Cognitive approaches: how to "do" research

J. McCalley

EE/WESEP 594, EPES Seminar

August 29, 2017

- In WESEP 594, during the first four semesters, 15 faculty gave 50 min lectures on how to "do research."
- In these slides, I have modified my own 594 lecture on this topic and integrated them with excerpted slides or parts of slides from some of other faculty presentations.
- You will find the slides used by others on the WESEP 594 website; it will be useful for you to go through them and reflect, even if you heard them before.

http://home.engineering.iastate.edu/~jdm/wesep594/index.htm

Objective:
Strengthen cognitive approaches to research

Now: Write down immediate thought beside at least one of below.
During presentation: Update as you think best (need not agree with me!)

Questions to be addressed:

- What is "doing research"?
- What is a "researcher"?
- What organizational structures and modes of human interaction are effective in facilitating research?
- How do we become aware of the problems we work on?
- What are the attributes of a "good research problem"?
- To what extent can research be planned? How are solution approaches identified? What is the interplay between creativity and literature review?
- What is the desired "end-product" of a research project (paper? "contribution"? patent? technology transfer? impact? graduated student?); how in the research process does choice of "end-product" affect what happens?
- What attributes to obtain to become a good researcher?

I think what follows is "on the right track," but you must synthesize, extend, refine, and apply considering your own personal strengths and weaknesses.

What is "doing research"?

The scientific method:

1. Observations: Observe and describe some phenomena.

2. Hypothesis: Formulate a hypothesis to explain the phenomena.

3. Prediction: Use the hypothesis to predict the existence of other phenomena or to predict the results of new observations.

4. Testing: Perform experimental tests of the predictions.

5. Repeating: Modify hypothesis as necessary and repeat 3 and 4.

What is "doing research"?

Research as a Process

1. Observations

2. Hypothesis

3. Prediction

4. Testing

- Problem definition: What is the question that needs to be answered?
- What related things have been done previously (literature search)?
- What data are available (getting appropriate data can be a challenge)?
- What assumptions are needed? What is an appropriate model?
  - Describe the data
  - Answer the problem question
- What is an appropriate level of abstraction?
- What algorithms will be needed? How will they be implemented (R, C, FORTRAN)?
- Begin formalization and writing up rough notes early (also helps communication)
- Validation of statistical methods
  - Large-sample theory
  - Monte Carlo simulation
- Write-up, presentations, and publication(s)
- Areas for future related research
- Feedback and revision
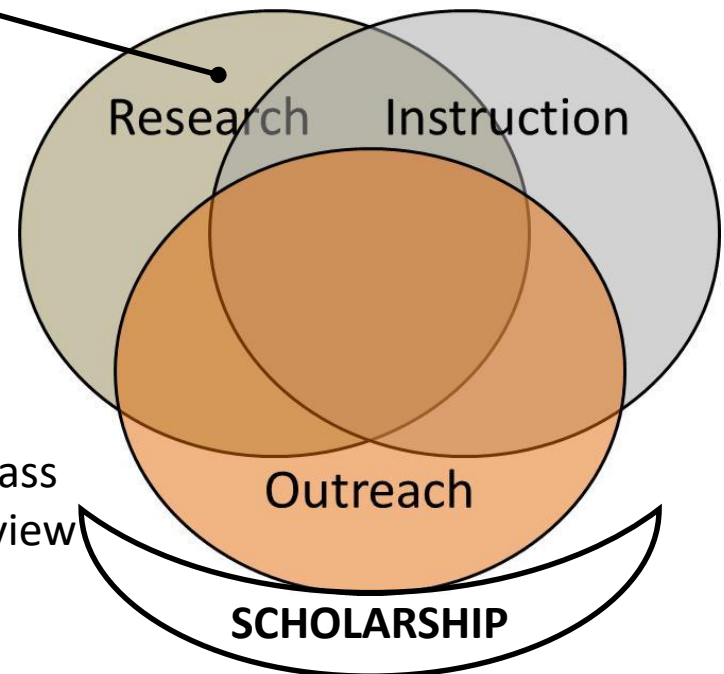
- Bill Meeker, Statistics

What is "doing research"?

DAILY ACTIVITIES
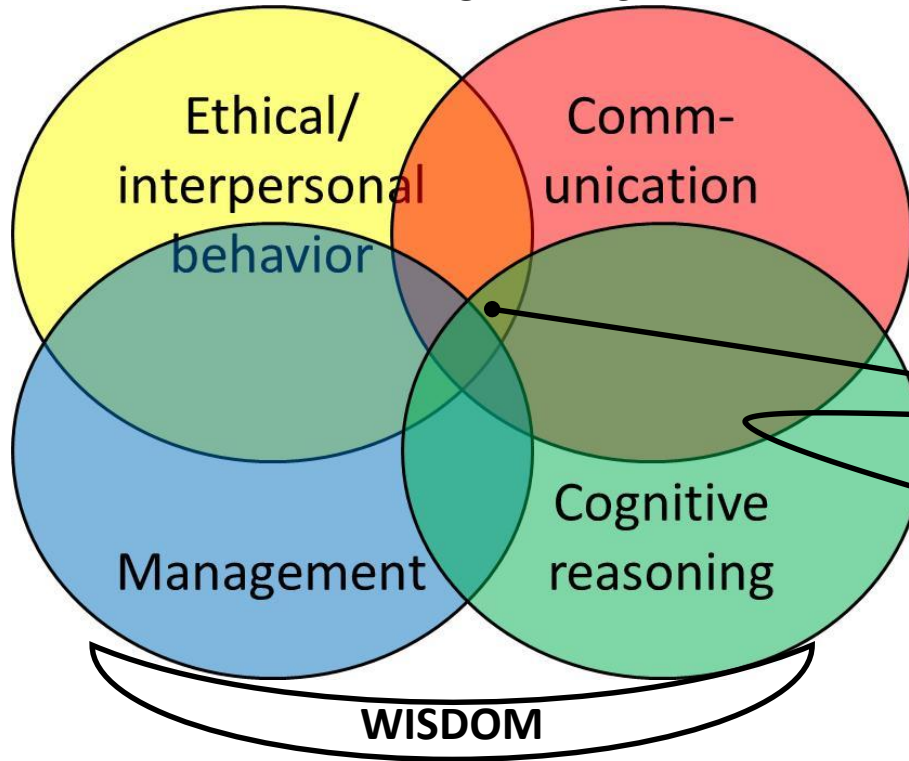
Research as activities & enterprises

FORMAL ENTERPRISES

...being alert to other effects on the mind

- reviewing papers
- attending a seminar
- preparing a lecture
- reading a novel
- reading trade journal
- reading the paper
- listening to a webinar

- visiting a company
- talking with a student
- answering a question in-class
- participating in a panel review
- taking a shower
- prayer
- driving...

"Doing" research at odd times seems to help...

5

Can "odd times" be strategically designed?

- I prefer to work on real problems, because of the motivation and knowing that the probability for impact is high
- For many of us, some hours of the day are better for creative thinking that others. Try to understand what are your best hours and use them accordingly.
- Reserve big blocks of time to do research, but take frequent breaks
- When at conferences seek out individuals who might have interesting problems to discuss and engage them
- Some things that work for me:
  - Think about a challenging problem before going to bed. Continue thinking about it while going to sleep.
  - If you wake up and have a good idea in mind, get up and write it down.
  - Thinking about a challenging problem before certain kinds of physical exercise can also be productive.

- Bill Meeker, Statistics

What is a researcher?

A recent conversation on a research list-serve…

Request: Hello, I am a first year M-Tech student my topic for thesis is demand side management with the help of renewable energy resources/generation. Can anybody give me some literature and papers related to demand side management and renewable energy resources/generation.

Response 1: It is exactly the point of doing a literature survey that YOU have to look for and survey literature rather than relying on someone doing it for you.

Response 2: I am a Professor Emeritus, and in my 35 years I never, ever, handed a topic to any one of my graduate students who did their MS Theses (20) or Doctoral Dissertations (14) under my supervision…

What is a researcher?

<u>Response 3</u>: While I agree with the comments made by Professors 1 and 2, I also suggest that you find an opportunity (through your advisor) to talk to industry folks before you embark on a specific research topic and solution approach…. Among all the papers that you will read, you soon will find out that some provide a solution to a non-problem, some provide a non-solution to a problem and worst, some provide a non-solution to a non-problem…. Anyway, please do yourself a big favor and talk to the industry folks. You will be glad that you did. By the way, I will hate to review and reject your paper in the future because it provides a non-solution to a non-problem. Good luck.

Industry	**Academia**
• Problem identified for you	• You find the problem
• Imprecise environment → don't know everything for a *complex system*	• Pristine/ideal environment → know everything precisely for a *simple system*
• Impact → real products that affect daily lives	• Impact can be elusive … distant … but revolutionary

- Anupam Sharma, AeroE

What is a researcher?

Response 4:

1 - Originally, a PhD Research does not need be have an immediate practical application - that is, it does not have to solve an existing problem. PhD means Doctor in Philosophy and consequently it has a more broad / analytical nature. It could a clarification of concepts, a new interpretation of a phenomena, etc.

2 - ...We cannot limit the scope of a PhD thesis to solving practical problems; otherwise, they will become consulting reports (which are tremendously important). Alternatively, pure mathematical sophistication, without physical intuition, is not sufficient to guarantee the relevance of the results.

What is a researcher?

Response 4 (continued):

3 - …The PhD student is essentially a different person from the under-graduate candidate. He or she is not a patient; nor is his/her supervisor an operator who is doing something to him/her. The student is, or ought to be, an individual who is already beginning to follow learning for its own sake - - - who found a topic that he/she is passionate about - and becomes totally immersed in the process. For nothing that the supervisor has to offer will do you good unless you are persuaded to forget all about writing good papers and to absorb yourself in getting to know some part of your discipline.

4 - The key to creativity and success in a PhD research is receptivity - a kind of openness to other ideas and tolerance to chaos - and gusto / delight for the work at hand.   Do not be afraid of being wrong or being called an eccentric. Be curious and playful. In addition, do not wait for your supervisor to tell you what to do - after all it is your work and responsibility. The function of the supervisor is to become superfluous in the process.
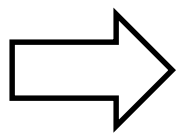
⇒ Intellectual aggressiveness!!!! Tethered to wisdom & strategic thinking ☺.

What organizational structures and modes of human interaction are effective in facilitating research?

Iowa State University

Graduate students

Faculty

Post-docs

Undergrad students
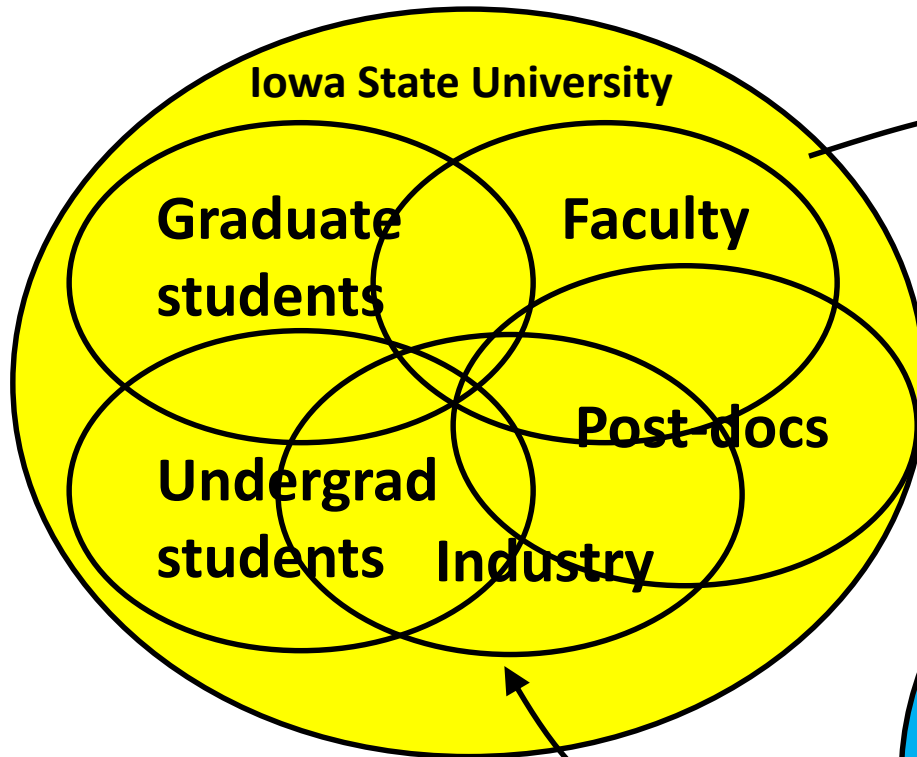
Industry

Develop short-term, long-term groups.
Leap at interdisciplinary opportunities.
Leap to talk to and with industry folks.
Be intentional to schedule times to present to each other.
Take time to attend, and when you do: listen, think, comment, question – have an awake mind!
(and stay off your phones)
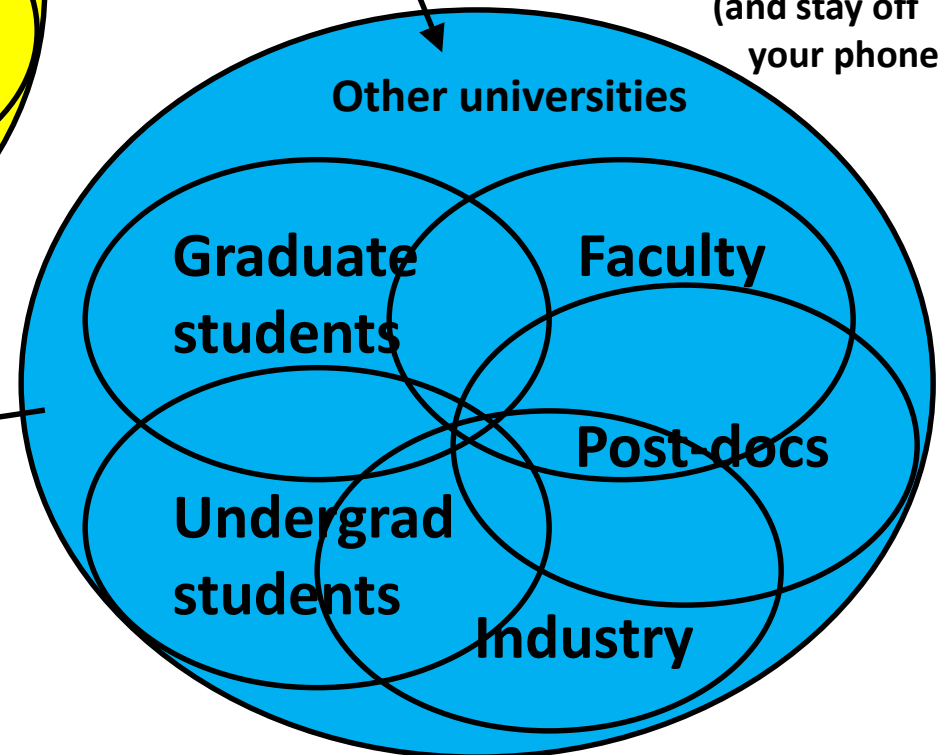
Other universities

Graduate students

Faculty

Post-docs

Undergrad students

Industry

<u>Do scholarship</u>: "Scholarship is creative, systematic, rational inquiry into a topic and the honest, forthright application or exposition of conclusions drawn from that inquiry."
ISU Faculty Handbook, Sec 5.2.2.2, pp. 54-55.
www.provost.iastate.edu/resources/faculty-handbook

How do we become aware of the problems (areas) we work on?

#1: Do not be afraid….
- to imagine,
- to create and
- to express it.

#2: Be patient: it is a process that benefits from learning deeply about the area and its attributes.

Some take-aways from the next slide:
- My "research problems" have evolved over much time
- Proposals are fertile ways to dream, imagine, create,…
- Students have helped me in this process a great deal!
- Teaching academic and short courses have also helped
- Earlier, partly-related experiences contributed.
- I can, in hindsight, recognize pivotal moments
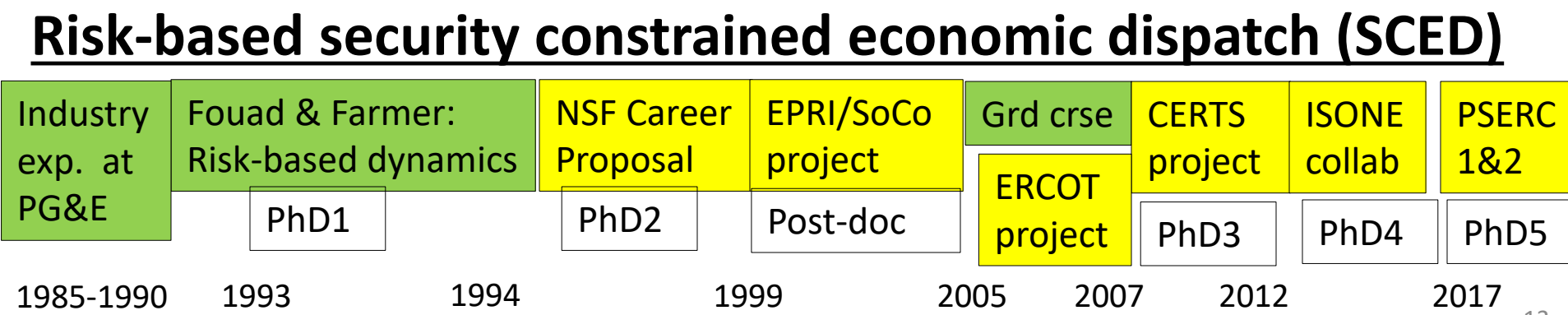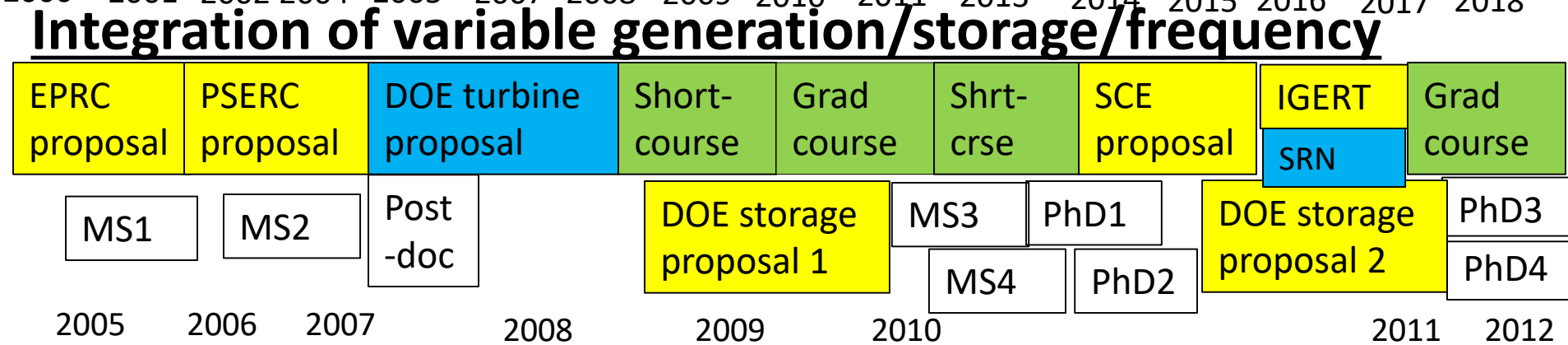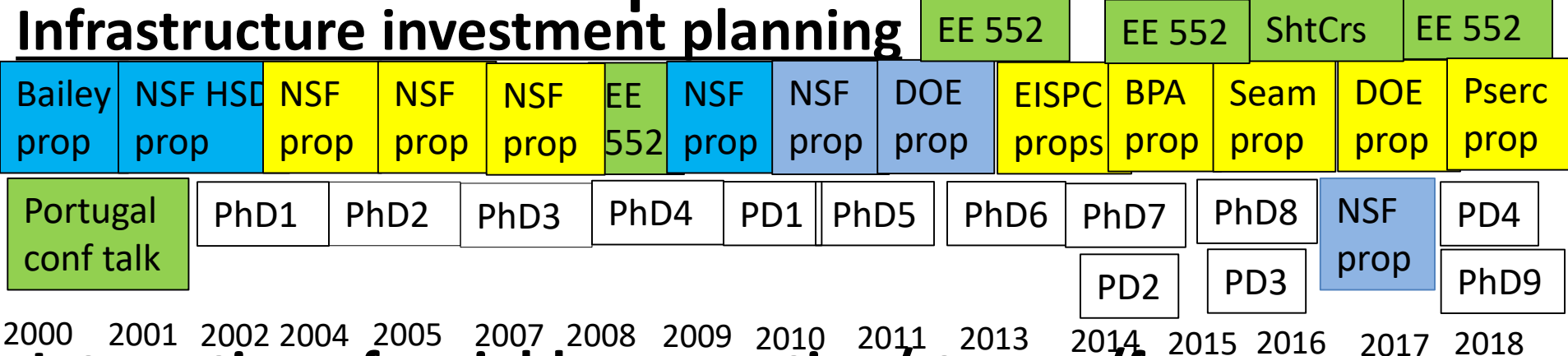
How do we become aware of the problems (areas) we work on?

Where Do My Research Problems Come From?

- Problems that arise when consulting with "Industry"
- Problems that arise through other contacts with "Industry"
- On campus collaboration
- Resolving technical issues that arise in practical applications and previous research
- Important extensions of previous work (almost all of my research papers end with a section "Areas for Further Research")

Bill Meeker, Statistics

How do we become aware of the problems (areas) we work on?

Not your adviser ... you!

1. Gathering of raw material
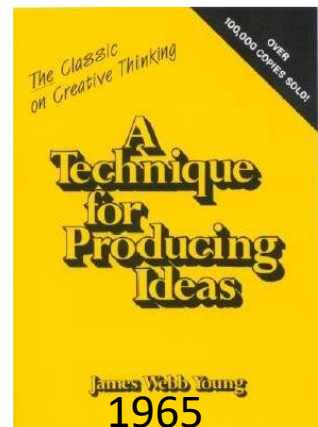
2. Digestion of gathered material

3. Incubation stage

4. Birth of the idea

5. Shaping & development of the idea

- Think like a cow! "Masticate" the material

- Rephrase each data/paper in your own words ... specific contributions? Assumptions? To do items? Gaps?

- Divide gathered material into subgroups ... identify themes / trends

- A lot of thinking goes here. Think hard!
  - Elon Musk: "If your head doesn't hurt, you are not thinking hard enough"

- As you analyze data you will find more references ...
  - Invariably go back & forth between steps 1 & 2
  - At some point you will close the loop (on most items) ... judiciously choose when to stop

The Classic on Creative Thinking

OVER 100,000 COPIES SOLD!

A Technique for Producing Ideas

James Webb Young

1965

- Anupam Sharma, AeroE

What are the attributes of a "good research problem (area)"?

#1. YOU: You are intrigued (excited) by something in it

#2. THEM: You can see the larger picture and express why in terms that show the potential for positive impact in the world we live

#3. RICHNESS: You can identify several general directions of exploration

#4. SCHOLARSHIP: You (eventually) see that there is some perspective related to your intrigue/interest that needs exposition/articulation/application.

Do scholarship: "Scholarship is creative, systematic, rational inquiry into a topic and the honest, forthright application or exposition of conclusions drawn from that inquiry."
ISU Faculty Handbook, Sec 5.2.2.2, pp. 54-55.
www.provost.iastate.edu/resources/faculty-handbook

What is a good research problem ?

David Jiles, ECpE

- impacts the lives of many people
- many people are interested in
- has a chance of success
- is of personal interest
- is challenging / non-trivial

16

To what extent can research be planned? How are solution approaches identified? What is the interplay between creativity and literature review?

- It is more like entering a deep forest at night than it is like reading Mapquest instructions
- But we can still plan: With k=1
  - Identify research step k given what you know
  - Project/hypothesize what you expect to learn in step k
  - k=k+1 and return
- Be comfortable to change plans when you learn something (e.g.., when projection/hypothesis was wrong)
- Creativity comes first (trust your instincts): Write down problem/objective/solution/plan before reading much literature, then change it as you read and learn.

To what extent can research be planned? How are solution approaches identified? What is the interplay between creativity and literature review?
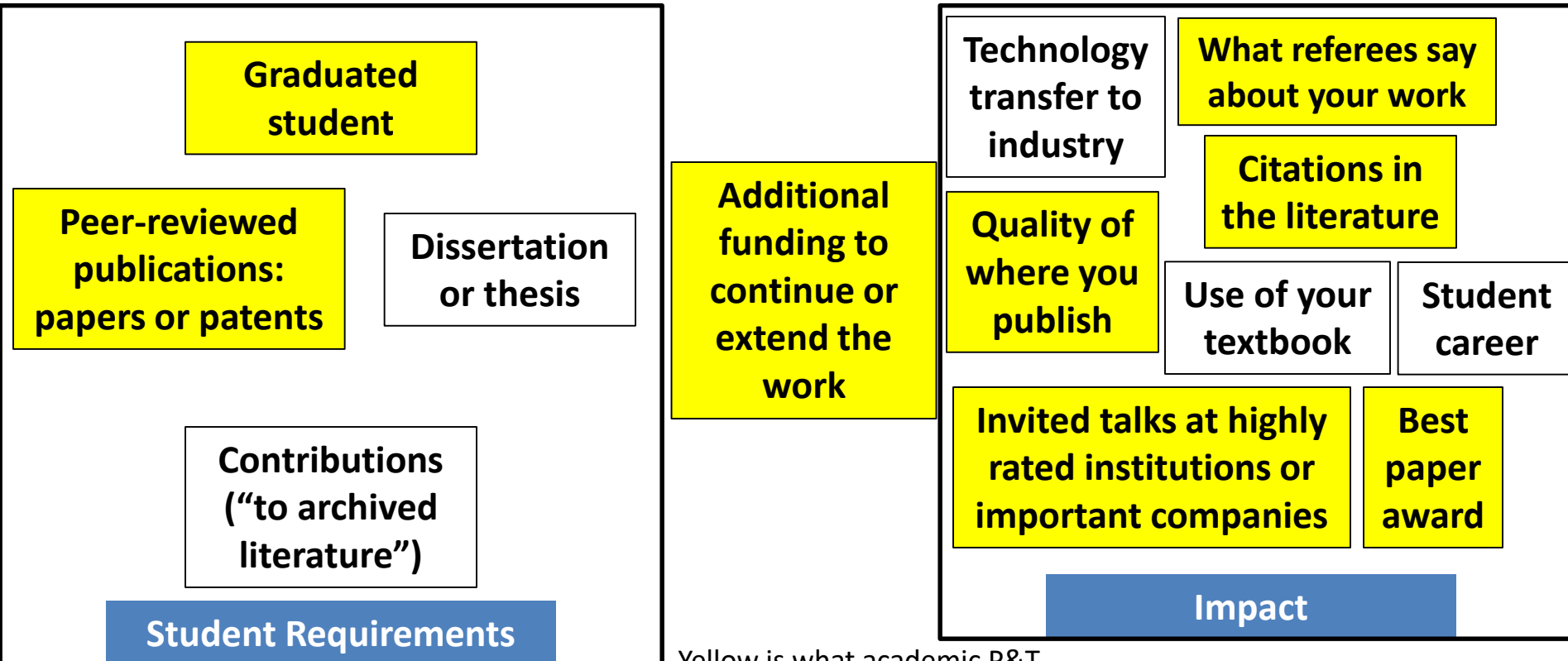
To what extent can research be planned ?

- ◆ Objectives can be set
- ◆ Activities can be organized
- ◆ Short term reports can be scheduled
- ◆ Time lines / Gantt charts can be produced

- ◆ but you can't know what you are going to find !

- David Jiles, ECpE

What is the desired "end-product" of a research project (paper? "contribution"? patent? technology transfer? impact? graduated student?); how in the research process does choice of "end-product" affect what happens?

Student Requirements

- Graduated student
- Peer-reviewed publications: papers or patents
- Dissertation or thesis
- Contributions ("to archived literature")

Additional funding to continue or extend the work

Impact

- Technology transfer to industry
- What referees say about your work
- Quality of where you publish
- Citations in the literature
- Use of your textbook
- Student career
- Invited talks at highly rated institutions or important companies
- Best paper award

Yellow is what academic P&T committees easily count/assess.

"In 5 years, I would rather assistant professors produce 5 excellent papers than 20 mediocre papers."
- Arun Somani, ECpE Chair, 03-10, COE Assc Dean for Research, now

Short-term perspective maximizes publication count.
Long-term perspective maximizes impact.

What is the desired "end-product" of a research project (paper? "contribution"? patent? technology transfer? impact? graduated student?); how in the research process does choice of "end-product" affect what happens?

a. Development of people is the most important task of being a faculty; human development includes teaching technical competence; it also includes building confidence and professional behavior into the student. The goal of graduating a student who will have a successful/impacting career is more important than the goal of maximizing publications and funding. Finding ways to achieve both goals is ideal.

b. Although the major professor/student relationship is more than that of an employer/employee relationship, it is not less. Major professors should hold students accountable while treating them in a way that is fair & consistent with expectations of university employer-employee relationships. Students must learn to fulfill the obligations of an employee in the workplace.

Student career

Impact
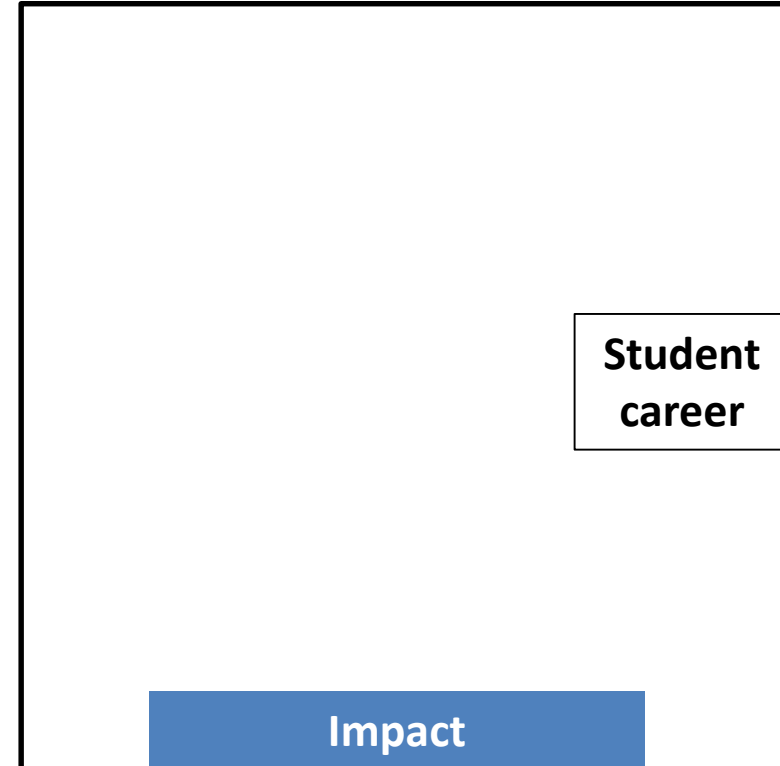
What attributes to obtain to become a good researcher?

A willingness to accurately self-assess:

Some good attributes, or at least, not bad….
- Research, instruction, and outreach are heavily dependent
- Look for efficiencies: do 1 thing, use it in 2-3 ways
- Like to work with/learn from industry folks
- See big picture well
- Understand the value of recognizing good work/effort in others
- Put much intellectual effort in proposals; intend to win all
- Look to avoid pride in knowledge; remain teachable

Some bad attributes, or at least, not good….
- Less patient exploring details of a problem
- Expect all students to be very autonomous
- Do not say "no" often enough and become overloaded
- Often don't do what I don't like to do until I have to
- Don't allocate reading time: read only for directed purpose

What attributes to obtain to become a good researcher?

Successful PhD students have the following attributes:
- Steady, continuous work habits
- Visible, involved, proactive on day-to-day basis
- Not command and control people but rather
  - **Good listeners, autonomous thinkers, objective decision-makers**
- Willingness to learn new things
      …and to attack hard parts of the problem
- A good communicator…

Communication…

Organizing information for

- Writing… proposals and papers

    GRADUATE PEER-WRITING GROUPS:
    http://cce.grad-college.iastate.edu/gpwg

- Speaking… presentations to 1, 10, 100 people

    …Just do it

- Communicating with the media

    We should consider it a basic part of the research function to communicate with the media. …but we do not know how.

    - Lulu Rodriguez,

    Journalism & Mass Communication 347/547, Science Communication

- 6/1/17: ISU story on Seams project
- 7/14/17: Interest from US Governor's Wind & Solar Coalition
- 8/15/17: Additional speaking opportunities
- 8/24/17: Multi-organizational group of people to push it

Conclusions

- Do research at odd times
- Put yourself into a variety of "idea" opportunities
- Proposals are an effective medium to create
- A good research problem should (a) interest you, and (b) you should see potential for its significance
- Have a "living" research plan; think first, then read and iterate
- Strive for long-term impact
- Do not hide: take advantage of interaction opportunities
- Teach yourself to communicate

- The most difficult problems arising in research require broad knowledge, creativity, and take time
- Certain parts of the research process can be highly frustrating (getting stuck on a problem for a long time), but with success comes great satisfaction. Sometimes it is good to take a break for a while and work on things where progress will be more rapid.
- Research should be fun. Having a project that is of high interest to you helps make the research fun.

- Bill Meeker, Statistics

- Read, observe, & analyze a lot!
  - When you think you are done, spend 2X more effort
  - A *tall pyramid requires a very wide base*

- Understand the raw material
  - Rephrasing helps
  - Identify gaps / opportunities
  - Think hard … till your head hurts

- Focus on the above two … ideas will come
  - Roger Federer: *"I try to give myself opportunities"*

- When you get an idea, nurture it … but, don't get too hung up!
  - Be ready to throw away ideas upon critical, objective review. You have many more in store!
  - *Become a weed*!

- Anupam Sharma, AeroE