

From Solving Homework Problems
to
Solving Research Problems
to
Solving Real-World Problems

Minh N. Do

Vice Provost, VinUniversity

Professor of Electrical and Computer Engineering

University of Illinois at Urbana-Champaign

Co-founder and CTO, Personify; Chief Scientist, Misfit

Introduction

- Transition from an **undergraduate** student to a **graduate** student and then **after graduation**
- Before graduate school:
 - Mostly trained to solve **homework** problems
- In graduate school:
 - Ability to solve **research** problems is the key for success
- After graduation, in industry and entrepreneurship:
 - Must solve **real-world** problems

Solving Homework Problems

- **Example:** Prove that $\{\text{sinc}(t - n)\}_n$ is an orthogonal basis for bandlimited functions $\text{BL}([-\pi, \pi])$
- **Required skills for solving homework problems:**
 - Knowledge
 - Creativity
 - Persistence
- **Typical:** Problem \rightarrow Solution
 - Problem is well defined
 - **Know that a solution exists!**

Solving Research Problems

- **Example:** Can we recover a function from its samples?
- Research problems are typical fuzzy and open ended
 - Problems are **not** clear and well-defined
 - Problems are **not** even exist before
- **Key:** being able to ask the right questions and refine them
- We need not just to solve the problem but also convince the world that we actually solve it!
 - Perform experiments to confirm the theory
 - Demonstrate the impacts in **real** applications and technology

Solving Real-World Problems

- **Examples:** Apple, Google, Facebook
- Key is to find a **product/market fit**, or figure the **right thing to build**
– the thing customers want and will pay for
- **Require:**
 - Understand **customers** and **market**
 - Identify the **value proposition**
 - Get product out quickly: **minimum viable product**
 - **Iterate:** build, measure, learn (repeat)
 - Know how to **sell**

Research Model

“Most advances are made in response to a need, so that it is necessary to have some sort of practical goal in mind while the basic research is being done; otherwise it may be of little value.”



John Bardeen

University of Illinois Professor in

Electrical Engineering and Physics

Two-time Nobel Prize winner in Physics

Baarden's Criteria for Choosing Research

The research problem has to be strong in all following 3 criteria:

1. The supporting technology must be ready
 - Can NOT be “pie on the sky”
2. The research must be intellectually challenging
 - Can NOT just be on a “back of an envelop”
3. The outcomes of the research must help the society

Five Steps in Solving a Research Problem

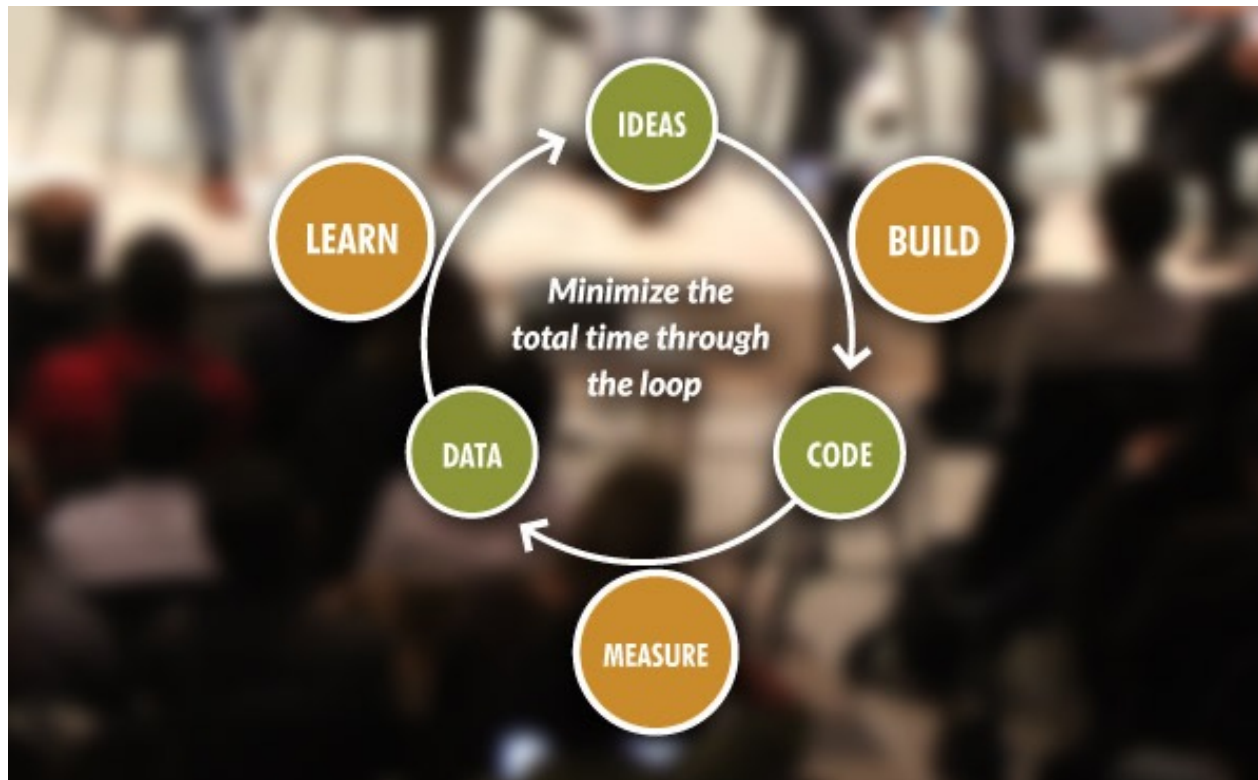
- **Step 1: Define** the problem (scope, area,...)
 - Review literature (lot of reading, but *not* too much)
 - Gain deep understanding *by doing* (implement, experiment,...)
- **Step 2: Formulate** the problem (into a homework problem)
 - Find the right model, setup
 - Introduce assumptions to simplify the problem
- **Step 3: Solve** the problem (like solving a homework problem)
 - Many times need to validate with experiments, applications
- **Step 4: Interpret** the solution
 - Go back to the original problem: new insights, new methods,...
- **Step 5: Disseminate** the results
 - Papers, presentations, patents,...

“There are many things one doesn’t understand and therefore, we ask them why don’t you just go ahead and take action, try to do something? You realize how little you know and you face your own failures and you simply can correct those failures and redo it again and at the second trial you realize another mistake or another thing you didn’t like so you can redo it once again. So by constant improvement, or should I say, the improvement based upon action, one can rise to a higher level of practice and knowledge.”

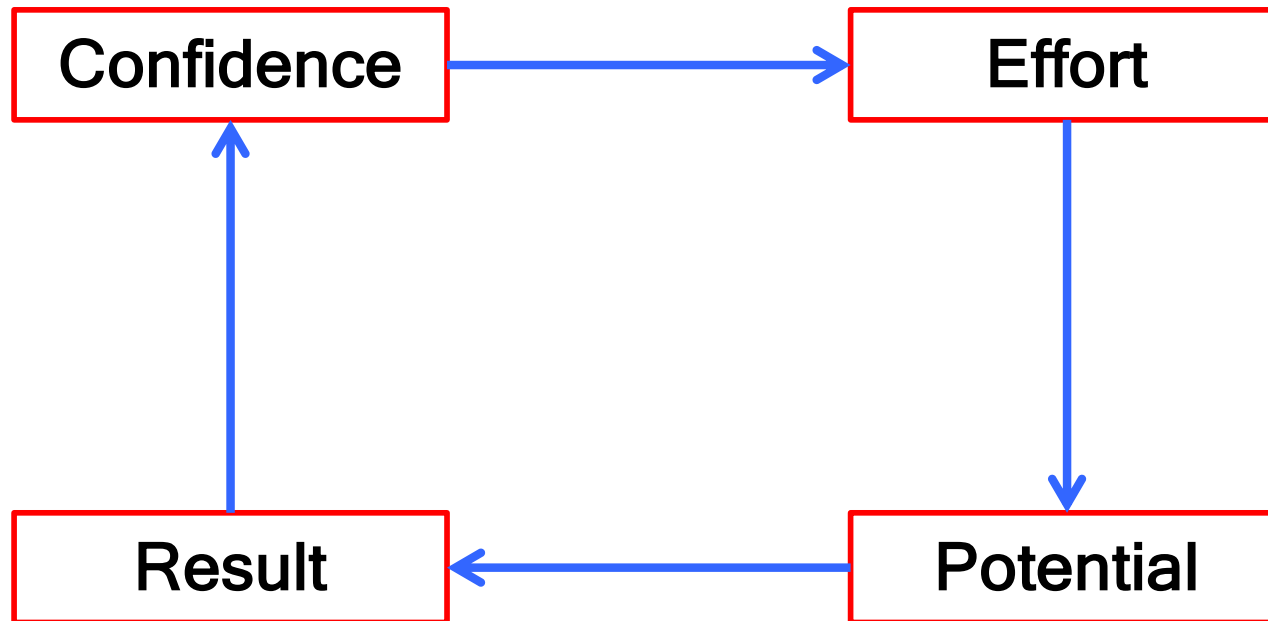
Fujio Cho (President of Toyota)

Lean Process

- Introduced by Toyota for **lean production**
- Popularized by Eric Ries for **lean startup** [see figure below]
- Research should follow the same process: **lean research**



The Flying Wheel



Define/Formulate a Research Problem

- **Fact:** Most of engineering problems are ill-posed!
- Often we need to redefine/reformulate the problem to make it solvable
 - Imposing realistic assumptions
 - Add constraints
 - Simplify the problem or model
- **Engineers:** We are allowed to **change the problem!**
- Many times, being able to define/formulate a research problem is half of the work!

Some Techniques in Formulating Problems

- The key is to **reframe the problem**; i.e. **look at the problem from different perspectives or lenses**
- Keep **simplifying** the problem until it is solvable (e.g. to a special case) and then try to generalize/extend the solution
 - Simple problem often gives clear insight and intuition
 - If we cannot solve a simple version of the problem then we also cannot solve the complex version
- **Multiresolution** technique: start with a coarse and solvable problem and successively extend it to make it more realistic
- Ask the **converse questions**
 - **Example**: we know that **bandlimitedness** leads to **samplable**; but what are **other samplable signals**?
- Some time need to **hack** or **build**, then **look at the data!**

Questioning Attitude

- **Questioning attitude** is one of the most important qualities of a creative person
 - Mistake: a question is an admission for not knowing something
- A creative person should have a **healthy skepticism** about existing answers, techniques, and approaches
 - Questioning attitude helps to sense the problem and lead to creative solution
- Primary quality of creative problem-solver: constantly developing **Constructive Discontent**
- The most admired one at meetings is the **penetrating questioner**

The Power of Figures and Lists

- Figures are very powerful for **visual thinking** and **developing intuition**
 - Try to draw figures of what you are thinking or presenting
 - Figures of results with signals and images often lead to the right intuition
- Lists effectively **focus conceptual energy** and produce written record of the output
 - Keep a notebook that list all of the thoughts that have occurred
 - Make a list during brainstorming sessions: ideas lead to ideas
 - List the attributes. Below each attribute, list many alternates
Consider different combinations.
 - Use “check list” such as one in *How to Solve It* by Polya

Using Other People's Ideas

- An especially powerful way of increasing creativity is to **interact with other people**, especially if they think differently than you
 - Do homework together
 - Take courses outside your traditional areas
 - Ask for ideas on your problem from a large number of people
 - Bounce ideas off of a peer or group of people
- The main distinction of “star performers” is they have a **reliable network of information/advice providers**
[from a study of Bell Labs researchers in 1992]
- Much creativity now is taking place **between disciplines**

Look at Data

- **Get insight from data** and experiments
 - If you find an interesting algorithm or method, go ahead and implement it and test it on your data
 - Print out the results, stuck them on the wall, stared at them...
 - Eventually ideas for improvements and novel methods came up...
- **Use metrics** on obtained data to track your progress
- Talk and seek comments/feedback from other people

Active Education

1. Emphasis on **doing**

- Clearly stated in course objectives
- Weekly homework and projects
- Do **not** just “*provide information*”
but instead focus on “*learning to learn*”

2. **Immersion**

- Teach knowledge in context of problems, issues, and questions
- Iterate: learn-do-learn-do-...
- Hand-on design projects throughout the 4 years of study

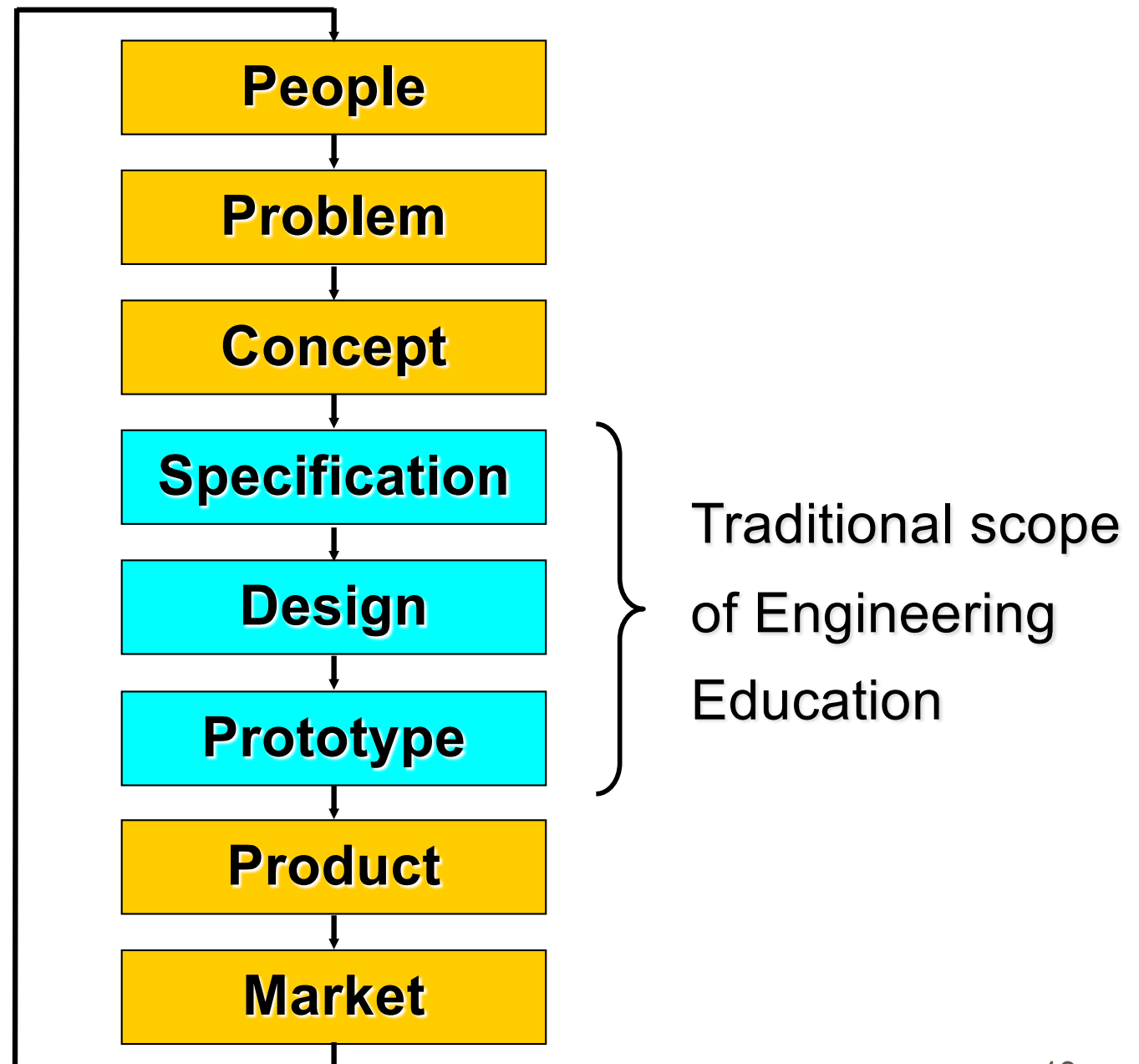
“The great aim of education is not knowledge but action”

Herbert Spencer (1820 - 1903)

Required Skills for Solving Research and Real-World Problems

- Knowledge (much broader)
- Creativity
- Persistence (much more)
 - If we keep trying hard, something good will come out
 - Faith (this problem can be solved!)
 - Flexibility (if not, how can I reformulate it to be solvable!)
- Ask good questions
- Communication skills for disseminating results
 - Building **prototype** is often the most effective way
 - Start-ups use **minimum viable product (MVP)**
- See the the big picture
- Organized, motivated, and have a sense of purpose

Engineering in the Real World



“Your work is going to fill a large part of your life, and the only way to be truly satisfied is to do what you believe is great work. And the only way to do great work is to love what you do. If you haven't found it yet, keep looking. Don't settle.”

Steve Jobs (CEO of Apple Computer)

VinUni Research: The Overarching Goals



Research with *REAL* *Impact*

1. Develop Future Talent

- Research is an integral part of education to develop talented future leaders including innovators, scientists, entrepreneurs.
- Robust research environment and resources are essential to the recruitment and development of highly talented faculty.

2. Develop Innovative Solutions

- Innovative solutions are needed to propel Vietnam from relatively low/medium income country to much higher prosperity and quality of life.
- VinUni's research will enable Vingroup to become successful in becoming a leading techno, industrial, commercial and service company in the region.

3. Enhance Reputation

- Research is essential for VinUni's stated objective of recognition as "50 under 50", QS 5*, international accreditation (AACSB, ABET) and other reputable university rankings.
- VinUni's research accomplishments will lead the way for the Vietnamese education system towards higher standards, reputation and respect worldwide.

New Coming Graduate Programs at VinUni

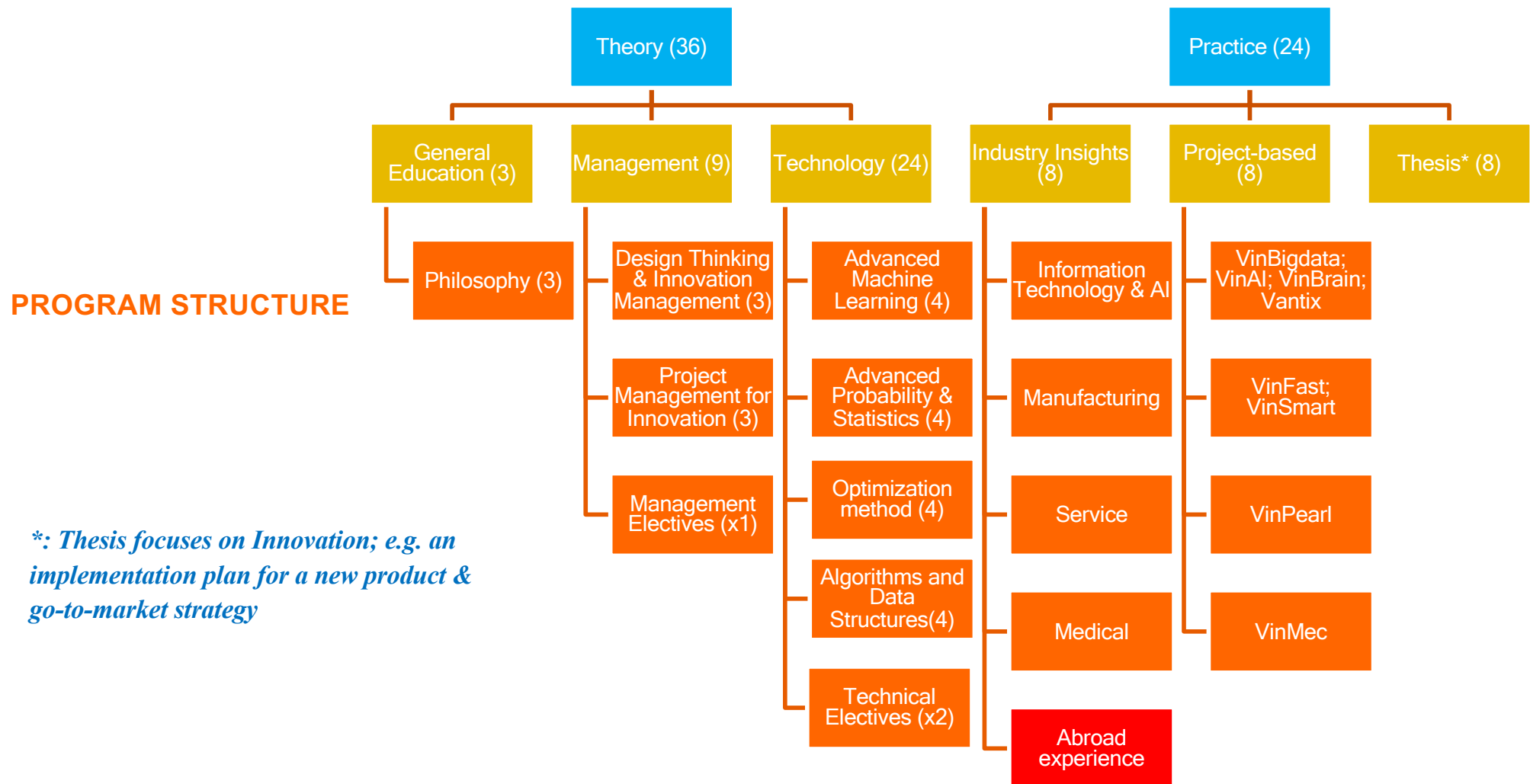
- 1. Master of Innovation in Artificial Intelligence (industry-oriented)**
- 2. Doctor of Philosophy in Computer Science (research-oriented)**

1. Master of Innovation in Artificial Intelligence

Program Description

- ❑ Degree Name (MOET Code): MS in Information Technology Management
 - ❑ Program Name: Master of Innovation in Artificial Intelligence
- ❑ Number of credits: 60
- ❑ Length: 18 months (50% on-campus, 50% co-op)
- ❑ Entrance requirements:
 - ❑ Bachelor degree in Computer Science, Computer Engineering, Electrical Engineering, Mechanical Engineering, Applied Mathematics or similar
 - ❑ English: 6.5 IELTS or equivalent
 - ❑ Good GPA; AACCC; **recommendation from leaders**, guaranteed projects and time for studying

Master of Innovation in Artificial Intelligence



2. Doctor of Philosophy in Computer Science

Program Description

- ❑ Degree Name (for MOET code): Doctor of Philosophy in Computer Science
 - ❑ Program Name: PhD in Computational Data Science
- ❑ Number of credits: 90 credits for MS degree holders and 120 credits for BSc degree holders
- ❑ Length: 3 years for MS degree holders and 4 years for BSc degree holders
- ❑ Entrance requirements:
 - ❑ Bachelor degree with very good GPA or Master degree in Computer Science, Information Technology, Information Systems, Computer Engineering, Electrical Engineering, Mechanical Engineering, Applied Mathematics, Cryptography or similar
 - ❑ English: 6.5 IELTS or equivalent

Doctor of Philosophy in Computer Science

□ Admission plan

- **First student intake: AY 2021-2022**

Year	2021-2022	2022-2023	2023-2024
Number of students	10	15	20

□ Tentative plan for tuition & scholarships:

- **Tuition waiver if working as TA or RA @ VinUni (\$1000 salary/stipend per month)**
- **10-20 students/year have scholarship from the Vingroup 1100 scholarship program to spend 1-2 years doing research abroad at a partnered labs/universities**

□ Support for pre-doctoral students to meet the admission requirements

- **VinUni Research Assistant positions (\$1000/month) to work on projects leading to publications, and to improve English communication skills**

VinUni MS/PhD Programs Led by World-Class Distinguished Professors



Prof. Laurent El Ghaoui
Dean of the College of
Engineering & Computer
Science

TOP 0.3% of the world's scientists based on the impact of his publications in the field of Industrial Engineering & Automation, H-index 58.

Prof. El Ghaoui taught at the Department of Electrical Engineering & Computer Science and Department of Industrial Engineering & Operations Research at University of California, Berkeley (#32 worldwide). He also taught Data Science within the Master of Financial Engineering at UC Berkeley's Haas Business School.

Has over 30 years of experience in the field of optimization, over 20 years of experience working with enterprises to solve real-life issues.



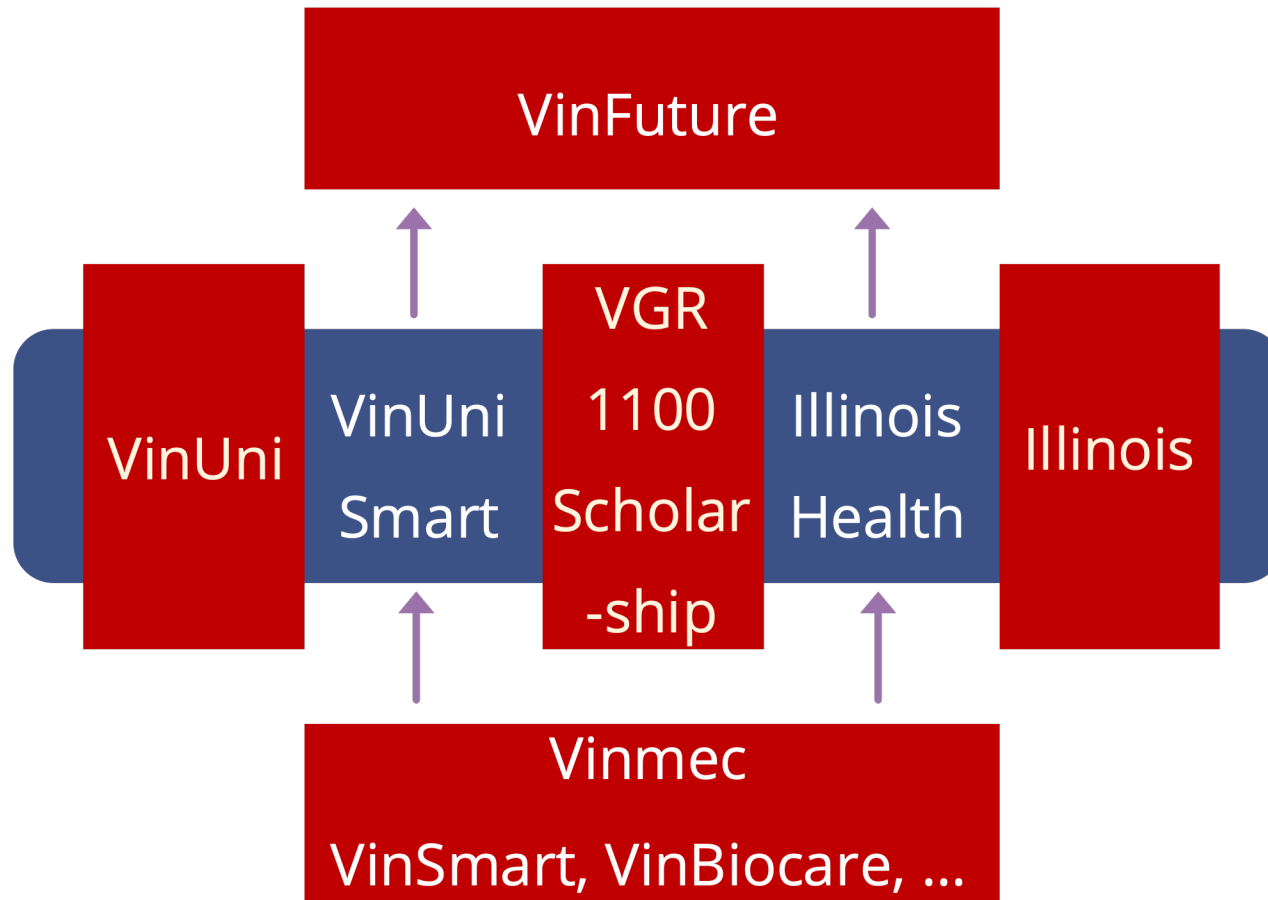
Prof. Wray Buntine
Director of the
Computer Science Program

TOP 0.75% of the world's scientists based on the impact of his publications in the field of Artificial Intelligence and Visual Processing, H-index 42.

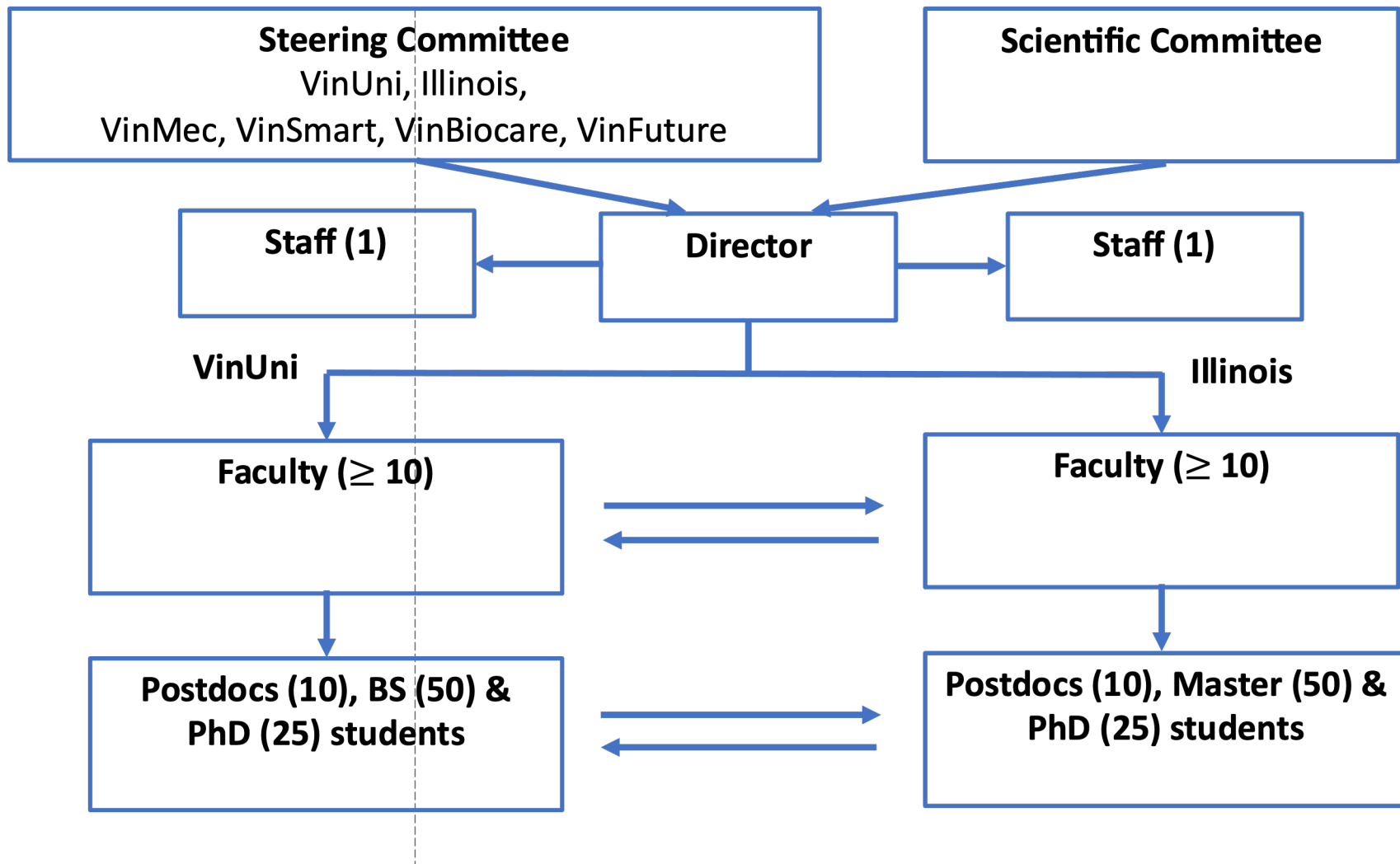
Prof. Wray was the Founding Director of the Master's of Data Science program and the Director of the Machine Learning Group at Monash University, Australia (#58 worldwide).

More than 30 years of teaching and research experience in the field of computer science at leading universities, such as Stanford University; University of California, Berkeley (USA); University of Helsinki (Finland); and Monash University (Australia).

VinUni-Illinois Smart Health Center (VISHC)



VISHC Organization



Sign-up to get updated information

