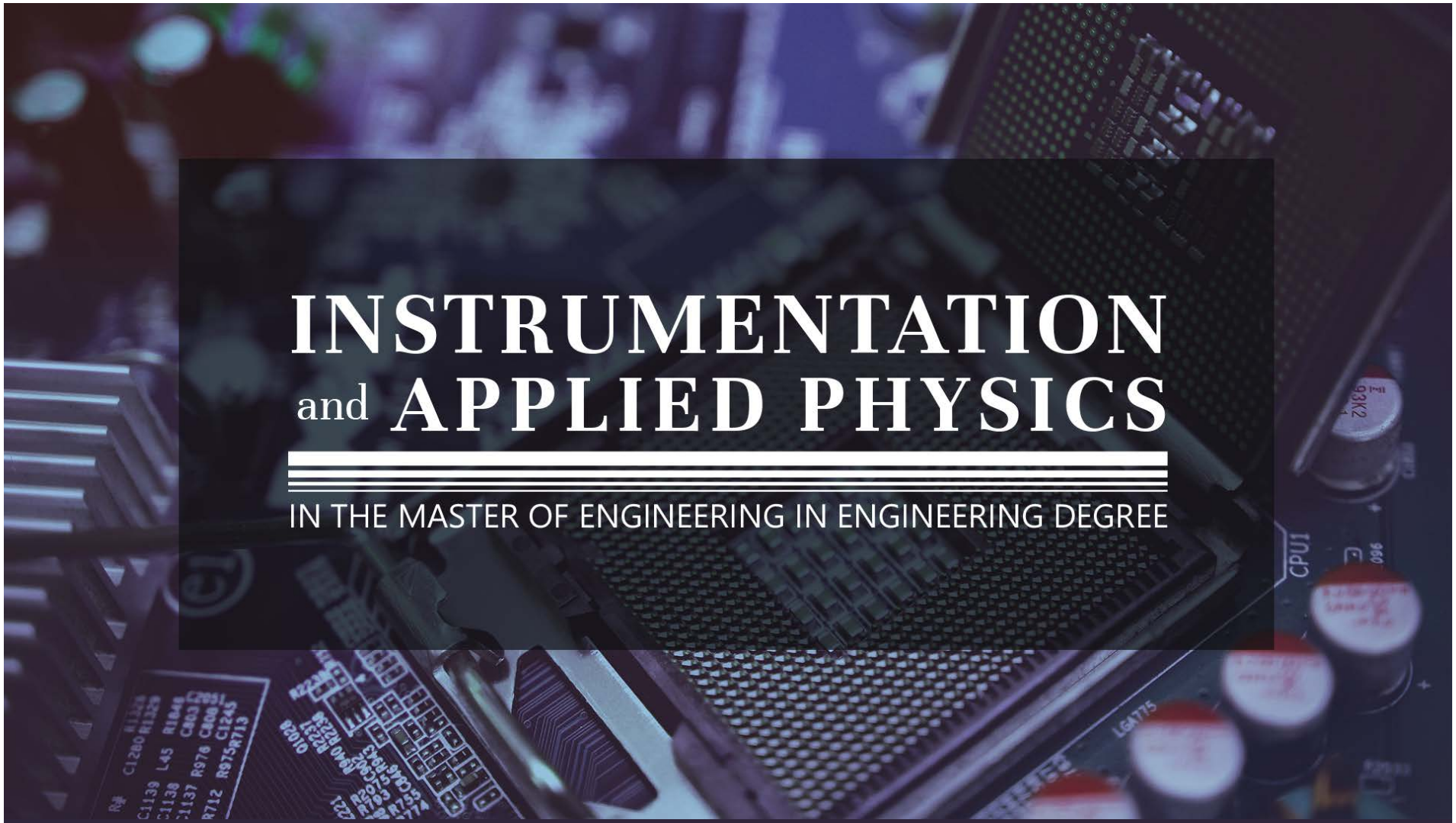


INSTRUMENTATION and APPLIED PHYSICS

IN THE MASTER OF ENGINEERING IN ENGINEERING DEGREE

A professional master's program…

- Awards a terminal degree not intended as a waypoint before the PhD;
- focuses on workforce development, employability of its graduates, and the needs of prospective employers;
- teaches a mix of hard and soft skills (e.g. instrumentation design and data analysis as well as communication and collaboration);
- is designed with significant input from potential industry/commercial/ laboratory partners.

We are designing a new professional master's in "Instrumentation and Applied Physics."

If all goes well, the UIUC Faculty Senate will approve our proposal. We hope to be allowed to accept students in time for the Fall 2021 semester.

But why should we do this?

- About half of our students choose not enroll in PhD programs. Some (many? most?) seek employment in technical fields.
- There are advantages to entering the workforce with a master's degree in hand.
- The UIUC physics department does not currently host a program to service the post-baccalaureate (non-PhD-bound) educational needs of these students.
- National Academies/National Research Council: the U.S. postsecondary system is failing to meet the large national need for new master's-level scientists. (2008)
- The UIUC mission includes workforce development.
- If all goes well, such a program can be self-supporting.

Learning about the master's landscape

I hired a dozen student hourlies to scrape departmental web sites of all 760 physics bachelor's-granting institutions known to the AIP.

193 of these schools awarded at least one master's degree.

Students tried to find answers to these questions for the 193 schools:

- is the master's program "independent" of the PhD program? (this'll be true of professional master's programs)
- if so, is it a residential program?
- how much does it cost?
- what is the time-to-degree?
- what's the program called?
- contact information for the program director?

Programs tend to be small. Largest is U. Oregon, with 24 graduates in 2017.

Results from scraping (data are kinda noisy)

We have data for 192 of 193 master's-granting physics departments.

- 142 appear to have a PhD-separate (and ∴ probably professional) master's, 34 only award a master's as a waypoint towards a PhD, and 15 were too obscure for my helpers to figure out.
- these 142 schools awarded 717 master's degrees and 913 PhDs in 2017;
- ~90% of these master's programs are residential;
- average minimum time-to-completion is 18.8 months;
- many of the master's programs are run by non-PhD academic professional staffers rather than teaching/research faculty.
- the largest programs: U. Oregon (24), Stanford (19), Brown (19), Arizona State (18), Columbia (18), Cal State Long Beach (16), U. Washington (14).
- program costs (tuition + fees) vary widely: Stanford ~ $84k, Brown ~$82k, ASU ~$69k, Columbia ~$62k, U. Washington ~$40k, CSLB ~$14k.

Concentration in Instrumentation and Applied Physics in the Master of Engineering in Engineering degree

We are an R1 school. We should teach our students to "think like physicists" and to confront complex technical challenges, rather than outsourcing this to an industry partner.

We should not be preparing narrowly-educated graduates for their first project at a new employer. We should empower them to take on a broad range of technical endeavors.

Preliminary thoughts on the curriculum : 32 credit hours including…

- 2×5 credit lab/project work
- 4 credit machine learning/big data analysis course
- 4 credit core graduate-level physics course (choose from a list)
- 10 credits of STEM electives (choose from a much larger list)
- 4 credit "professional development" course, e.g. "Finance for engineering management"

A possible curriculum (1)

18 credits of core courses:

- 2×5 credit lab/project work (2 afternoons per week, 1 pm – 5 pm)
- 4 credit machine learning/big data analysis course
- 4 credit graduate-level physics course: choose one of
  - ☆ Physics 504 (stat mech)
  - ☆ Physics 505 (electrodynamics)
  - ☆ Physics 560 (condensed matter 1)
  - ☆ Physics 580 (quantum 1)
  - ☆ Physics 51x (atomic, optics, quantum information,…)
  - ☆ others, with permission of program coordinator

10 credits of STEM electives:

- Other core courses besides those chosen to satisfy the core requirement
- Any 500-level course offered by Physics, with permission of program coordinator
- Biophysics, pre-approved NPRE, pre-approved Mat Sci… courses as available

A possible curriculum (2)

4 credits of professional development courses: select one of…

- TE 450: Startups: incorporation, funding, contracts, and intellectual property;
- TE 566: Finance for engineering management;
- others, with approval of program manager.

Capstone project is actually the two-semester lab/project course (preferably done with support from an industry partner), and whose goals are to

- introduce students to a wide range of laboratory tools spanning electrical and mechanical engineering, materials science, mathematics, coding, embedded systems design, 3D printing, CAD/CAM;
- teach students to collaborate effectively and communicate clearly;
- teach students to conceive, propose, plan, perform, analyze, and report valid measurements;
- do something of value to an industry partner.

Graduate certificates

Some professional master's programs include the award of certificates (in addition to the master's degree) to identify focus areas pursued by a student.

We should issue this additional credential to students who select several electives and a project from a single area like biophysics. Possibilities:

- Computational physics
- Applied biological physics
- Atomic, molecular, and optical physics; quantum information systems.
- Condensed matter and materials physics
- Nuclear instrumentation
- Acoustic physics
- Environmental sensor technology
- Transportation instrumentation
- Agricultural instrumentation, modeling, and analysis

Learning about the post-baccalaureate educational landscape.

AIP data, 2016-17 school year

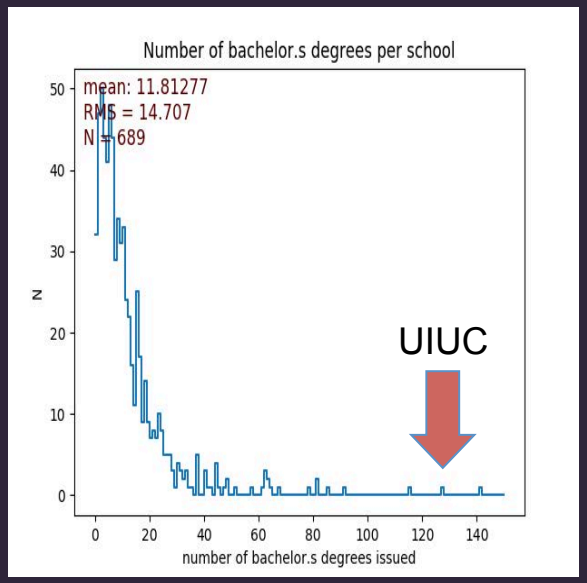
- 760 bachelor's-granting institutions have physics programs.
- I hired student hourlies to scrape their web sites for departmental contact information, and to dig into the masters-granting schools' M.S. programs
- I now have email addresses for 753 department heads/chairs and 490 departmental directors of undergraduate studies.
- I sent email 9/24/19 to ask for participation in a short survey:
  - ✯ % of graduating majors applying to PhD programs?
  - ✯ % …applying to master's programs?
  - ✯ % …going directly into (STEM or teaching) professions?
  - ✯ would you distribute a survey to your juniors/seniors?
- 266 replies, from 257 schools. ~195 were willing to send a survey to junior/senior physics majors.

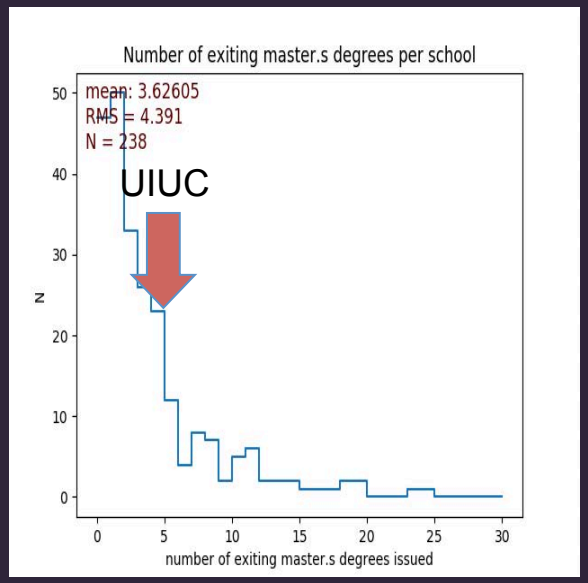
[plots on next two slides]

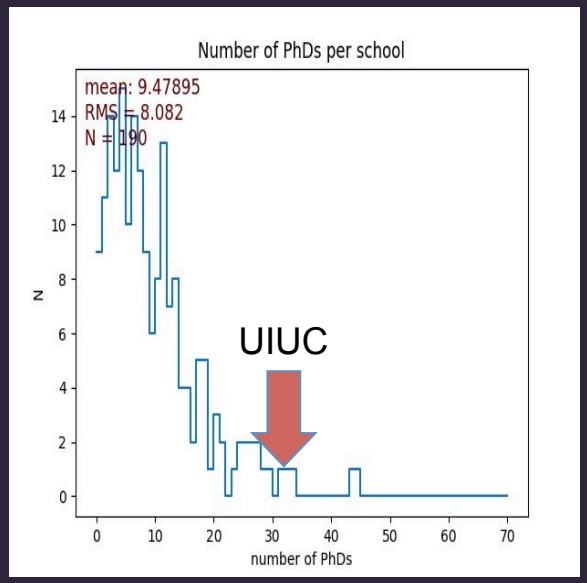
Schools granting physics degrees (AIP data)

AIP: 2016-17 academic year, 760 schools (estimates for non-responsives).

- 8,633 bachelor's granted
- 930 exiting master's (only some are from professional programs)
- 1,862 PhDs





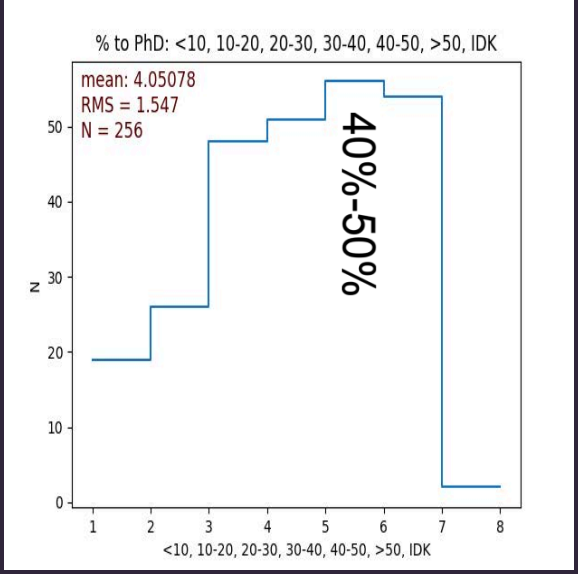


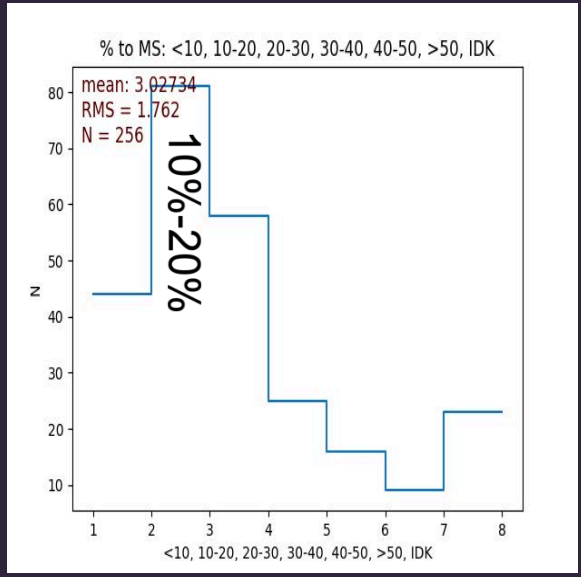
https://www.aip.org/sites/default/files/statistics/rosters/physrostr17.1.xlsx

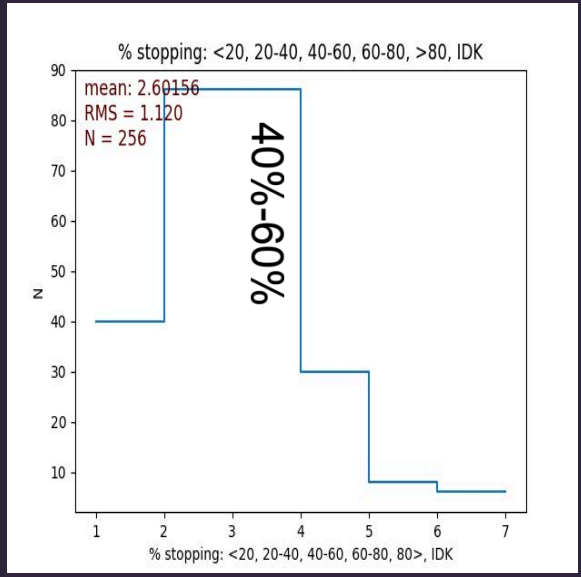
Schools that have replied to my survey

What percentage of your graduating bachelor's students will

- apply to PhD programs (first histogram)?
- apply to master's programs (second histogram)?
- go directly into STEM or teaching professions (third histogram)?





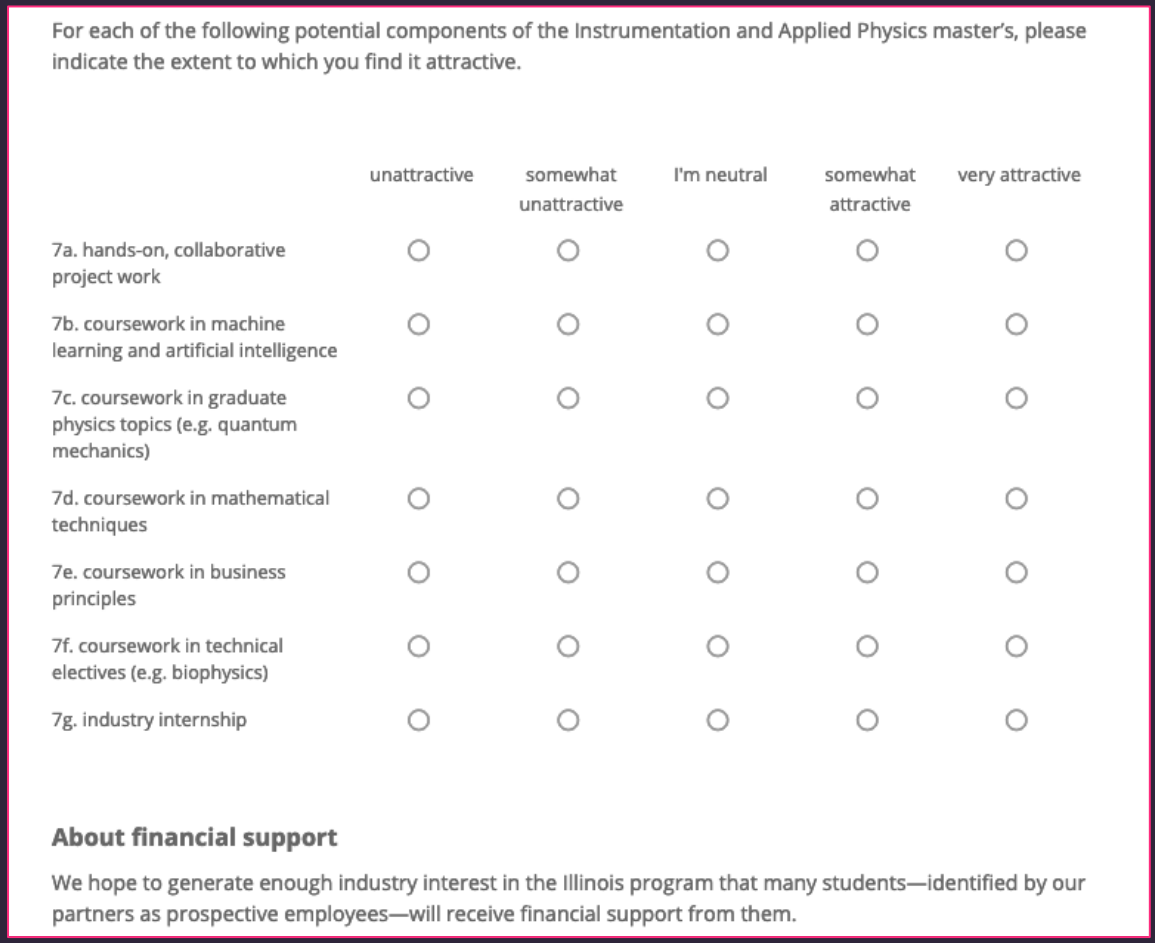


Python!

Gauging the potential level of student interest

Another survey, designed with help from UIUC's Center for Innovation in Teaching and Learning (CITL):

- I asked respondents to the dept. head/UGS director survey to distribute a link to a student-interest survey to their physics majors.
- Incentive: $20 Amazon gift card to the first 100 respondents (limited to 3 per school)



For each of the following potential components of the Instrumentation and Applied Physics master's, please indicate the extent to which you find it attractive.

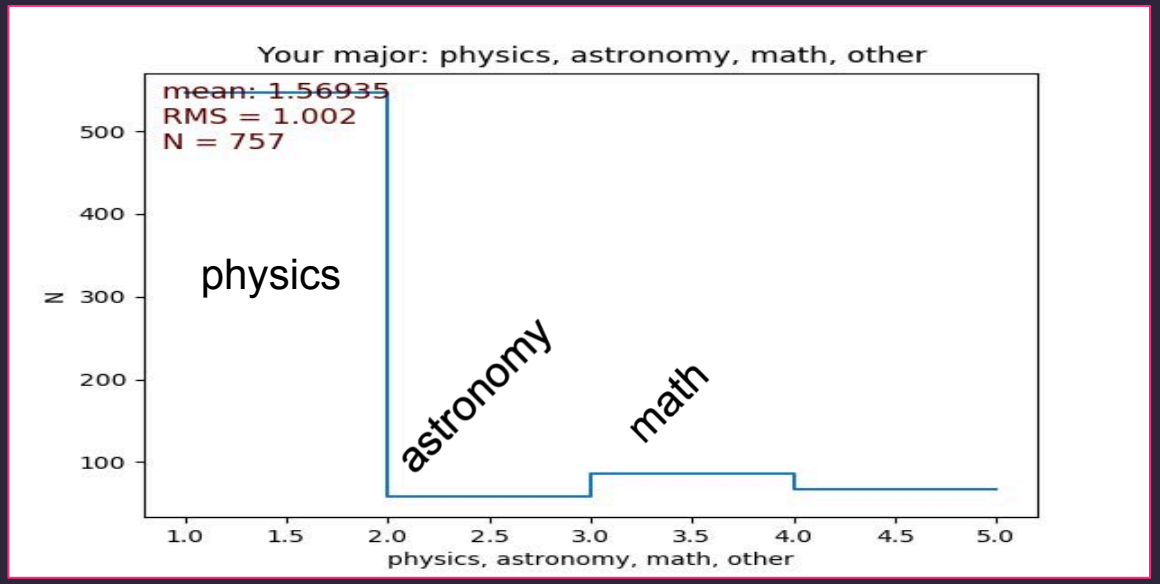
	unattractive	somewhat unattractive	I'm neutral	somewhat attractive	very attractive
7a. hands-on, collaborative project work	○	○	○	○	○
7b. coursework in machine learning and artificial intelligence	○	○	○	○	○
7c. coursework in graduate physics topics (e.g. quantum mechanics)	○	○	○	○	○
7d. coursework in mathematical techniques	○	○	○	○	○
7e. coursework in business principles	○	○	○	○	○
7f. coursework in technical electives (e.g. biophysics)	○	○	○	○	○
7g. industry internship	○	○	○	○	○

About financial support

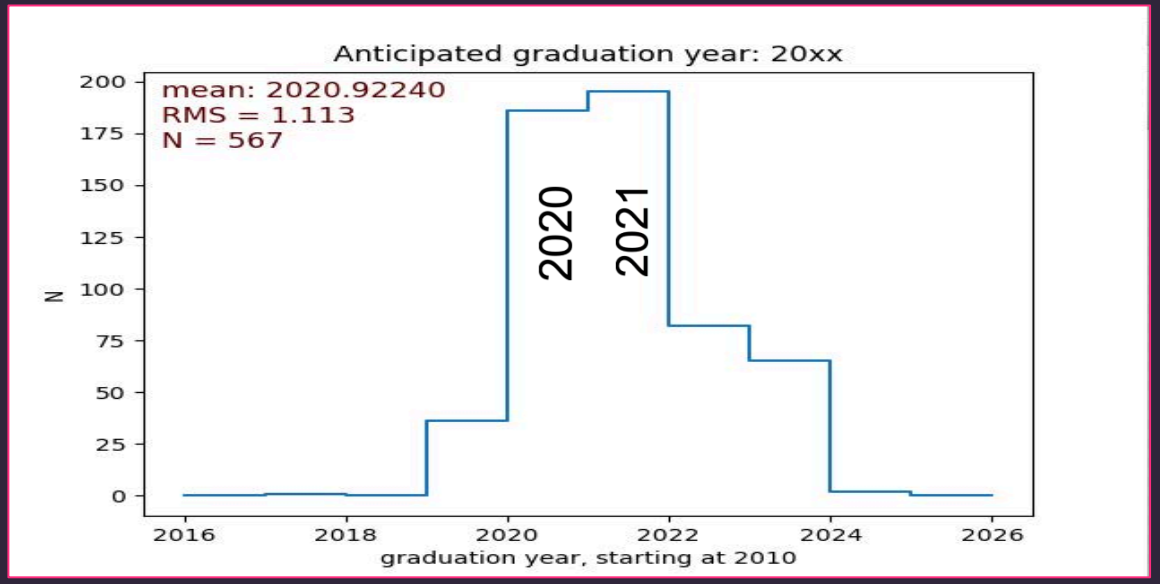
We hope to generate enough industry interest in the Illinois program that many students—identified by our partners as prospective employees—will receive financial support from them.

Undergraduate physics major survey

Your major(s):



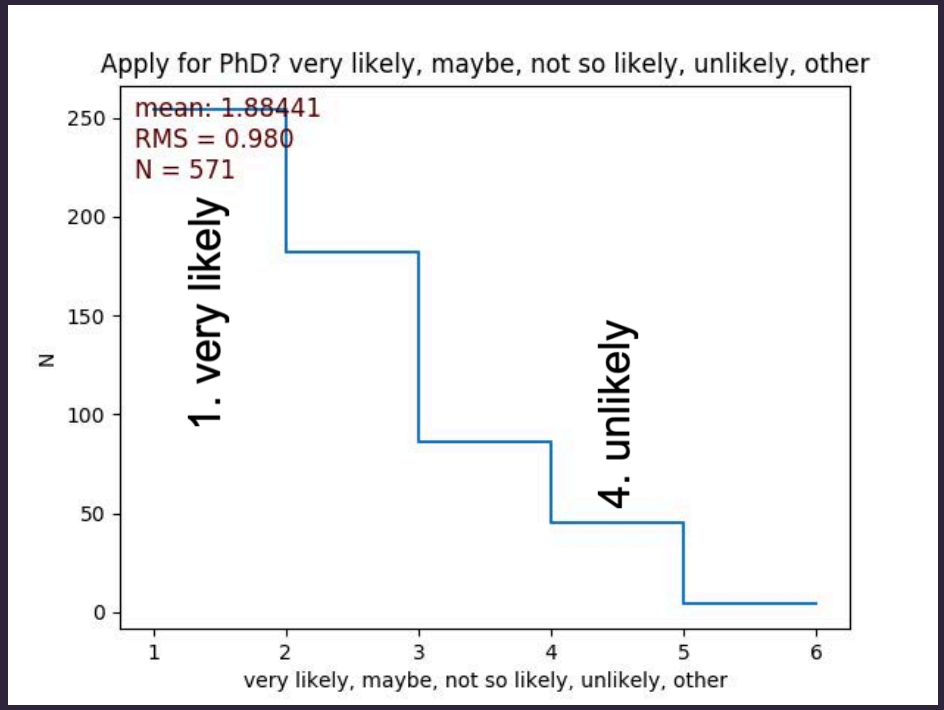
Expected year of graduation



Graduate school plans: PhD?

"Assuming that financial support is available, how likely is it that you will apply for admission to a PhD program in physics (or a related field) within two years after you've finished your bachelor's degree?"

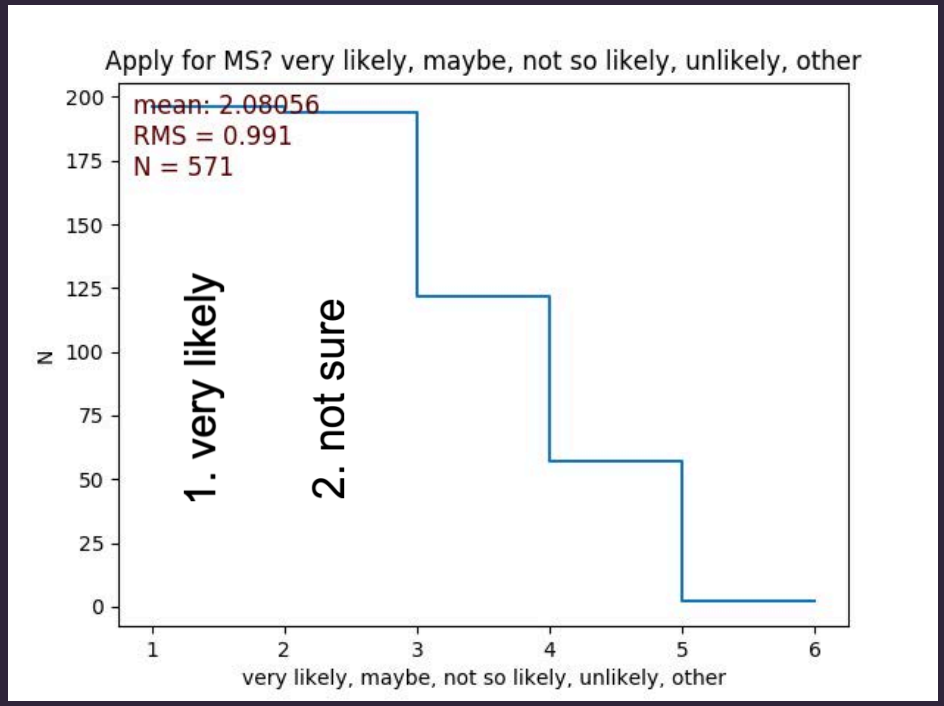
1. Very likely
2. I am not sure, but am giving it serious consideration
3. Possible, but not very likely
4. Unlikely
5. Other



Graduate school plans: master's?

"…you will apply for admission to a master's (but not PhD) program in physics (or a related field)… "

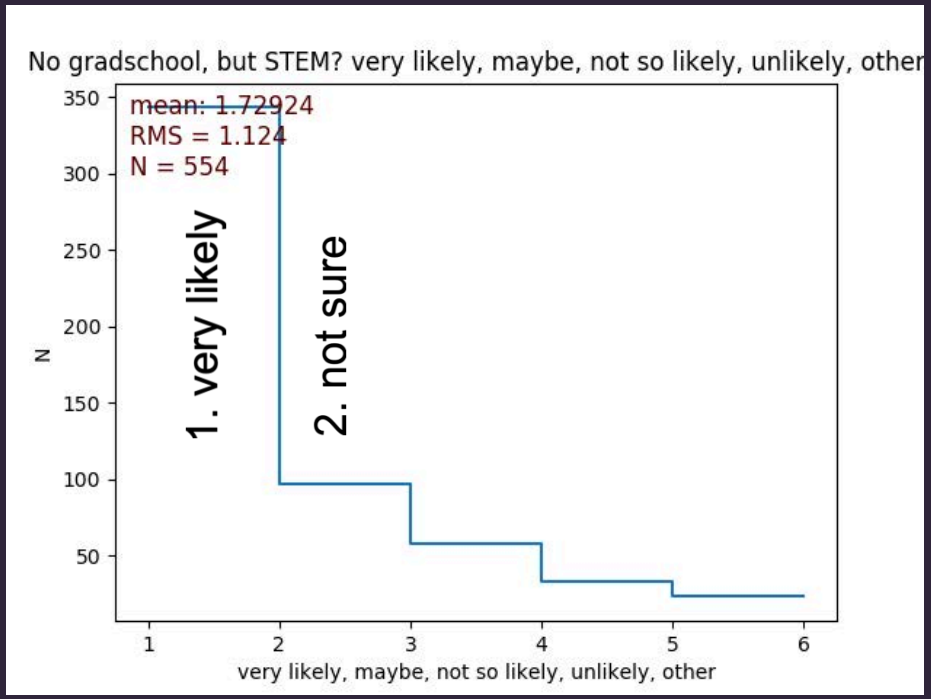
1. Very likely
2. I am not sure, but am giving it serious consideration
3. Possible, but not very likely
4. Unlikely
5. Other



Enter the workforce upon graduation?

"If you do not plan to apply to a graduate program within two years of graduation, how likely is it that you will seek employment in the scientific, technical, manufacturing, or other STEM-related sector (including pre-college science teaching) after you graduate?"

1. Very likely
2. I am not sure, but am giving it serious consideration
3. Possible, but not very likely
4. Unlikely
5. Other



Appeal to students of program components

"For each of the following potential components of the Instrumentation and Applied Physics master's, please indicate the extent to which you find it attractive."

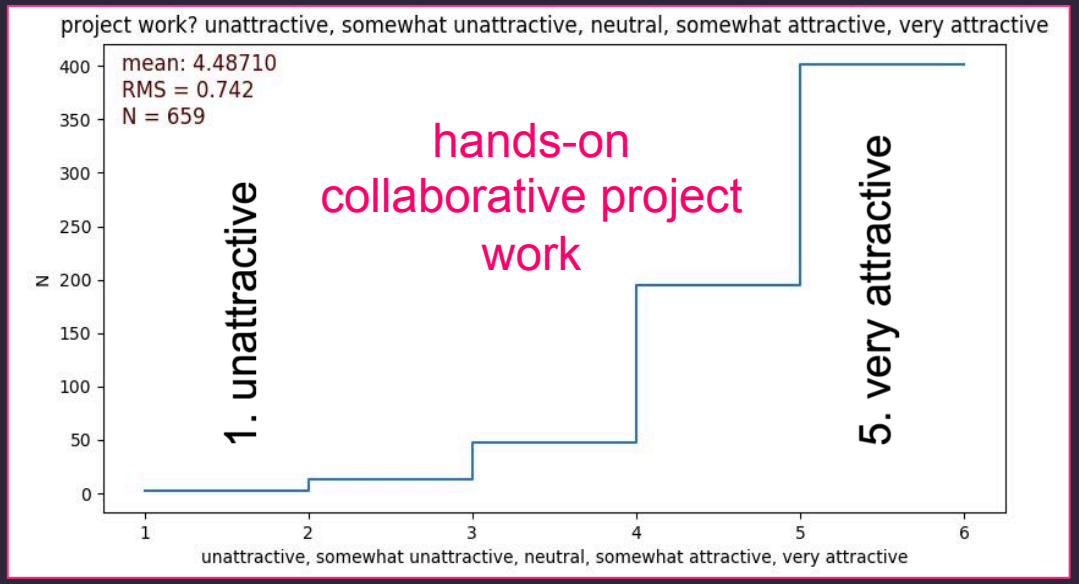
	unattractive	somewhat unattractive	I'm neutral	somewhat attractive	very attractive
7a. hands-on, collaborative project work	○	○	○	○	○
7b. coursework in machine learning and artificial intelligence	○	○	○	○	○
7c. coursework in graduate physics topics (e.g. quantum mechanics)	○	○	○	○	○
7d. coursework in mathematical techniques	○	○	○	○	○
7e. coursework in business principles	○	○	○	○	○
7f. coursework in technical electives (e.g. biophysics)	○	○	○	○	○
7g. industry internship	○	○	○	○	○

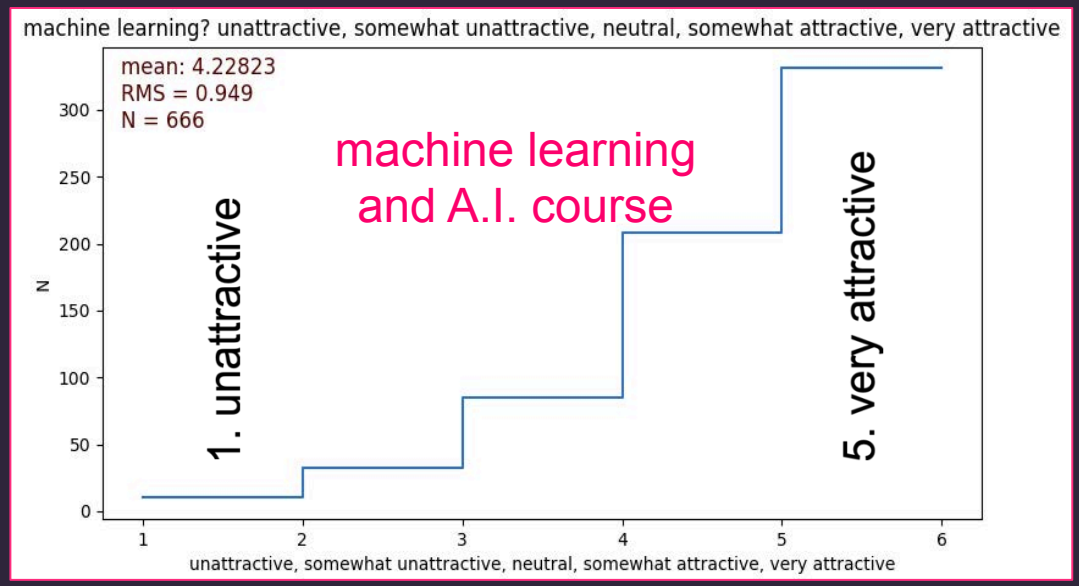
Student preferences (1)

Keep an eye on the means to compare plots.

Answer choices:

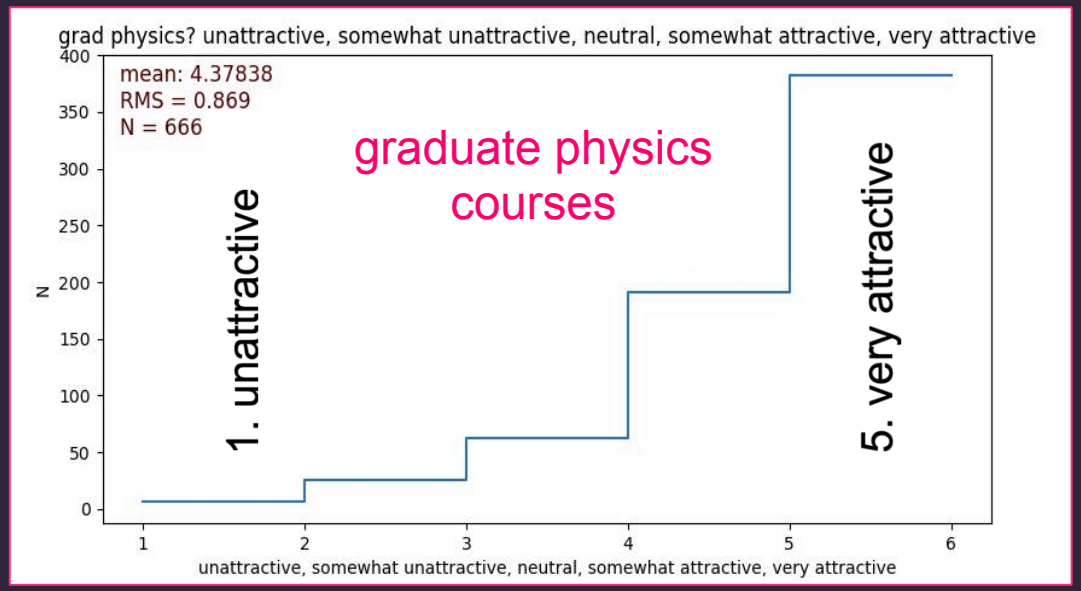
1. unattractive
2. somewhat unattractive
3. I'm neutral
4. somewhat attractive
5. very attractive

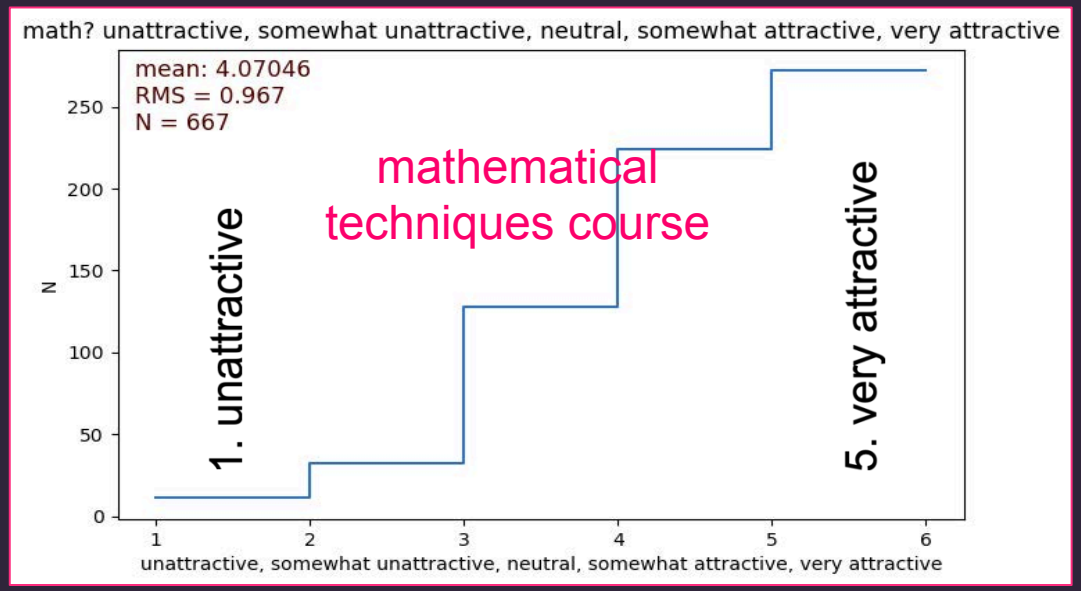




Student preferences (2)

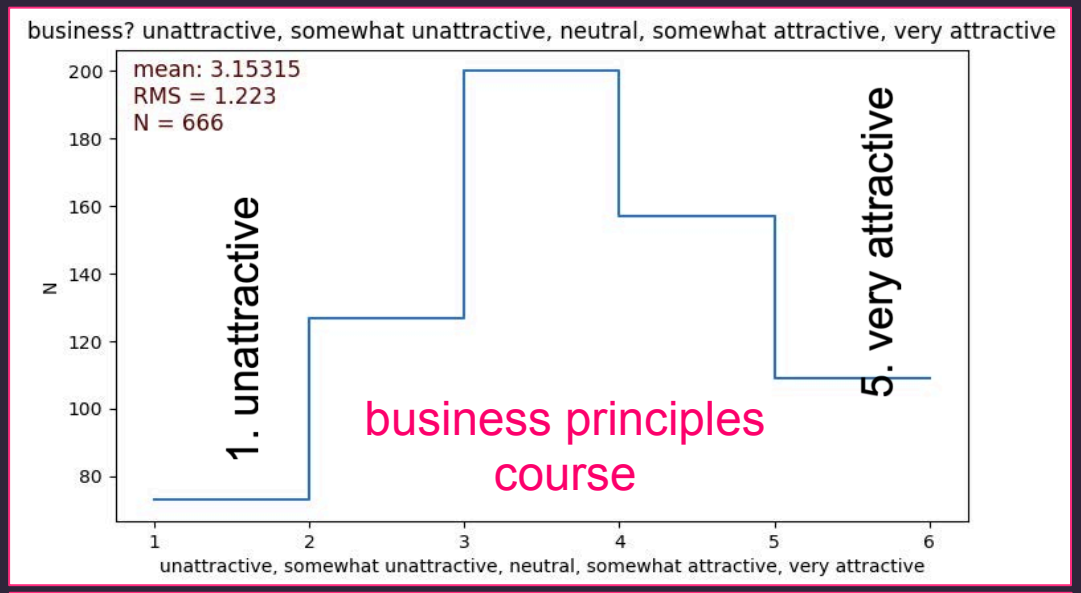
1. unattractive
2. somewhat unattractive
3. I'm neutral
4. somewhat attractive
5. very attractive

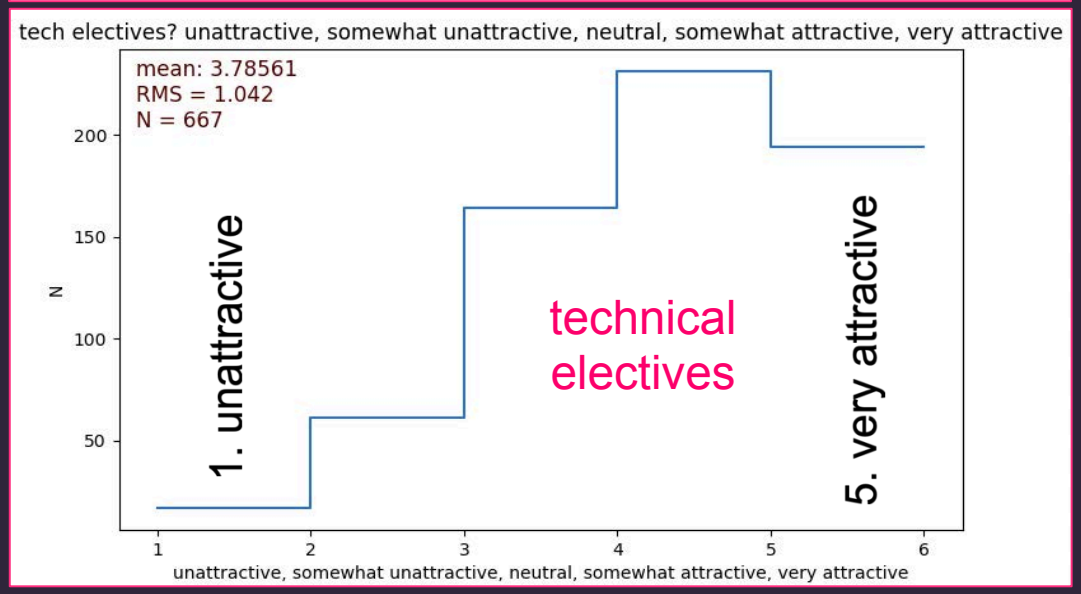




Student preferences (3)

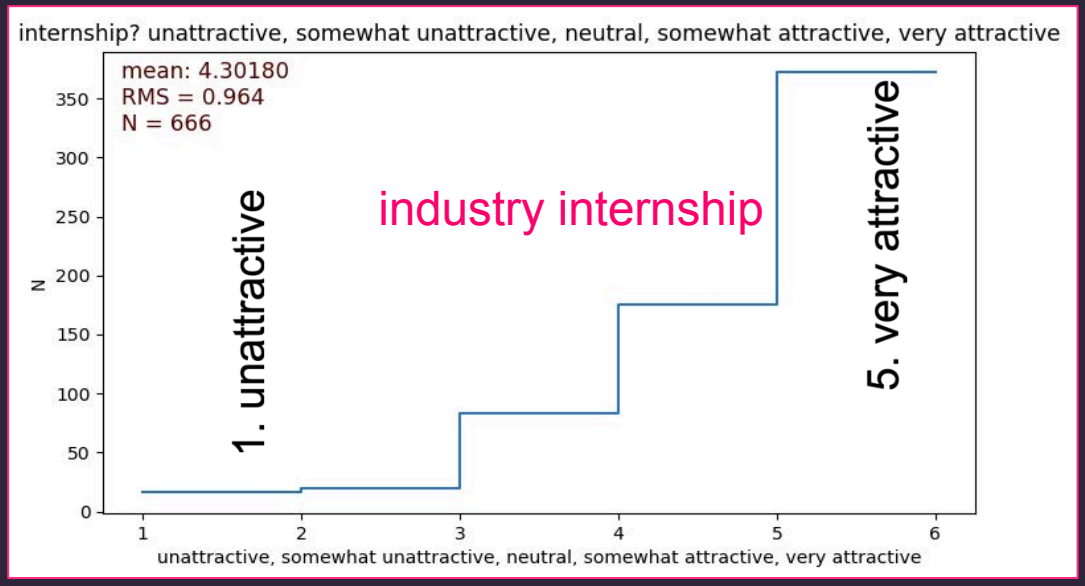
1. unattractive
2. somewhat unattractive
3. I'm neutral
4. somewhat attractive
5. very attractive





Preferences (4)

1. unattractive
2. somewhat unattractive
3. I'm neutral
4. somewhat attractive
5. very attractive

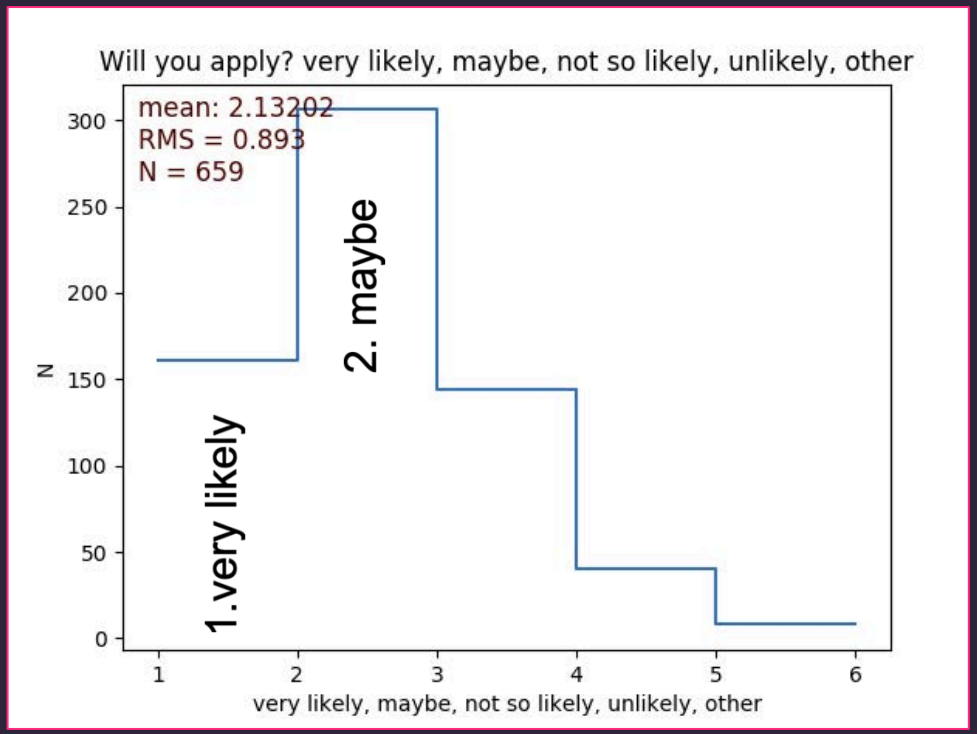


program component	mean "attractiveness"
hands-on, collaborative project work	4.49
coursework in machine learning and artificial intelligence	4.23
coursework in graduate physics topics (e.g. quantum mechanics)	4.38
coursework in mathematical techniques	4.07
coursework in business principles	3.15
coursework in technical electives (e.g. biophysics)	3.79
industry internship	4.30

Would you consider enrolling?

"After the details of the program are finalized—Faculty Senate approval, curriculum definition, industry support, total cost—how likely might you be to consider enrolling in the Instrumentation and Applied Physics master's?"

1. Very likely, if it is available in the near future
2. I am not sure, but will give it serious consideration
3. Possible, but not very likely
4. Unlikely
5. Other



Industry partnerships

We want industrial partners to

- sponsor enrollment of existing employees
- use the M.Eng. as a recruiting tool for attracting new employees
- develop a hiring pipeline that receives our graduates at the input side
- suggest (and pay for) interesting projects
- tell us what they want our students to have learned

We need to develop a strong pitch to advocate for consideration of broadly-trained physicists rather than narrowly educated engineers when hiring.

Some of us (you) hold (or have held) industry jobs. Please please please share stories with me that I can use to good effect.

The process of identifying, then contacting a potential partner contains a large random component. But my initial experiences are encouraging.

Initial contact with industries

Randoms:

- Physics398DLP projects at KCPA → Meyer Sound (Berkeley, CA)
- Cordelia's middle school friendships → Petronics (cat toys: *NY Times*)
- OVCR martini party → Jeld Wen (world's largest window manufacturer)
- Research Park 20th anniversary party → lots and lots and lots

With intent:

- GCOE job fair → initial conversation (and exchange of contact information) with 65 recruiters
- Meetings with GCOE Office of Advancement (one-at-a-time links)
- Meetings with GCOE Office of Corporate Relations (perhaps much larger yield: we'll see)

The initial pitch… What should we teach? What projects should we undertake? Would you consider joining our advisory board? Would you consider sponsoring students?

The first (of many) promotional documents

Recto-verso

BROAD TRAINING IN HARD AND SOFT SKILLS

THE ENGINEERING PHYSICS TRADITION AT ILLINOIS

- We train our students to communicate clearly.
- We teach our students to collaborate effectively.
- We encourage intellectual fearlessness.
- We introduce students to a wide range of laboratory tools spanning electrical and mechanical engineering, materials science, mathematics, coding, embedded systems design, 3D printing, CAD/CAM.
- We teach students to conceive, propose, plan, perform, analyze, and report valid measurements.
- We teach students to be skeptical of naïve interpretations of data.

PARTNER WITH US

- The university's mission includes workforce development.
- The National Research Council has urged U.S. universities to substantially increase the annual number of master's-level scientists entering the workforce.
- Please help us understand your needs.

HOW TO HELP

- What skills would you want potential interns and prospective employees to have learned from our program?
- Are there projects you would like our students to undertake, once the program is established, even if they haven't (yet) established a relationship with you?
- Would you consider joining our advisory board when it is time for us to organize one?
- Would you consider sponsoring some of your bachelor's level staff to enroll in our program?

For more information visit
https://physics.illinois.edu/masters

ILLINOIS

Industry survey (1)

We're currently working on the list of recipients: there are about 110 so far. I'll probably launch the survey in early November.

Some of the questions:

6. Please tell us some of the disciplinary skills (for example, familiarity with electrodynamics) that you'd like us to emphasize. You can use the next two pull-down menus, as well as the free response box.

7. …instrumentation skills (for example, familiarity with 3D printing and rapid prototyping)…

8. …computational tools and techniques (for example, familiarity with machine learning algorithms)…

9. …business/commerce skills (for example, familiarity with accounting principles)…

10. …"workplace" skills (for example, the ability to collaborate effectively)…

Industry survey (2)

Most of the rest of the questions:

12. Does your organization offer educational benefits/tuition assistance to employees?

13. Would your organization offer release time to employees who pursue a master's degree?

14. Would you be interested in partnering with us to…

- develop a recruiting pipeline for new employees from the Illinois program
- suggest (or sponsor) projects of interest to you, to be undertaken by Illinois master's students
- provide input on curriculum
- offer short-term internships to Illinois master's students
- offer scholarship to students, whom you might recruit as employees
- Other

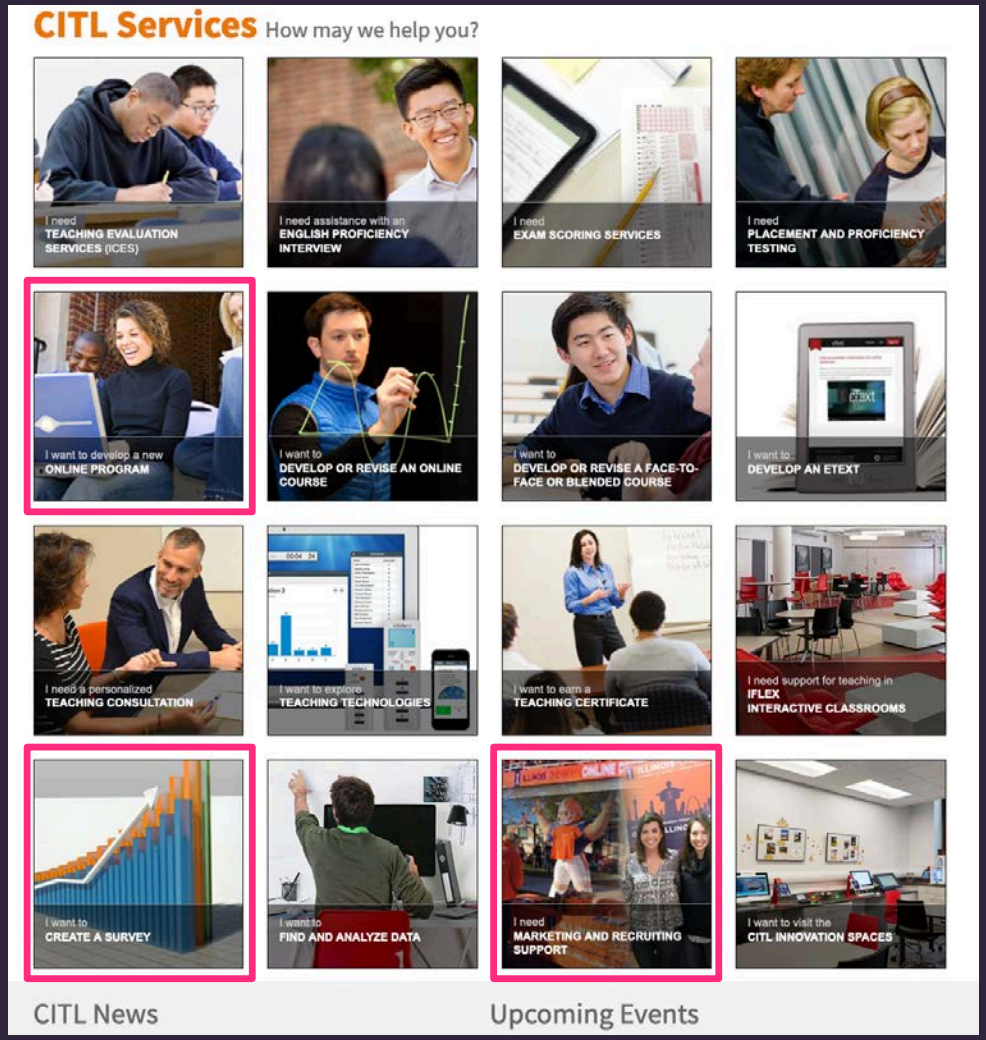
Collaboration with CITL includes development of a marketing plan

CITL (Center for Innovation in Teaching and Learning) does more than manage course satisfaction surveys.

Working with me are…

- Two design/graphics experts
- One marketing plan developer
- One survey construction and analysis expert.

Marketing will cost $1k - $2k per student we eventually enroll.



There's lots more…

Questions? Contact me.