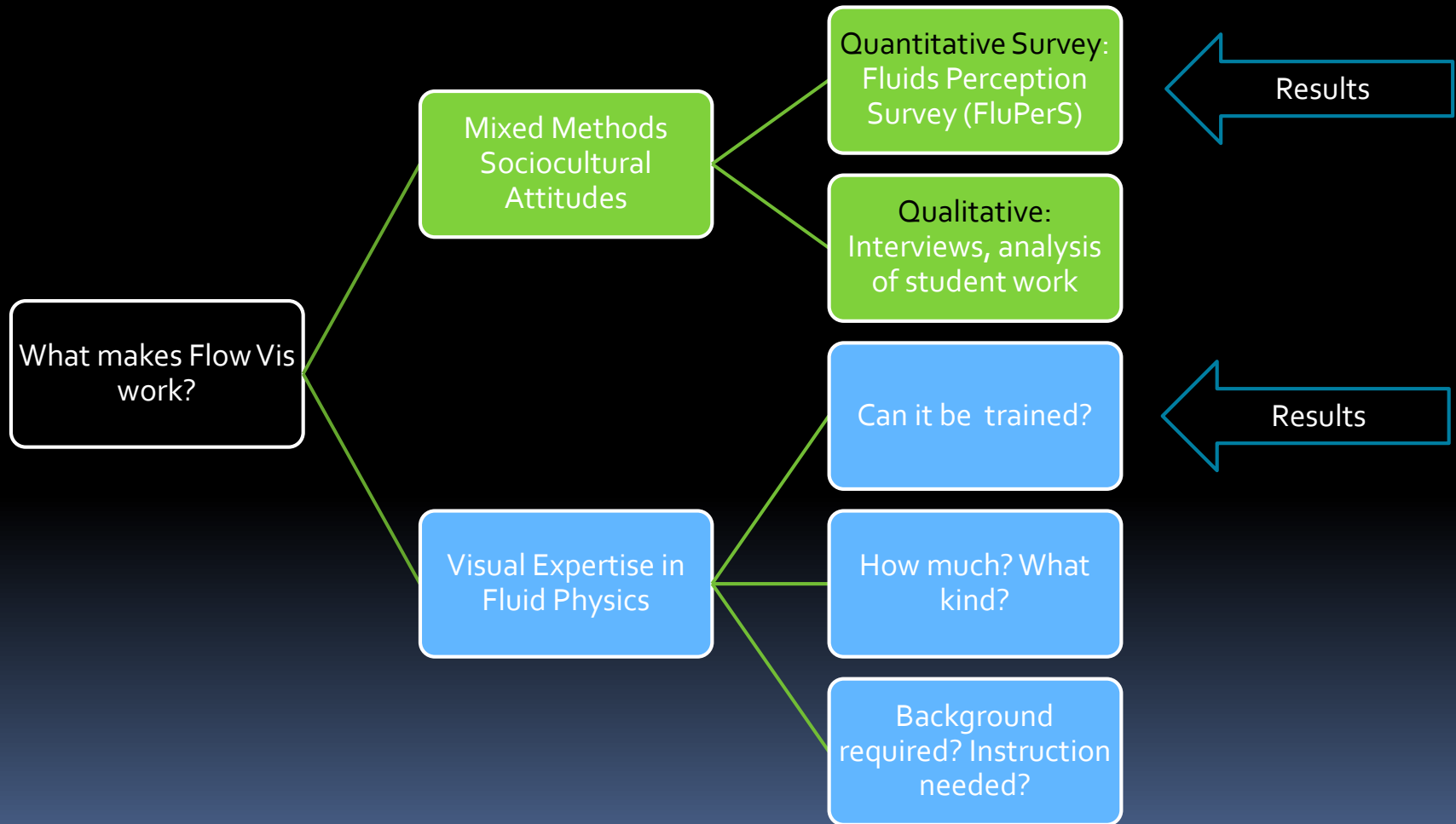
- Visual perception = seeing and perceiving an abstract construct such as fluid physics or mechanical design as ubiquitous in the environment
  - Educational outcomes = recruitment and retention in school and the workforce, attitudinal shifts, cognitive gains and evidence of 'life- long learning'
- 



# Research Questions: Specific

1. Does a Flow Vis experience increase visual expertise? How much and what type of experience is needed?
  2. Does increased visual expertise impact educational outcomes?
  3. Does Flow Vis improve affect/attitudes towards fluid mechanics? If so, why? Is it related to the pedagogical techniques employed in the course, or to the emphasis on aesthetics? Does this improved affect result in better outcomes?
  4. What aspect of increased visual perception has the most impact on educational outcomes? Specifically, does aesthetics give Flow Vis its power? Is it the creativity required to make images? Or is it love of fluid physics?
- 

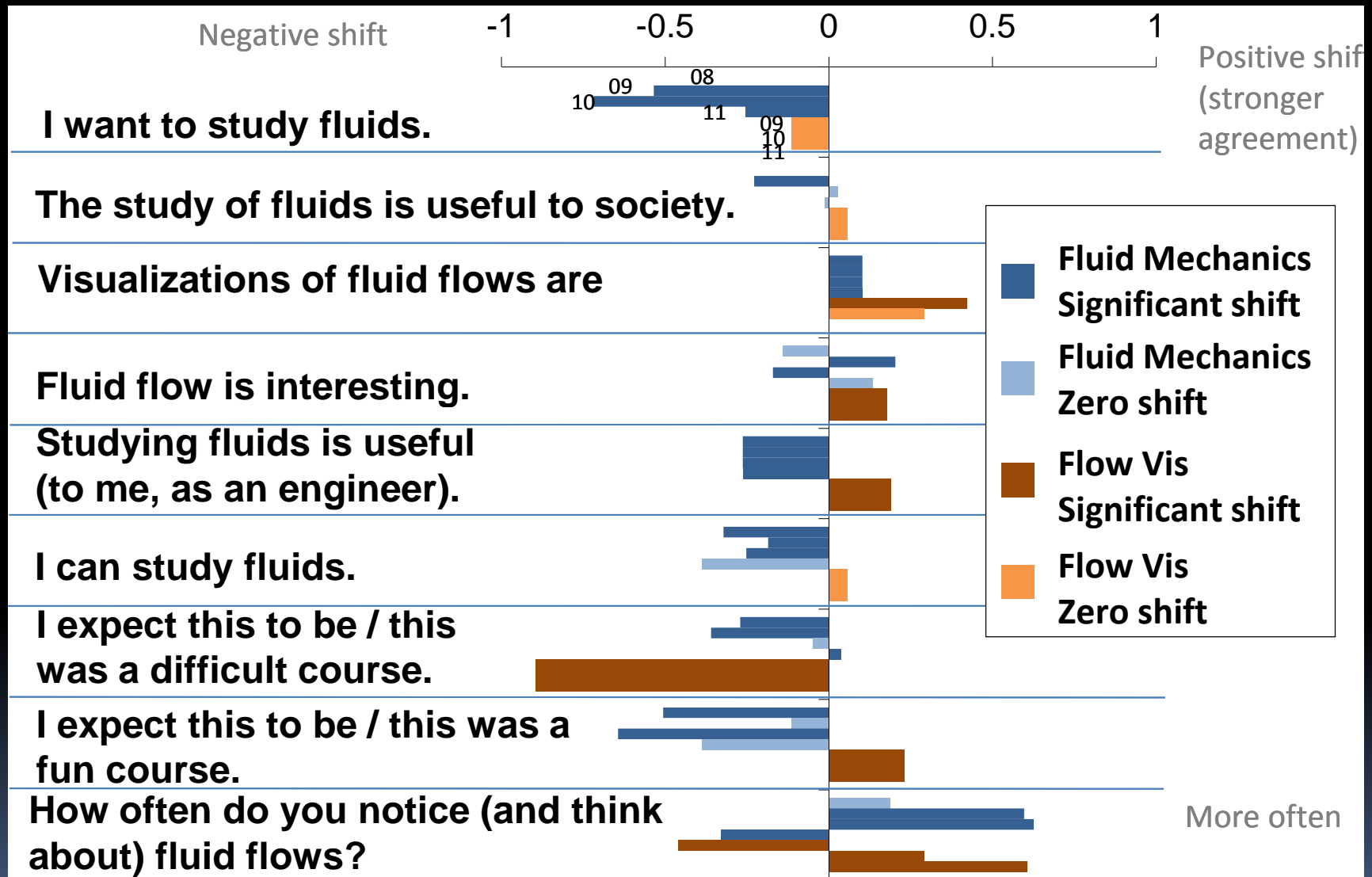
# Research Approach



# FluPerS Sample Questions

- 5 point Likert scale: strongly agree to strongly disagree. Loosely based on CLASS attitude survey
  - Fluid flow is interesting.
  - I can study fluid flow.
  - I want to study fluid flow
  - Studying fluid flow is useful to society/ to me as an engineer
  - Visualizations of fluid flow are very beautiful.
- How often do you both notice and think about fluid flow ?


# Pre – Post Comparisons FV and FM



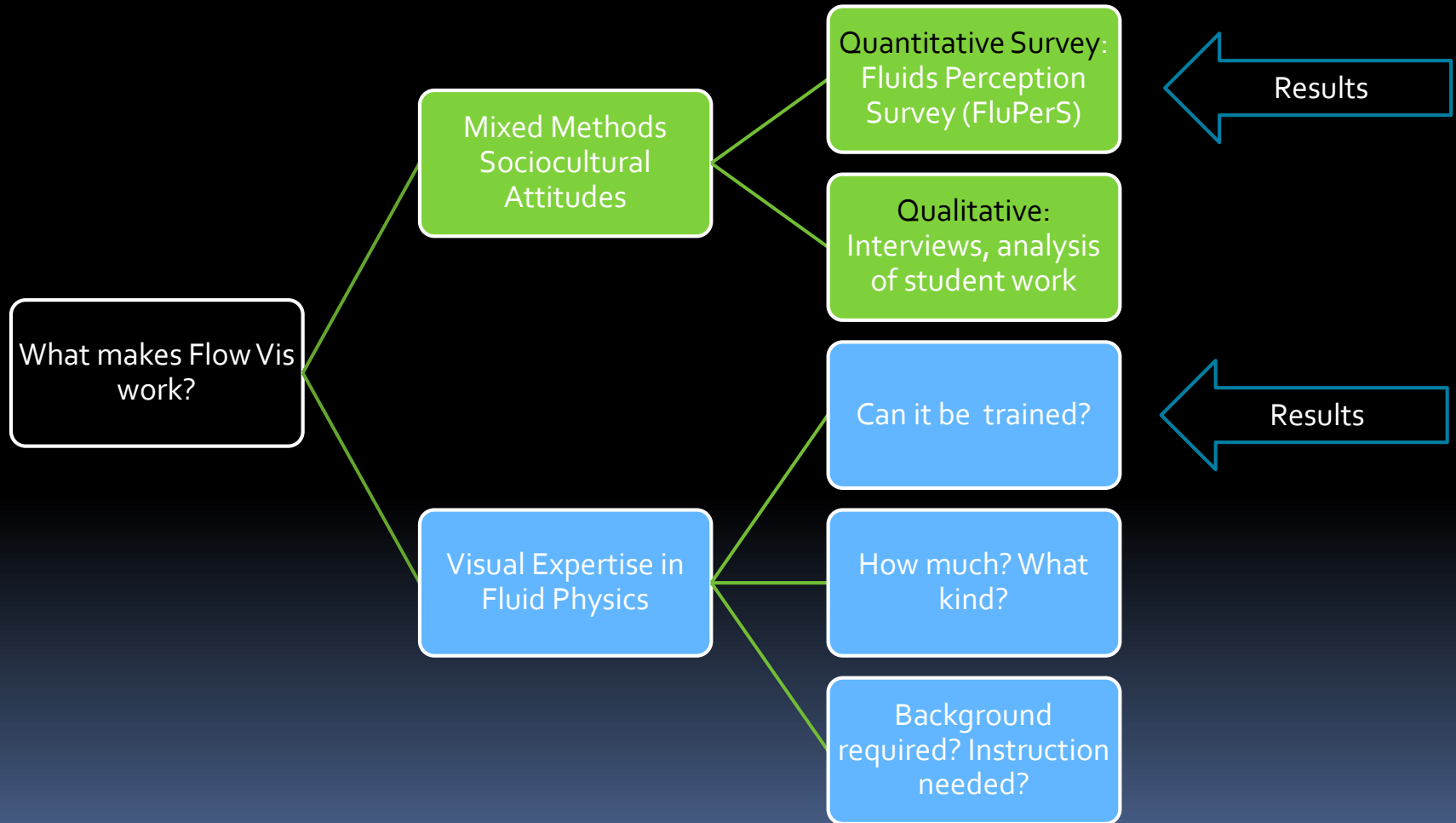
If p values between all years were above .05, data was pooled.



# FluPerS Summary

- FV had significant positive impact on student attitudes compared to FM and other controls
    - More useful
    - Want to study etc
  - Other electives had near zero shifts
    - Explains some, but not all of FV +
  - Qualitative validation has already proven important: 'noticing' included classwork.
  - POD did not show similar results
- 

# Research Approach




# Visual Expertise

- “I see fluids everywhere now” = visual expertise?
- Perceptual experts (bird watchers, dog show judges) categorize at the ‘**subordinate level**’; (mountain chickadee, not small bird) as fast as typical ‘**basic level**’.
- Most humans have expertise in faces of own race.
- Investigated by
  - fMRI
  - event-related potential (ERP) components (signature waveforms derived from EEG)
  - matching speed tests
- Achievable in lab studies. RQ: can this be applied to abstract constructs, i.e. fluid physics?



# Method: Visual Expertise Training

- RQ: can novices be trained to immediately recognize the difference in visual appearance between a laminar and a turbulent flow in either the context of a Karman vortex street (KVS), or in a more general context?
- 

# Method: Visual Expertise Training

- Error-driven training
- Is this Category 1 or Category 2?



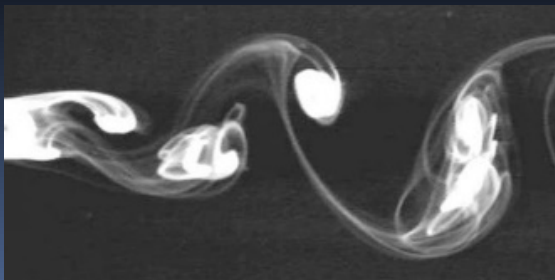
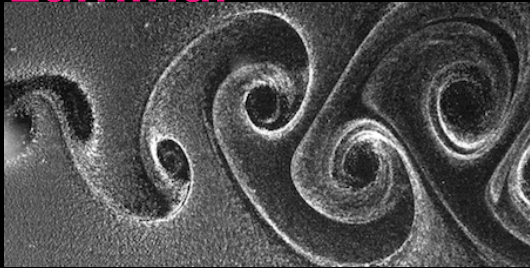
# Method: continued

- Image appears for 0.8 seconds. Comparable to other visual expertise studies.
- 1. Pretest (Match task 1). No answers given. 20 images of each type (lam, turb) randomized from pool of 40 images per type.
- 2. Training. 10 images of each type, Beep **CORRECT** or Boop **INCORRECT**
- 3. Post test (Match task 2) Same images as in Pretest.
- 4. Alternate Test (Match task 3) If subject trained on KVS images, are given 40 general laminar and turbulent images. Also vice versa.

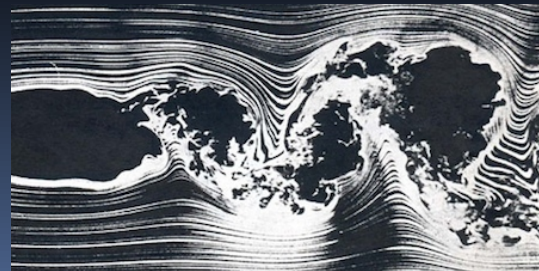
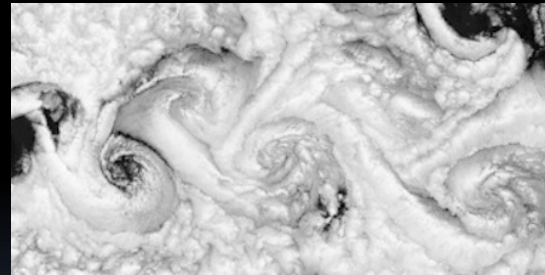
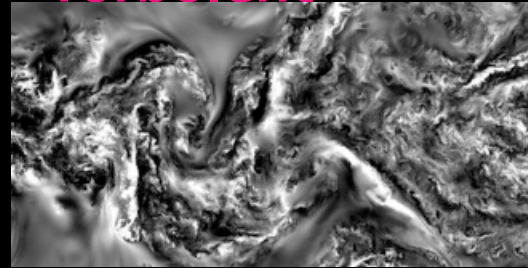


# Example images: KVS

Laminar



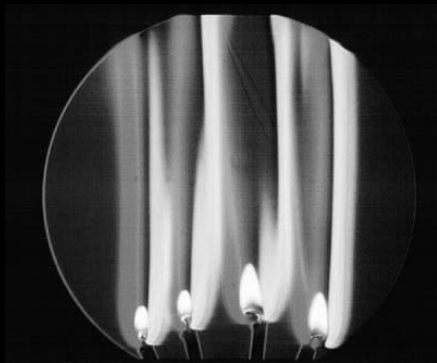
Turbulent



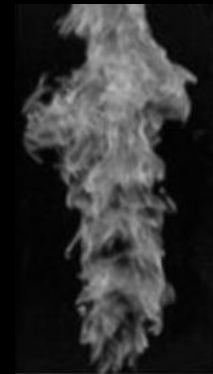


# Example images: General

Laminar




Turbulent

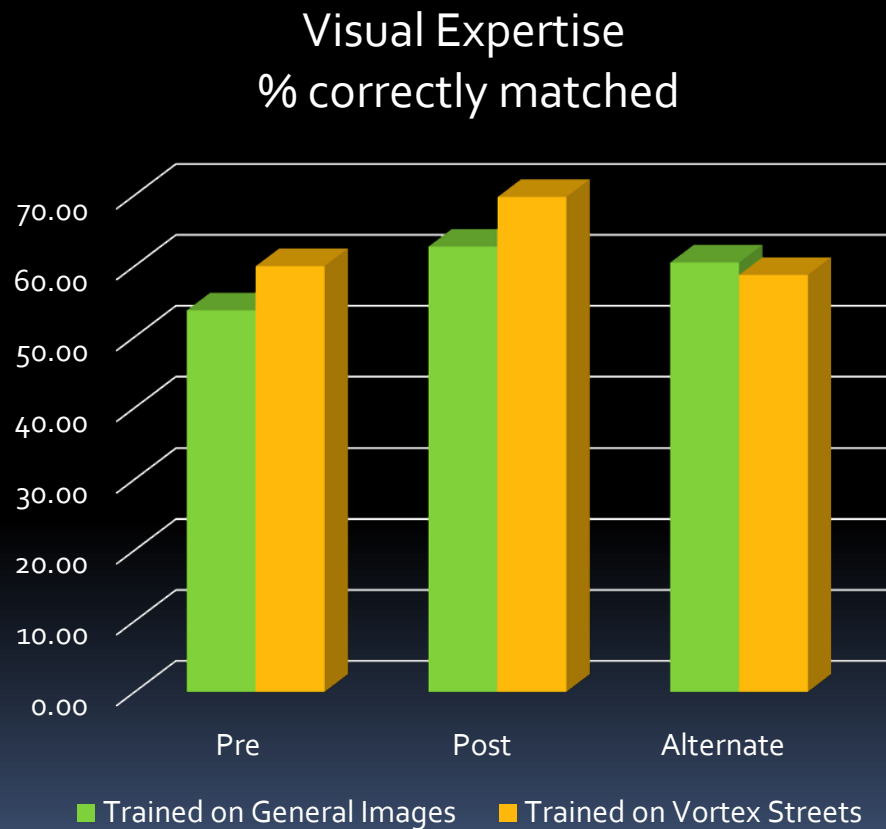




# Subjects

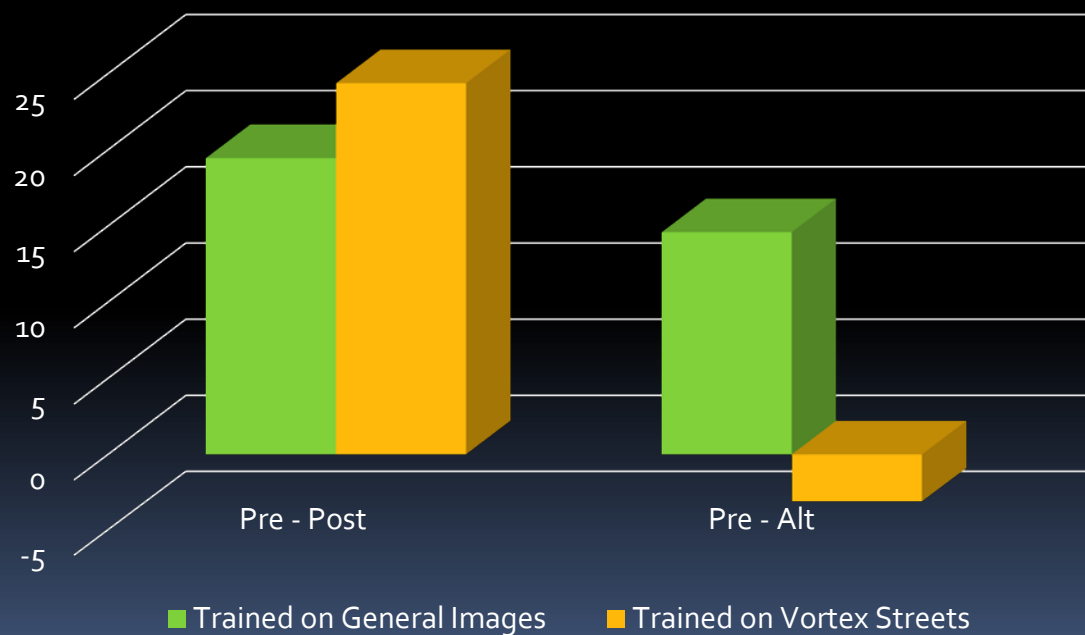
- 20 novices (Psych pool students, no fluid mechanics training) out of 40 planned.
  - Next stage: current Junior Fluid Mechanics students (20).
- 

# Preliminary Results

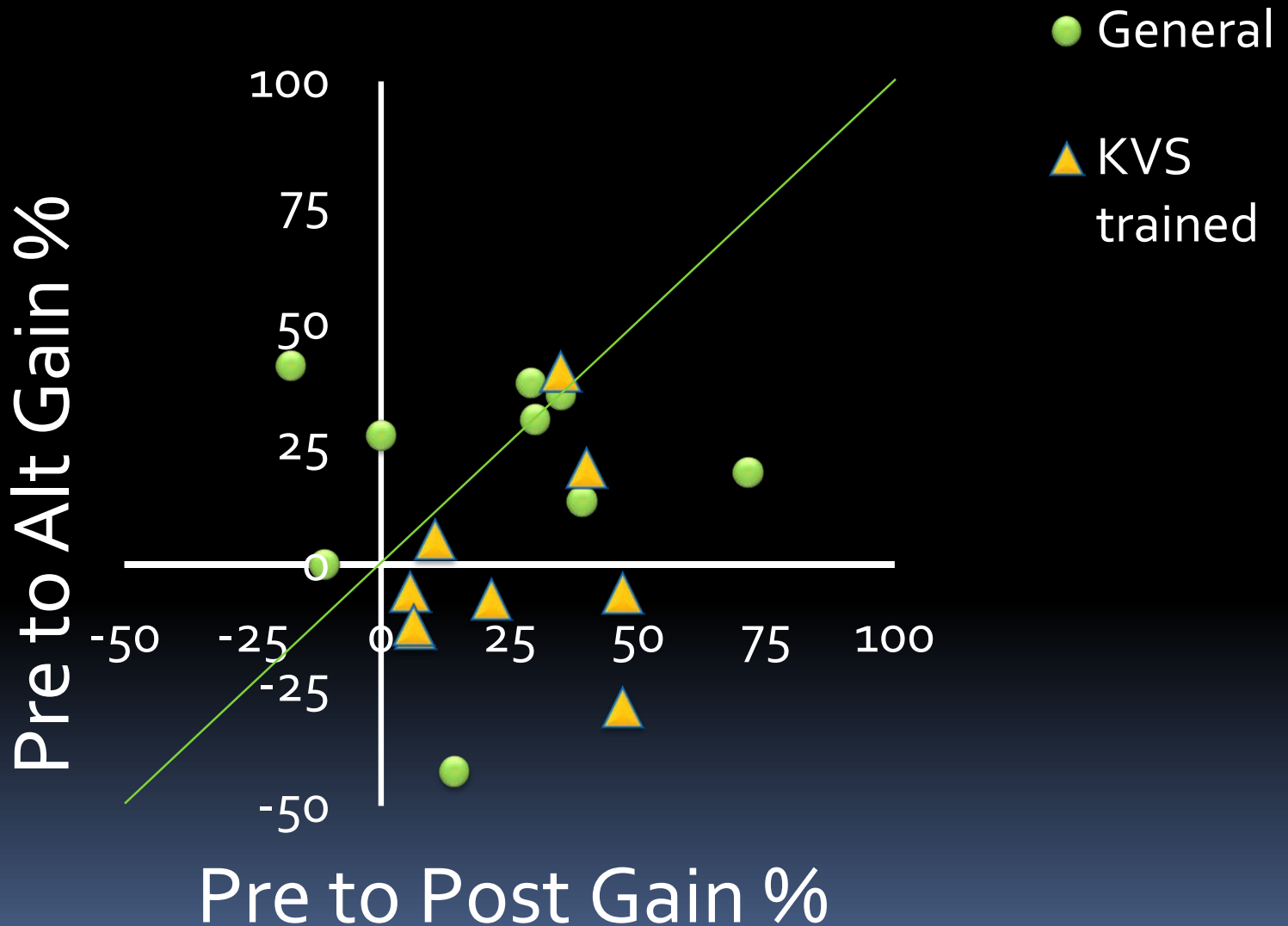


# Does Expertise Transfer?

Visual Expertise  
<g> = % of possible gain,  
based on class average




# Does Training Generalize?






# Conclusion

- Can Visual Expertise be applied to abstract concept: Laminar vs Turbulent flow?
  - So far, qualified yes. Visual expertise training does improve performance
  - Does visual expertise generalize?
    - Training on KVS images does not improve performance on general images
    - Training on general images provides equal performance on KVS images
- 



# Future work

- Mixed methods sociocultural study
    - Quantitative analysis and validation of Fluids Perception Survey
    - Qualitative analysis of affect and attitudes using interviews and analysis of student work in FV and other control courses
  - Visual expertise:
    - Test fluids students
    - Study subject attitudes
    - Expand study to other types of physics
- 

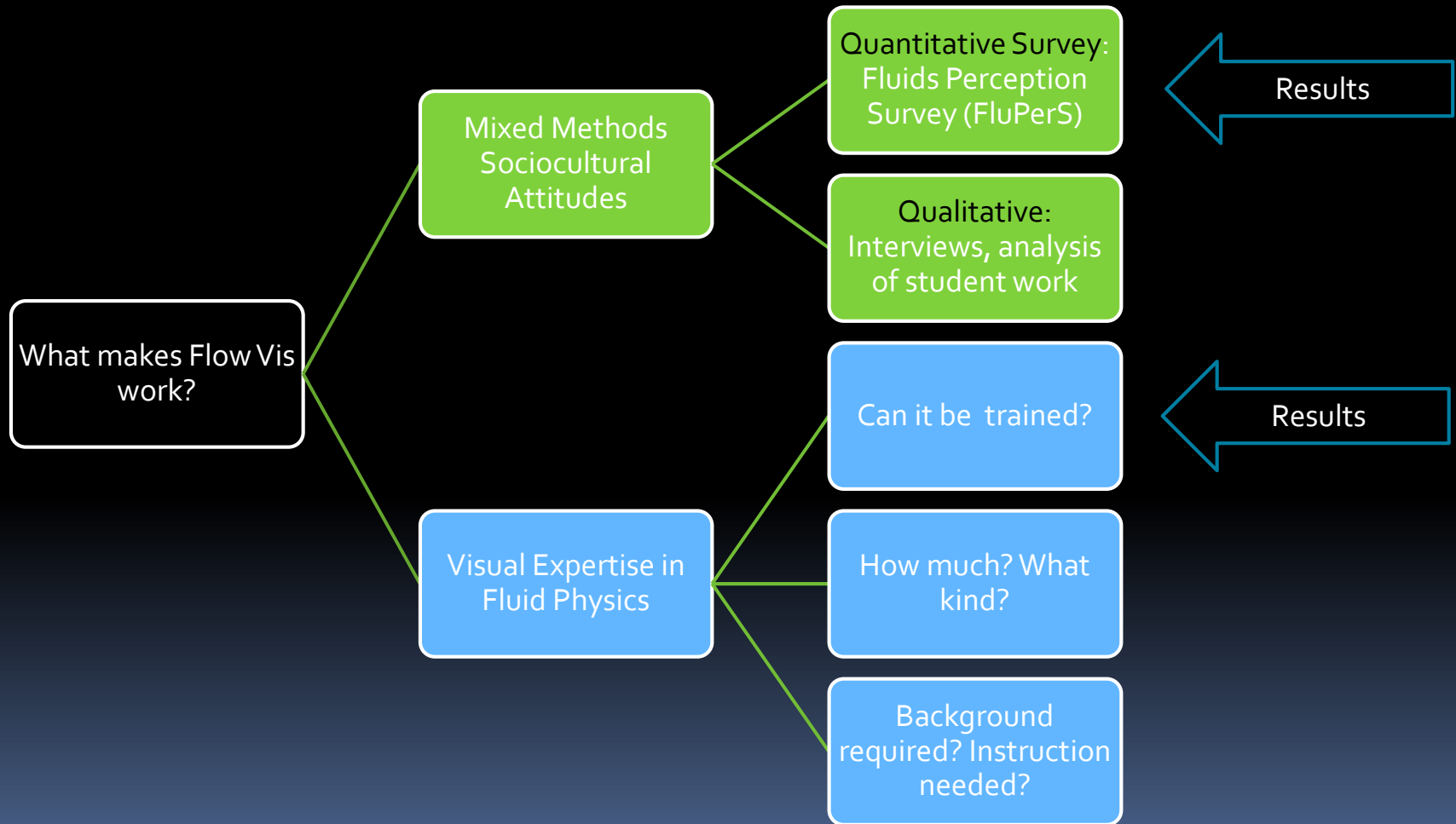
# Thank You

- Google “Flow visualization” for course website and student image galleries, or
- [Flowvis.colorado.edu](http://Flowvis.colorado.edu)
- Join the Flow Visualization Facebook group




- Flow Visualization Vimeo channel

# Research Approach





# Research Questions: Specific

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- 



# FLUPER Details

Fluids Perception Survey Development, Validation  
and Results





# Survey Development: Item Response Model

- Define “appreciation of fluid flow”
- Hypothesize levels of expertise
- Develop survey questions
- Develop a rubric to score these questions
- Pilot test the survey
- Analyze for spread per question
- Revise

# First Step: Define concepts

Appreciation of  
Fluid Flow

Emotional/  
Affective  
response to  
fluid flow

Awareness of  
Fluid Flow

Fluid flow is  
beautiful

Fluid flow is  
interesting

I can study fluid  
flow

## Expert

### Awareness of Fluid Flow

Always notices fluid flows. Realizes that fluid flow happens all around us in gases, combustion, liquids, etc

Notices fluid flows often. Fluid flow happens in nature but involves only liquids

Notices fluid flows occasionally. Fluid flow is only created in the lab with a variety of substances

Fluid flow is only created in the lab with liquids

Fluid flow is just a course/ theory that has nothing to do with the real world

Never thought about fluid flow before

### Affective Response to Fluid Flow

A completely positive response. The person finds the fluid flow very interesting, beautiful, and useful. The person is influenced by any interaction with the topic.

A somewhat positive response. Finds much interest, beauty, or usefulness in specific fluid flows.

A somewhat positive response. The person may find some interest, beauty, or usefulness in fluid flow

A neutral, or no response to fluid flow.

A somewhat negative response. It may be considered boring, useless

A completely negative response to fluid flow. There is no beauty or interest in the subject. Any interaction with fluid flow does not change their opinion.

### Interest in Studying Fluid Flow

Wants to know all about fluid flows; what creates them, why they behave and look as they do. Enjoys the mathematical formalism of fluid mechanics.

Wants to know all about fluid flows; what creates them, why they behave and look as they do. Tolerates the mathematical formalism of fluid mechanics.

Wants to know about fluid flows; what creates them, why they behave and look as they do, but is only interested in qualitative explanations.

Is mildly interested in the physics of fluid flows, and finds them too difficult to study.


May be content to admire fluid flows, but isn't curious about them.

Isn't interested in flows or their physics at all

## Novice

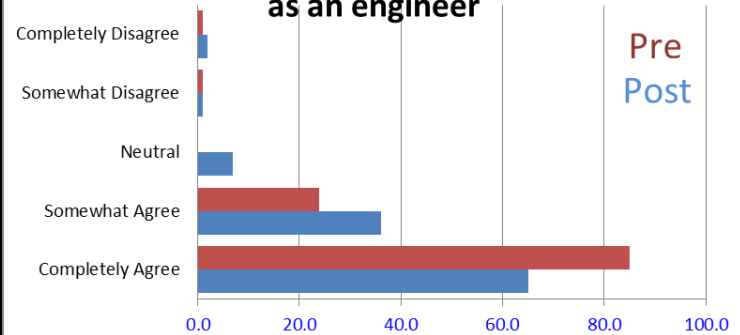


# Survey Administration

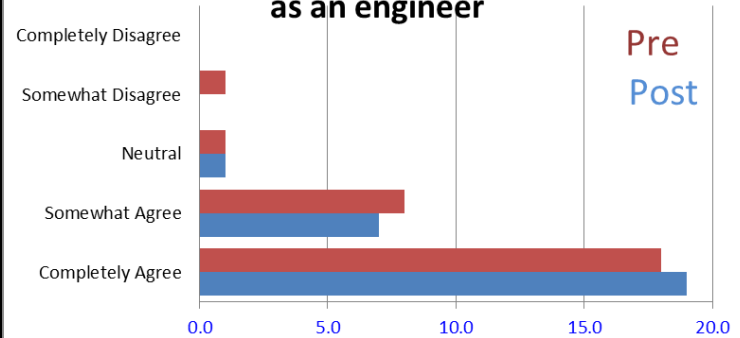
- Required in Jr level Fluid Mechanics (FM), and in Flow Visualization (FV), Perception of Design (PD) and Sustainable Energy (SE)
  - Administered pre- and post- course.
  - Individual student responses matched pre/post.
  - Continual development of questions w.r.t. scaling, validity and reliability.
  - Item Response analysis partially completed. Numerical values assigned to gauge expert vs novice responses.
- 

# Results

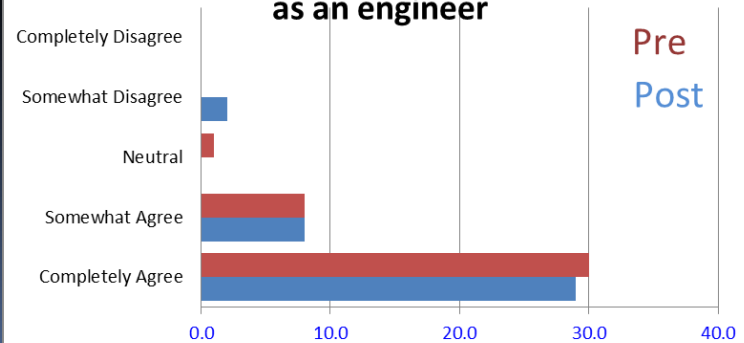
**FM: The study of fluids is useful to me as an engineer**



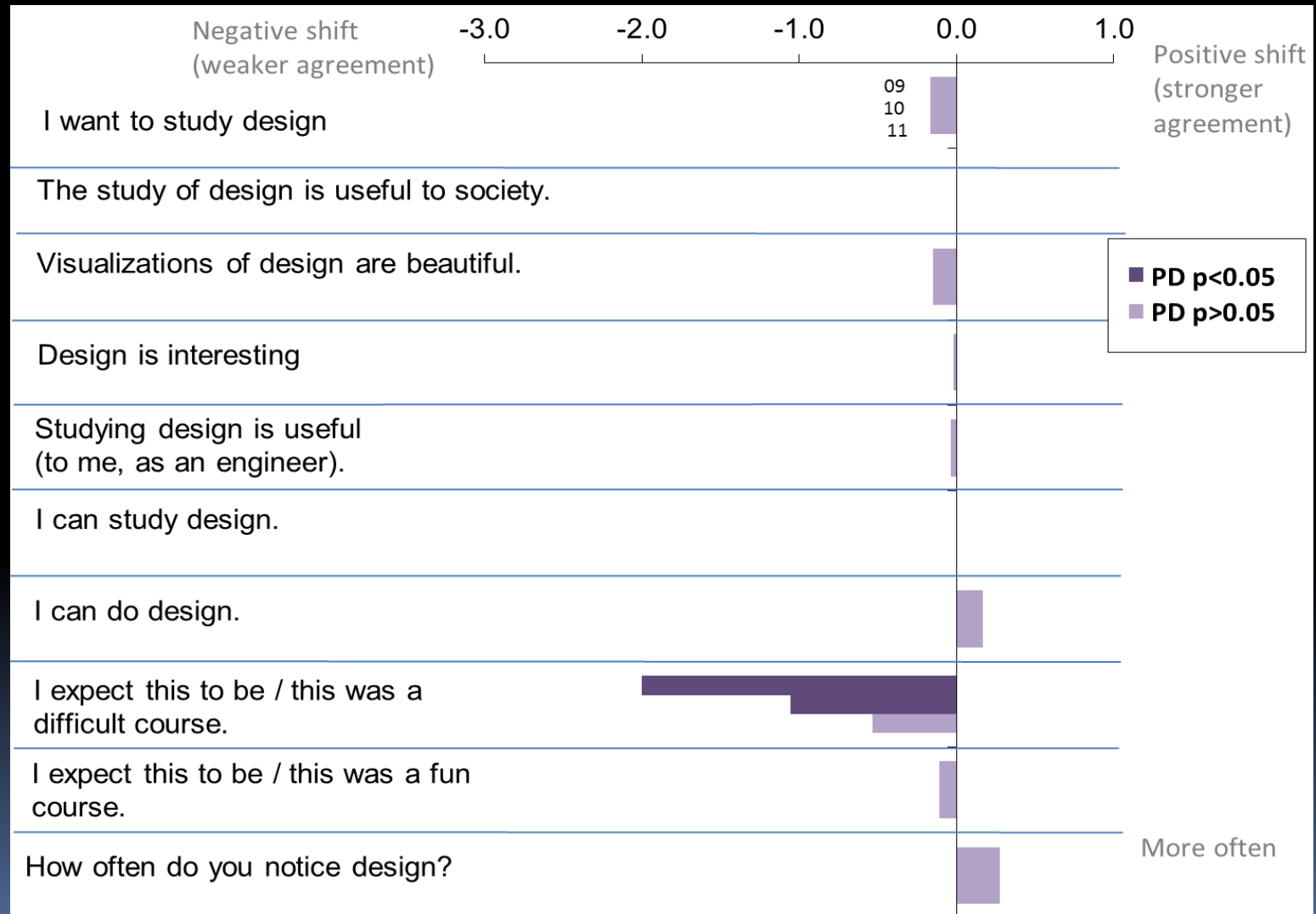
**FV: The study of fluids is useful to me as an engineer**



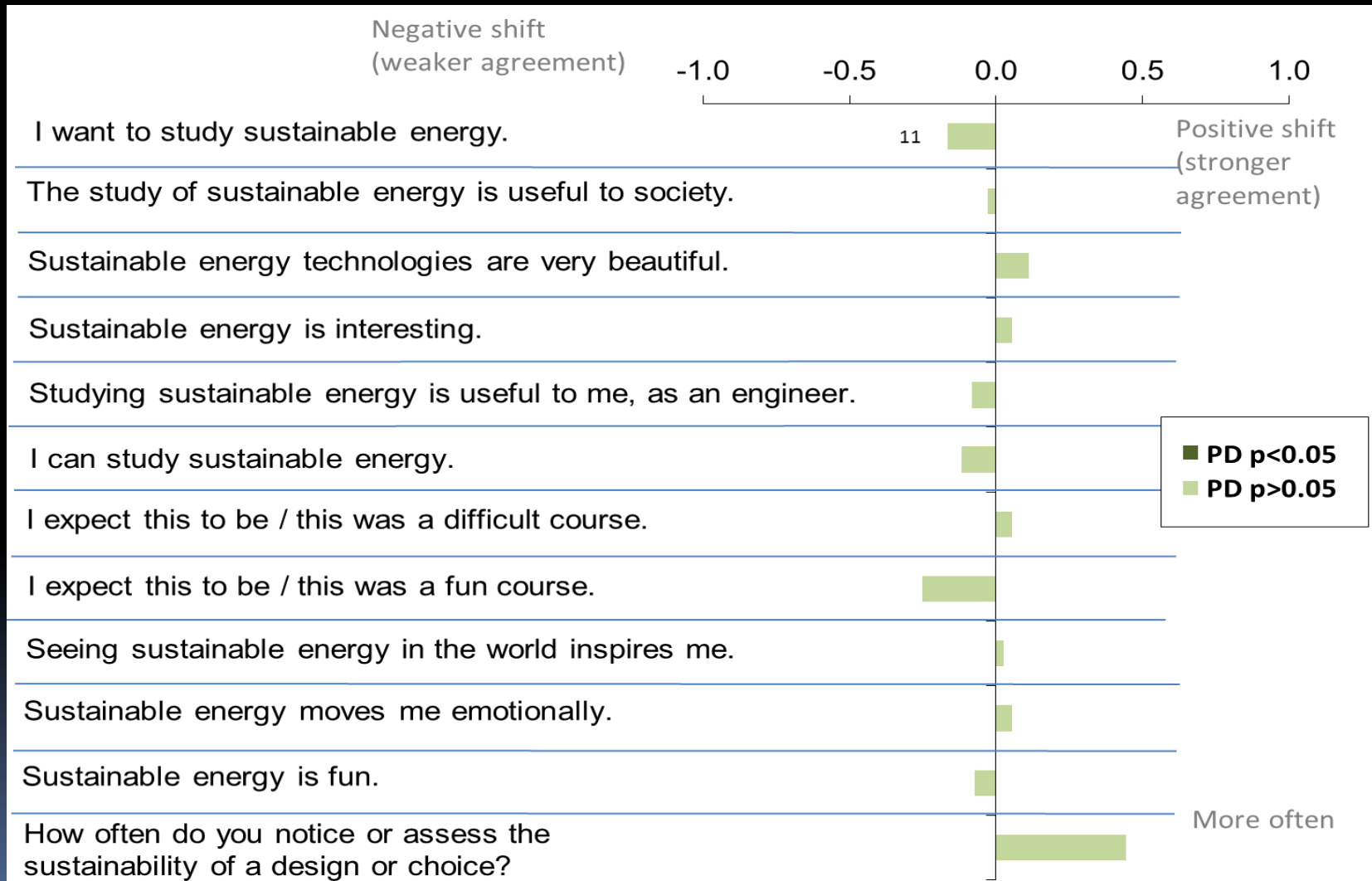
**PD: Studying design is useful to me as an engineer**



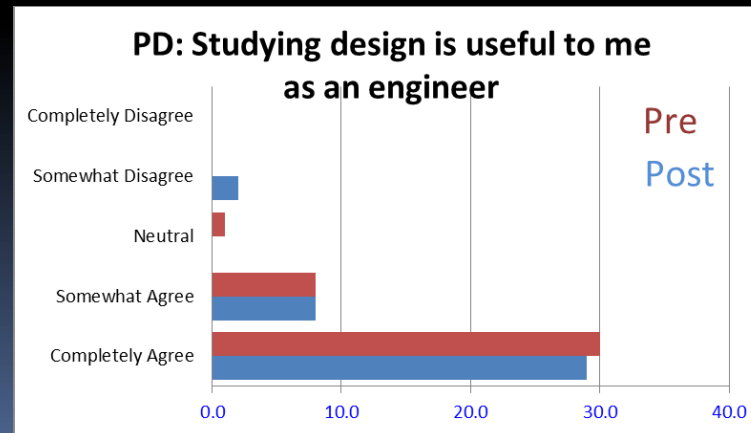
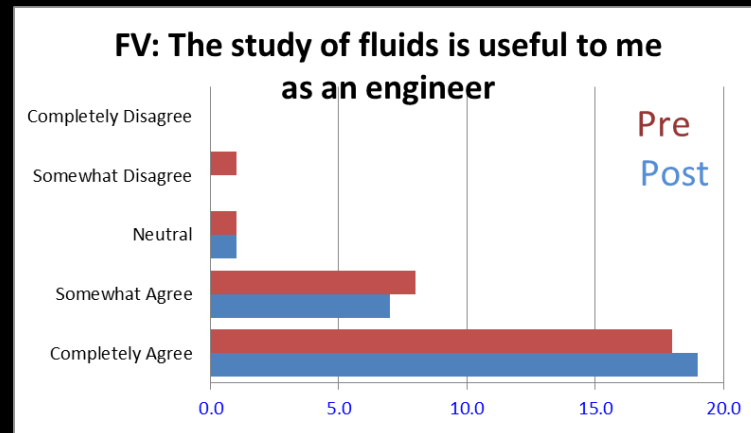
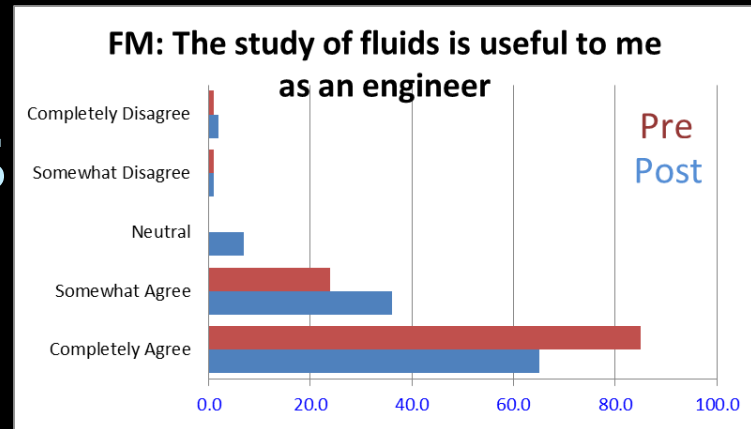
# Perception of Design



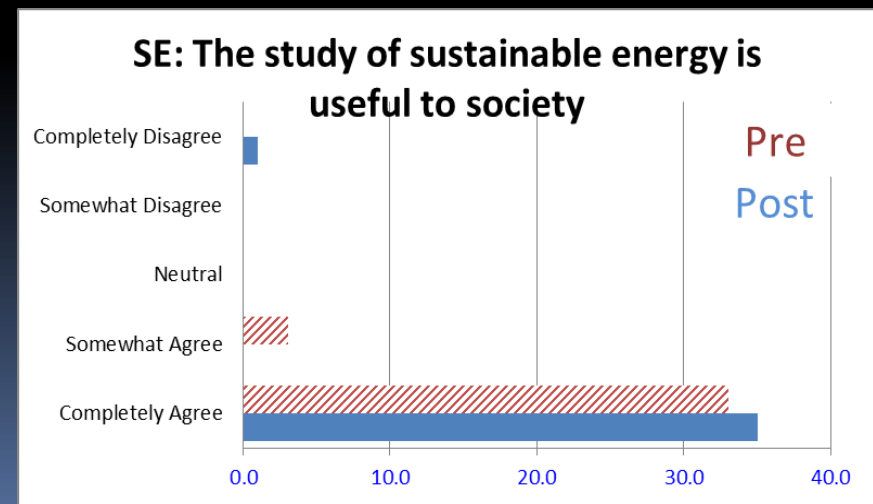
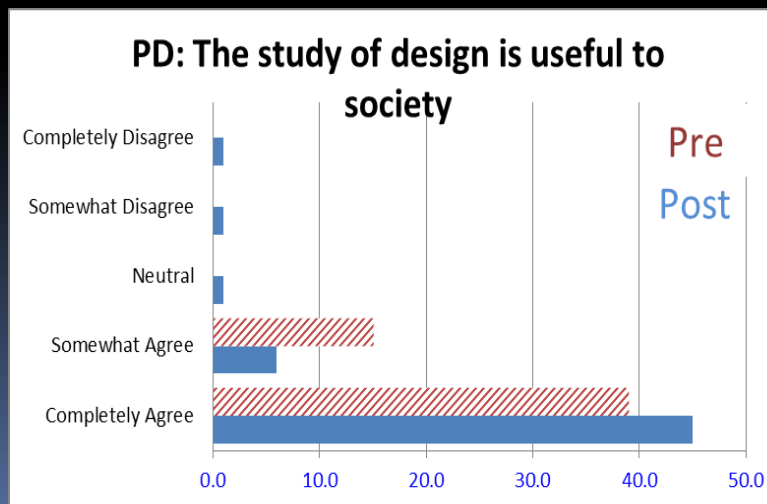
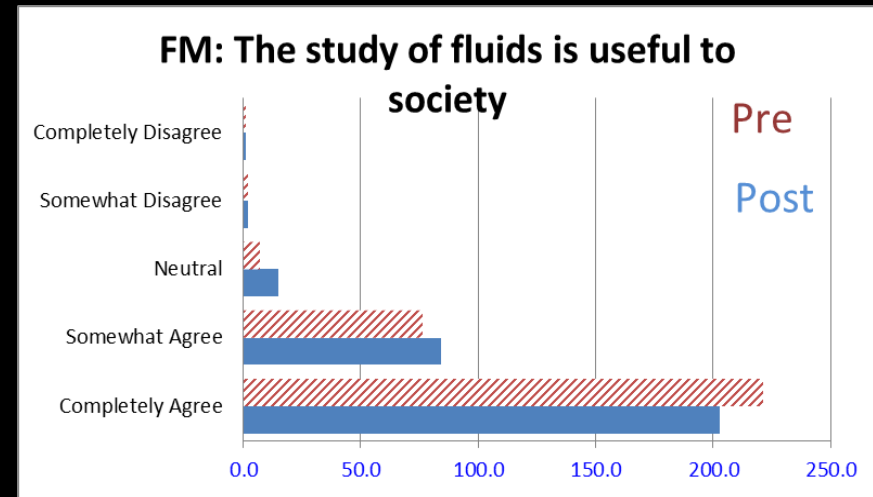
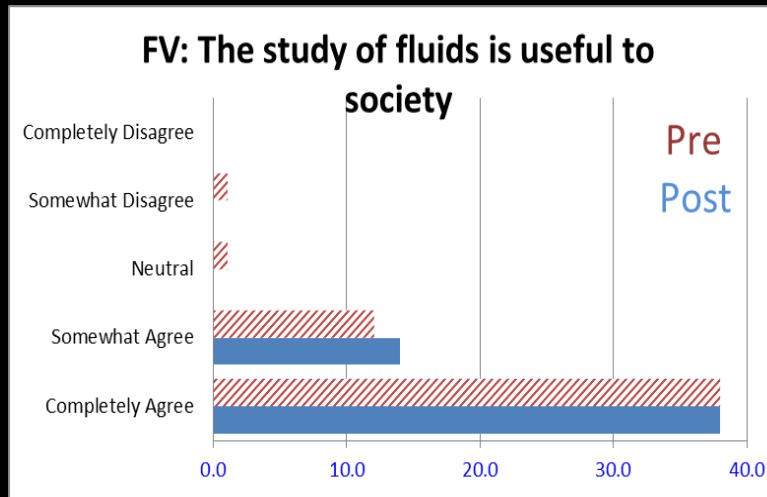
# Sustainable Energy



# PD: Questions are not saturated



# SE is saturated





# Qualitative approach: Interviews

- Must pay \$20 per 20 minute interview.
- Transcription is significant amount of work
- Common themes are 'coded'
- Prelim results:
  - Number of times noticed: includes classwork
  - Some items need rewording; others not
- Will be used to refocus and validate quantitative surveys