

Improving Access to STEM Education: Colorimetry as a Low-Cost Alternative to Traditional Titration Experiments

Sara McCauley

Advisor: Dr. Thomas Schuman

Chemistry



Kummer Institute

My Background

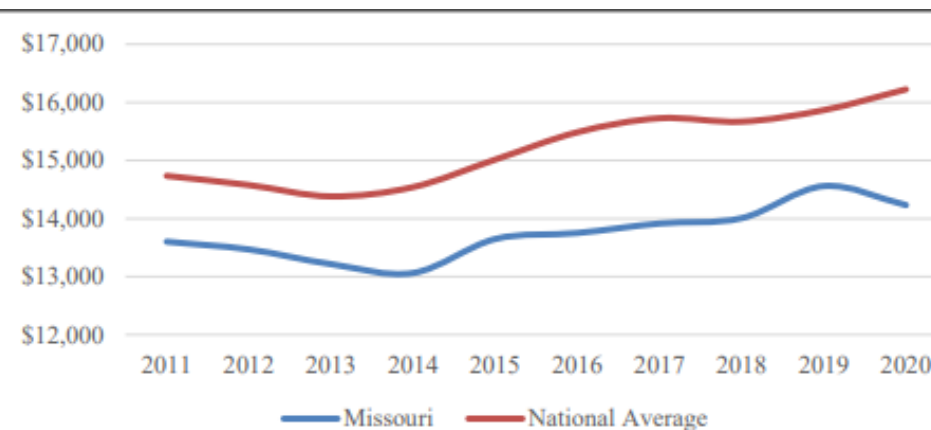
- Rockwood School District, St. Louis County
 - Total Expenditure Budget 2019/2020: \$234.2 million
 - Total Student Body: 20,958 students
 - B.S. in Chemistry with Polymers Emphasis, Missouri S&T
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- Newburg School District, Phelps County
 - Total Expenditure Budget 2019/2020: \$4.2 million
 - Total Student Body: 405 students



Education Funding in Missouri

- **Missouri ranks 49th in the nation in funding for K-12 schools.**
- **In 2019, the State Auditor found that Missouri schools are funded from primarily local sources of revenue— sources that vary widely by location.**

Figure 3: Missouri's elementary and secondary education funding per ADA compared to the national average, adjusted for inflation, fiscal years 2011 to 2020



Areas and Causes of Inequity

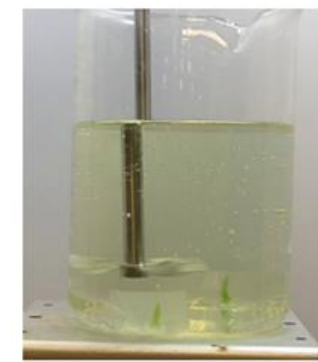
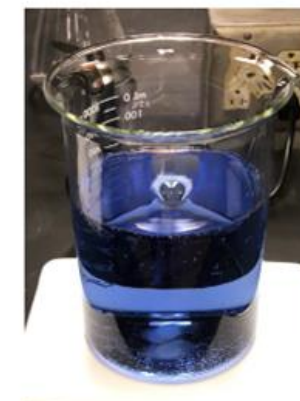
- According to the Department of Elementary and Secondary Education (DESE), high-poverty, high-minority, and rural schools experience more teaching ineffectiveness than do more affluent schools.
- 13% of teachers in rural schools are less than fully qualified.
- There is a greater shortage of math and science teachers in Missouri than in any other subject.
- 65% of schools with underqualified teachers do not offer college preparatory STEM classes.
- DESE projects a 15% growth in STEM jobs in Missouri in the next 10 years.

The Belousov-Zhabotinsky Reaction

- Metal-catalyzed bromate oxidation of malonic acid
- Colored metal catalyst is repeatedly oxidized and reduced
- **Vector Projection (VP) Method** can extract the concentration of a colored solution from an image of the solution

Schell, J.; McCauley, S. C.; Glaser, R. Video colorimetry of single-chromophore systems based on vector analysis in the 3D color space: Unexpected hysteresis loops in oscillating reactions. *Talanta*, 2020, 220, 121303-121313.

Right (top): Fe²⁺ (red), Fe³⁺ (blue)
Right (bottom): Ce³⁺ (clear), Ce⁴⁺ (yellow)
Below: Unstirred Fe-catalyzed BZR



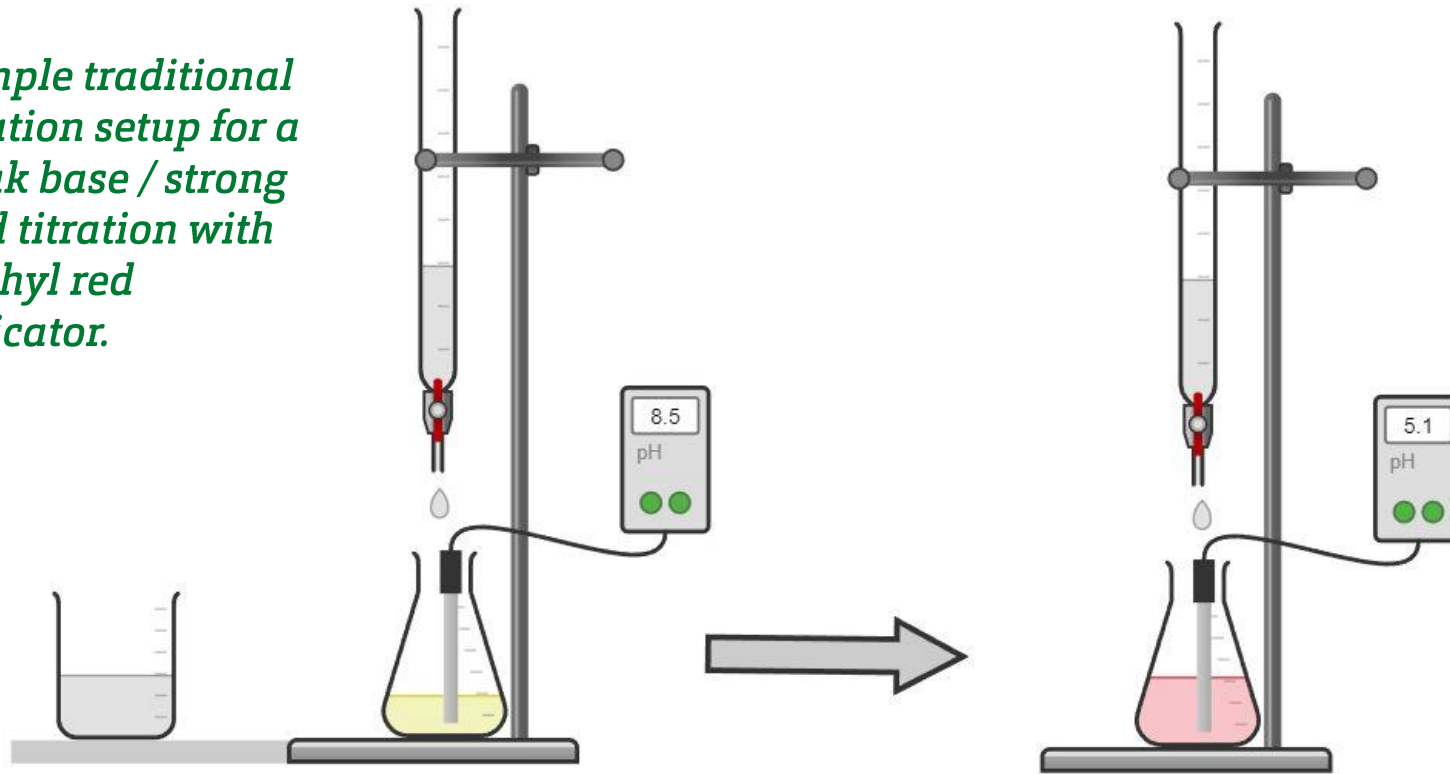
Titration Experiment using VP Method

Specific Goals:

1. Develop and test prototype software using the VP Method; provide this software to the public for free.
2. Develop a standardization titration, and test the experiment under a variety of conditions to determine the most optimal setup.
3. Develop educational materials for teachers and students and explore various outreach venues.

Traditional Titration Experiment

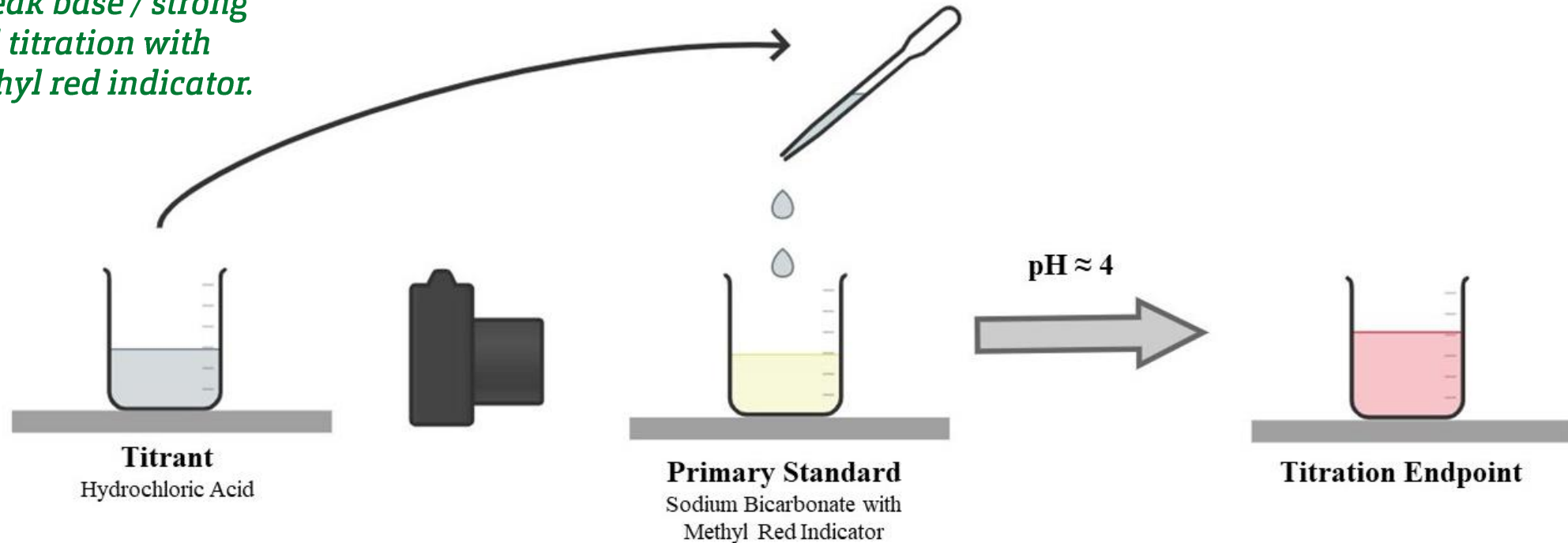
Sample traditional titration setup for a weak base / strong acid titration with methyl red indicator.



- Acid/base reaction
- **Primary Standard (yellow):** concentration known
- **Titrant (gray):** concentration unknown
- **pH indicator** changes color at a certain pH
- **Burette** measures volume very accurately
- **pH meter** reads the pH throughout the titration


Titration Experiment using VP Method

*Sample titration setup
using the VP Method for
a weak base / strong
acid titration with
methyl red indicator.*



Prototype Software

- **Software Features:**
 - User-friendly interface
 - Photo upload
 - Region selection for analysis
 - Unit selection
 - Graphical display
 - Export to spreadsheet
- **Software will be provided to the public for free on Github.**



Input the desired coordinates to read from.
On the left is your original image
On the right is a preview of the cropped image

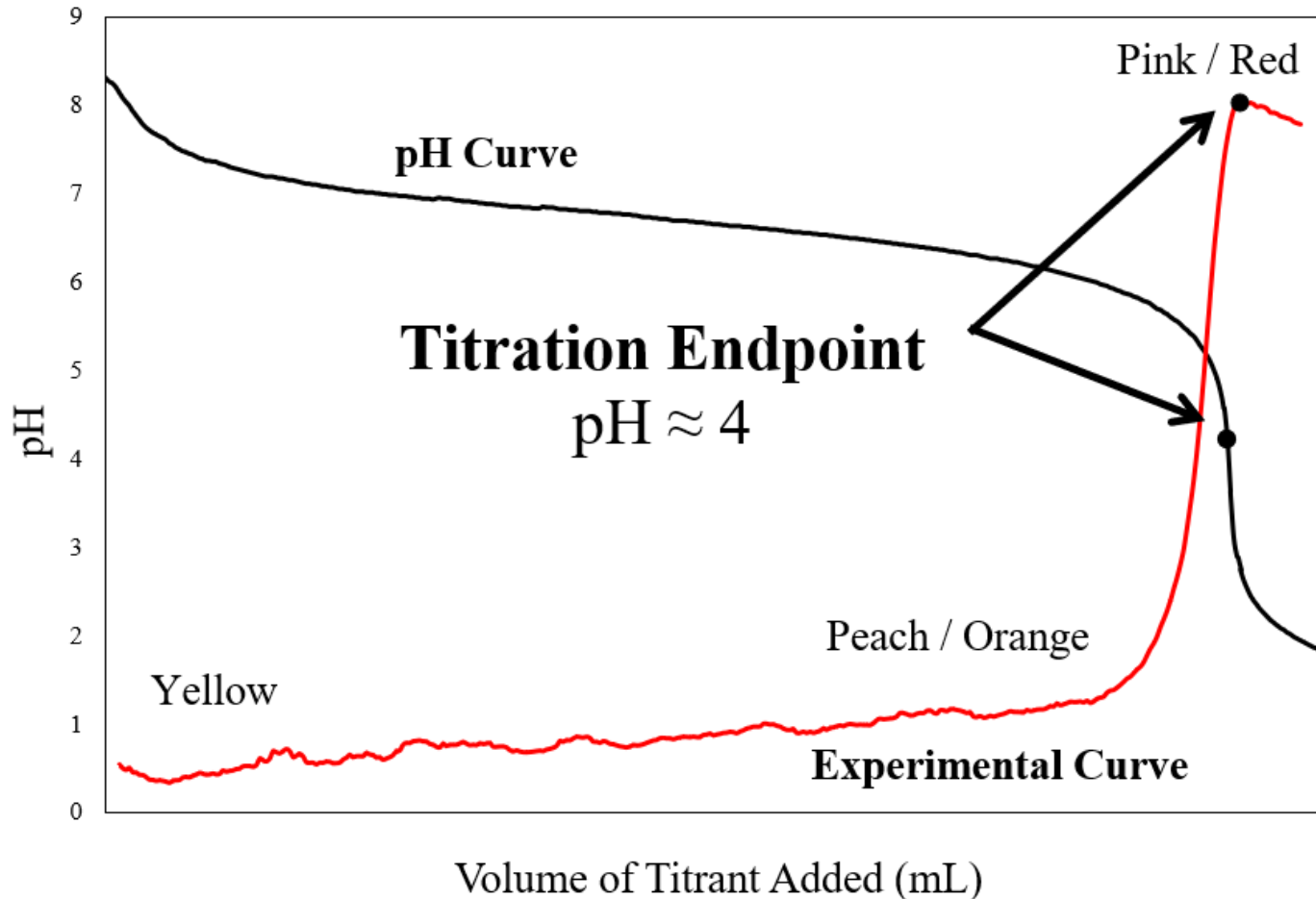
X Min X Max

Y Min Y Max

Concentration Units

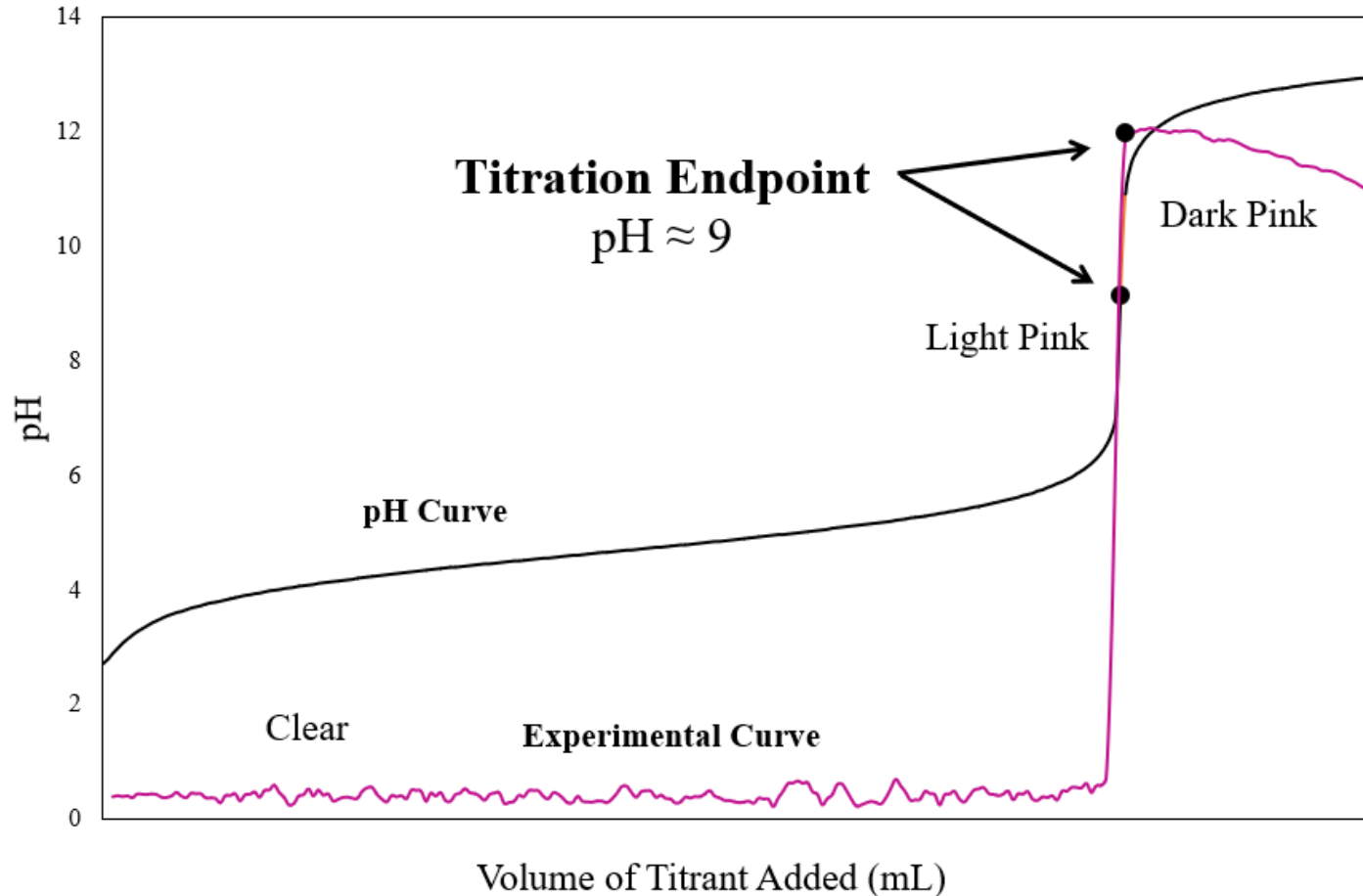
User-friendly interface showing how the user would input a standard and select area for analysis.

Titration with Methyl Red: Results



- Strong acid / weak base titration
- Primary Standard: sodium bicarbonate
- Titrant: hydrochloric acid
- pH indicator: methyl red
- Quantitative results from these two methods are interchangeable

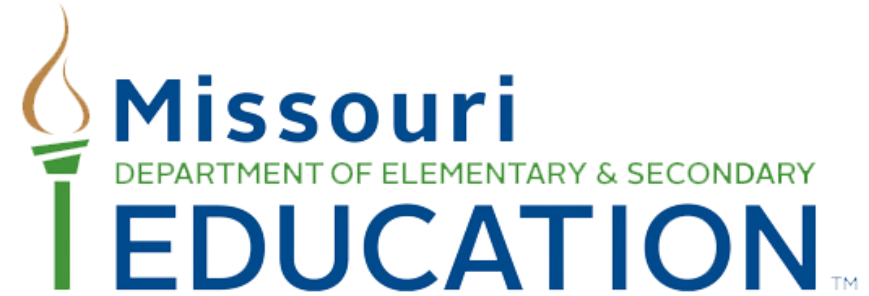
Titration with Phenolphthalein: Results



- Weak acid / strong base titration
- Primary Standard: acetic acid
- Titrant: sodium hydroxide
- pH indicator: phenolphthalein
- Quantitative results from these two methods are interchangeable

Next Steps

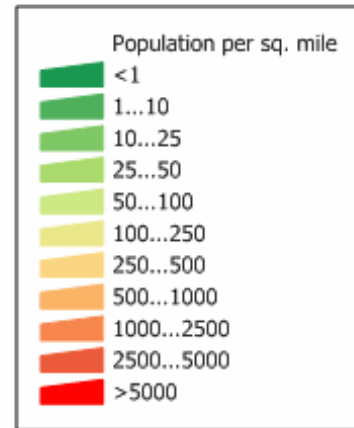
- Office of Engagement – make and disseminate informational videos about the titration experiments
- Missouri South Central Regional Professional Development Center (RPDC)
- Missouri S&T's Department of Teacher Education and Certification
- Publication
- Software Dissemination



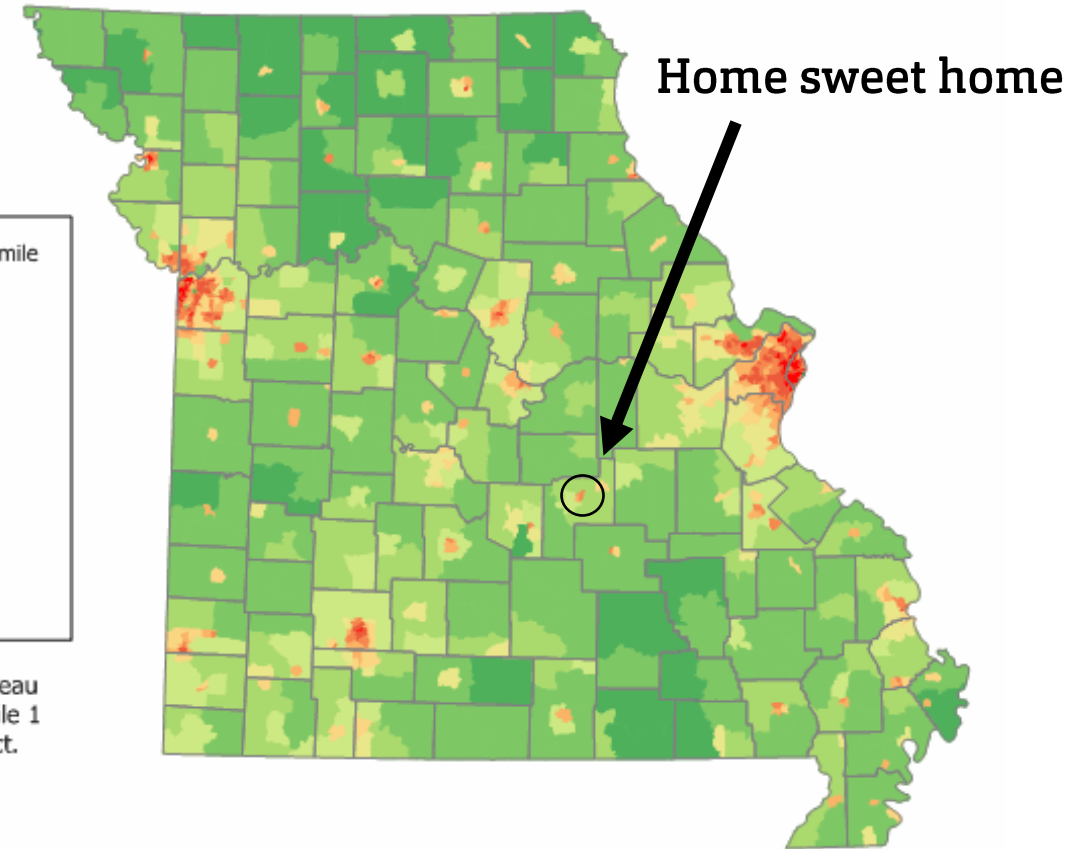
Why S&T Matters in Missouri

- Missouri S&T is uniquely positioned to provide resources for the local community.
- Teaching labs, instruments, funding, and specialized expertise.

How can we mobilize these assets to benefit underserved communities?



Source: U. S. Census Bureau
Census 2000 Summary File 1
population by census tract.



Acknowledgements

Funding:

I would like to acknowledge support by the First Year Research Experience (FYRE) Program of the College of Arts, Sciences, and Business, the Undergraduate Summer Research Scholarship (UGSRS) Program of the Department of Chemistry supported by the Pefer H. Pietsch Memorial Scholarship and by the Carey & Christine Bottom Endowed Scholarship in Undergraduate Chemistry Research, and by the Opportunities for Undergraduate Research Experiences (OURE) and OURE Fellows Program of Missouri S&T.

I am also supported by the Kummer I&E Doctoral Fellows program.



Advisor: Dr. Thomas Schuman,
Department of Chemistry

Software Collaboration: Ethan Galloway

Contact: scmnr8@mst.edu