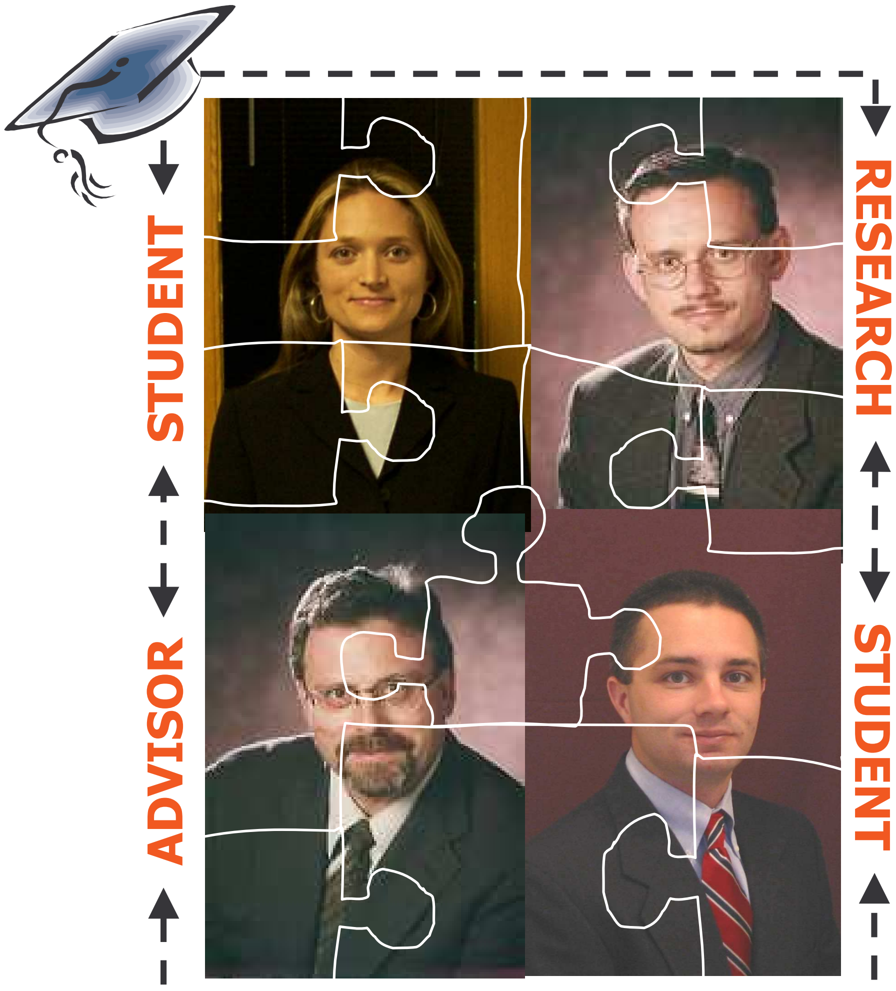
How to do research?

A MEGA Panel Discussion



How to make all the pieces fit?

Jennifer Muncy

Ryan Johnson

Prof. McDowell

Prof. Fedorov

Our panelists!

Prof. David McDowell

- Ph.D. UIUC 1983
- Fall 1983 as Asst Prof
- Now – Regent's Prof and Carter N. Paden, Jr. Distinguished Chair in Metals Processing
- Outstanding Doctoral Thesis Advisor Award, 2000
- American Society for Engineering Education Dow Outstanding Young Faculty Award, 1990

Our panelists!

Prof. Andrei Fedorov

- Ph.D. Purdue 1997
- Winter 2000 as Asst Prof
- Russian Federation Outstanding Young Investigator Award, 1994
- 2nd International Conference on Current Problems of Fundamental Sciences, Best Student Research Paper Award, 1994
- Bauman MSTU Best Student Research Award, 1989

Our panelists!

Jennifer Muncy

- Ph.D. Proposal – Jan 2003
- M.S. GTech 2001
- B.S. UIUC 1997
- Motorola Inc. 1997-99
- Manufacturing Education Program Fellowship
- Intel PhD Fellowship, 2002-2003
- Georgia Tech Women's Forum Scholarship, 2001
- Woodruff Fellowship, 2001
- Presidential Fellowship, 2001

Our panelists!

Ryan Johnson

- Ph.D. Proposal – May 2003
- B.S. ('00), M.S.('03) - GTech
- Sam Nunn International Security Fellowship
- Integrated Approach to Technological Innovation Program Fellowship
- Manufacturing Education Program Fellowship
- Georgia Tech Presidential Fellowship

A researcher's perspective on research

Prof. Andrei G. Fedorov

Research: Some Definitions

- ***Webster***: "Diligent and systematic inquiry or investigation into a subject in order to discover or revise facts, theories, applications."

- ***Einstein***: "Science (research) is nothing else but refinement of everyday thinking."

- ***Keywords***:
  - discover à original contribution!
  - revise à critical thinking!
  - refine à diligent work!

Research: Unique Features/Challenges

- You are confronted with a challenge of making an ***"original contribution"*** à create an intellectual product that has never existed before in the world of smart people!

- You have to operate in an ***ambiguous environment*** à find or develop something that is not fully defined. ***Lesson***: definition of the problem is an integral and perhaps the most important part of good research.

- You have to be very ***patient*** à you could go through "dry spells" lasting months or even years when no significant results emerge although you seem to work as hard as one can.

Research: Unique Features/Challenges

- The moment of ***gratification*** of solving the problem is ***very sweet, but also very short*** à and it is time to move to another problem.

- You have to be ***fiercely competitive/aggressive*** but not in a "sport/ military" sense à you should confront the problem, not people as if it is a personal challenge, so you cannot sleep and eat until you win.

- ***No 8 to 5 work days and no weekends*** à problem occupies your brain all the time when you walk, eat, drive the car, sleep.

Research: Tips on Good Practices

- ***Defining the problem***: why is it important?

  Ø Problem definition is perhaps the most important à when you have done it, you are ready to present your Ph.D. proposal.

  Ø Once you really defined the problem, solving would require efforts and certain refinement of the idea à the major work is done when the problem is properly defined.

  Ø Defining the problem does not mean saying “I will look at, for example, machining of the titanium alloys, since nobody looked at it before based on my literature search” à it means formulation of a clear hypothesis and performing basic scaling analysis and/or simple experiments that support your hypothesis, so it is now worthwhile refining the idea and looking at the details.

Research: Tips on Good Practices

• ***Defining the problem***: what makes problem be good?

Ø Know the state of the art in the field, but be careful not to let the experts’ opinion to influence your take on the problem à that is where the role of the thesis advisor is perhaps most significant.

Ø Work on the important problems only à these are hard, but could lead to the original and significant results.

Ø You must have a very deep knowledge of the fundamentals in one, two, or at most three basic science disciplines in which you are trying to make your contribution à it is equally applicable to traditional uni-disciplinary and interdisciplinary work.

Ø True contributions are still made in certain disciplines (not between disciplines), but you should use knowledge developed by people in other fields to advance your discipline à that is where the value of multidisciplinary approach or “strong peripheral vision” comes into play.

Research: Tips on Good Practices

- ***Defining the problem:*** how to approach it?

  Ø Utilize what I call "after a big party table cleaning practice" in guiding your thinking process to define the problem à first put biggest dishes away to clear up your path to those smaller and dirtier items that are hardest to clean. The latter are potentially good topics for the original research proposal.

  Ø Start with very deep understanding of basic fundamental issues of the problem you are confronted, then find the bottleneck à this is a research problem of potentially high impact.

  Ø Think how you could attack a bottleneck problem without looking at the prior work (i.e., no in-depth literature review, yet) à record in details your thoughts and observations

  Ø Do not rush here, spend your time on developing your original thoughts/ideas.

Research: Tips on Good Practices

- ***Defining the problem***: how to approach it?

  Ø Do not let your knowledge of certain methods, techniques, etc. drive your approach to the problem & do not select the problem just because it fits the skill set you have à there is a great chance that such a problem won't be original and worthwhile attacking.

  Ø Now, review the literature in depth, critically compare your well-recorded thoughts/ideas with the current state-of-the-art à hopefully, through this comparison and consultation with your thesis advisor the preliminary problem definition will emerge.

  Ø Finally, it is time to do simple analysis/experiments à make sure you do not violate basic fundamental laws of physics or chemistry.

  Ø If everything looks good à it is time to write a Ph.D. thesis proposal!

Research: Tips on Good Practices

- ***What else to pay attention:*** Know/exploit your strengths & weaknesses

  - Ø You could be an excellent theorist or clever experimentalist à possible, but seldom you have equal strengths in both aspects.

  - Ø Do not go against nature in Ph.D. level research à for example, don't try to focus on theoretical work if you think this is your weakest point and by doing an original research you would hope be able to remediate it.

  - Ø It won't work, simply sharpen your weaker points through the extensive coursework, but try to make an original contribution using the best skills you have.

  - Ø It is already hard to make an original research contribution, so it may never work for you if you will try to do it where you are not naturally good.

Research: Tips on Good Practices

- ***What else to pay attention:*** Environment is soil for good research

    - Ø Cultivate smart and intellectually curious friends/colleagues who are interested in bouncing ideas and are themselves doing an original work in their disciplines.

    - Ø These friends could be the best critics of your work à you would not believe how many good ideas come up when you talk to a smart non-expert in your field.

    - Ø Exploit hidden resources à involve your spouse or girl/boy friend into your scientific pursuits, but not during an anniversary dinner.

Research: Tips on Good Practices

- ***Last words…***

  Ø There is no such a research field/discipline where all original and important problems have already been solved à good news!

  Ø In the new emerging fields, these original problems could be hanging low to be picked à so the challenge is to recognize them.

  Ø In more mature disciplines, the challenges are often deeper and much more profound and often already formulated (e.g., in 20 most important problems in math by Hilbert) à here, the success would heavily depend on your solid mastery of fundamentals and creative application/development of new concepts/analytical or experimental tools.

  Ø Regardless of the specific research field, your best partners are à deep understanding of fundamentals, creativity and originality of your thought process (often going against the tide), and hard work.

Research: Tips on Good Practices

- Good luck and remember that, by definition, there is “good research” but no unique “good way to do research”

- Developing your own unique approach to research is a **BIG PART OF YOUR GRADUATE EDUCATION & RESEARCH!**

An Advisor's perspective of research

Prof. David McDowell

The Process – Best Laid Plans of Mice and Men (and Women)

- An advisor’s view of the incoming student – the process of screening
- Student-Advisor ethics
- Getting into the grind – early stages of program
- The nonlinear nature of research and personal growth
- The final stages – when will it be finished?
- Zeroing in on positions
- The continuing saga – life past GT

Round Pegs in Elliptical Holes

- Initial interview with student is important to establish vision, interests
- Life is too short to commit to something just for the sake of support
- Trust your “gut instincts”
- Fields of study – who can predict the future?
- Do not accept that you fully understand your strengths and weaknesses at the point of entry into graduate study, based on views of others

Student-Advisor Ethics

- Commitment to
  - Honor
    - Seeing tasks through to completion
    - Strong spirit of collaboration
    - “Buckle chinstrap” when necessary to pursue or defend work - research work is a “contact” sport, requiring intellectual engagement
  - Excellence
    - Writing
    - Calculations
    - Experiments
    - Presentations
    - Self-motivation to do the job right

Student-Advisor Ethics

- Commitment to
  - Insight and intellectual debate
    - Learn subject well à read literature! Reflect…
    - Learn how to provide caveats/limits on research
    - Build on knowledge and insight to spark two-way discussions with advisor – do not simply mimic views, as advisor must also learn from student
  - Jointly working towards goals
    - Give and take
    - Increasing role/input of student with time
    - Meet and exceed project goals
    - Student works with, not for, faculty member

Student-Advisor Ethics

- Energetic and productive work habits
  - Positive attitude – every day is an opportunity for growth and could affect the rest of your life
  - Discuss work with others, and learn about their work
  - Plug into the intellectual capacity and energy of this environment
  - Commitment of students and advisors to read literature!!
    - If you aren't bringing new literature to the attention of your advisor and your research group, you will likely not succeed in research career later.
    - How can you innovate if you don't know what others have thought or done, by definition.
    - Do not depend on your advisor to "spoon-feed" you the literature – he/she is not good enough to keep up with their own work and feed you all the latest developments to support yours
    - Take the time and devote effort to scholarly work

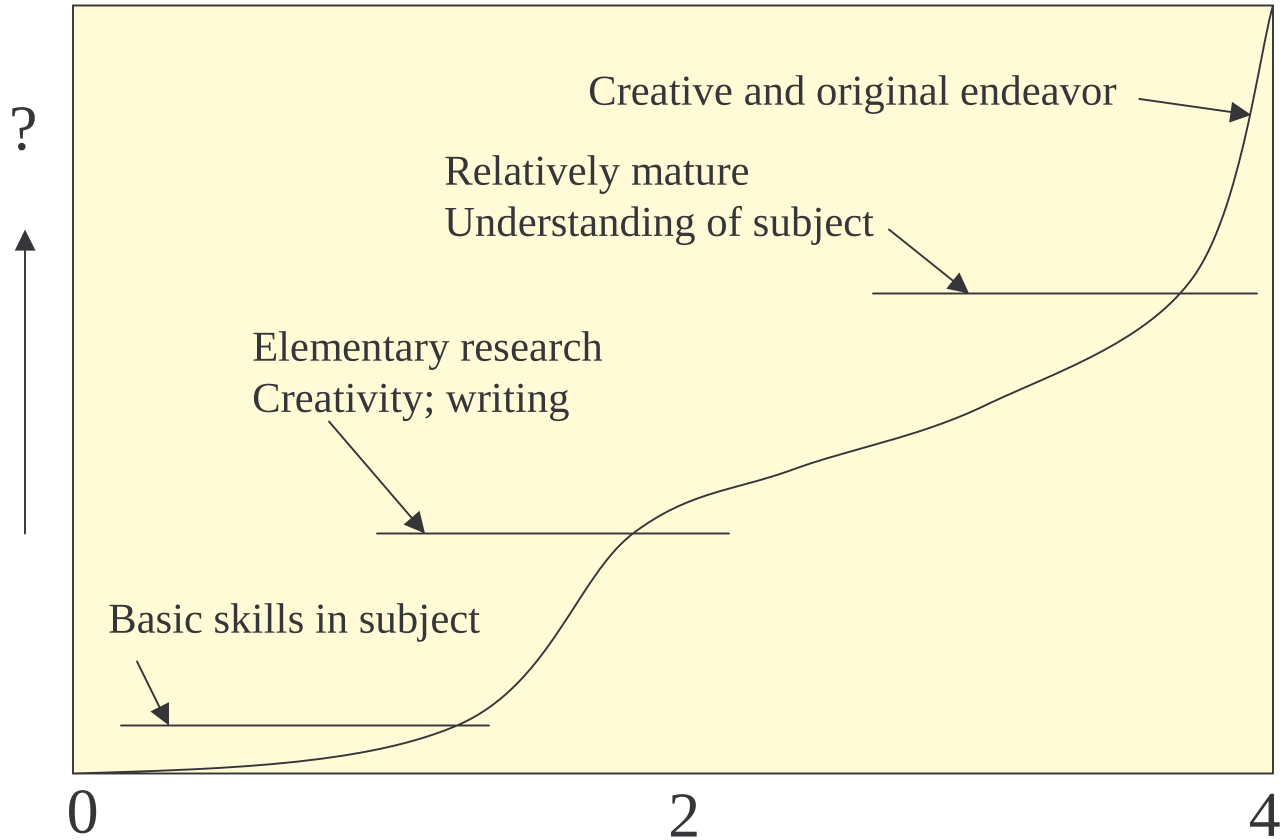
Student-Advisor Ethics

- Goal Oriented
  - Look for applications/innovations of the work
  - Develop a timeline for thesis work, with milestones
    - Student must be proactive
    - Student must be realistic
  - Provide reports of progress without being asked to do so
  - Provide draft outlines of papers, theses
  - Keep in mind what must be delivered to gain entry into the workforce (some call it "to graduate"). Negotiate a moving target as necessary, but in fairness and firmness.

Getting into the grind – early stages of program

- Terminal M.S. Degree – dive into coursework and research; keep mind open to post-MS directions
- New PhD – emphasize coursework first 6-9 months
  - Make way for later research emphasis
  - Build background
  - Read literature

The nonlinear nature of research and personal growth



The final stages – when will it be finished?

- It is something the Advisor senses, and most often the student as well
- Must master written and oral communication in addition to technical aspect (in fact, they go together)
- 1-2 articles, MS
- 3-5 journal articles, PhD (academic profile)

Zeroing in on positions

- Be honest –
  - Are you a "parallel processor" or do you work best sequentially executing tasks/projects?
  - Do you operate best in structured environment or do you relish freedom of unstructured environments?
  - Do you want to emphasize managing people or performing technical work?
  - What is your "risk quotient"? (e.g. small start-up companies)
- Seek the counsel and assistance of your advisor
- Build relationships with other faculty to serve as references as well.

The continuing saga – life past GT

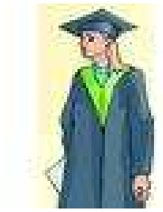
- Statistics show financial and personal satisfaction values of delayed gratification with respect to MS and PhD degrees
- Pursue what you love, not just where the money is at a given moment
- Maintain contact with your Advisor via periodic updates
- Be bold and make a name for yourself and GT

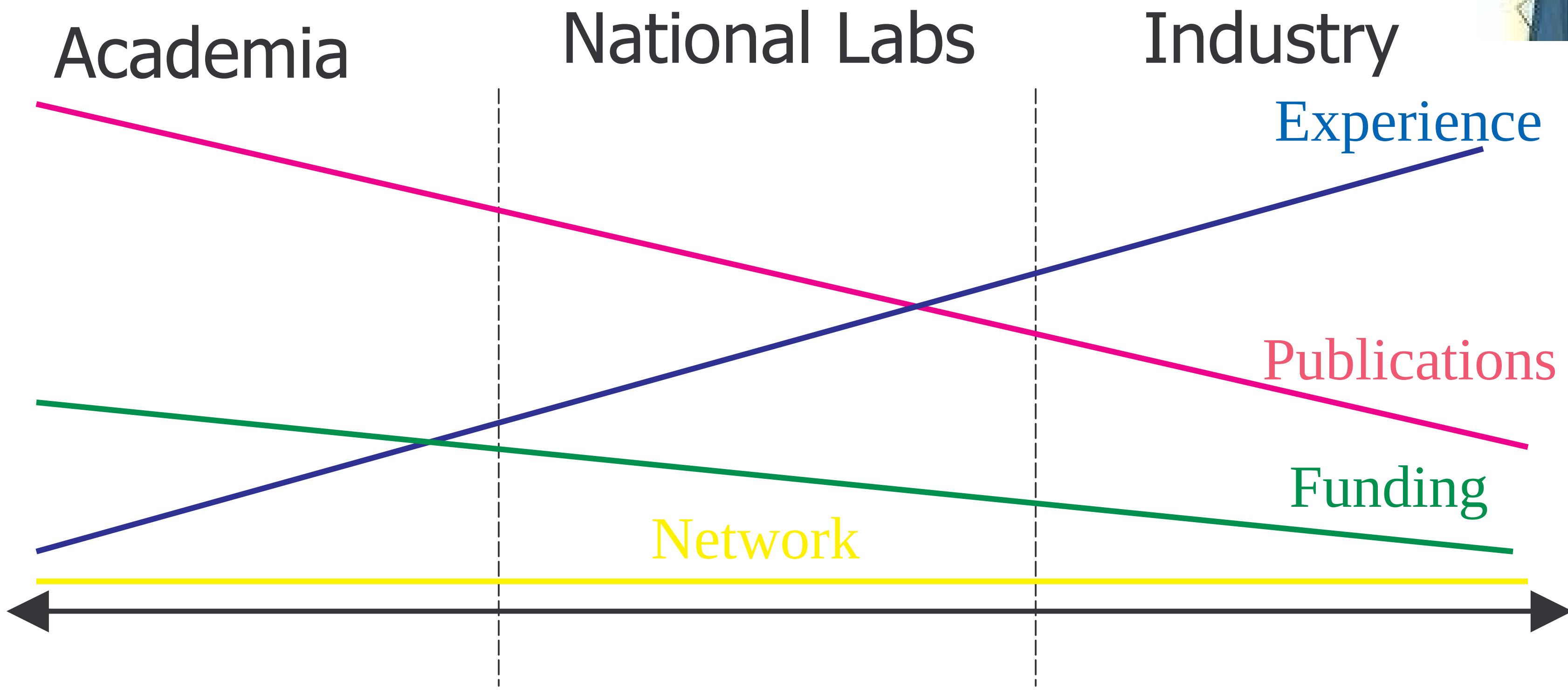
Student's perspective of research

Jennifer Muncy

Ryan Johnson

What do you want to do when you graduate?





Means to a beginning: Graduate school is not a career

Preparing to do Research

- Classes
  - Difficult/time consuming classes should be taken early
    - Continuum mechanics, mechatronics, many 6000 level courses.
  - Amount of time needed for research will typically ramp up with time
  - What fundamental concepts do you need for your research
  - For PhD people – QUALS
  - Other things: Major/minor, summers

- Literature Review
  - Learn the library! – get a copy card
  - Print papers and save them – organization/method is important

- Apply for funding even if your advisor already has $$

Research Project Paths

- <u>E</u>xperimental
  - Hardware/equipment
- <u>C</u>omputational
  - Software driven
    - Own
    - Commercially available packages
- <u>A</u>nalytical
  - Theory/mathematics

$$degree = x * E + y * C + z * A$$

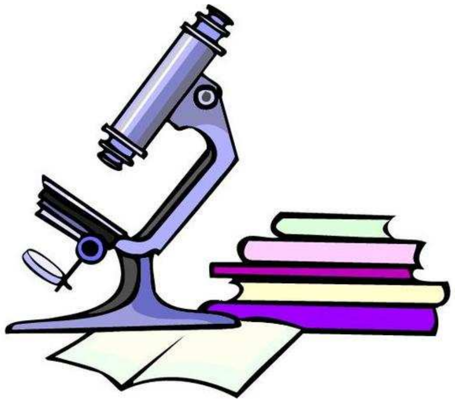
$$where:$$

$$x + y + z = 1$$

This is a group decision

- Advisor bias
- Committee expertise

Experimental



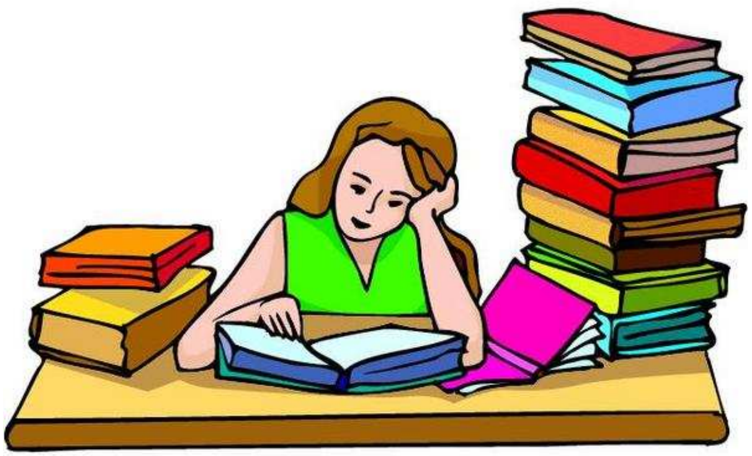
- Words that should describe you:
  - Hands on
  - Willing to be trained
  - Creative
  - Persistent/Patient
  - Resourceful
    - Beg
    - Collaborate
    - You need to know or know the people that do
  - Practical – I/O
  - Methodical - document
- Know the limitations of your equipment
  - Gage R&R – Repeatability and Reproducibility
  - Physical limitations
- Analysis tools:
  - Design of Experiments
  - Parametric experimentation
  - Regression Analysis
  - Analysis of Variance

Computational

- Words that should describe you:
  - A little nerdy
  - You like to program
  - Practical – I/O
  - Skeptical
    - If the code is not flawed you will get an answer
  - Willing to learn software packages
  - You make good engineering decisions
- Know the limitations of your software
  - forte
  - Physical limitations
- Analysis tools:
  - Hand calcs to verify
  - Compare your results to others published work

Analytical

- Words that should describe you:
  - Aloof
  - Comfortable with math
  - Book smart – interdisciplinary sense
  - You had a nose-bleed GPA in undergrad
  - You make good engineering decisions, you are comfortable with making assumptions
  - Willing to take hard classes
  - Independent
  - Thinks deeply about problems
  - Persistent
- Know the limitations of your mind



Initial Steps

Experimental

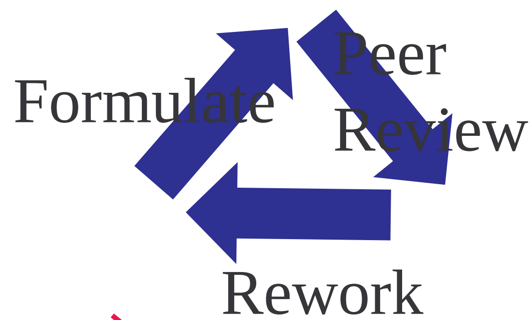
- Learn equipment
- Order materials
- Outline experimental design
- Trial builds with analysis to make sure you are on the right track

Computational

- Learn a software package
- Start small
  - 2D Model
- Acquire information for model – such as input material properties
- Run initial models – verify with others work

Analytical

- Bound/Outline Problem
- Extensive literature review & potentially rework others methods



DETERMINE CONTRIBUTION

(Probably Propose – for PhDs)

Finish

- Run final experiments, develop final computational, and analytical models
- Interpret findings
- Publish work (write thesis)

Means to a beginning: Graduate school is not a career

Additional Considerations

(Distractions)

- Attend conferences – even if you are not presenting
- Intern
  - National labs – academic focus
  - Company – industry focus
- TA for classes – undergrad, grad, lab
- Job search
- Quals – opportunity to solidify fundamental understanding of engineering concepts which are necessary for your research
- You can hire help - undergrads