Math: The gateway to Great Careers

Rob Ploutz-Snyder, PhD
Universities Space Research Association
NASA Johnson Space Center
What I’ll Talk About Today

• Why I think that math is important for everyone in this room
• “Common Denominators” of Great Careers
• An example of how I use math at NASA
Career versus Job

- **Career** is defined by the Oxford English Dictionary as an individual's "course or progress through life (or a distinct portion of life)". It is usually considered to pertain to remunerative work (and sometimes also formal education).

- **A job** is a regular activity performed in exchange for payment, usually as one's occupation. The duration of a job may range from an hour …to a lifetime …The series of jobs a person holds in their life is their career.

Career versus Job

• Most of us use the two terms interchangeably
  – But when you think about it, they are different

• Age relates to which you have and which you want to have

• My goal is to get you thinking about what Career you want to develop, and about charting your path
What makes a great career?

• It depends on what matters to you, but there are some common things that many people value...

• What are some things that YOU consider important in a career?
...Things to consider...

- Salary & Benefits
- Hours
- Physical Demands
- Mental Demands
- Skill Sets Required
- Education Required
- Work Environment
- Stress
- Hiring Outlook
- Sense of Worth

- Job Security
- Flexibility
- Predictability
- Travel Requirements
- Family-Friendly
- Prestige
- Opportunities for Advancement
- Interesting!
- Co-workers
Things to consider...

- Salary & Benefits
- Hours
- Physical Demands
- Mental Demands
- Skill Sets Required
- Work Environment
- Stress
- Hiring Outlook
- Sense of Worth
- Job Security
- Family-Friendly
- Prestige
- Opportunities for Advancement
- Interesting!
- Co-workers

Many, MANY things contribute to Career Satisfaction!!
What are some great careers?

• Again, it depends on what matters to you, but when asked, many people rattle off the same short list…

• What do you think is on that list??
What are some great careers?

• JobsRated.com evaluated 200 jobs in 2010, considering five “Core Criteria”
  – Environment, Income, Outlook, Stress, Physical Demands

• Each of these criteria had several components to them (ex. “income” included salary data plus growth potential)

• 200 Jobs were rated in each Core Criteria, and an overall score was created so that jobs could be ranked.

http://www.careercast.com/jobs/content/jobs-rated-methodology-2010
“Top-10” Careers?

1. **Actuary** Interprets statistics to determine probabilities of accidents, sickness, and death, and loss of property from theft and natural disasters.

2. **Software Engineer** Researches, designs, develops and maintains software systems along with hardware development for medical, scientific, and industrial purposes.

3. **Computer Systems Analyst** Plans and develops computer systems for businesses and scientific institutions

4. **Biologist** Studies the relationship of plants and animals to their environment.

5. **Historian** Analyzes and records historical information from a specific era or according to a particular area of expertise.

6. **Mathematician** Applies mathematical theories and formulas to teach or solve problems in a business, educational, or industrial climate.

7. **Paralegal Assistant** Assists attorneys in preparation of legal documents; collection of depositions and affidavits; and investigation, research and analysis of legal issues.

8. **Statistician** Tabulates, analyzes, and interprets the numeric results of experiments and surveys.

9. **Accountant** Prepares and analyzes financial reports to assist managers in business, industry and government.

10. **Dental Hygienist** Assists dentists in diagnostic and therapeutic aspects of a group or private dental practice.
See any patterns here???

1. **Actuary** Interprets statistics to determine probabilities of accidents, sickness, and death, and loss of property from theft and natural disasters.

2. **Software Engineer** Researches, designs, develops and maintains software systems along with hardware development for medical, scientific, and industrial purposes.

3. **Computer Systems Analyst** Plans and develops computer systems for businesses and scientific institutions

4. **Biologist** Studies the relationship of plants and animals to their environment.

5. **Historian** Analyzes and records historical information from a specific era or according to a particular area of expertise.

6. **Mathematician** Applies mathematical theories and formulas to teach or solve problems in a business, educational, or industrial climate.

7. **Paralegal Assistant** Assists attorneys in preparation of legal documents; collection of depositions and affidavits; and investigation, research and analysis of legal issues.

8. **Statistician** Tabulates, analyzes, and interprets the numeric results of experiments and surveys.

9. **Accountant** Prepares and analyzes financial reports to assist managers in business, industry and government.

10. **Dental Hygienist** Assists dentists in diagnostic and therapeutic aspects of a group or private dental practice.
The Common Denominator:

• All of the “top ten” careers identified by JobsRated.com (CareerCast.com) involve math

  ➢ Math is part of the job

  ➢ Knowledge of math is necessary to get the job
Do you agree with the list?

- This is one example of a “job survey”
- Other methods will shuffle the rankings, depending on how the survey was conducted, and how the data were analyzed (by statisticians!)

- But I would argue that the common denominators in “best” careers, regardless of how you do the math, hold true.
Math as a Gatekeeper

• Good Jobs Require…
• Good Careers Require…
• Great Careers Require…

• Most experts agree that education is a critical factor
Setting your Sights High!

• College is a no-brainer

• Graduate School is something to consider too

• What does it take to get into an excellent College or University? Graduate Program?
College Entrance Requirements

• Admissions Offices use many criteria, but most emphasize:
  – Your High School Performance
    • Cumulative GPA
    • GPA in specific courses
    • Other factors that separate you from “the pack”
  – Standardized Test Scores
    • ACT
      – Math, English, Reading, Science, Optional Writing Test, Composite
    • SAT
      – Math
      – Writing
      – Critical Reading
Graduate School?

- Admissions Offices & Disciplines for Graduate School mimic Undergrad:
  - Your Performance in College/University
    - Cumulative Undergraduate GPA
    - GPA in specific courses
    - Other factors
  - Standardized Test Scores
    - GRE
      - Quantitative Reasoning
      - Verbal Reasoning
      - Analytical Writing
    - MCAT or OTHER Discipline-Specific Tests
      - ...have a math component!
What most applicants want?

• Opportunity
  – to highlight our strengths
  – to address our weaknesses
  – to learn what it takes to succeed

• …We need to get our foot in the door
What are the “gatekeepers?”

• Standardized Test Scores
  – SAT, ACT, GRE, etc.
• Cumulative GPA
Why is Math so Important as an Entrance Requirement?

• People with math skills typically learn *other* academic and career-related disciplines, so they are a good risk for colleges/universities

• People who have solid math skills are thought to be “smart people,” and thus are welcomed into college programs, training opportunities, and great careers

• Math is part of most careers at some level
Recent Example of NASA work

The Challenge?

- Need to be able to accurately predict when an astronaut will run out of “consumables” during Extra Vehicular Activities
- There are several ways to estimate this, but sometimes the estimates don’t match
- How best to combine predictions from multiple methods of estimating??
Recent Example of NASA work

Oh, and one more thing…
- Find a method that works even when things go wrong!
  - Crazy readings from a sensor
  - Flaky sensor that goes in/out
  - Completely broken sensor
  - Combinations of the above
  - Other stuff that we’ll think of too!
What the data looks like?
Our “Best Estimate”

W4 Coefficients
O2: 0.52
CO2: 0.11
LCG: 0.11
HR: 0.26
Our “Best Estimate”

W4 Coefficients
- O2: 0.52
- CO2: 0.11
- LCG: 0.11
- HR: 0.26

Estimated MetRate vs Hours
What if a sensor fails?
How did we do it??

Summary of Met Rate (\( \mu \)) Estimation Process

Step 1. Preliminary estimation of \( \mu \). Apply principal-
axis analysis to \( x_1, x_2, \) and \( x_3 \), with one re-
tained factor assumed to be proportional to \( \mu \). Use (2)-(4) to get preliminary estimate \( \hat{\mu}(0) \).

Step 2. Preliminary calibration of heart rate (HR). Assume for some \( \alpha_0 \) and \( \alpha_1 \) that \( \alpha_0 + \alpha_1 (HR) \) is also an unbiased estimate of \( \mu \). Regress \( \hat{\mu}(0) \) on \( HR \) to get preliminary calibration \( \chi_0 = \alpha_0 + \alpha_1 (HR) \).

Step 3. Intermediate estimation of \( \mu \). Repeat factor analysis with 4 variables \( x_1, x_2, x_3, \) and \( x_4 \). Again use (2)-(4) to get new estimate \( \hat{\mu}(1) \) of \( \mu \).

Step 4. Final calibration of heart rate. Regress \( \hat{\mu}(1) \) on \( HR \) to get final calibration \( \chi_0 \) of \( HR \).

Step 5. Final estimation of \( \mu \). Repeat factor analysis with 4 variables \( x_1, x_2, x_3, \) and \( x_4 \) and use (2)-(4) to obtain final estimate \( \hat{\mu} \).

Met Rate Factor Model

Principal factor (f)

\[
\mu = \alpha \times \text{vector of true met rate values}
\]

\[
\hat{\mu} = \alpha (\mu - \bar{j})
\]

\[
\bar{\mu} = \frac{\text{r}}{\text{n}} \mu
\]

\[
\bar{j} = (1, 1, \ldots, 1)^T
\]

Observed estimators of met rate (assumed unbiased)

\[
x_i = \mu + e_i \quad (i = 1, \ldots, k)
\]

\[
x = (x_1, \ldots, x_k) = \mu + e
\]

Factor estimation

\[
f = XR A
\]

\[
x = (X - JD^{-1}R^{-1}A)^T
\]

where \( A = k \times k \) factor loading matrix

\( M = \text{mean of } x_i \)

\( D = \text{diag}(\sigma_i^2) \)

\( R = \text{correlation matrix of } x \)

Weight vector (b)

\[
\hat{\mu} = \frac{1}{b} b (\mu - \bar{j})
\]

\[
\hat{\mu} = \frac{1}{b} b (\mu - \bar{j})
\]

\[
\hat{\mu} = \frac{1}{b} b (\mu - \bar{j})
\]

\[
\hat{\mu} = \frac{1}{b} b (\mu - \bar{j})
\]

(Note: \( b = \frac{1}{D^{-1}R^{-1}A} = 1 \))

Estimate of BTU's used (\( \hat{b} \))

\[
\hat{b} = \mu \hat{j}^T x
\]

\[
\hat{b} = \mu \hat{j}^T x
\]

\[
\hat{b} = \mu \hat{j}^T x
\]

\[
\hat{b} = \mu \hat{j}^T x
\]

Let \( V(\hat{b}) = \sum_{i=1}^{n} \hat{b}_i^2 \) and assume \( V(\hat{b}) \) independent.

Then \( V(\hat{d}) = \sum_{i=1}^{n} \hat{d}_i^2 \), estimated by \( \sum_{i=1}^{n} \hat{d}_i^2 \).

Estimation of \( \Sigma \)

Step 1. Assume the components of each \( e_i \) follow a second-order autoregressive model.

Step 2. \( e_i = \rho e_{i-1} + \rho e_{i-2} + \epsilon_i \) \( (0, \sigma_i^2) \).

Step 3. Perform AR(2) regression of \( x_i \) on \( \mu \) to obtain estimates of \( \sigma_i^2, \rho_1, \) and \( \rho_2 \).

Step 4. Calculate \( \Sigma_i = \text{diag} \left( \hat{e}_i \right) \).

Step 5. Assume uncorrelated \( e_i \):

\[
\Sigma = \text{diag} \left( \hat{e}_i \right)
\]

Estimation of Allowable Time Remaining in EVA

Write \( \hat{B}(T) = \hat{b} \) after \( T \) hours of EVA.

Assume spacesuit life support system can accommodate a maximum energy expenditure of \( R_{max} \) (BTU).

Then the time remaining \( T_r \) is estimated by

\[
T_r = T - \frac{R_{max}}{B(T)}
\]

Use \( \Delta B \) (BTU) as SE of \( B(T) \) to get confidence limits for \( T_r \).
Problem Solved??
Final Remarks...
Take-Home Lesson #1?

• Math Matters
• Math can be a career in and of itself
• Applied math leads to many careers
• These careers tend to be highly praised, with attributes that most people value
For the Math Lovers…

• Good news for us!

• Jobs requiring what we like to think about and do are “out there!”

• All that “math stuff” that we learn in school really has a purpose in life and work!

• We can get paid to do stuff that we love to do anyway!!

• And we can make a difference in the world too.
Take-Home Lesson #2?

• Math Matters

• Math is a “gatekeeper” to great careers not typically thought of as “in the math field” because it is a key component to the entrance exams required for College, University, and Post-Graduate education
For everyone else??

- There are many great careers that don’t involve (as much) math as part of daily “work-life”
  - Historian
  - Dental Hygienist
  - Paralegal Assistant
  - Philosopher
  - Technical Writer
  - Web Developers
  - Pharmacist
  - …many others

- With equal benefits to self and society

- Nevertheless, many of the jobs that people rate highly require knowledge of math
  - If for no other purpose, math serves as a “gate keeper” to great careers
Where will your career take you?

Go down deep enough into anything and you will find mathematics.

~Dean Schlicter