Incorporating a Global Perspective in STEM Education Through Interdisciplinary Projects

Erika T. Camacho
erika.camacho@asu.edu

MIT MLK Visiting Professor
Arizona State University

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"Education is not preparation for life; education is life itself." - Dr. John Dewey (1859-1952)
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STEM education is part of who we become and the trajectory we take in the process of becoming scientists or quantitative individuals.

- It is not a tool or utility but a necessity.
- It is what will allow us to shape and mold our lives and that of future generations to come.
- It is not just a universal language but rather the language of the future.
- It is the biggest equalizer of life.
Discussion Within Context

What led each of you to become an academic administrator or a faculty?
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What led each of you to become an academic administrator or a faculty?

- Motivated by a need in your community or populations you care about
- Driven by a problem that was personal to you
- Familiarity of path, process, or profession
- Your experiences carved that path
Would you have still taken this path or profession if you were told to put the motivation or the driving force that led you to become X aside for a decade or more and learn the tools without relating it back to that perspective?
Feasibility of Becoming

Would you have still taken this path or profession if you were told to put the motivation or the driving force that led you to become X aside for a decade or more and learn the tools without relating it back to that perspective?

- Is it fair to ask our students to learn STEM and completely embrace the learning process of STEM but neglect/separate their cultural perspective and experiences to do this and become scientists?
- It is fair to talk about science in a way and context that is never relevant to what they care about or to never connect it to relevant issues in their communities?
- It is fair to say that science is very important and give them general examples or examples to which they can’t really relate in order to support a given statement?
Starting Point

A student’s personal experiences, cultural perspective, interests and passion should be the starting point of all education, including STEM education.

- Problem solving skills, creativity, analytical skills, and mathematical knowledge cannot be fully developed if we neglect the very foundation of who we are, what makes us tick, and what is so familiar to us.
- Learning starts by being interested, having curiosity, and finding the particular topic important.
- We may not need to change what we cover in class and what we teach students but just how we cover it and how we teach it.
- We need to make a conscious and proactive effort to be inclusive.
- Culture perspective and personal experiences do not necessarily change how we do math (or STEM) but it does change what we view as important.
Developing Quantitative Citizens and Scientists

We, as educators, have a responsibility to help students develop as future scientists or quantitative individuals.

- We must help them develop, using who they are and what they bring as a foundation, and incorporate a global perspective in what they are learning.

- This requires taking time to know what is important to them so we can tailor topic motivations/ explanations/ examples.
  - e.g., calculus course with mainly pre-med versus business majors or engineering /physics majors

- It also calls for having student-driven projects, i.e., letting students select their project question (in general) and, with the help of the faculty, form it into a concrete feasible project.
  - Multiple meetings/discussions (where student does most or all of the explaining) will be needed.
  - The question will be reformulated multiple times as the student’s and the faculty understanding of the project becomes clearer.
  - The project must be broken into smaller tangible tasks/ phases.
Building Up From Students’ Interest

Student-driven research projects allows faculty to

- make STEM topics relevant to the students
  - Teach them science but keeping it within the context of the students’ experiences and what is familiar to them as much as possible

- leverage from students’ passion, sense of social responsibility, and personal experiences
  - Put course material and topics/subjects in concrete real world examples
  - Have creative projects that are open-ended questions that allow them to think, explore, and realize why what they are learning is necessary in order to change the human conditions of their communities.
Global Perspective Through Research

Interdisciplinary research and projects that are student-driven and motivated by their cultural experiences or by the needs in their community

- Projects that are not professor-selected, from the back of a book, or that necessarily have a final answer.

- Projects that are hands-on and in which students can contribute in a significant way.

- This can be embedded within a course or offered as a separate research project (as part of a summer or year-long program) within the department.
Small Samples of Projects

- “Substance Abuse via Legally Prescribed Drugs: The Case of Vicodin in the United States”
  - Goal: to determine the most effective strategies for reducing the overall population of Vicodin abusers
- “Iron Accumulation in the Cell: A Mathematical Model of Friedreich’s Ataxia”
  - Goal: to understand the role iron plays in the development of Friedreich’s Ataxia
- “Fanatic Consumerism: A mathematical model on the influence of mass media on a capitalist population”
  - Goal: to understand the influence of media and age on impulsive behavior
- “Understanding the influence of charismatic leaders through a dynamic network model of the NAZI regime”
  - Goal: to see how charismatic leaders can lead an entire population to become fanatic
- “A Network Model for the "Melting Pot" of Cultures”
  - Goal: to see how groups are influenced to become "Americanized" based on characteristics such as race, income, gender, and level of education
- “Deterministic and Small-World Network Models of College Drinking Patterns”
  - Goal: to examine the spread of college drinking on campus
Vicodin Abuse

Figure 1: CVT Model. This figure shows the linear representation of a population of Vicodin patients as they transition through chronic use, abuse, treatment, and possible relapse.

Table 1: Parameter Explanations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Lambda$</td>
<td>rate of new medical Vicodin users entering the population</td>
<td>people/\text{month}</td>
<td>[2671212, 3303044]</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>rate of acute users becoming chronic users</td>
<td>1/\text{month}</td>
<td>[0.175, 0.240]</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>rate of acute users ending Vicodin treatment</td>
<td>1/\text{month}</td>
<td>$1.762\alpha_1 \leq \alpha_2 \leq 7.850\alpha_1$</td>
</tr>
<tr>
<td>$\beta$</td>
<td>rate of chronic users ending Vicodin treatment</td>
<td>1/\text{month}</td>
<td>$0.205\beta \leq \delta \leq 0.513\beta$</td>
</tr>
<tr>
<td>$\delta$</td>
<td>rate of chronic users moving to next compartment</td>
<td>1/\text{month}</td>
<td>$0.0862 - \beta \leq \delta \leq 0.256 - \beta$</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>rate of abusers entering treatment for Vicodin abuse</td>
<td>1/\text{month}</td>
<td>[.014,.042]</td>
</tr>
<tr>
<td>$\gamma_1^*$</td>
<td>relapse rate (CVT Model)</td>
<td>1/\text{month}</td>
<td>[.046,.45]</td>
</tr>
<tr>
<td>$\gamma_2$</td>
<td>successful treatment rate</td>
<td>1/\text{month}</td>
<td>[.038,.55]</td>
</tr>
</tbody>
</table>

*For both the SIC and SIAD Models, the units of $\gamma_1$ change to $1/\text{people months}$, where people is defined by the population of the United States in recent years, and its value range is $[1.26 \times 10^{-10}, 1.50 \times 10^{-9}]$. Refer to Appendix IV for derivations and references.*
Figure 2: CVT Model Simulation with Arbitrary Parameter Values. The plot above displays a 40-month period with arbitrary parameters selected from the acceptable ranges according to data. It predicts that although the first 12 months show a peak in the population of Vicodin abusers, the number of abusers decreases in the next 24 months.

Figure 3: CVT Model Pessimistic Curve. This plot displays the scenario in which all of the parameters assume values of the least desirable outcomes. In this case, the abuse population grows by a large degree, so it is necessary to enhance Vicodin abuse prevention and treatment methods.
Role of Iron in Friedreich’s Ataxia

Cellular iron homeostasis
Role of Iron in Friedreich’s Ataxia

Gene Therapy Treatments

- Onset at $t=60$
- Treatment at $t=180$ of $\downarrow \alpha_{T-R1}$
- 11% Below
- Treatment at $t=240$ of $\downarrow \beta_{ISC} \downarrow \beta_{IRP}$
- 17% Above
- Treatment at $t=240$ of $\downarrow \alpha_{FPN}$
- 53% Above
- Treatment at $t=180$ of $\downarrow \alpha_{TfR1}$
- 28% Above
Fanatic Consumerism

The parameters and stale variables are describe as follows:

- $T$ = Total population at any time, $t$.
- $M$ = Moderate buyers at any time, $t$.
- $I$ = Impulsive buyers at any time, $t$.
- $R$ = Rational buyers at any time, $t$.
- $\varphi$ = Birth rate of each class
- $\lambda$ = Death rate of each class
- $\sigma$ = The shift in death rate ($\lambda$) due to buying decisions
- $\kappa$ = The amount of media influence on buyers
- $\alpha_i(a, \kappa)$ = The rate of change from moderate buyers to rational or impulsive buyers
- $\beta_i(a, \kappa)$ = The rate of change from rational or impulsive buyers to moderate buyers
Similarly, we are modeling the effects of mass media marketing on excessive consumerism in a population based on the capitalist United States' economy.

Given the background information we have found, we are basing our models on the work from Stauffer and Sahimi, and Garcia, et al., taking into account the effect of mass media marketing on consumer societies and how the behavior of one population group directly affects surrounding groups. Birth and death rates are accounted for but immigration and emigration are not. Variables such as gender, race, and geographic location are not accounted for.

**IV. Mathematical Model**

Our mathematical model is based upon the idea and assumption that everyone in the general population falls in the category considered as "Moderate Buyers," labeled $M$. Their decisions are loosely based on media influence and they make relatively equal quantities of impulsive and rational purchasing decisions. Depending on the media's influence on society, people can shift their habits that propagate either impulsive purchasing decisions or rational purchasing decisions. The "Impulsive Buyers," defined by the class $I$, and "Rational Buyers," defined by the group $R$, do not play any impact on each other in our model as we believe that the rates of change between moderate and impulsive or rational buyers average in any possible competing forces associated with interpersonal contact with an individual belonging to another category.

\[
\begin{align*}
T &= \text{total population} \\
M &= \text{Moderate buyers} \\
I &= \text{impulsive buyers} \\
R &= \text{rational buyers} \\
\phi, \lambda &= \text{birth, death rate} \\
\sigma &= \text{shift in death rate} \\
\alpha_i &= \text{change from M to R or I} \\
\beta_i &= \text{change from R or I to M}
\end{align*}
\]
As $\kappa$ increases it is clear that the proportion of the population that falls into the impulsive buyers, $I$ category drastically increases. The moderate buyers $M$ and rational buyers $R$ proportions become significantly low. This demonstrates the power that media influence has over the general population; as the population becomes more impulsive, the proportion of moderate and rational buyers becomes exceedingly low.
Charasmatic Leaders in the NAZI regime

Multiple agents are working against one another to change group membership and social ideology, but it should be noted that we assumed each member of a group only has so much potential to convert others. The more dedicated to the ideals of the fanatics, their ability to persuade increases accordingly. Members of each group are given a maximum value on the uniformly distributed interval \([0,1]\) where their ability to persuade is restricted (as shown below). We assume there is a compounded value for multiple agents attempting to persuade an individual. Rather, it is only the average value of all the agents attempting to persuade that is utilized.

\[
P(G) = [0, .25]; \ P(S) = [0, .5]; \ P(E) = [0, .75]; \ P(F) = [0, 1]
\]
Charismatic Leaders in the NAZI regime

Three separate network graphs generated for our simulations. Left: 50 nodes. Middle: 75 nodes. Right: 150 nodes.
"Melting Pot" of Cultures

Revised Diagram of Our Model

\[ \delta_1 \rightarrow N_L \rightarrow \alpha_1 \rightarrow S_L \rightarrow \beta_1 \rightarrow A \]

\[ \delta_2 \rightarrow N_C \rightarrow \alpha_2 \rightarrow S_C \rightarrow \beta_2 \rightarrow A \]

\[ \delta_3 \rightarrow N_A \rightarrow \alpha_3 \rightarrow S_A \rightarrow \beta_3 \rightarrow A \]
"Melting Pot" of Cultures

Effects of the Melting Pot

Padberg, Yong

Graph with Respect to Language for $(0,0,0,0,0,0,0,A^*)$
"Melting Pot" of Cultures

Results and Analysis

Figure: Plot of nodes at time=0 for $\alpha = 0$, $\gamma = \delta = \epsilon = 1$ and $\beta = 3$, where $\alpha$, $\beta$, $\gamma$, $\delta$ and $\epsilon$ are weights for income, education, age, language and predisposition values, respectively. Legend: blue=$N_H$, yellow=$S_H$, cyan=$A_H$, red=$N_A$, green=$S_A$, dark grey=$A_A$, magenta=$N_{AA}$, black=$S_{AA}$, light grey=$A_{AA}$
College Drinking Patterns

The Complete Four Compartment Model

Abstainers ($N_1$)

Social Drinkers ($N_2$)

Problem Drinkers ($N_3$)

Binge Drinkers ($N_4$)

$d_1$

$d_2$

$d_3$

$d_4$

$n_{12}$

$r_{21}$

$s_{12}$

$r_{31}$

$s_{23}$

$r_{23}$

$s_{24}$

$r_{24}$

$n_{24}$

$r_{42}$

$s_{42}$

$r_{43}$

$s_{43}$

$r_{44}$

$d_i$

$r_{ij}$

$s_{ij}$

$n_{ij}$

Deterministic and Small-World Network Models of College Drinking Patterns

Almada, Rodriguez, Thompson, Voss
Simulations - Average School

\[ s_{12} = [0.1, 0.8], s_{24} = [0.1, 0.7], s_{42} = [0.4, 1], s_{23} = [0.01, 0.2], s_{43} = [0.01, 0.2], n_{12} = [0.08, 1], \\
 n_{24} = [0.08, 1], r_{21} = [0.2, 0.09], r_{42} = [0.2, 0.08], r_{24} = [0.01, 0.15], r_{23} = [0.05, 0.1], r_{31} = [0.8, 0.5], r_{43} = [0.05, 0.08] \]

\[ d_1 = 0.1, d_2 = 0.2, d_3 = 0.2, d_4 = 0.2 \]
Network Model - Standard Population at $t_0$

20% Abstainers, 30% Social Drinkers, 6% Problem Drinkers and 44% Bingers
Key Ingredients for Research Projects

- They must be motivated by tangible examples in which science is used that affects the students’ communities in an intimate way.

- They should be designed in a way to allow students to be scientists and take part in the research enterprise.

- The question/problem should focus on what is important to the students and what brings out their passion.

  - Students should be strongly encouraged or mandated to work on a question/problem in which they are passionate.
  - They must design their research topic in consultation with a faculty research mentor or course professor and within the context of what they have learned in the course.

- From day 1 of the course or research program, faculty should make students aware of where the course fits globally, why it is important to learn this material to answer real-world problems, give them some concrete real-world problems that have been addressed in the past (even if answers are just partial), and give them reasons to want to study this material and topic.
Institutional Commitment

Bringing problems to the classroom that are relevant to students requires an interdisciplinary approach and true institutional commitment.

- Forming faculty interdisciplinary groups that are capable of guiding research projects and co-teach courses that bring multiple disciplines together to address and present real-world problems.

- Alternatively, having a group of faculty with interdisciplinary expertise (i.e., applied mathematicians, computational modelers, quantitative sociologists, etc.) that cross multiple departments and even colleges.

- Possible groups within the same college
  - mathematical biology group, systems biology, computational modeling group

- Possible groups between colleges/schools
  - complex systems group, climate change group, mathematical sociology
Examples of Interdisciplinary Courses

- Quantitative human genetics course co-taught by a statistician/mathematician and a genetics/biology faculty
- Forensic science with a lab component co-taught by criminal justice and a pure science faculty (e.g., engineer, biochemist, etc. with expertise in DNA sequencing or image processing)
- Epidemiology course co-taught by a public health and computational/mathematical modeler (that can address health issues, disparities, epigenetics, and infectious disease models)
- Eye physiology co-taught by an applied mathematician and a faculty from the medical school with expertise in the eye (e.g., the retina)
- Models in math biology co-taught by a math/computer science faculty and a biologist
Examples of Interdisciplinary Projects

- Spread of gangs and fanatic groups
- Modeling the rise of diabetes within a certain environment or population group (either at the population or genetic level)
- Finding a potential way to mitigate diabetes through community projects (e.g., La Comadre)
- Spread of social epidemics such as alcoholism or drug-addiction within a given network (school, neighborhood, etc.)
Potential Big Challenge and Learning Curve

Forming interdisciplinary groups that can truly transform STEM education (particularly for URMs and women) will be almost impossible for faculty (including interdisciplinary faculty) without support.

- Student-driven project might not necessarily be within the faculty’s expertise or training.
- Faculty will need to seek collaborators that can co-lead students’ projects.
- Faculty will need to learn to communicate and transmit ideas outside of her/his field to potential collaborators (i.e., co-research advisors/mentors).
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Faculty must be fully committed:

- willing to put the extra time to mentor students and guide student projects;
- willing to learn new topics and areas outside her/his comfort zone.
An Investment from the University

The efforts of one or a few faculty members will not be sufficient to bring about real change in STEM education.

Administrators must be willing to invest in these systematic changes.

- Give faculty perks and benefits for transforming and sustaining STEM education through interdisciplinary work.
  - E.g., course releases, monetary awards, stipend for research supplies and expenses.
- Facilitate the creation and sustainability of interdisciplinary groups.
  - E.g., training workshops, funding for interdisciplinary conferences, seed money to springboard their group research.
Win-win Situation for Everybody

- **For faculty**
  - new collaboration and more publications.
  - new research agenda that branches into other fields
  - expansion of expertise and research networks both within and outside of institution
  - potential course releases after X semesters of co-advising research projects or co-teaching a course
  - potential seed funding or small stipend for supplies (e.g., computer software) and research meetings

- **For administrators and institution**
  - attain higher success among URMs and women in STEM
  - achieve access, excellence, and impact within STEM education
  - entice partnerships with community leaders and the communities
  - can “sell” the collaboration to alumni as having a real impact in society
  - can lead to new grant possibilities

- **For students**
  - will teach them to follow their passions to make a difference even if the problem hasn’t been approached before or not in that way
Thank you!

Questions?