Illinois Automated Software Engineering (ASE) Group

PhD-Program Preparation for Successful Post-PhD Career

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Slides: http://web.engr.illinois.edu/~taoxie/advice/preparecareer.pdf

Advice Portal: http://web.engr.illinois.edu/~taoxie/advice/

Disclaimer

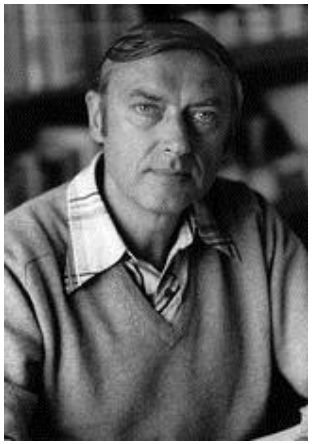
- This talk doesn't imply the speaker has a successful post-PhD career already; his career hasn't ended yet and is being worked on ☺
- There is no single way of accomplishing a goal so please use critical attitudes towards what will be discussed
- Talk contents are primarily based on the speaker's continuous improvements and innovations on his research advising and management, and discussion with students and colleagues

Disclaimer cont.

- This talk's slides don't reflect good or suggested presentation styles
  - Slides are intentionally made to accommodate both the audience in the presentation room and later the readers who read the slides offline.

Advising: Students vs/and Research

- "Focus on the **students**, since graduating **great students** means you'll produce great research, while focusing on the research may or may not produce **great students**."

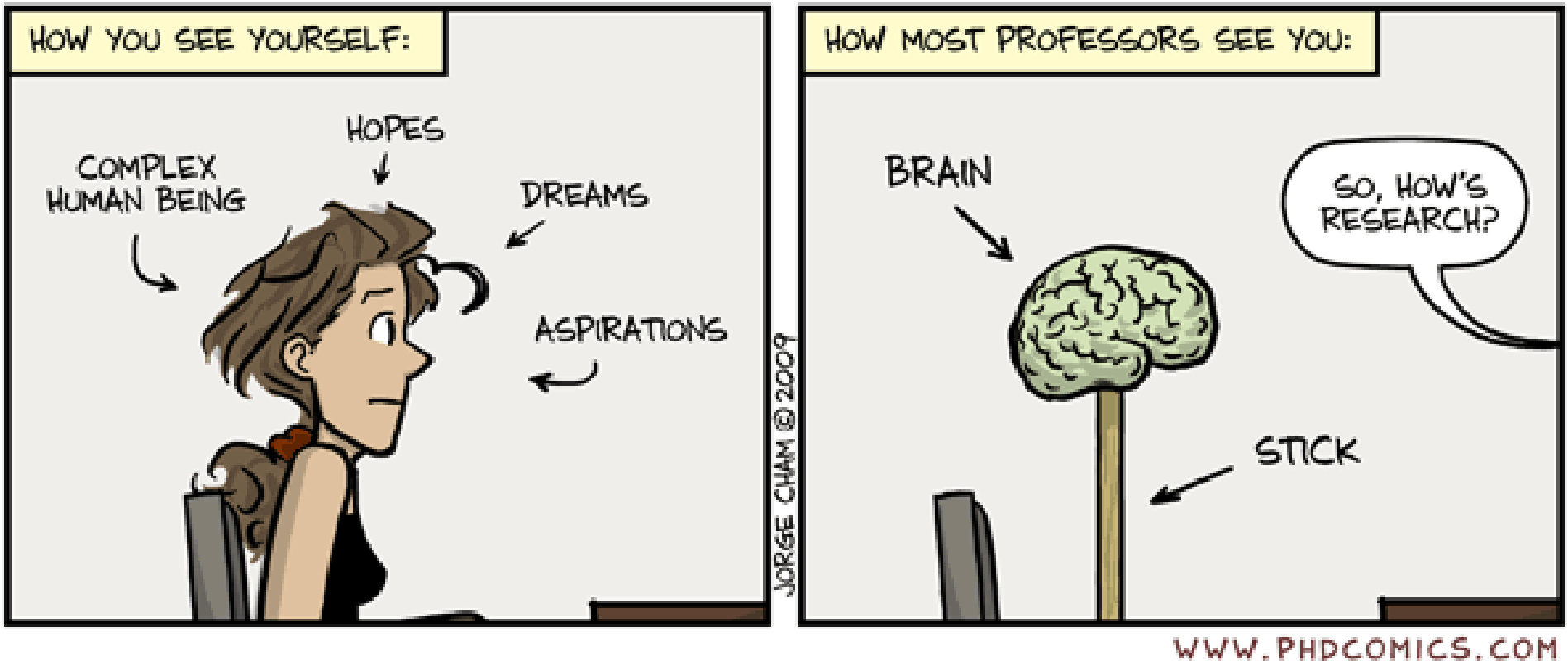


Nico Habermann
(1932-1993)

David Notkin
(1955-2013)

http://www.cs.washington.edu/people/faculty/notkin/students/

Brain on a Stick? Oh, No…



'*Brain on a stick*'

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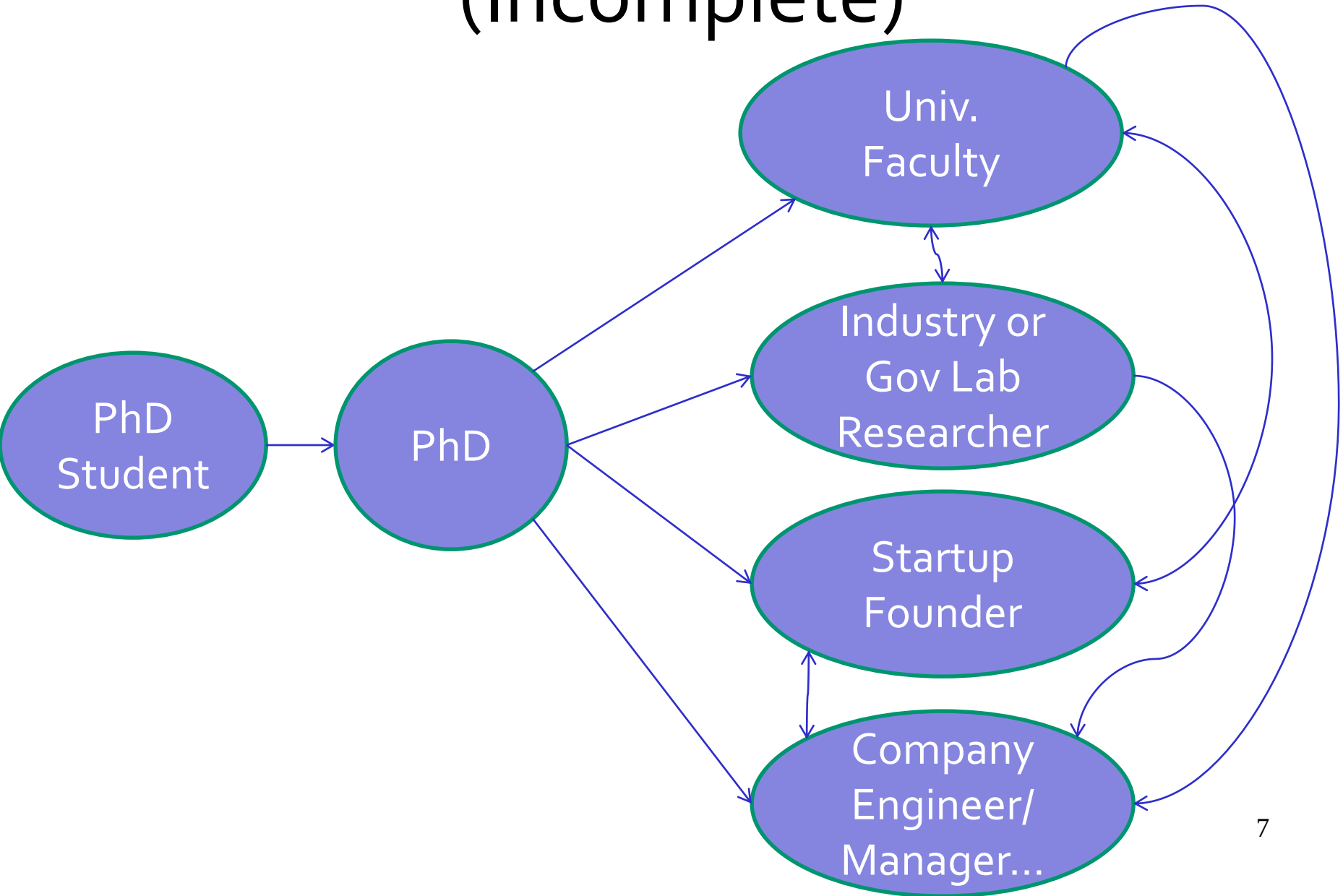
Learning: Students vs/and Research

- "Focus on **yourself**, since graduating **great yourself** means you'll produce great research, while focusing on the research may or may not produce **great yourself**."

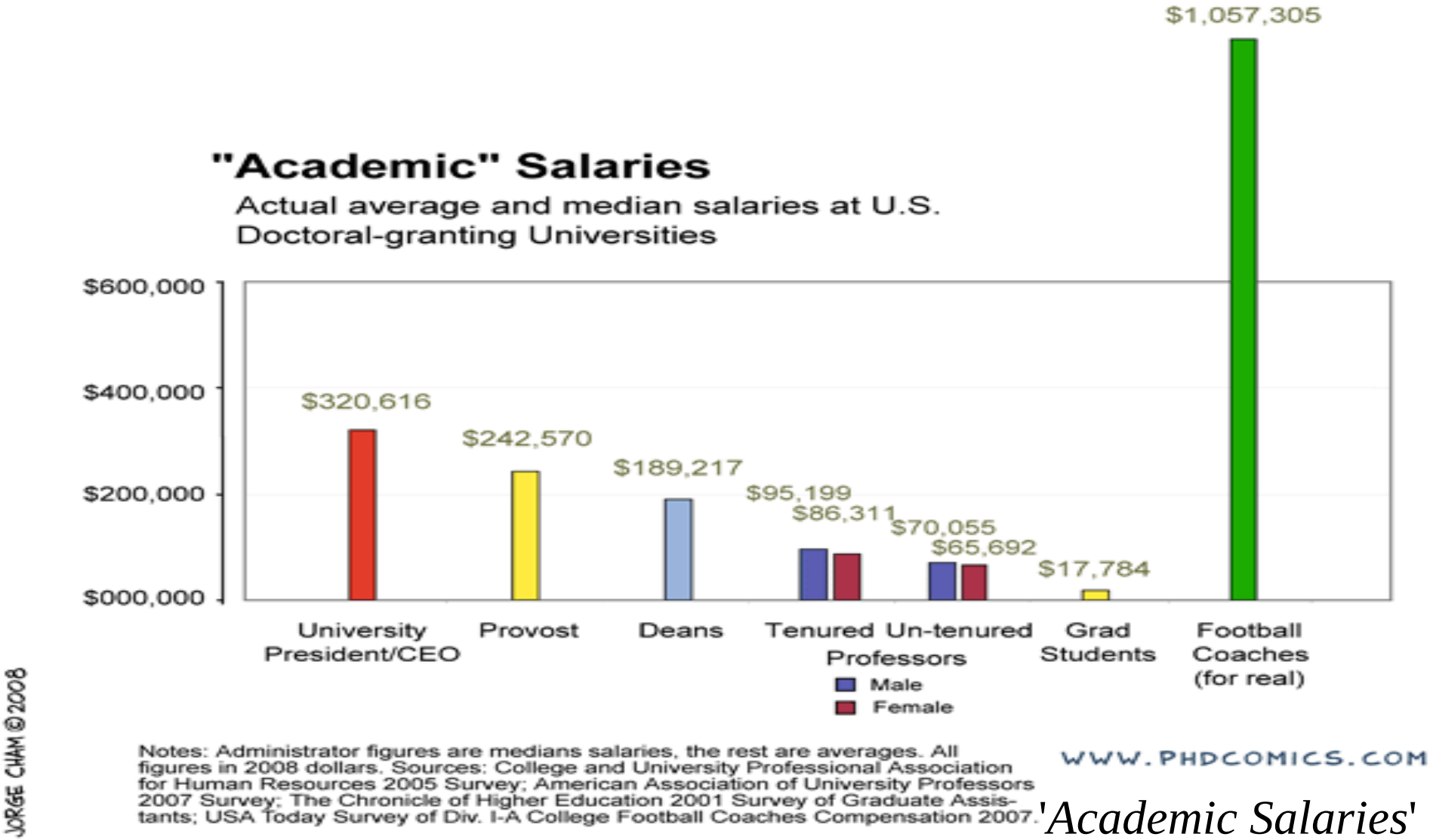
You should still pay attention to this talk's contents even if you already have a great advisor/collaborator who

- picks great problems for you to work on
- produces great ideas for you to implement the solutions
- writes great introductions or whole drafts for your papers
- …

Statechart of Post-PhD Career (Incomplete)



You Don't Choose to Be a Professor (or even a PhD) Because of Money



'*Academic Salaries*'

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Brainstorming Group Discussion: Get into a group of 2 or 3 students, discuss your answers to the question below

Based on **what** do I consider myself ready to graduate with a PhD?

Essential Skills for a (PhD) Researcher

- is able to independently
  - **Assessment**
    - Others' Work (e.g., conference PC members, journal reviewers)
    - Own Work
  - **Vision** (e.g., per n years, research agenda)
  - **Design** (e.g., per paper/project)
    - Problem
    - Solution
  - **Execution** (e.g., time/risk/team management)
    - Implement
    - Evaluate
  - **Communication**
    - Written
    - Oral

AVDEC

→ high-quality/impact research

Critical, Visionary, Creative, Strategic/Engineering, Logical… Skills

Discussion Framework

For each AVDEC skill

- **What** is the skill about?
- **How** to train/learn such skill?
  - E.g., practices conducted at ASE group
- What success **criteria** can be used to judge the accomplished level of the skill?
- How will such skill **impact** post-PhD career?

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Assessment – What

- Assessment of **others'** work
  - Later serving as program committee members or journal reviewers
  - Later advising more-junior collaborators in research development
- Assessment of **your own** work
  - Which ones are better among your *n* ideas?
  - What pros/cons of each of your *n* ideas?

Assessment – How

- Serve as **co-reviewer** of conference/workshop submissions reviewed by the advisor (as PC member)
  - Note that the advisor still needs to read and do the review himself/herself (likely based on the student's co-review)
- Review other students' **co-review**
  - Each submission has both primary co-reviewer and secondary co-reviewer
  - Secondary co-reviewer reviews primary co-reviewer's review & gives improvement suggestions

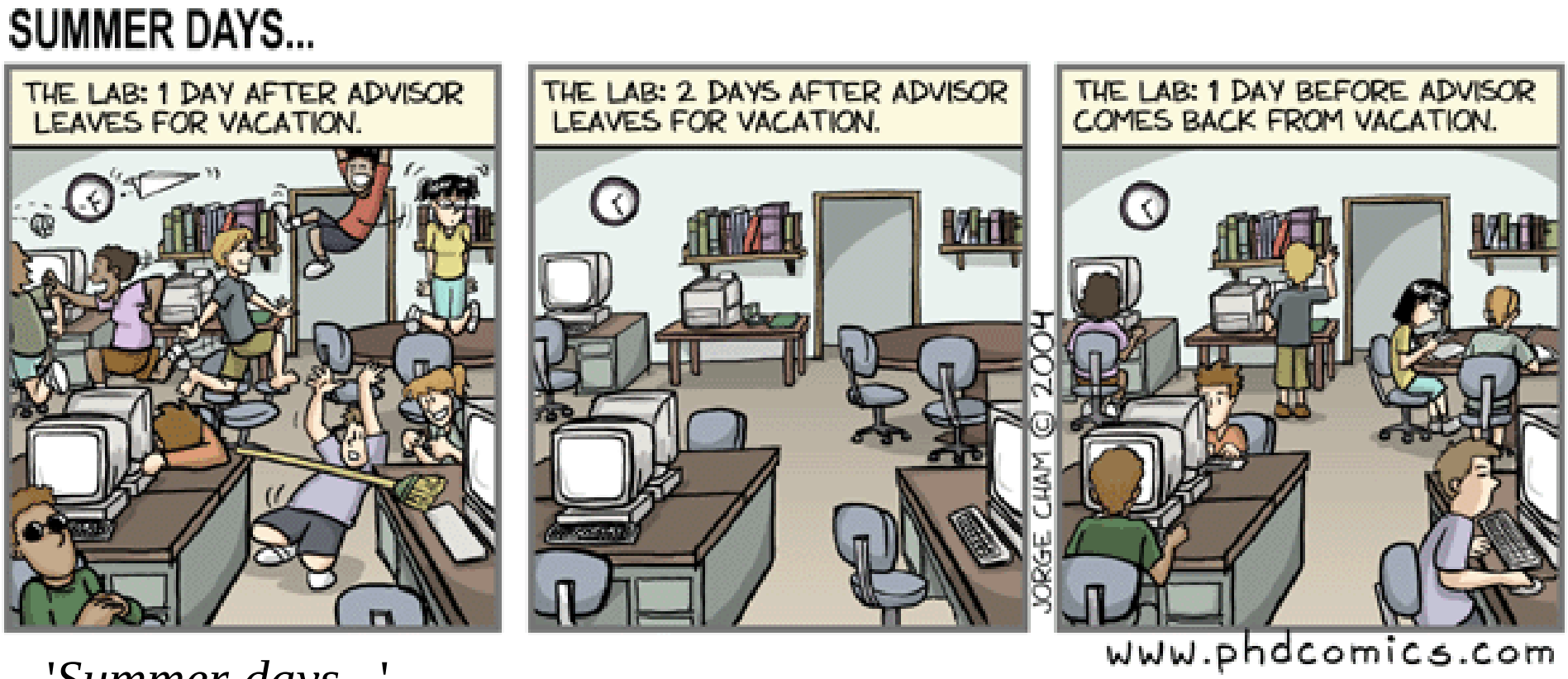
Assessment – How cont.

- Serve as **peer shepherd** for other students' papers/projects
  - In ASE group, each student's paper/project has a peer shepherd (non-author student), being "co-advisor" on the paper/project
    (side-benefit: offloading some advising effort)
  - Initial policy: after the author student sends writing (paper portions/ideas) to the group mailing list, the shepherd is suggested to send feedback before the advisor does; otherwise, the shepherd needs to send feedback *n* hours after the advisor does so
  - Question for the audience: Do you think the policy would work well?

Assessment – How cont.

- The answer is “No”
- Key management principle: Don’t put the manager as the bottleneck of group-activity workflow
- Common reality: If no clear/strong incentive or checking, students typically don’t follow a policy

An Example Case Where Advisor is the Workflow Bottleneck



'Summer days...'

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Assessment – How cont.

- The answer is "No"
- Key management principle: Don't put the manager as the bottleneck of group-activity workflow
- Common reality: If no clear/strong incentive or checking, students typically don't follow a policy
- Effective patch later:
  - the shepherd must send feedback before the advisor does (i.e., the advisor won't send feedback if the shepherd hasn't)

Assessment – How cont.

- After finishing your review, **compare** your review with the advisor's final review (and other students' reviews) to learn how to improve your future reviews

More advice on technical reviewing at
http://web.engr.illinois.edu/~taoxie/advice.htm#review

Assessment – Criteria

- **Closeness** of your review with your advisor's final review (e.g., complete, constructive, …)
- **Inclusion** of important points (in your review) that your advisor even does not think of, i.e., complementing your advisor's opinions
- …

Common patterns of students in initial phases

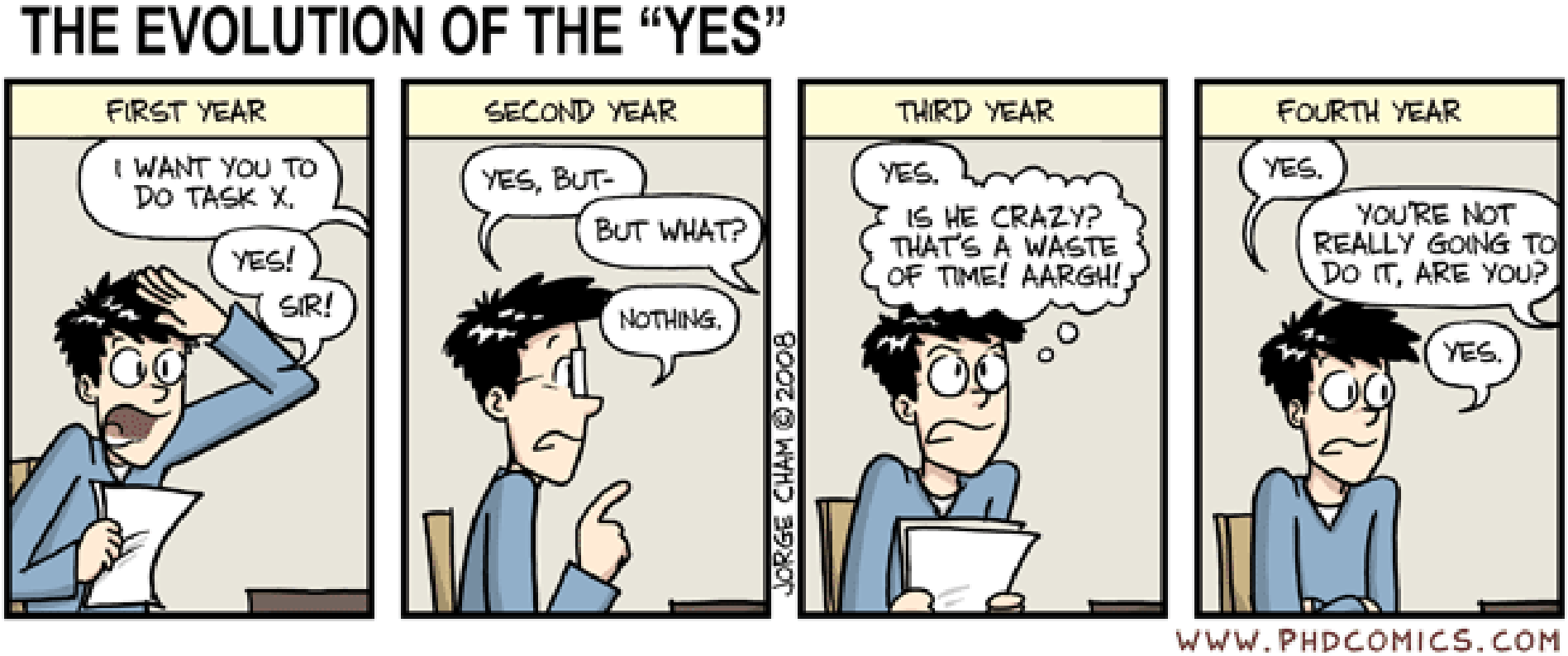
- Write very brief review comments (saying only good things)
- Write detailed comments on only writing issues
- Fall into two tendencies
  - not critical enough (accepting papers rejected by advisor)
  - over-critical (rejecting papers accepted by advisor)

Assessment – Impact

One of the two most critical among AVDEC along with **vision** (as faculty member)

- Advisor's role: **sounding board** (instead of idea generator?) for students
  - **Shaping** students instead of driving students
  - Analogy: search-based software engineering
    - **Fitness function**: advisor
    - Student's responsibilities: search strategies; production, mutation, crossover of chromosomes; …
- Serve on conference/workshop program committees or journal editorial boards/reviewers

Progression of Assessment Skills



'The evolution of Yes'

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Vision – What

- If you are given 1 (4) **million dollars** to lead a team of 5 (10) team members for 5 (10) **years**, what would you invest them on?
- In 5 (10 or n) years, in what **X** (a research subarea), you want your name to be associated with?
  - Not just when mentioning your name, people think of X but when mentioning X, people think of your name!
- US NSF CAREER award topic is somewhat like that
- Not just a single paper but built/reflected with **N papers** along with **M talks/tutorials/conversations**

Vision – What cont.

Examples

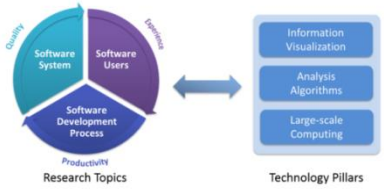
- Computational thinking (Jeannette Wing@MSR)
- Model checking (Ed Clarke@CMU)
- Software process (Lee Osterweil@U Mass)
- Search-based soft eng (Mark Harman@UCL)
- Software analytics (Dongmei Zhang@MSRA)
- …
- My own "under-qualified visions": problem-driven mining of SE data, cooperative testing and analysis, technology transfer/adoption, educational SE, … (elaborated more later)

Vision – How

- Think and articulate underlying **assumptions** and **principles/themes** of your (past/ongoing) research - how do you (systematically) choose what to pursue?
  - core values that drive your research agenda in some broad way
- Figure out or form your **taste** of choosing problems (and solutions)

Example Principles

- Question **core assumptions** or **conventional wisdoms** about SE
  - D. Notkin: Software, Software Engineering and Software Engineering Research: Some Unconventional Thoughts. J. Comput. Sci. Technol. 2009
- Play/work around **industrial tools** to further improve them, e.g., Parasoft Jtest, MSR Pex/Pex4Fun/TouchDevelop
  - http://research.microsoft.com/en-us/projects/pex/community.aspx#publications
  - http://research.microsoft.com/en-us/projects/pex4fun/
  - http://research.microsoft.com/en-us/projects/touchdevelop/
- Collaborate with **industrial collaborators** to focus on high-practice-impact research problems and solutions, based on powerful infrastructure/data, e.g., MSR Pex/Pex4Fun/TouchDevelop, MSRA Software Analytics
  - http://research.microsoft.com/en-us/groups/sa/



Example Principles cont.

- Investigate SE mining **requirements** and adapt or develop mining algorithms to address them, e.g., Suresh Thummalapenta [ICSE 09, ASE 09]
  - http://researcher.watson.ibm.com/researcher/view_pubs.php?person=in-surthumm&t=1
- Cooperative testing/analysis: enabling effective and efficient cooperation of **tools** and **human** (for tasks traditionally tackled with tools/algorithms), e.g., Xusheng Xiao [Covana ICSE 11]
  - https://sites.google.com/site/xushengxiaoshome/
- **Integration** of static and dynamic analysis
- Using dynamic analysis to realize tasks originally realized by static analysis (or the other way around)
- …

Vision – How cont.

- Start writing your **Research Statement** (RS) earlier in your PhD program especially the **Future Work** section
  - Collect and learn from RSs released by those currently in the job market (from their homepages)
- Attempt to improve your answer to "What is your long-term research **vision**"?
- Be prepared to answer high-level questions such as "What is **beauty** of X"? (X being your chosen approach type such as dynamic analysis)

Vision – Criteria

- Satisfactory level of answering those **questions** earlier discussed in "What" slides
- Satisfactory level of "**Future Work**" in your Research Statement
- Make a successful submission to a **Visions and Challenges** track (such as the one for FSE 2014), different from the NIER track
- …

http://fse22.gatech.edu/cfp/visions-and-challenges

Vision – Impact

- A researcher with vision may provide more **inspiration/impact** to others

- A researcher with vision may become a **thinker** (thought leader), **strategist**, or **futurist** (beyond just a "doer")

Vision – Impact cont.

- Step back and think about what research problems will be most important and most influential/significant to solve in the long term
  - Long term could be the whole career
- People tend not to think about important/long term problems

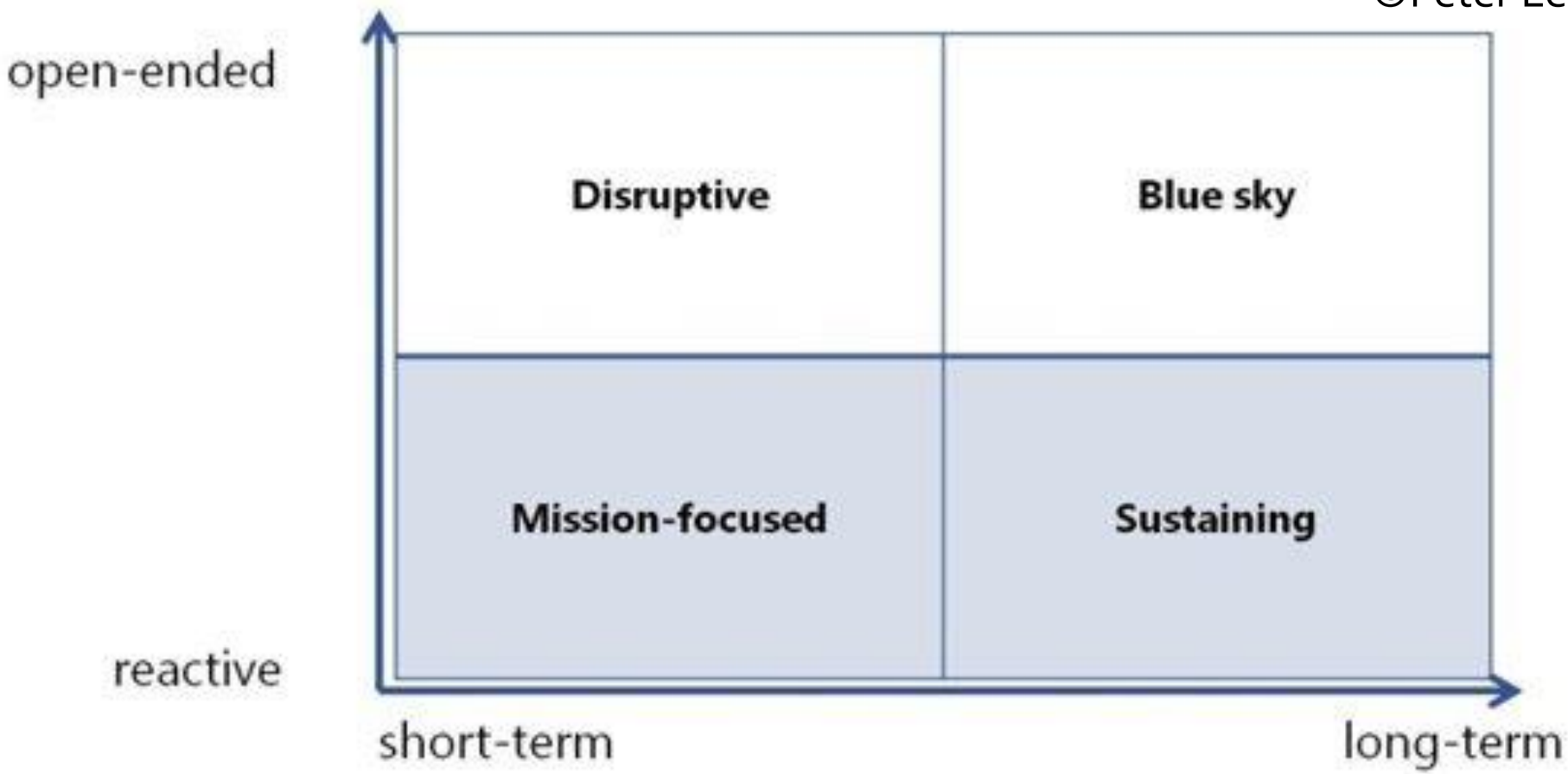
	Less important	More important
Shorter term		
Longer term		√

Richard Hamming "**you and your research**"
http://www.cs.virginia.edu/~robins/YouAndYourResearch.html
Ivan Sutherland "**technology and courage**"
http://cseweb.ucsd.edu/~wgg/smli_ps-1.pdf

This slide was made based on discussion with David Notkin

Research Space

©Peter Lee



http://blogs.technet.com/b/inside_microsoft_research/archive/2011/12/31/microsoft-research-redmond-year-in-review.aspx a blog post by Peter Lee@MSR

Talk: The Pipeline from Computing Research to Surprising Inventions by Peter Lee@MSR
http://www.youtube.com/watch?v=_kpjw9Is14Q

Your Advisor's Vision?

'*The grandeur of his vision*'

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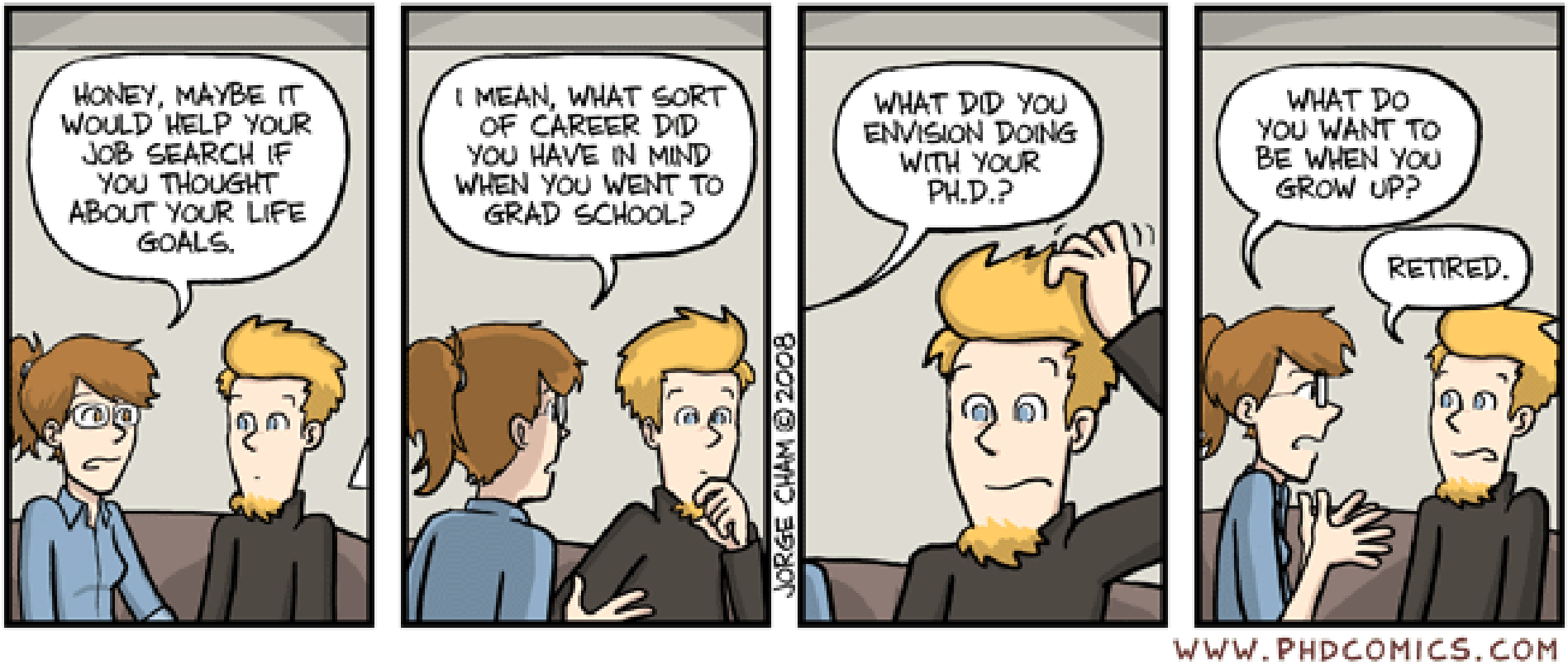
and Your Vision?



'*What do you want to be?*'

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Life Ambition May Go Down But Keep Your Vision Up

'*Your Life Ambition*'

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Design – What

- Pick what (good) problem to work on
  - Working on good problems or asking good questions is much appreciated in SE field

- Design what (good) solution/ideas to solve the problem

Compared with vision on ***n*** papers/projects, design is typically on ***one*** paper/project at a time

Design – How

Adopted in ASE group

- Document ideas in research idea log
  - You need to produce many ideas first before you accomplish producing new and good ideas
- Present in weekly group meeting for summarizing a specific sub-area
- Organize and participate small-group discussion
  - No advisor's participation
- Recommend/brainstorm papers to the advisor, who never read the papers
- Write down ideas in formal writing

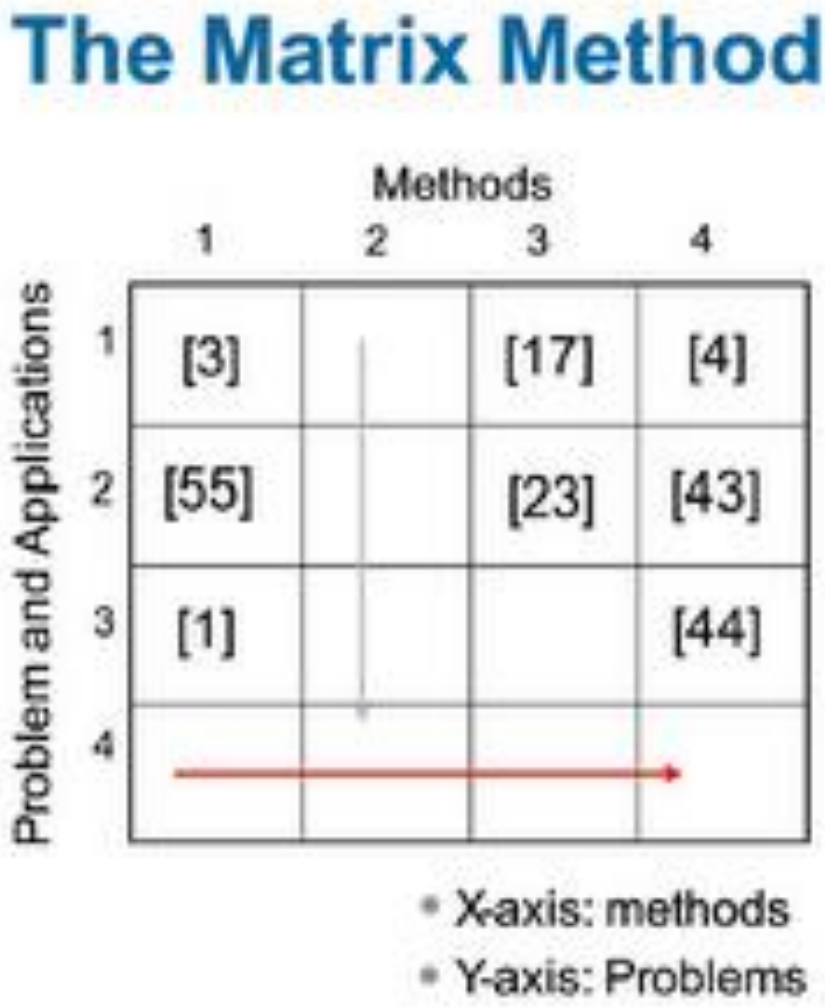
Get ***feedback*** from advisor/peer shepherd on ideas

Design – How cont.

- Research Matrix (Charles Ling and Qiang Yang)
- Shallow/Deep Paper Categorization

More details, see my slides on "Mapping Out a Research Agenda" at http://web.engr.illinois.edu/~taoxie/advice/

Technique: Research Matrix



Adopted by ASE group

See Book Chapter 4.3: Crafting Your Research Future: A Guide to Successful Master's and Ph.D. Degrees in Science & Engineering by Charles Ling and Qiang Yang

http://www.amazon.com/Crafting-Your-Research-Future-Engineering/dp/1608458105

Technique: Shallow Paper Categorization

- See ASE group's shallow paper category:
  - https://sites.google.com/site/asergrp/bibli
- Categorize papers on the research topic being focused
- Both the resulting category and the process of collecting and categorizing papers are valuable

Adopted by ASE group

Technique: Deep Paper Categorization

- Categorize papers on the research topic being focused (in a deep way)
- Draw a table (rows: papers; columns: characterization dimensions of papers)
- Compare and find gaps/correlations across papers

Adopted by ASE group

Example Table on Symbolic Analysis:

Paper	Category/Categories	Inputs	What to turn Symbolic	Manipulation of Symbolic Expressions/Path Conditions	Aggregation Across Runs	Outputs
DySy: Dynamic Symbolic Execution for Invariant Inference. Christoph Csallner, Nikolai Tillmann, and Yannis Smaragdakis. ICSE 2008	**Invariant Inference**	Existing Tests	Inputs from the existing test		Yes, since invariants stay the same after all transformations.	Inferred invariants from code. Abstract conditions over program variables that the concrete tests satisfy.
Precise Identification of Problems for Structural Test Generation. Xusheng Xiao, Tao Xie, Nikolai Tillmann, Jonathan Halleux. ICSE 2011.	**Problem Identification**	program under test	input parameters	User guidance???	Yes	
Precise Interface Identification to	Web	Web application	web application		No	Accepted interface

Design – Criteria

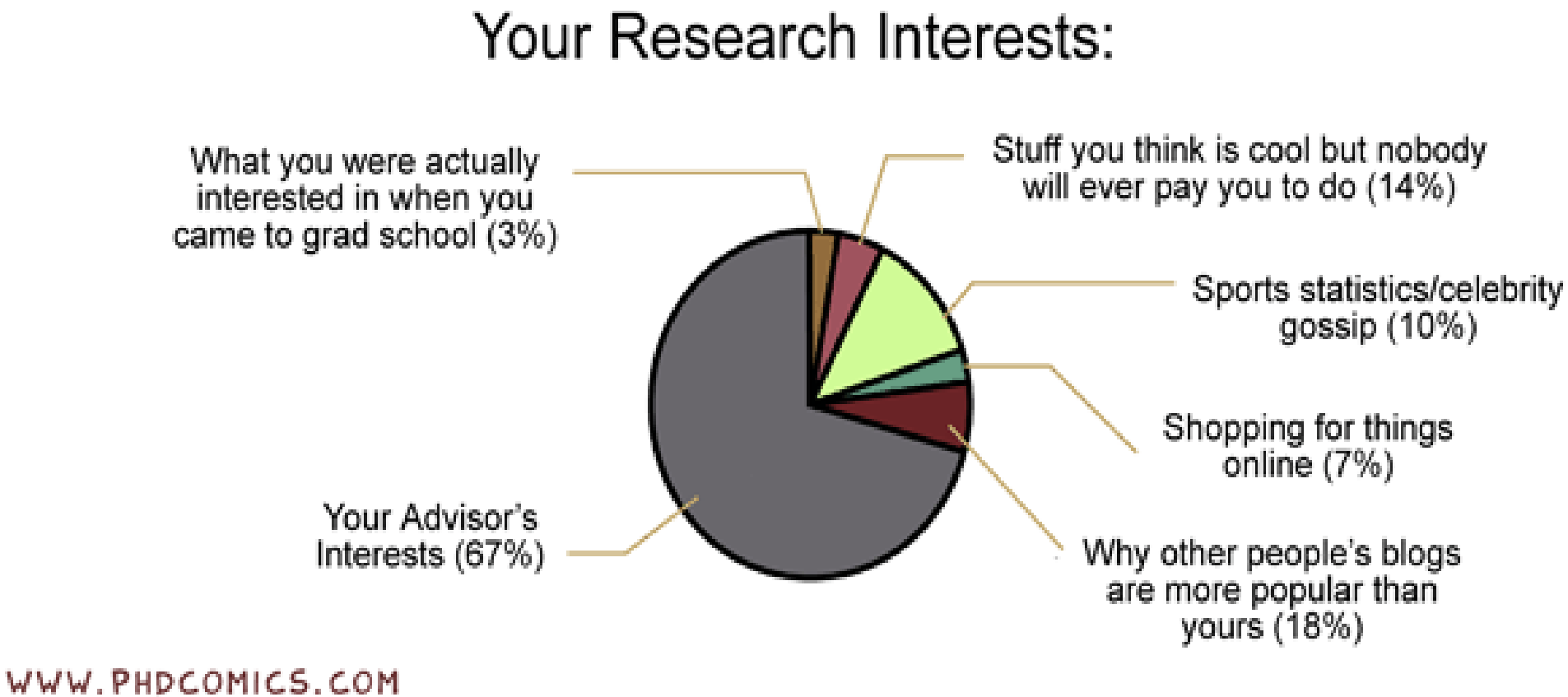
- For a high-quality paper published by you, did **you** pick the problem there?
  - Or **how much contribution** did you make in picking the problem?
- For a high-quality paper published by you, did **you** produce the ideas for the solution there?
  - Or **how much contribution** did you make in producing the ideas?
- For a successfully funded proposal, **how much contribution** did you make in picking/producing the problems/ideas there?
- …

Design – Impact

- All researchers need to pick good problems and produce good ideas to solve the problems
  - A big part of research innovations
- Faculty members need to have strong innovative capability in order to train students to be able to innovate, e.g.,
  - Collaboratively brainstorming new ideas with students
  - Implicitly guiding students to produce/own good ideas whose initial version was in the advisor's mind

Your Research Interests?

- Determining what problems/solutions/ideas to work on?



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Execution – What

- Implement a tool **prototype** for the research
  - Tool development skill
  - Debugging/problem-solving skill
  - …

- Conduct **evaluation** to validate the research
  - Rigor skill
  - Analytic skill
  - …

Execution – What cont.

- **Team** management
  - Even if you are a single student working on your paper/project, your advisor (and other senior collaborators) is your team member managed by you
- **Risk** management
  - Identify, mitigate, manage risks
- **Time** management
  - Last-minute is not bad as long as you make the deadline and deliver high-quality deliverables
  - But often the time, you need help from your advisor (and collaborators) to improve your deliverable quality, and they are typically busy people

Execution – How

- Use **Gantt chart** for your project and paper-deadline catching
- Conduct **weekly meetings** with peer **shepherd**
  - review your Gantt chart and identified risks along with risk-management actions
- Write **weekly progress reports** (informal writing in wiki) to the advisor and **monthly progress report** (formal writing in papers) to all senior collaborators

Adopted by ASE group

Execution – Criteria

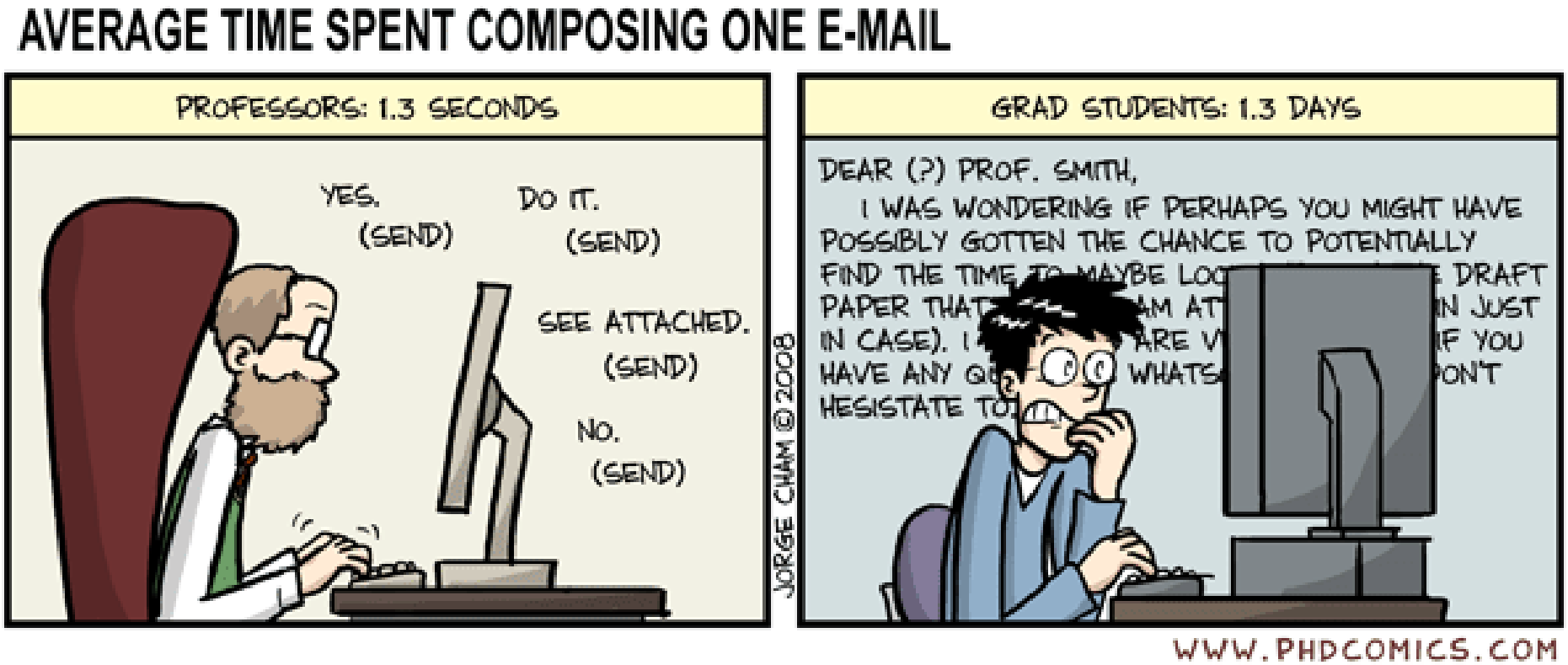
- How often do you **make deadlines** with high-quality submissions?
- How often do you need to **change** your **Gantt chart** along the way?
- How often do you **send** your drafts **late** to your advisor/senior collaborators, who couldn't spend time to give you feedback before submission?
- …

Execution – Impact

- All researchers need to carry out work effectively and efficiently
  - Be a reliable person to get things done!

- Faculty members especially often have many tasks at hand

Your Advisor is Much More Efficient



'Average time spent writing one e-mail'

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When Your Advisor Wants to be Hands-On

'*An impending sense of doom*'

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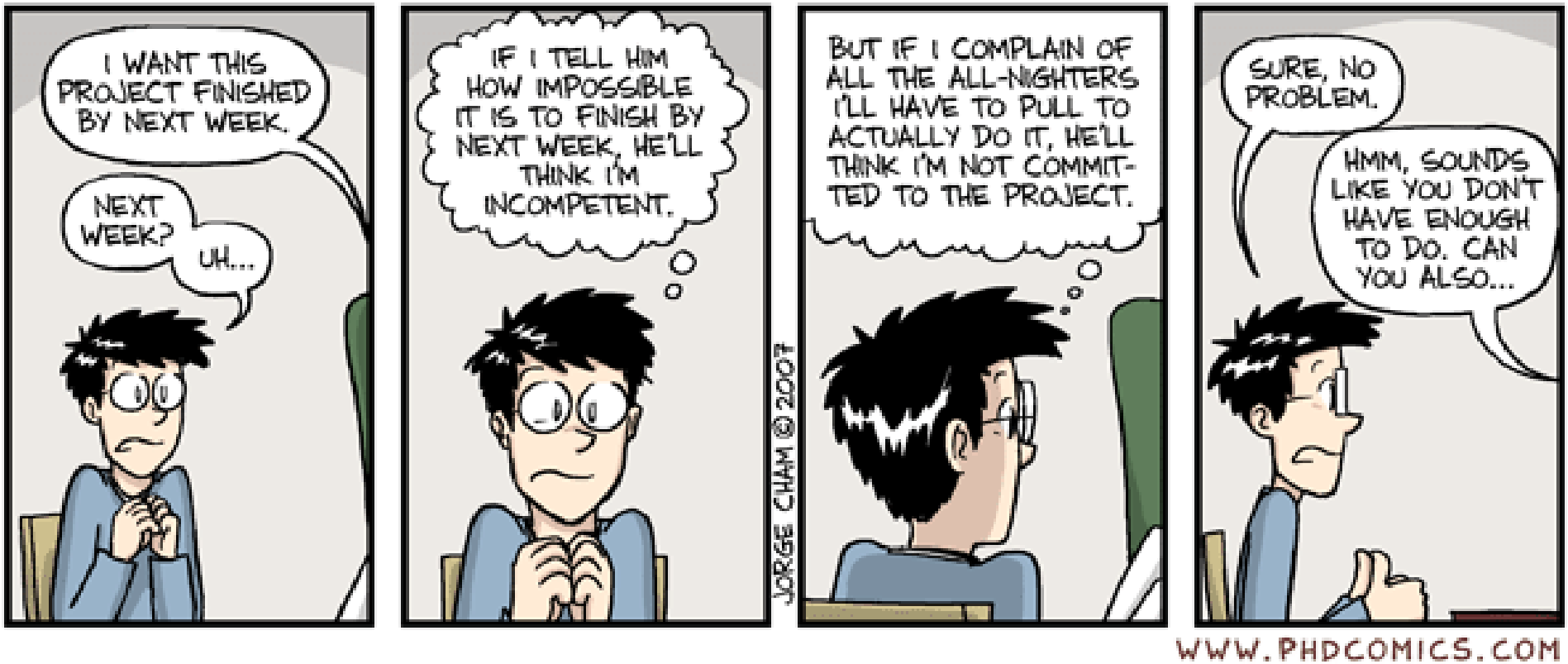
And You Do the Impossible



'*Doing the impossible*'

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And Face Problems

'*Problems*'

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Not Spend Your Day Like

'Why? Why??'

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How Long Your Prof. Thinks It Should Take to Do Something

How long your Prof. thinks it should take to do something		How long it'll actually take you to do it
"Trivial"	=	There goes your week.
"Easy enough"	=	Pull your hair out for a month.
"About a week"	=	Actually, this is pretty easy. He/she doesn't know there's technology that will do this for you now. Take the week off!
"Should keep you occupied for the rest of the term"	=	He/she will forget they asked you to do this by the end of the term. Don't even bother.
"This might make a good thesis topic"	=	Say hello to your thesis topic.
"Hmmm..."	=	Uh oh.

How long your Prof. thinks it should take to do something'

WWW.PHDCOMI

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Communication – What

- Writing communication
  - Write a technical paper
  - Write a PhD thesis proposal (funding proposals later)
  - Write a PhD dissertation
- Oral communication
  - Present 5-min elevator talk
  - Present 25-min conference talk
  - Present 50-min seminar/job talk
- Listening comprehension
  - Understand what others say in Q/A of your talk, others' talks, causal conversations, …

(Written) Communication – How

- Write early and often
- Understand rationales of writing "rules" besides the "rules" themselves
  - See my slides on "technical writing issues", "how to write research papers" at http://web.engr.illinois.edu/~taoxie/advice.htm
- Use writing defect logs
- Learn how to communicate ideas clearly (e.g., structured/top-down and logical ways)
- Principle of advisor:
  - Never (re)write on students' papers except marking (on hardcopy); Iterate on giving guidance/explanation

Example Technique: Dotting Dragon Eyes

- Spot out "eyes" of a paper from ideas in the paper (e.g., general/interesting/inspiring ideas)
- Summarize the "eyes" in one phrase
- Promote the "eyes" in the paper title if possible
- Examples from our papers
  - **Context-Sensitive Delta Inference** for Identifying Workload-Dependent Performance Bottlenecks. Xusheng Xiao, et al. ISSTA 13
  - Automating Presentation Changes in Dynamic Web Applications via **Collaborative Hybrid Analysis**. Xiaoyin Wang, et al. FSE 12
  - **Iterative Mining** of Resource-Releasing Specifications. Qian Wu, et al. ASE 11
  - Alattin: Mining **Alternative Patterns** for Detecting Neglected Conditions. Suresh Thummalapenta, et al. ASE 09

http://web.engr.illinois.edu/~taoxie/publications.htm

Adopted by ASE group

Example Technique: "Balloon"/"Donut"

- Adopted by ASE group
- *Balloon*: the process is like blowing air into a balloon
- *Donut*: the final outcome is like a donut shape (with the actual realized problem/tool as the inner circle and the applicable generalized problem/solution boundary addressed by the approach as the outer circle)
- Process: do the following for the problem/solution space separately
  - Step 1. Describe what the exact concrete problem/solution that your tool addresses/implements (assuming it is X)
  - Step 2. Ask questions like "Why X? But not an expanded scope of X?"
  - Step 3. Expand/generalize the description by answering the questions (sometimes you need to shrink if overgeneralize)
  - Goto Step 1

Example Application of "Balloon"/"Donut"

- Final Product: Xusheng Xiao, Tao Xie, Nikolai Tillmann, and Jonathan de Halleux. Precise Identification of Problems for Structural Test Generation. *ICSE 2011* *http://web.engr.illinois.edu/~taoxie/publications/icse11-covana.pdf*
- Problem Space
  - Step 1. (Inner circle) Address too many false-warning issues reported by Pex
  - Step 2. Why Pex? But not dynamic symbolic execution (DSE)?
  - Step 3. Hmmm… the ideas would work for the same problem faced by DSE too
  - Step 1. Address too many false-warning issues reported by DSE
  - Step 2. Why DSE? But not symbolic execution?
  - Step 3. Hmmm.. the ideas would work for the same problem faced by symbolic execution too
  - ….
  - Outer circle: Address too many false-warning issues reported by test-generation tools that focus on structural coverage and analyze code for test generation (some techniques work for random test generation too)

Example Application of "Balloon"/"Donut"

- Final Product: Xusheng Xiao, Tao Xie, Nikolai Tillmann, and Jonathan de Halleux. Precise Identification of Problems for Structural Test Generation. *ICSE 2011* *http://web.engr.illinois.edu/~taoxie/publications/icse11-covana.pdf*
- Solution Space
  - Step 1. (Inner circle) Realize issue pruning based on symbolic analysis implemented with Pex
  - Step 2. Why Pex? But not dynamic symbolic execution (DSE)?
  - Step 3. Hmmm… the ideas can be realized with general DSE
  - Step 1. Realize issue pruning based on symbolic analysis implemented with DSE
  - Step 2. Why DSE? But not symbolic execution?
  - Step 3. Hmmm … the ideas can be realized with general symbolic execution
  - ….
  - Outer circle: Realize issue pruning based on dynamic data dependence (which can be realized with many different techniques!), potentially the approach can use static data dependence but with tradeoffs between dynamic and static

(Oral) Communication – How

When holding 1-1 meeting with the advisor

- Avoid using **slides**
- Avoid using **examples** as first resort
- Avoid using **white board** as first resort

These three "avoid" are on the opposite of helping communication – the reason is for the advisor to debug the student's communication bug

  - Going from the failure to the bug location instead of temporary "healing" or "workaround"

(Oral) Communication – How

- **Recommend** papers to the advisor, who never read the papers before
  - Learn how to explain things clearly
  - Learn (through the advisor's questions) what are important to communicate when reading a paper or conveying your own paper
- **Present** your or other's work to the advsior and the group (in 1-on-1 or group meetings)
- **Practice**, practice, practice before a talk

See more presentation advice at
http://web.engr.illinois.edu/~taoxie/advice.htm#presentation

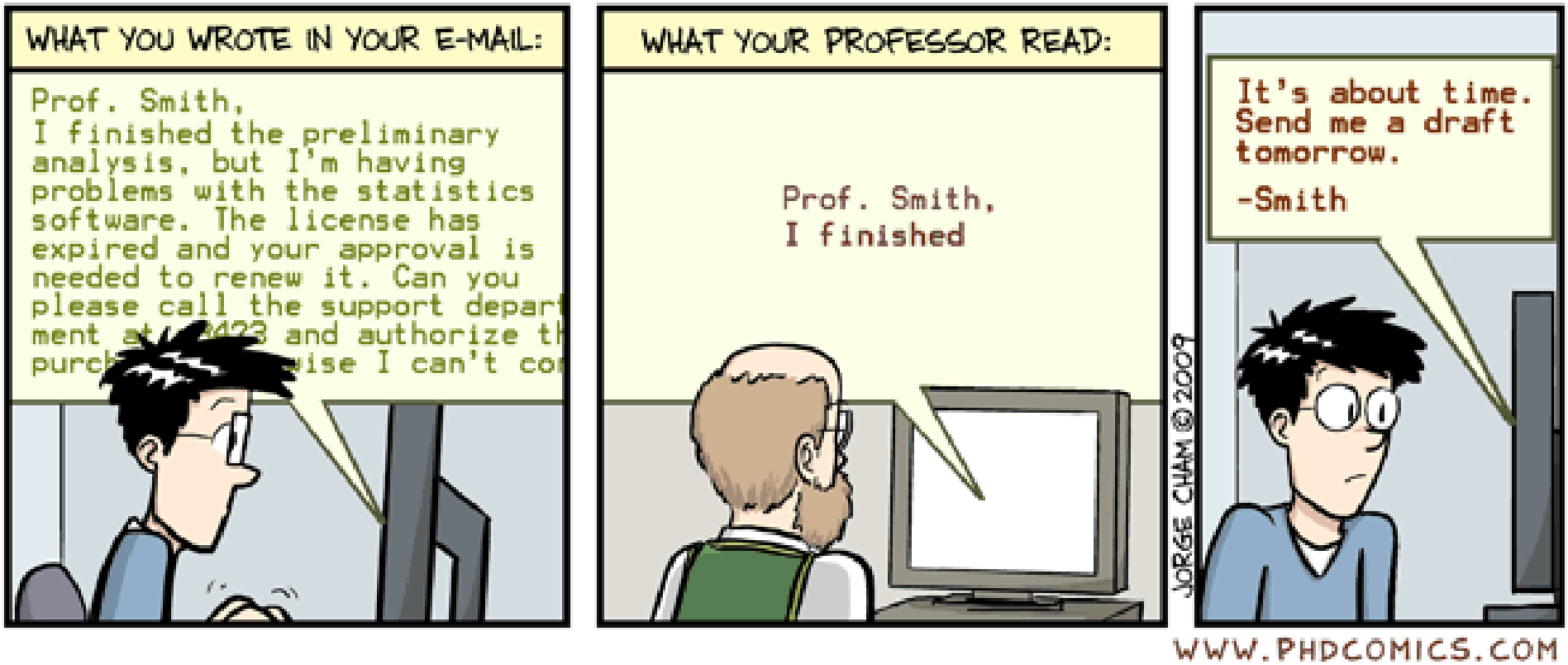
Communication – Criteria

- How high percentage of writing was **written by you** within a high-quality paper?
- How high density of marks were **made by your advisor** within your high-quality paper?
- Satisfactory level of presenting 5/25/50 min **talks**
- Satisfactory level of understanding and answering **questions**
- **…**

Communication – Impact

- Critical for faculty members
  - Write **proposals** (even when papers are primarily written by students)
  - Communicate research to **funding-agency managers** and **other researchers** in various meeting occasions
  - Advise **students** how to write better
- Critical for others too
  - Write **papers** (for researchers) and **tech docs**
  - Communicate with **team members** and **supervisors**
  - Communicate with **others** in various meeting occasions

Formal Writing (in Paper Draft) is Good…



'*What your Prof. read*'

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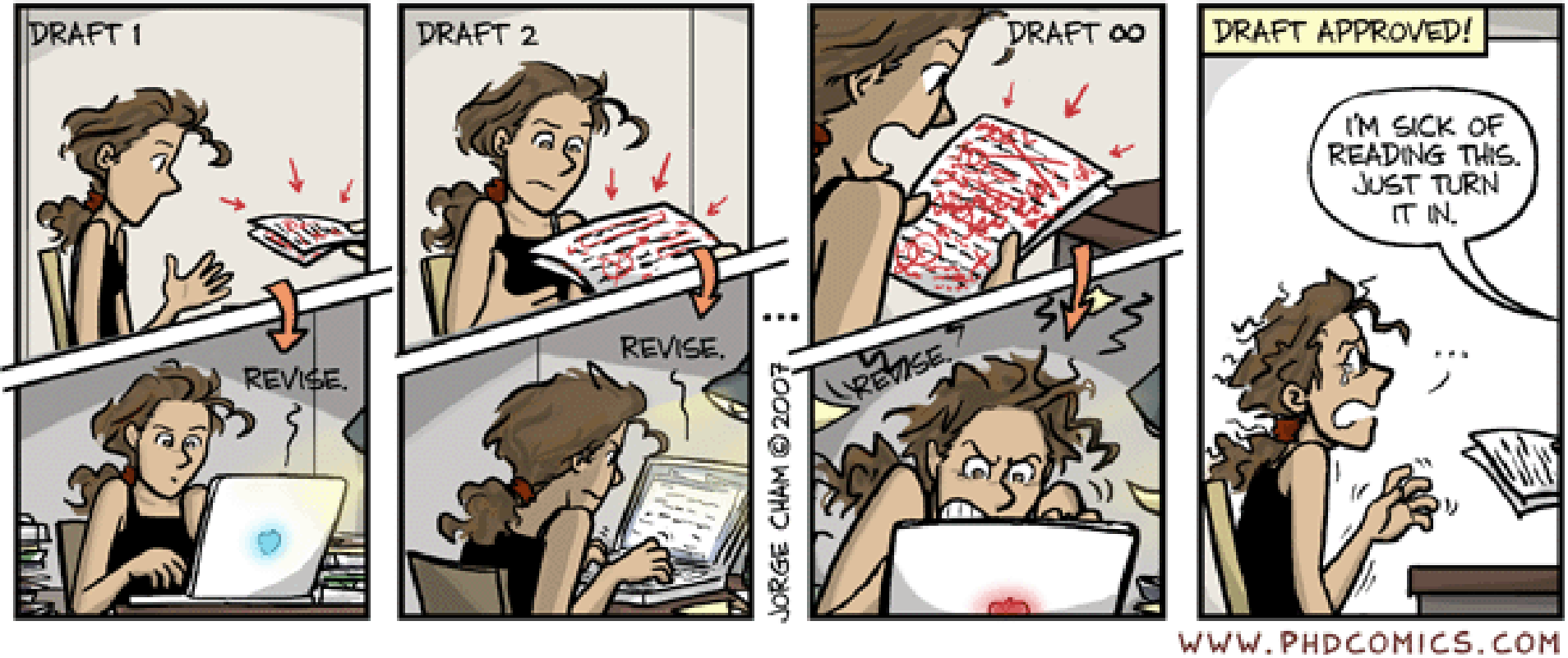
Feedback Hurts But Helps

http://www.phdcomics.com/comics/archive/phd030706s.gif

If Your are Lucky, when Preparing Your Submission (write early!) …



'*Draft approved!*'

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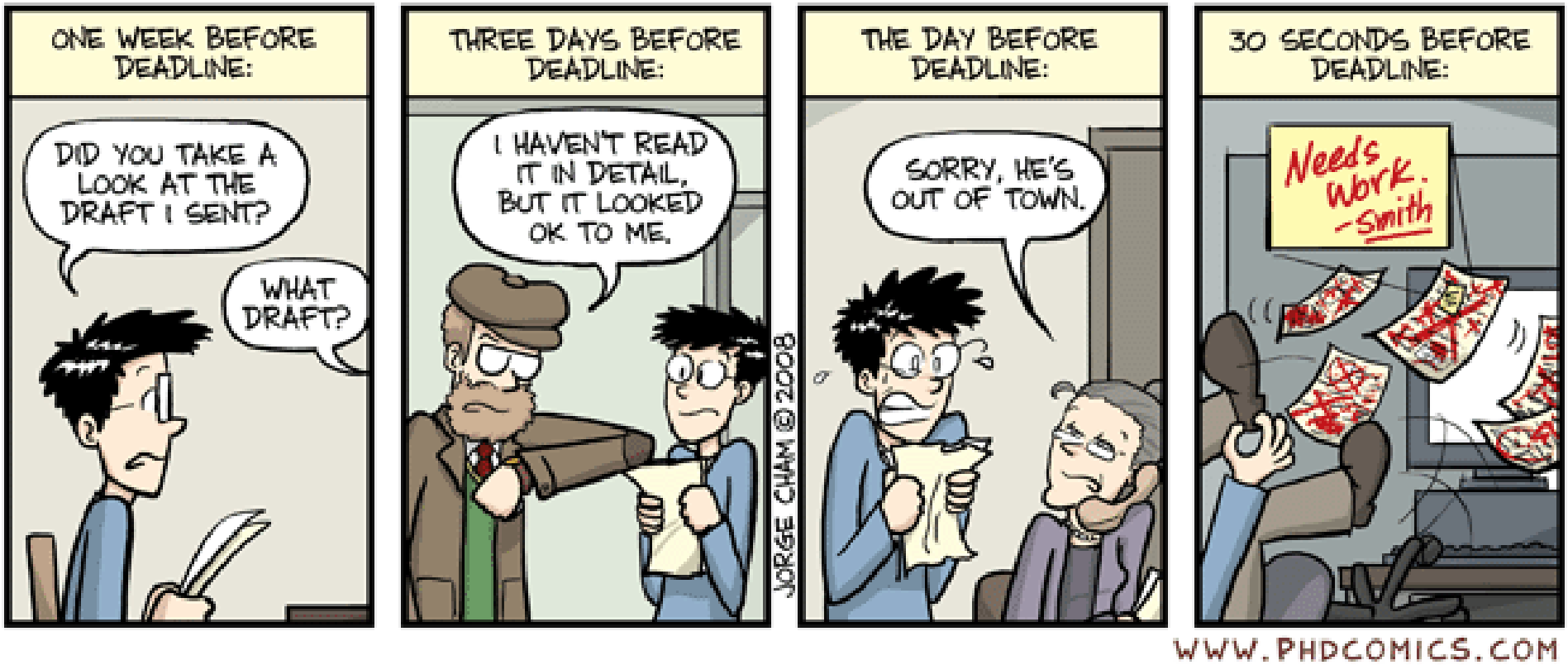
If not Lucky, (Don't Expect Your Advisor's Only Task is Just Working with You) …



'*Needs work*'

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Conclusion

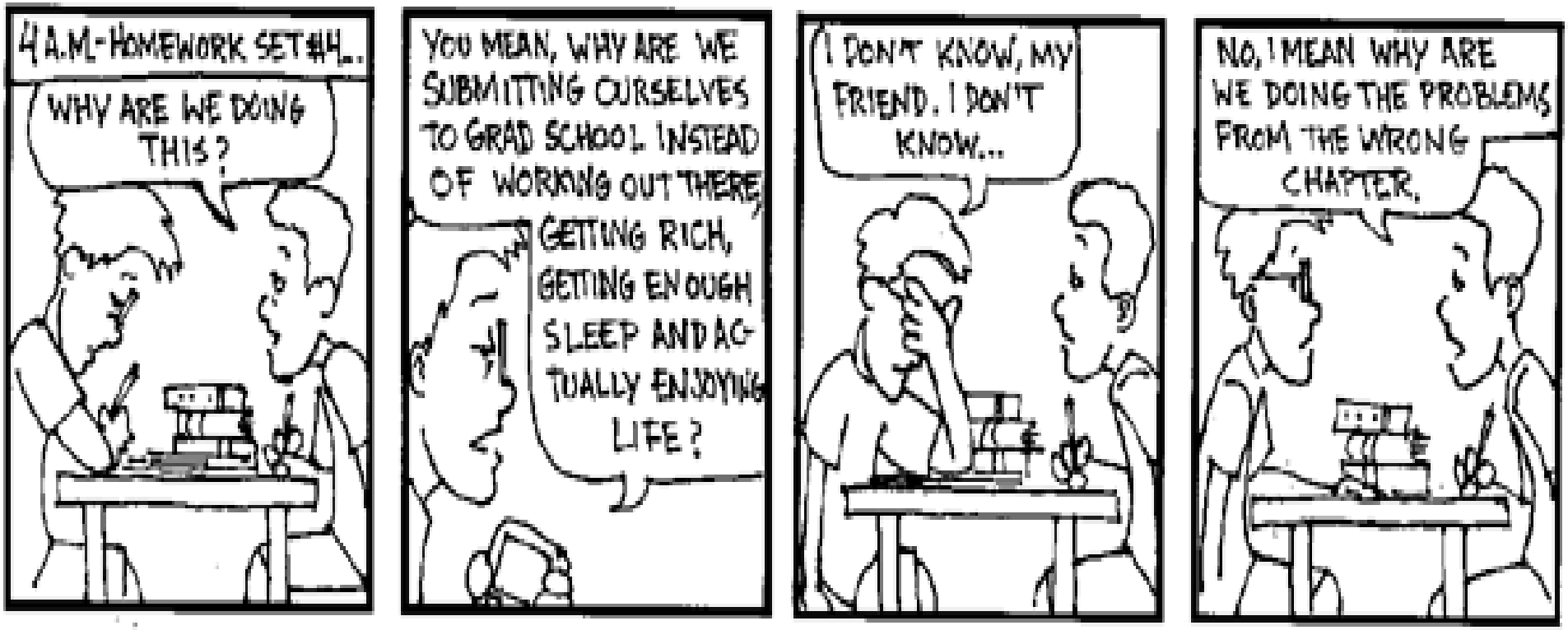
- is able to independently
  - **Assessment**
    - Others' Work (e.g., conference PC members, journal reviewers)
    - Own Work
  - **Vision** (e.g., per n years, research agenda)
  - **Design** (e.g., per paper/project)
    - Problem
    - Solution
  - **Execution** (e.g., time/risk/team management)
    - Implement
    - Evaluate
  - **Communication**
    - Written
    - Oral

AVDEC

high-quality/impact research

Critical, Visionary, Creative, Strategic/Engineering, Logical… Skills

Be Prepared.. A Lot of Hard Work But Work Hard and <u>Smart</u>!



'Why are we doing this?'

http://www.phdcomics.com/comics/archive/phd1029.gif

Thank you!

Questions ?

https://sites.google.com/site/asergrp/

Read more from my **advice portal**:
http://web.engr.illinois.edu/~taoxie/advice/