The direction of post-secondary STEM education & research and how this impacts your students

Kerry O. Cresawn, Ph.D.
Department of Biology
James Madison University
My path and those who most influenced it

Ms. D. Yates
High School Bio Teacher

Dr. D. Dennis
College professor

Dr. H. Brem
Johns Hopkins Oncology

The Pompe Disease Community

My example followers
What gets me up in the morning

First Year Biology Majors

~2000 3rd, 4th, and 5th graders/yr

Future Science Teachers
Top 5 Issues in Higher Education Science Programs

- Increasing diversity in STEM
- Solving big problems using scientific, quantitative, and ethical reasoning skills
- Community and Civic STEM Engagement
- Preparing scientifically literate, life-long learners
- Better preparation for non-traditional careers STEM careers
Diversity in STEM

• It’s more than a social justice issue. Research shows socially diverse groups are more creative and effective than homogenous groups.

• PCAST (2012): 1 million more STEM workers needed over next 10 yrs than anticipated by standard economic growth

• STEM jobs ranging from STEM capable to STEM professional will be available for your students.
These jobs don’t all require Ph.D. or even B.S. in STEM

[Diagram showing categories of workforce]

PCAST  
https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf
Projected STEM Job Openings 2008-2018

Figure D-7. Projected Job Openings in STEM Occupations, 2008–2018

- Mathematical science occupations: 33.9 / 23.0
- Physical scientists: 81.3 / 41.7
- Engineering technicians, except drafters: 99.1 / 25.8
- Life scientists: 69.1 / 74.6
- Life, physical, and social science technicians: 128.8 / 44.1
- Social Scientists and Related Occupations: 158.4 / 116.7
- Engineers: 353.0 / 178.3
- Computer Specialists: 620.9 / 762.7

Number of Job Openings (Thousands)

- Replacement Needs
- Growth Needs
Unemployment lower in STEM

STEM versus non-STEM laborforce
Unemployment

Percent Unemployment

STEM Non-STEM

2005 2006 2007 2008 2009
Diversity in STEM

• It’s more than a social justice issue. Research shows socially diverse groups are more creative and effective than homogenous groups.

• PCAST (2012): 1 million more STEM workers needed over next 10 yrs than anticipated

• Recommendations are to improve retention in college STEM programs
Persistence in STEM programs is low.
We need to do more than increase retention of students, most of which are white.
What are we doing about this in higher education?

• **National Initiatives:** HHMI: $60 million to fund programs designed to support under-represented minorities and non-traditional students in college STEM programs

Click on HHMI bulletin image to hyperlink to program description

• **JMU Initiatives:** Chemistry Success Director targeting high-risk students

• **JMU Biology Initiatives:** Peaking early interest through K-5 outreach
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What do you consider to be the biggest problems in biology facing the world today?

Of 26 Biology faculty: 13 Climate Change, 9 biodiversity loss, 4 biomedical issues,
Current, Local, and Urgent Research in Biodiversity Loss

_Batrachochytrium dendrobatidis_ (Bd) or “Chytrid Fungus”:

- Aquatic fungal pathogen (1998)
- Greatest disease-caused loss of biodiversity in history
- In last 30 years: 200 species of frogs extinct or in catastrophic decline
- 1st emerging disease shown to cause the decline or extinction of 100s of species not otherwise threatened.
- Currently over 350 amphibian species are known to have been infected
Pathology of Chytrid

- Infects the keratin-containing layers of amphibian skin
- This affects osmotic regulation: electrolyte blood levels drop, leading to death from cardiac arrest.
- Death ensues in adult frogs once the individual has reached an infection load of about 10,000 fungal zoospores

http://htwins.net/scale2/
Discharge papilla forms

Mortality ~2 weeks

Cap lost, zoospores escape through skin

23°C Critical temp.

Growth in diameter & complexity

Motile zoospores: swim in water, penetrate skin & form zoosporangium
Click in pres mode for hyperlink
How did it get here and how is it spreading?

- Not clear. Earliest specimen with visible signs of Chytrid infection (1938) coincides with shipping of African clawed frogs for use in scientific research and pregnancy testing.

- Novel pathogen theory favored over theory of endemic pathogen that has become more virulent or amphibians more susceptible because of environmental changes.

- Climate change impact unclear: affect on fungus survival versus affect on amphibian immune system.

- Spread through illegal pet trade, native species have no evolved defense mechanisms.
Local Impacts of Chytrid

- Appalachia region has more species of salamanders than anywhere else in world
- Survived >200 million yrs through 3 mass extinctions, but now rapidly declining due to:

  Habitat loss: agriculture, urban development, and pipeline
  Climate change: forcing migration to unsuitable habitats
  Chytrid Fungus: *Batrachochytrium salamandrivorans* (Bsal)

http://www.savethesalamanders.com/threats.html
http://rsos.royalsocietypublishing.org/content/royopensci/3/2/150616.full.pdf
http://amphibiaweb.org/chytrid/Bsal.html
Local Impacts of Chytrid

Coming from Asia: Billion dollar amphibian and reptile illegal animal trade industry
Local Impacts of Chytrid

*Batrachochytrium salamandrivorans* (Bsal):

http://www.savethesalamanders.com/threats.html
In the group we exposed to chytrid, about 50% to 60% have died," he told BBC News. "But of the ones where we added the bacterium (*Janthinobacterium lividum*) none have died, and we're about 140 days in now."
Field surveys of the local and rare cow knob salamander

Chytrid fungus-induced amphibian decline in S.E. Asian frogs and salamanders.

Large-scale screening for Chytrid

More about their research, especially Dr. Mcleod found on JMU Bio website ("people")
Amazing Experiences for JMU Students

Study Abroad in Burnei
(like “David Mcleod lab facebook page for more: https://www.facebook.com/David-S-McLeod-Lab-at-James-Madison-University-787110321326774/)

Community Outreach

Presenting Research at Conferences
Incorporating this Story into Your Biology and Environmental Courses

- Local issues, ethical reasoning, populations, habitats, invasive species, human impact on environment, life cycle biology, microorganisms

- Many popular press articles

- "Science in the Classroom"
  [Link](http://scienceintheclascroom.org/research-papers/tiny-fungus-causing-big-problems/university)

- They’re in our backyards

- JMU HOP
  [Link](http://mcleodds.wixsite.com/labresearch/jmu-hop)
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What do you consider to be the most ground-breaking/game-changing technology in biology that has emerged in the last 5-10 years?

17 of 26: CRISPR/CAS (Gene Editing)
CRISPR is a way to edit DNA

- Part of bacteria’s natural immune defense against viruses and allows scientists to edit genomes with unprecedented precision, efficiency, & flexibility.

- In last year: creating monkeys with targeted mutations, preventing HIV infection in human cells, treating nonviable human embryos showing potential to cure any genetic disease

Video for general audience
http://www.wsj.com/articles/why-gene-editing-technology-has-scientists-excited-1434985998

- Major ethical implications
Rewriting the Code

Scientists can use the gene-editing technology called Crispr-Cas9 to correct disease-causing mutations. Here's how it works:

A chunk of RNA is programmed to look for a specific problem segment of DNA. It is paired with a natural protein called Cas9 taken from bacteria, where it functions as a genetic scalpel.

Once inserted into a cell, the RNA/Cas9 combination looks for a DNA sequence that matches its RNA.

When it finds a match, the Cas9 cuts both strands of the DNA.

Repair enzymes can fill and seal the gap in the DNA with new genetic information to change the underlying genetic code.

Source: Innovative Genomics Initiative
John Gould / The Wall Street Journal
• In June: approved the first CRISPR study in patients to create genetically-altered immune cells to attack three kinds of cancer (U. Penn)

• Still needs the approval of the medical centers where it would be conducted, and FDA. If approved, it would enroll patients with multiple myeloma, melanoma, and sarcoma,

FDA approval

http://scienceintheclassroom.org/research-papers/can-we-handle-power-crispr/university
Want to learn more about gene editing and genomics in general?

- Free 2-day workshop in June in JMU Biology department
- Breakfast and lunch provided
- Open to JMU students, high school science teachers and students, JMU faculty, & others in community
- Beginner level workshop

http://www.jmu.edu/genomics/
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Community and Civic STEM Engagement

JMU Vision Statement: To be the national model for the engaged university: engaged with ideas and the world.
Providing our future STEM professionals with skills and motivation to give back by getting involved in K-12 science outreach.

I'm currently sitting at my desk in my classroom at my school. Dude. I'm going to be a teacher.

It's called the new America school. It's an alternative high school for immigrants and ELL and generally underserved populations.

My website: Jmuscienceenrichment.org
Outreach Opportunities for K-12

https://www.jmu.edu/outreach/index.shtml

“As a parent, my heart was so full that week, to see her so enthusiastic and energized about science, learning, and viewing the universe in a new way.”

- Anita H.
My other interest: retention of our secondary science education students

- 0.1% of 1st year students declare the science major/secondary education (SEED) minor.

- 7 of the 55 declared students completed the program in 2015 and 5 in 2016.

- Most leave in sophomore or junior year.
Los pigmentos son productos químicos en frutas, hojas, plumas de aves, su piel, su ropa, su pelo y en esta cartulina y causan el color que tienen esas cosas.

¿Los pigmentos son muy buenos para usted!

Las artoxicinas
refleja la luz azul, rojo y morado

Los carotenoides
refleja la luz sobre todo de naranja y amarillo

Chlorofilas
refleja la luz verde

Esta hoja está absorbiendo todos los colores de la luz excepto el color verde. La luz verde está rebotando de la hoja.

Pigments are the chemicals in fruits, leaves, bird feathers, your skin, your clothes, your hair, and this poster card that cause those things to be the color they are.

Plant pigments are so good for you!

Sunlight Reflected light

Anthocyanins [an-tho-sy-a-nins]
Reflect blue, red, and purple light

Cartotenoids [kuh-r-o-t-in-oids]
Reflect mostly orange and yellow light

Chlorophylls [klor-o-fill]
Reflect green light

The pigment chlorophyll in this leaf absorbs all the colors of light except green so that's what we see!
Data:
These students were inspired by you!

Pre-Questions: “Who has influenced you?”

Summary: Teachers were the biggest influence on the students interests in both STEM and teaching (5 responses for each)

Summary of Responses:

- 4 credited specific high school science teachers as the reason they decided to pursue STEM
- 3 credited former teachers spanning K-12 and 2 credited teachers in their family as the reason they decided to pursue teaching.
Post-Question: “What have you gotten from this course...?”

Summary: Students gained insights into a teacher’s role, the demands on teachers, school cultures, and their own likes and dislikes and areas for improvement. They learned that teaching is hard. (13 responses)

Responses related to teaching in general:

“I realized how much work, research and focus on standards goes into teaching...The standards shaped everything we did”

“I learned how local teaching is: Spanish speakers, different learning abilities, and different school cultures”

“Now I know my goal and more motivated toward my goal”

“I developed a new appreciation for what teachers do”

“I liked getting to know what goes on behind the scenes”
Data: Reported Benefits of the Course

Post-Question: “What have you gotten from this course...?”

Responses related to elementary student experience:

“I noticed it is harder to work with children than I had expected”

“It is hard to bring content down to their level and explain why things don’t work the way they expect it to”

“I need more patience”
Post-Question: “What have you gotten from this course...?”

Responses related to research and the literature review:

“Learning about student misconceptions and that they can continue into adulthood. I have a new appreciation of misconceptions research and surveys”

“Learning about the research”

“Learning about the standards and the extent to which they drive instruction”
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Preparing Scientifically Literature, Life-Long Learners

- Metacognition
- Quantitate Reasoning
- Ethical Reasoning
- Communicating Science to the Public
- Connections to other disciplines
- Pseudoscience versus science
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## Preparation for non-traditional STEM careers

Most of our students don’t want to be us when they grow up!

<table>
<thead>
<tr>
<th>Informal or Formal Science Education</th>
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<tbody>
<tr>
<td>Technical writing</td>
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<td>Business analysis for venture capitalists or banking firms</td>
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<tr>
<td>Biotechnology sales</td>
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<tr>
<td>Health informatics</td>
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<tr>
<td>Medical communications and conference planning</td>
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<tr>
<td>Competitive industrial intelligence</td>
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<td>FDA investigator/reviewer/inspector</td>
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<td>CIA, DOD</td>
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<td>Quality control and assurance</td>
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<td>Pharmaceutical and biotechnology marketing</td>
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<tr>
<td>Business development</td>
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<tr>
<td>Legal assistant for patent law and other</td>
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</tbody>
</table>
Thank You!

- Center for Excellence in Education
- David Mcleod, Billy Flint, and Ollie Hyman (amphibian experts)
- Scott Paulson (diversity)
- JMU Biology department
- You: for all you do to prepare and inspire my future students