#### **Success as a Student Researcher:** A Discussion of Best Practices

#### Fall 2018 – Part 2

Dr. Scott Ferguson Dr. Kate Saul Dr. Mark Pankow





### Experimental design





#### **Experimental design**

- What are we trying to learn?
- What variables are important?

- How are you going to test those variables?
- Is this even feasible?

• Is there a major flaw?





#### Process

- Determine **objectives**
- Choose **response** 
  - (variable to be measured)
- Choose factors and level
  - (set independent variables)
- Choose experimental plan
- Conduct experiment
- Analyze data
- Draw conclusions and recommendations





#### **Before you run any experiments**

- Check the gauges and instrumentation
- Identify sources of error
- Have you made test as simple as possible
- Watch for drift (measurements and system)
- Avoid changes (don't go to lunch)
- Think about what can go wrong and how to prevent it
- Did you document everything
- Double check all your bolts
- What is your safety plan





#### Something will always go wrong

- Did you check the calibrations?
- Did you measure everything correctly?
- Did you check your units?
- Did you check your precision?
- Did you ground your equipment?





#### **Computer simulations**

- Can be used as surrogates for a physical experiment
- Many of the issues associated with a physical experiment still apply
  - If any randomness exists, a simulation must be run multiple times

• Validation?





#### **Reporting run-times**

• Is this the right metric to use?

- Be sure to maintain consistency
  Are you using the same computer?
  - What else do you have open?
  - What is running in the background?





#### Data management plan

- Is now an essential element of any NSF proposal
- What this means for you
  - All data must be saved
    - Only delete data associated with a mistake in the code
  - Data should be backed up in multiple locations
  - Public accessibility





## Writing





# "I can't write""I never really<br/>learned the right<br/>way to write""I don't like"I don't have to

"I don't like technical writing" "I don't have to write well to be successful"

"I'm an engineer and engineers don't write"





#### "WRITING IS NOT SOMETHING A SCIENTIST DOES, BEING A WRITER IS SOMETHING A SCIENTIST IS"





#### Writing is your currency

- Your success is measured largely by
  - How many papers you write
  - The reputation of the conferences and journals in which your papers are published
  - How many citations your papers get

	Scott Ferguson 🕜	6	FOLLOWING	Cited by	Cited by		
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#### You should write every day

• Summary of thoughts that you had

- Summary of papers you read
- Research ideas you want to explore

• Analysis of your data





#### To be a successful writer

- Write a lot of papers (good)
- Write a lot of papers that are good enough to get into reputable journals (better)

• Write papers that people want to read (best – these are "sticky" papers)





#### My sticky paper

 Hazelrigg, G. A., 1998, "A Framework for Decision-Based Engineering Design," *Journal of Mechanical Design*, 120: 653-658.

#### The Nature of Engineering Design

In reductio ad absurdum, engineering design involves only two steps: (1) determine all possible design options and (2) choose the best one. Simple as this may sound, engineering design is anything but simple for the reason that both steps are extremely difficult or impossible to perform for all but the most simple of products. Some of the difficulties encountered are the following:





#### My sticky paper

 Hazelrigg, G. A., 1998, "A Framework for Decision-Based Engineering Design," *Journal of Mechanical Design*, 120: 653-658.









#### **Traditional technical writing process**



#### A better technical writing process







#### A better technical writing process

Information Knowledge Understanding Data Full Farm Optimization, Unidirectional Case, 10 Turbines Final Layout Best practices 500 1448 840 1050 80 40 0.0015 100% Efficiency Fitness 568 40 239 40 3500 Case 1 EPS Evaluation 1293 998 101 1045 385 1264 1895 1448 381 1842 1032 956 1631 1001 1402 702 40 a 0.0014 -4th-Order Polynomial Fit for wind 40 1196 516 40 3000 1416 40 ě 1287 40 0.0014 1726 40 2500 y = 8E-11x<sup>4</sup> - 2E-08x<sup>3</sup> + 2E-06x<sup>2</sup> - 9E-05x + 0.0027 farm 869 919 395 248 558 1854 40 10 **J** 0.00135 40 11 12 13 14 15 16 17 2000 40 developers Obje 40 1500 0.0013 1755 40 867 1964 40 1000 and 0.00125 845 1497 1648 1394 40 18 28 33 38 43 48 53 58 63 68 73 40 19 278 20 Number(of(Turbines( 500 180 The final layout has a score of -3.82777e+07 optimization The total power generated was 3.59495e+07 W. 1000 2000 300 4000 Locations, X X Global 1800 X X X sizes, power 1600 X X X optimality 1400 Х X development, for wind 1200 X X 1000 X X X

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NC STATE UNIVERSITY



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#### When you write:

- Work backwards!
  - Start with the "understanding" this is your story!
  - Knowledge is generally related to your results
  - Information is generally related to your methodology/approach and introduction
  - Make your data publically available!





#### Write in Active Voice, not Passive Voice

Passive: "The hypothesis that smoking causes lung cancer was rejected by tobacco companies."

Active: "Tobacco companies rejected the hypothesis that smoking causes lung cancer."

- 1. Emphasizes author responsibility
- 2. Increases readability
- 3. Reduces Ambiguity

Sainani, Elliott, ad Harwell. "Active vs. Passive Voice in Scientific Writing". American Chemical Society Webinar Series. https://www.acs.org/content/dam/acsorg/events/professional-development/Slides/2015-04-09-active-passive.pdf



#### Avoid dead weight and empty words

- Dead weight words and phrases
  - As it is well known
  - As it has been shown
  - It can be regarded that
  - It should be emphasized that
- Empty words and phrases
  - basic tenets of
  - methodologic
  - important
- Long words or phrases that could be short

Sainani, Kristen. (2016) *Writing in the Sciences*. Massive Online Open Course, Stanford University. http://online.stanford.edu/course/writing-sciences-self-paced-spring-2016





#### Long words and phrases that can be cut short

Wordy Version	Crisp Version			
A majority of	most			
A number of	many			
Are of the same opinion	agree			
Less frequently occurring	rare			
All three of the	The three			
Give rise to	cause			
Due to the fact that	because			
Have an effect on	affect			

The expected prevalence of mental retardation, **based on the assumption that** intelligence is normally distributed, is about 2.5%. The expected prevalence of mental retardation, **if** intelligence is normally distributed, is 2.5%.

Sainani, Kristen. (2016) *Writing in the Sciences*. Massive Online Open Course, Stanford University. http://online.stanford.edu/course/writing-sciences-self-paced-spring-2016





#### Tips for being a better science writer

- Read, pay attention, and imitate.
- Write in a journal.
- Let go of "academic" writing habits (deprogramming step!)
- Talk about your research before trying to write about it.
- Write to engage your readers—try not to bore them!
- Stop waiting for "inspiration."
- Accept that writing is hard for everyone.
- Revise. Nobody gets it perfect on the first try.
- Learn how to cut ruthlessly. Never become too attached to your words.
- Find a good editor!
- You have to work at being a good writer, and being a good writer is the most important part of your job
- Give yourself time
- Don't write about the data, write about the understanding
  - And don't know the story before you start collecting data!
- Sketch your knowledge as a cartoon
- Write research objectives that speak to what you expect the knowledge to be

Sainani, Kristen. (2016) *Writing in the Sciences*. Massive Online Open Course, Stanford University. http://online.stanford.edu/course/writing-sciences-self-paced-spring-2016





#### Resources

- Writing Science by Joshua Schimel
- Made to Stick by Chip and Dan Heath
- Writing in the Sciences MOOC @ Stanford







#### Making figures from your data analysis





#### Data must be transformed before it can be understood

- This requires:
  - Formatting
  - Figures
  - Description
  - Evaluation

10	-20	20	-10	2636.81	4746.25	-80.00
-20	-90	30	-20	2428.04	1683.13	30.68
10	-10	30	0	3961.51	4103.52	-3.58
-20	90	30	-20	2428.04	1683.13	30.68
-20	-90	30	-20	2428.04	1683.13	30.68
-20	-90	30	-20	2428.04	1683.13	30.68
-30	-90	30	-30	1631.49	1062.10	34.90
10	-10	30	0	3961.51	4103.52	-3.58
0	-30	20	-10	2745.43	3847.66	-40.15
-20	90	30	-20	2428.04	1683.13	30.68
-20	-90	30	-20	2428.04	1683.13	30.68
10	-10	30	0	3961.51	4103.52	-3.58
-30	-90	30	-30	1631.49	1062.10	34.90
-30	-90	30	-30	1631.49	1062.10	34.90
-20	-90	30	-20	2428.04	1683.13	30.68
-20	-90	30	-20	2428.04	1683.13	30.68
0	-30	20	-10	2745.43	3847.66	-40.15
0	-20	10	-10	3962.40	4211.82	-6.29
-20	-90	30	-20	2428.04	1683.13	30.68
-30	-90	30	-30	1631.49	1062.10	34.90
-20	-90	30	-20	2428.04	1683.13	30.68
10	-10	30	0	3961.51	4103.52	-3.58
-20	-90	30	-20	2428.04	1683.13	30.68
-20	-90	30	-20	2428.04	1683.13	30.68
-20	-90	30	-20	2428.04	1683.13	30.68
-30	-80	30	-40	786.90	1995.60	-153.60
-30	-80	30	-40	786.90	1995.60	-153.60
-20	-90	30	-20	2428.04	1683.13	30.68
-20	90	30	-20	2428.04	1683.13	30.68
-30	-90	30	-30	1631.49	1062.10	34.90
-30	-90	20	-40	1090.39	1828.01	-67.65
-30	-90	30	-30	1631.49	1062.10	34.90
-20	-90	30	-20	2428.04	1683.13	30.68
-20	90	30	-20	2428.04	1683.13	30.68
-30	-90	30	-30	1631.49	1062.10	34.90
-20	90	30	-20	2428.04	1683.13	30.68
-30	-90	30	-30	1631.49	1062.10	34.90
-20	90	30	-20	2428.04	1683.13	30.68
-20	-90	30	-20	2428.04	1683.13	30.68
-40	-90	40	-40	718.55	642.42	10.59





# Calculating communication can improve information transfer

Probability-time curve

Knowledge-time curve



# Communication = $\int P(t)K(t)dt$







#### **Optimized storyboards can communicate more effectively**



# Three factors can influence storyboard optimization:



The Curse of Knowledge



Signal-to-Noise Ratio

This rectangle is purple

Assertion-Evidence Structure





#### **Curse of Knowledge**



 Deep knowledge of a topic as the presenter can make it difficult for you to see what may be confusing to a new viewer/reader

• Think about your audience and simplify your message





#### A collaborating surgeon termed this figure "engineering-like"



NC STATE UNIVERSITY Courtesy M3 group, UVA





# Three factors can influence storyboard optimization:



The Curse of Knowledge



#### Signal-to-Noise Ratio

This rectangle is purple

Assertion-Evidence Structure





#### A low SNR makes the message unclear

Doumont, 2009






#### A low SNR makes the message unclear

Doumont, 2009







#### A low SNR makes the message unclear

Doumont, 2009





Low SNR





# A high SNR communicates information quickly



#### **High signal**



#### **High noise**

















#### Choose the correct type of graph

• Scatter plots:



- with best-fit lines for linear continuous data
- Line graphs:
  - Continuously varying data with an expected relationship e.g. (roughly cyclical, episodic ...)
- Bar graphs:
  - Categorical data that does not vary continuously (Use a zero baseline!)
- Pie charts:
  - parts of a whole (only if absolutely necessary)





#### Should the points be connected?







#### Include error for context







### Good signals

Good scaling on axes, constant across panels

• Labels are clear

- Legends are present if needed, and printable in greyscale
- Appropriate graph type





### Noise problems

- Text too small (print it out to look at it in real size)
- Bounding boxes and grid lines
- Too many numbers or hashes on the axes
- Nonintuitive, inconsistent, or plain ugly colors
- Inappropriate scale on the axes
- Open or hashed data markers
- 3D graphics for 2D data





#### **Color transitions are not equal**

**Figure 2** | Color is not ideal for presenting quantitative data. (**a**) Shifts in color scales (circles) are not visually commensurate with change in value. Reprinted from *Nature Methods*<sup>2,5</sup>. (**b**) A gradation from 10–90% black produces even transitions.







### **Choose an appropriate font**



- Serif font (large blocks of text in a document)
- Sans serif font (easy to read for short text)
  - When in doubt, use sans serif font
  - Calibri, Arial, use courier for code
  - Do not use Comic Sans. Ever.
  - Do not use Papyrus. Ever.
    - ...unless you are making Avatar.

Wong. Nature Methods 8(3): 189, 2011.





#### Apply select color to direct attention







#### Annotations and visual cues







#### Show scale and function







#### Assertion-evidence avoids the Curse of Knowledge and communicates more in less time



The Curse of Knowledge



#### Signal-to-Noise Ratio

This rectangle is purple

Assertion-Evidence Structure



http://www.writing.engr.psu.edu/slides.html



#### A simple assertion can make a huge difference



**Assertion** Figure 1. Overview of noise cancellation process

Figure 1. We use a two-step approach to noise cancellation.





### Giving a (good) presentation





#### Who are you presenting to?

- Who is your audience?
- What is the purpose of the presentation?
- What do you want them to take away?
- How long should it be?





#### What is wrong with these slides?





Content from http://www.assertion-evidence.com/teaching.html



The Chesapeake Bay, which is the country's largest estuary, has only two places for traffic to cross





Content from http://www.assertion-evidence.com/teaching.html



# The assertion-evidence approach is an effective technique for designing slides

- Using the assertion-evidence approach leads to **better comprehension and recall by the audience** 
  - Joanna K. Garner, Michael Alley, Keri Wolfe, and Lauren Sawarynski
  - International Journal of Engineering Education (vol. 29, no. 6, 2013)
- Using the assertion-evidence approach leads to **deeper understanding of the content by the presenter** 
  - Joanna K. Garner. Michael Alley, and Shannon Aippersbach
  - International Journal of Engineering Education (vol. 32, no. 1(A), 2016)
- http://www.assertion-evidence.com/



# There are three main tenets driving the assertion-evidence approach

- Build talks on messages, not topics
- Support message with visuals, not bullets
- Explain visuals by performing sentences on the spot





#### Your slide design MUST be clean



Content from http://www.assertion-evidence.com/teaching.html

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## A title slide should convey information about the talk

- Things to include:
  - Catchy title
  - Not too long (Engineers do this LIKE CRAZY)
  - Your name
  - Names of your co-authors or co-presenters
  - Affiliation (School, Course, etc.)
  - Date





#### There are a few good strategies to get started

- Things to say:
  - Introduce yourself
  - "Today, I'd like to speak to you about [title]"
  - Look at audience
  - Don't put your hands in your pockets/cross your arms





#### Use a picture to kick off the presentation







#### Fact: The human brain is fighting you



Image: http://www.illuminati-news.com/technology.htm

#### You cannot read and listen at the same time.





#### About text .....

• If you need text, use animated bullets

• Define acronyms the first time

• No two consecutive slides should be text-only

• Watch your spacing





### Visualization opportunity

- Demand for electricity is expected to increase by 39% by 2020 [1]
- United States Department of Energy (DOE) wants to meet 20% of this total electricity need using wind power
- Right now, wind power is about 6% of the total electricity supply
  - Approximately 51 GW
  - Must increase to 305 GW
- Must make sure new farms are performing optimally in order to meet this goal





#### **Visualization opportunity**







#### **Final thoughts - style**

- Keep layout simple (don't clutter)
- Be consistent (color, font, emphasis, etc.)
- Visualize, but be smart about it!
  - Avoid using uninformative clipart or animations





## Use these principles to make a (good) poster





#### Why do we present posters?

- More personal interaction with people interested in your topic
- Ability to reach people you might not normally catch with a 15 minute talk

• People standing are more engaged than people sitting in chairs





## We all know good poster making is a challenge Bad poster bingo

Different parts of poster don't line up	Boxes within boxes	Zigzag reading order	More than three <b>typefaces</b>	Long-winded title
Gradient fills in coloured boxes	Big blocks of text	Photographic background	Unlabelled error bars on graphs	Pixelated pictures
More than five colours	Institutional logos bookending title	Free space	ALL CAPITALS	Text with shadows, outlines, or bevels
Abstract	Underlined text	Comic Sans	3-D graphs	Checking tablet or phone during presentation
Tables showing data that could be in a graph	Poster does not fit on poster board	Comic Sans (it's that annoying)	Objects almost touching or overlapping	Try unsubtle type

By Zen Faulkes, betterposters.blogspot.com

Inspired by: http://www.monicametzler.com/bad-presentation-bingo/





#### Think about the storyboarding lessons:

- Draw the eye to take home messages
  - Leave sufficient white space
  - Use logical column alignments
  - Use assertion-evidence in presenting results
  - Use color to aid in understanding figures
  - Avoid unnecessary noise (in background, color, figures, or text)
    - NO underlining
    - NO dark/patterned backgrounds
- Assume the viewer will see your poster alone
- Embrace the rough draft process




## **Presenting your poster**

- Do not chew gum
- Keep your hands out of your pockets
- Speak to your viewers
- Give a 2-sentence overview





#### References

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#### **Other references**

http://www.ncsu.edu/project/posters/index.html





## Time management





#### Why do I need a *strategy*?

• Demands on your time will only grow.

• Bad time management leads to stress and poor productivity

• LIFE skill!





#### Why is academic time hard to manage?

• Lots of choices ("academic freedom")

• Open ended tasks (research)

Bureaucracy inherent in research administration

 Short and long term tasks, and "thinking" time





#### Time management

DO IMMEDIATELY CRITICAL ACTIVITIES
<ul> <li>Top of your To Do list</li> <li>Deadline driven</li> <li>Emergencies</li> <li>Cannot procrastinate</li> <li>Minimise these through planning</li> <li>Space created for unexpected crises</li> </ul>
DELEGATE / RESCHEDULE
<ul> <li>Time wasters getting in the way of important activities</li> <li>Often caused by others</li> <li>Reschedule or to delegate</li> <li>Set boudaries</li> <li>Schedule times for interruptions and low value tasks e.g. email</li> </ul>





## Keep a time log

- For 2 weeks monitor your time DURING the day
- Are you being efficient?
- Where are you wasting time?
- Are you wasting OTHER people's time?
- Where could you delegate?
- Are you paying attention to the quadrants?





#### Learn your schedule

- What is your creative time and place? USE IT!
- When is your dead time?
- Work with your advisor to set up a semesterplan with deliverables that you both like
  - Make sure you stay honest, don't cheat





#### Things that waste time

• Interruptions

- Messy working area
- No calendar

- Being unprepared
- Lack of sleep





## Interruptions

- Keep idea list, Google tasks, notebook to pick up later
- Don't check email constantly

- Ignore your phone, chat
- Close your door





## Avoiding procrastination

- Set internal deadlines
- Make big projects into bite size pieces
- Identify why you aren't enthusiastic about something
- Challenge embarrassment or failure
- Find strategies to force you to get started (schedule meetings for accountability, make promises to someone else...)
- Ask for guidance if you're really stuck





## Accountability

- Set stretch goals for yourself, and realistic deadlines for items due to others.
- NEVER break a promise
  - If you need more time, try to renegotiate the deadline ahead of time NOT after
- Be clear about priorities
- Say no and don't overextend





#### Work / life balance

• Finding a balance is not easy

- It is important for your mental and physical health to have other interests
- Develop a schedule and be consistent
- Setbacks will happen. Have an action plan to handle them





# Managing your manager





#### What is the role of a research advisor?

- Boss AND a mentor
- Big picture research
- Research collaborator
  - Technical advice
  - Writing and presentation training
- Professional development and career advice
- Psychosocial
  - Putting it all in context
  - Handling adversity
- Mutual expectations must be CLEAR





## **Getting feedback**

• Accept course corrections graciously (revisions <u>will be</u> necessary)

 Anticipate requests for feedback (respond immediately when asked – if not sooner)

• Give presentations – within your own research group, at seminars, attend conferences





## How to hold a meeting

- Clear agenda
- Advance preparation
- Open discussion with constructive criticism and mutual participation
- Leader manages discussion and keeps on track
- Action items are clearly communicated





## Manage your advisor-advisee relationship

- Ask for time/help when you need it
  - Know EXACTLY what you want to accomplish
  - Express objectives clearly
  - Suggest next steps
  - Identify times and meeting styles most efficient for you both
- Understand your advisor's priorities and pressures
- Help with research proposals
- Go to conferences to identify what YOU want to know
- DON'T just wait to be told what to do next





## This is YOUR graduate career

- Be thoughtful about your course selection
- Be responsible for programmatic requirements and deadlines
- Know your career goals
- Within appropriate bounds for your advisor's preferences and expectations:
  - Be prepared for meetings
  - Know what needs to be accomplished
  - Take initiative to seek information for things you don't know
  - Suggest solutions
  - Identify journals, funding opportunities relevant to your work
  - Communicate



