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# POLICY INNOVATIONS TO ENHANCE THE STEM TALENT PIPELINE

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# Overview

- Enhancing K-12 STEM Readiness
- Enhancing STEM Major Retention in College

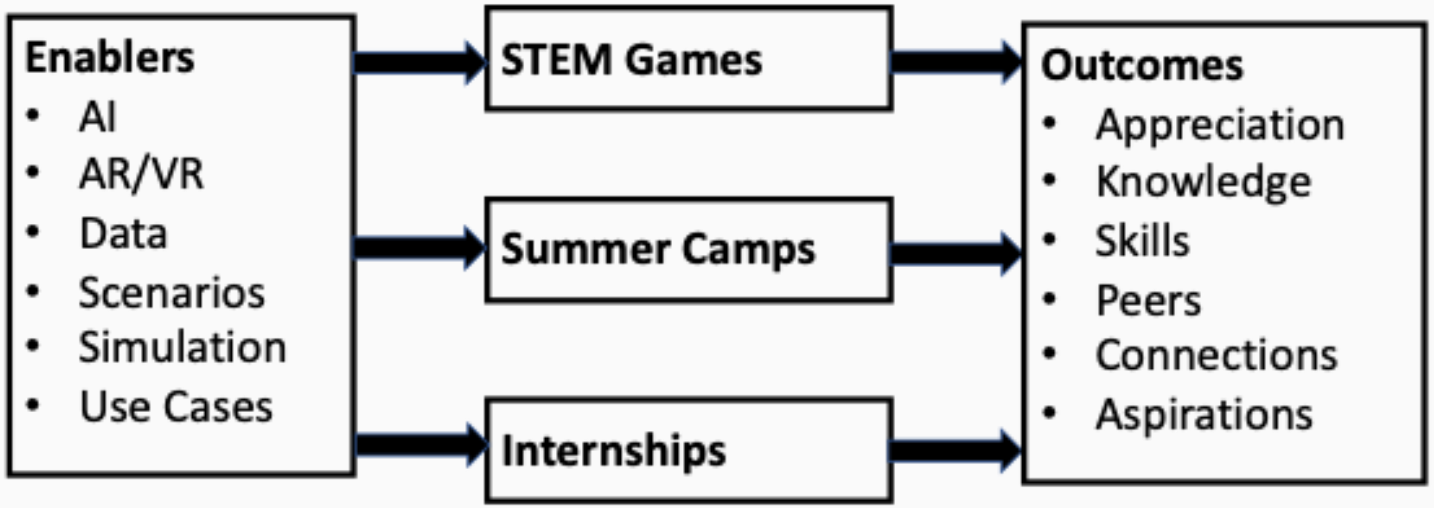
# STEM Talent Pipeline

- 16% of K-12 graduates are STEM ready
- 50% drop out of STEM majors in college
- 60% of STEM college graduates pursue non-STEM careers
- 3.2% of K-12 graduates pursue STEM careers

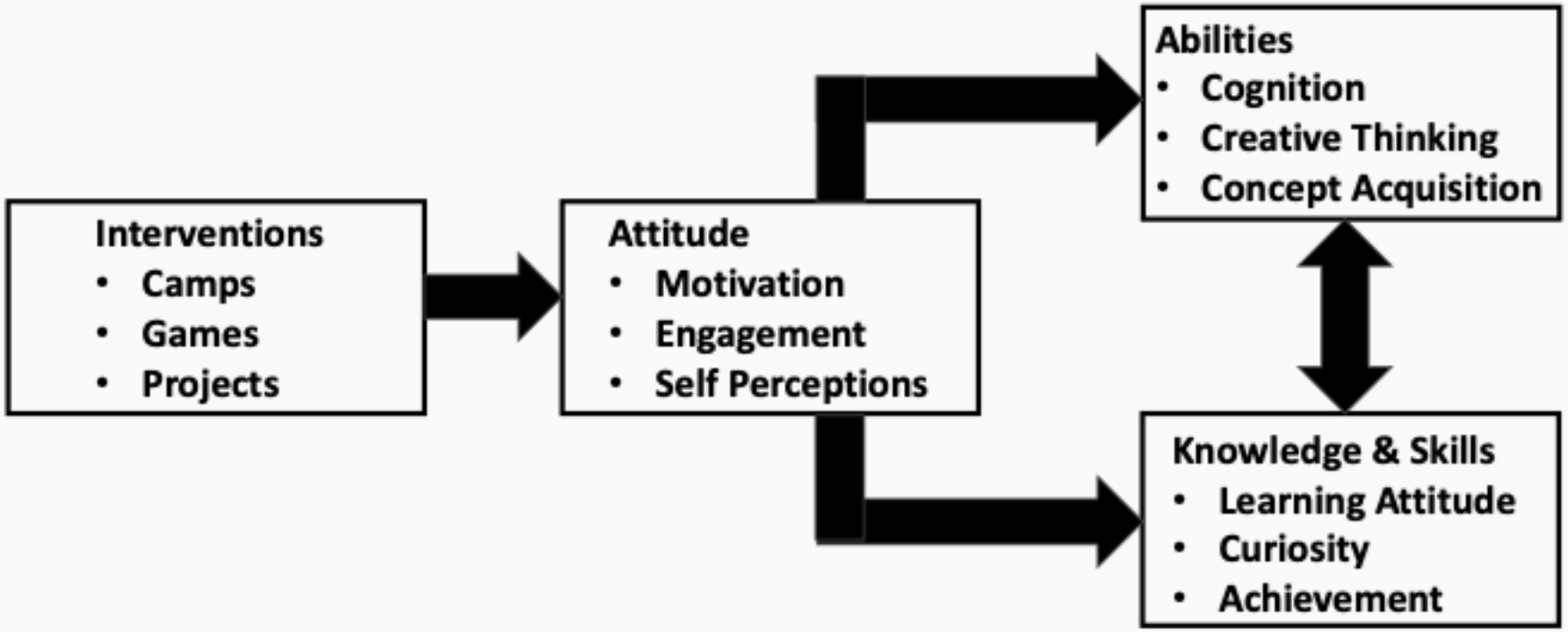
# Enhancing STEM Readiness

- Immersive STEM Experiences
- Interventions, Attitudes & Abilities
- Games That Enhance K-12 Outcomes
- Nature of Games
- Observations on Games

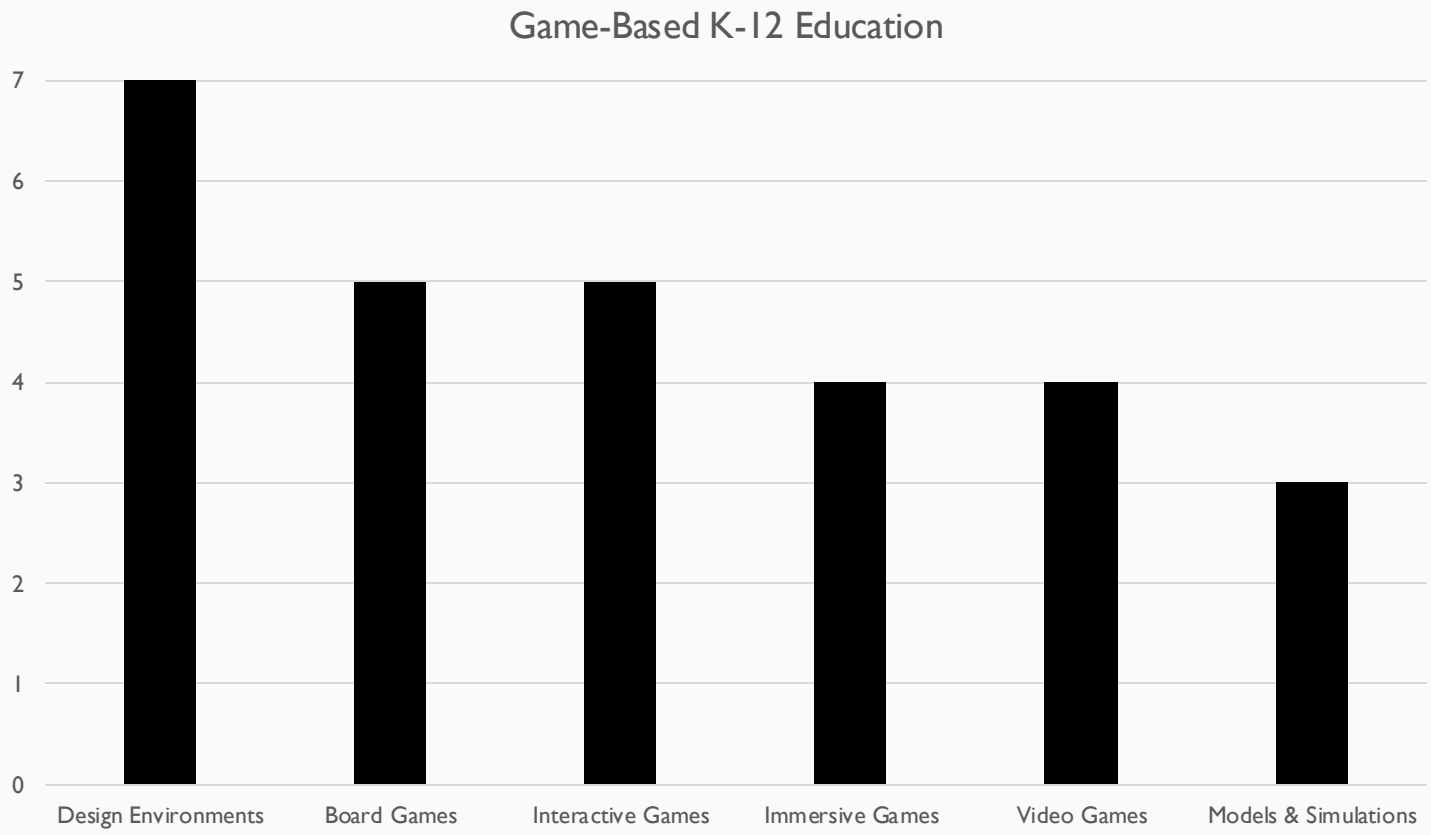
# Immersive STEM Experiences



# Interventions, Attitudes & Abilities



# Games That Enhance K-12 Outcomes



# Nature of Games

- Board games and video games tend to be targeted at younger children, often involving familiar games and video games that conclude with an online quiz.
- A few games involve interactive models and simulations, for example, science concept acquisition.
- For many games, the models and simulations are embedded in the game and are used to project future games states, but students do not interact directly with these models and simulations.

# Observations on Games

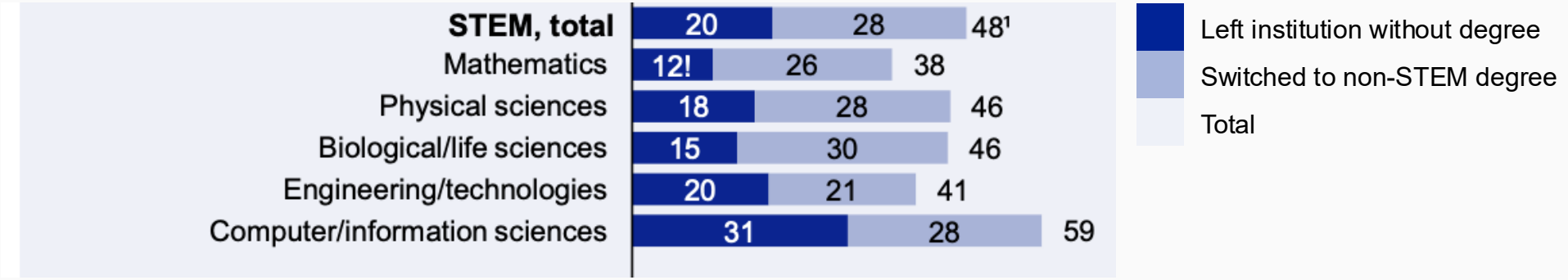
- These observations are based on several hundred studies of the efficacy of games for K-12 education, including several meta-analyses
- Games are more likely to contribute to achieving educational objectives if they are specifically designed to meet these objectives – we return to this need later.
- For older students, games often involve interactive, and possibly immersive, environments to support problem understanding and solution design
- For younger students, games are usually board games, often computer-generated, or videos that involves quizzes to prompt student understanding of content

# THE POWER OF GAMES

## *Business Impacts & Opportunities for Innovation*

# STEM pipeline in college

- STEM students support many engineering jobs that are critical to national priorities (e.g., defense)
- Only half enrolling in a STEM degree eventually graduate with one after 4-6 years
- A wide range of literature on factors affecting retention, but limited avenues to test interventions
- **Impetus for a modeling tool to calibrate policy interventions to raise STEM retention**



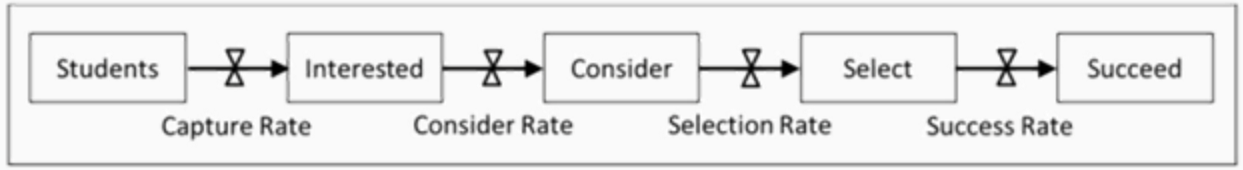

***Percentage of bachelor's degree students who left STEM, by major fields entered (2003-2009)***

*Source: Chen, X., and Soldner, M., "STEM Attrition: College Students' Paths Into and Out of STEM Fields Statistical Analysis Report," 2013.*

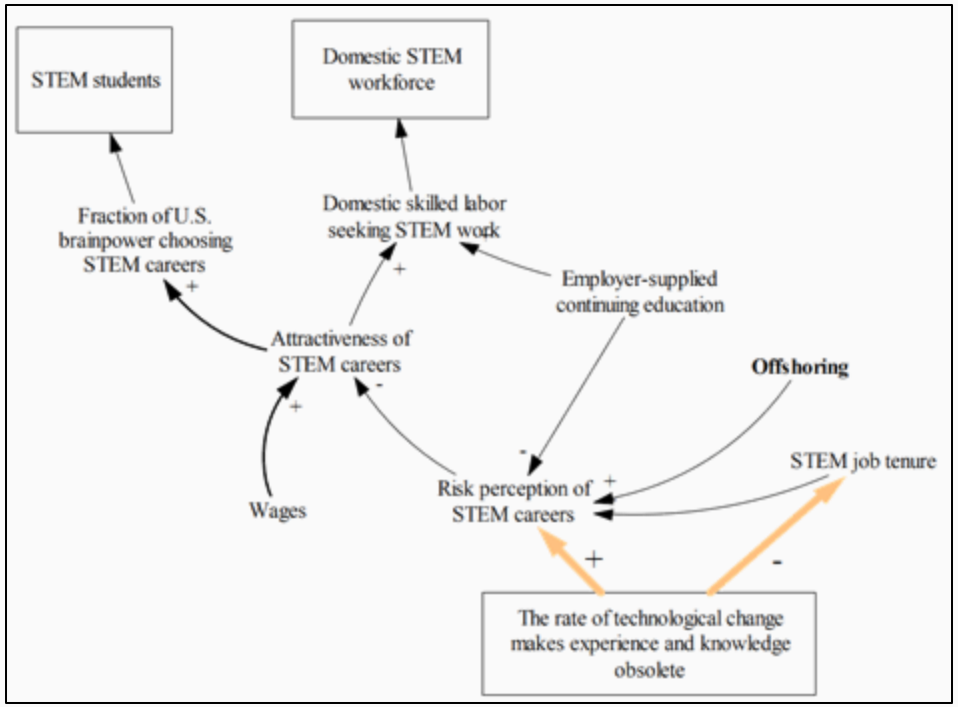
# Why system dynamics?

- Modeling approach that enables analysis of cause-and-effect relationships within complex systems

- Useful in many domains, including in supply and demand matching problems
- Also successfully applied to other parts of the STEM pipeline (e.g., STEM major declaration, STEM career attractiveness)
- Less focus on modeling factors within the college education segment
- Our research aims to fill this gap, given high STEM attrition rates at college level

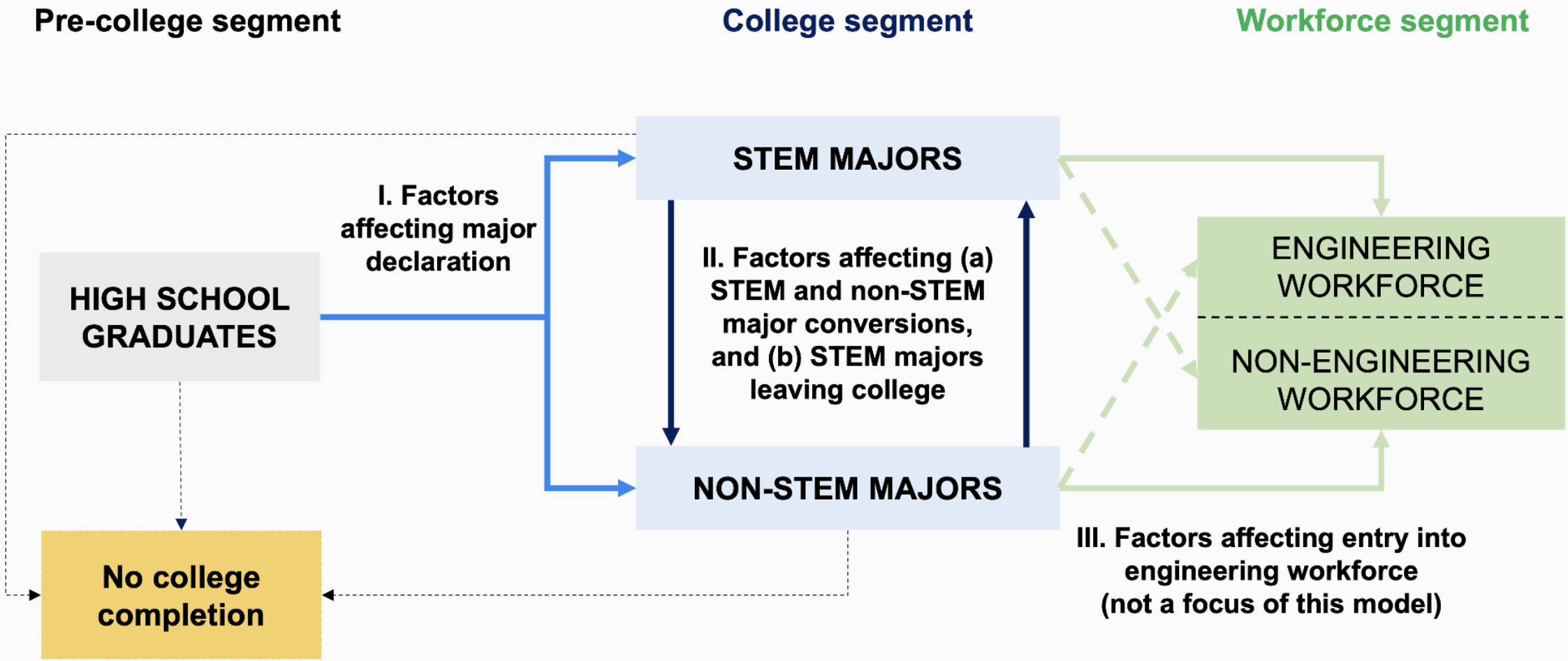



***SD modelling of STEM major declaration***
*Source: Appel, D. C., and Mansouri, M., "System Dynamics Modeling of the STEM Education and Outreach Career Pipeline," IEEE Transactions on Technology and Society, 2022.*

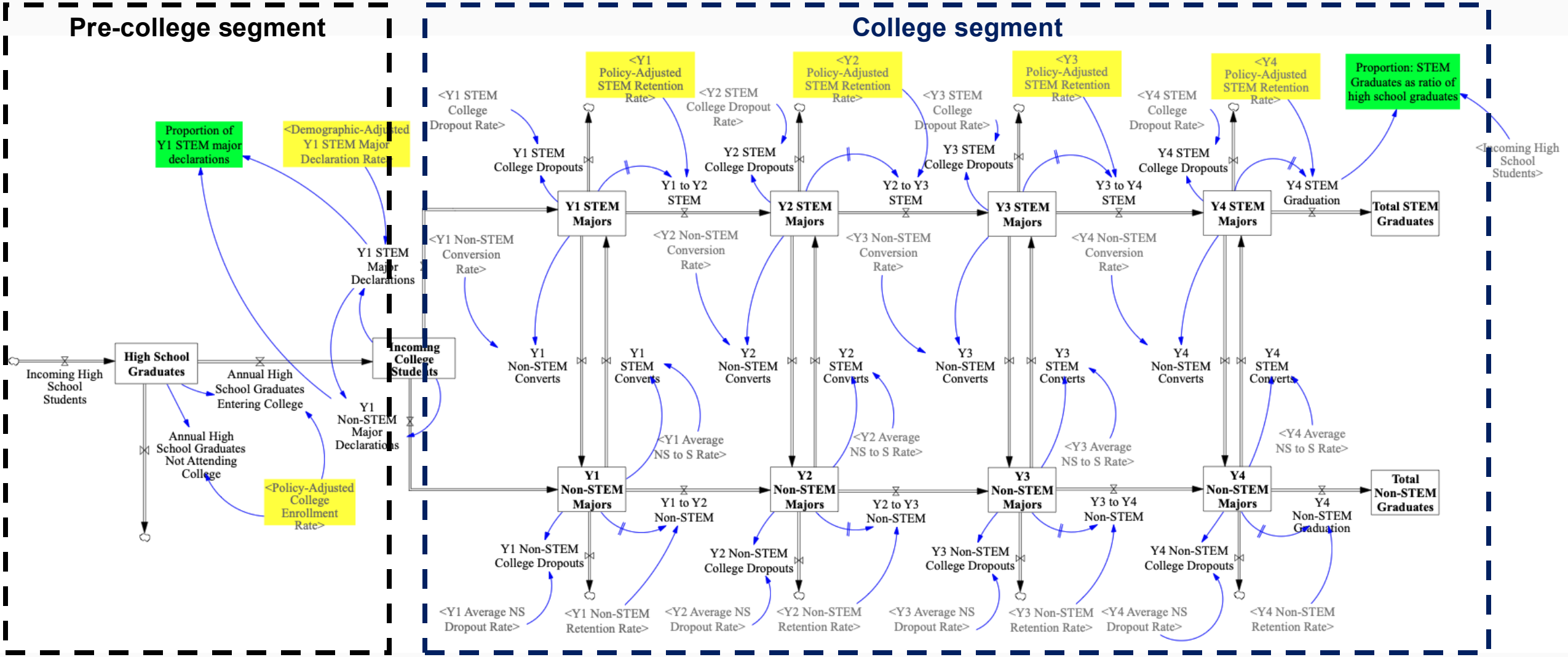



***SD modelling of STEM career attractiveness***
*Source: Kelic, A., and Zagonel, A. A., "Science Technology Engineering and Mathematics (STEM) Career Attractiveness." 2009.*

# Conceptual model of STEM pipeline (high school to workforce)



# System dynamics model of STEM pipeline



# Data sources

## A variety of data sources was used to design, calibrate, and test model

I. Demographic factors affecting STEM **major declaration** rates

**Regression analysis of High School Longitudinal Study of 2009 (HSLS:09)**

II(a). "Baseline" STEM **retention, conversion, and dropout** rates

**University-specific student transcript data**

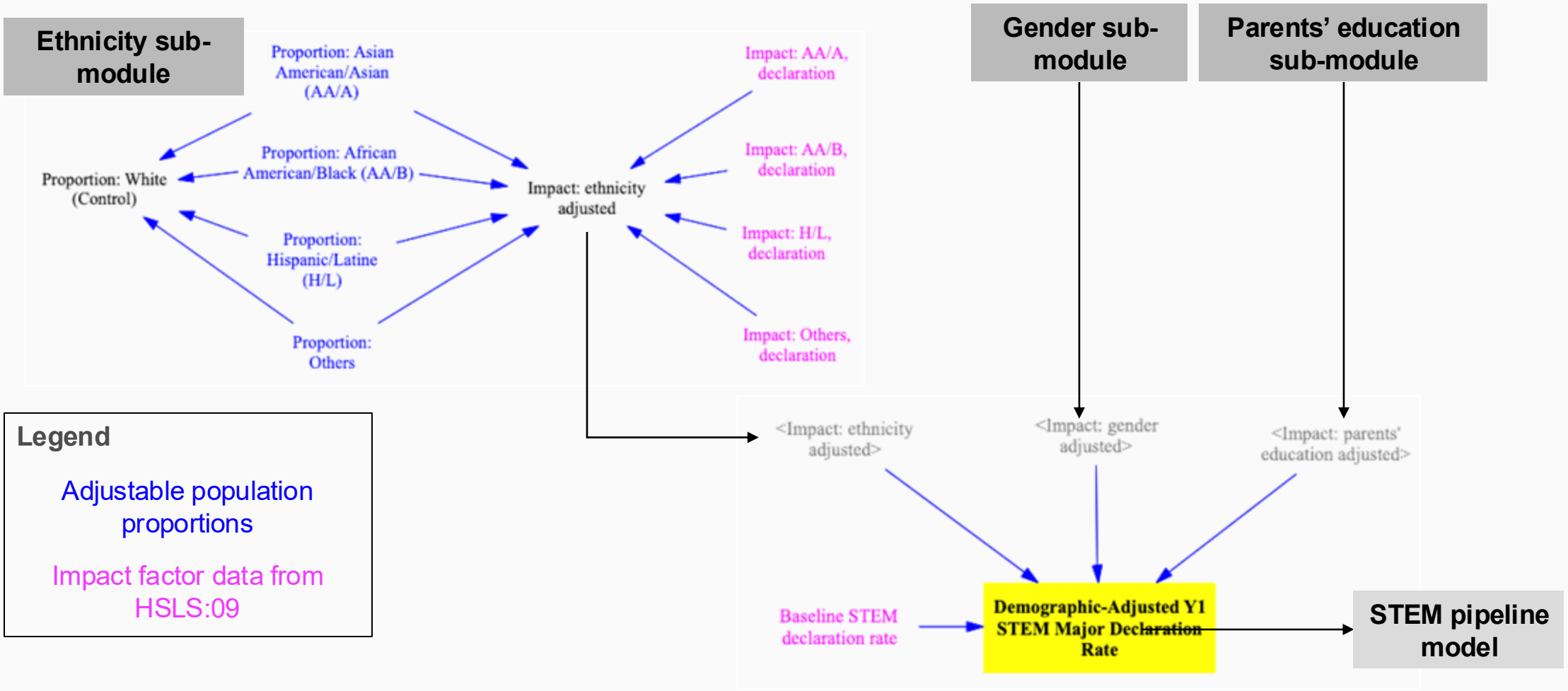
II(b). **Policy** impact on STEM retention

**reference baseline rates to evaluate policy impact*

**Literature review / meta-analysis**

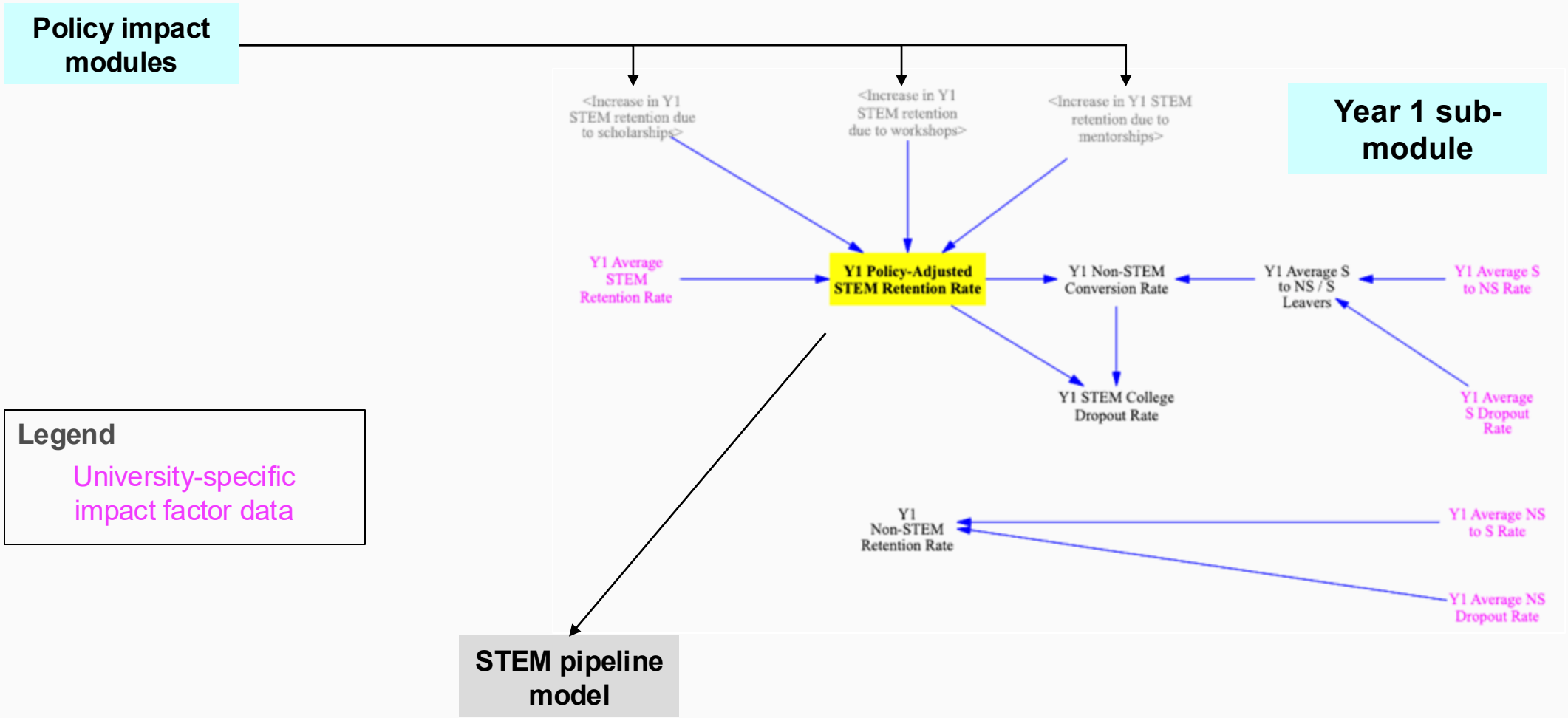
# Demographic impact module

- Calibrated with HSLS:09 data, with adjustable population proportions to match different scenarios/contexts



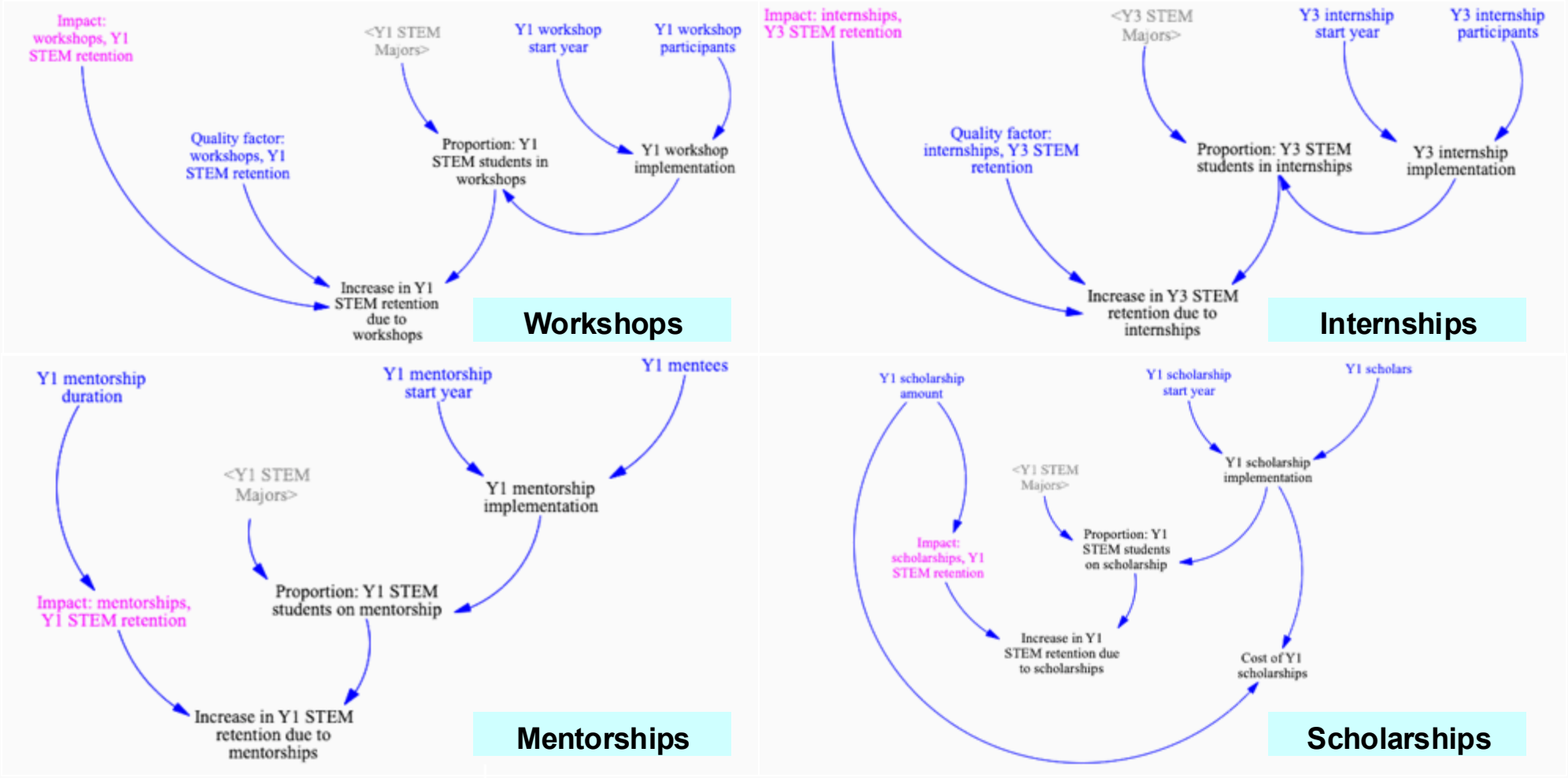
# Year-to-year college retention and flow modules

- Initialized with university-specific data for test scenarios; can be recalibrated with national, statewide, or other college-specific data



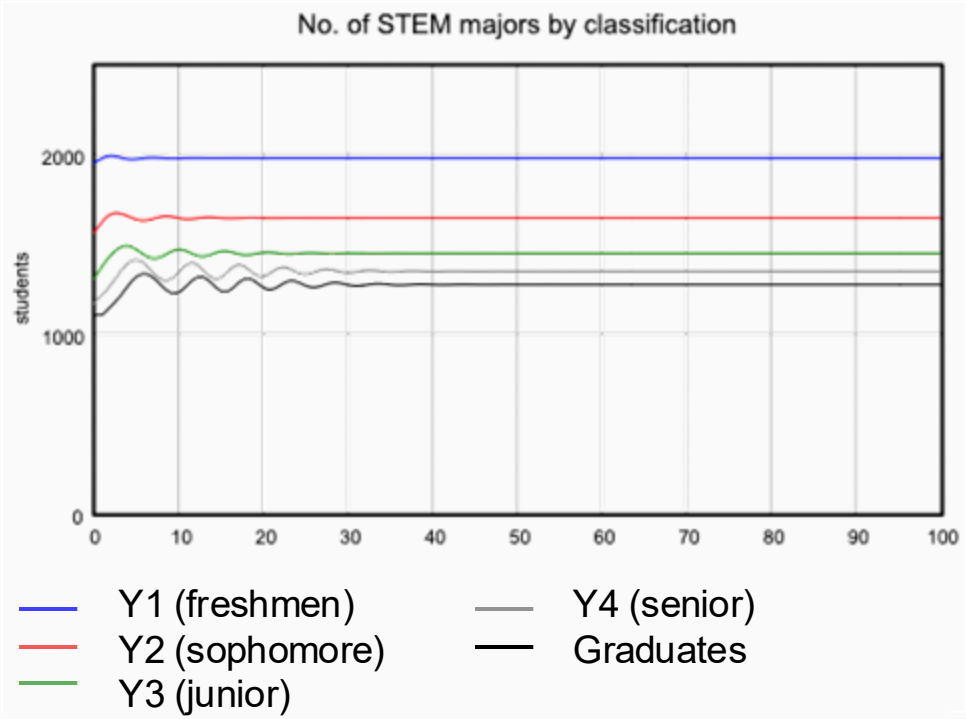
# Four policy impact modules

- Customizable parameters: target group(s), year and duration of implementation, capacity, cost, and policy-specific variables (e.g., scholarship amount)



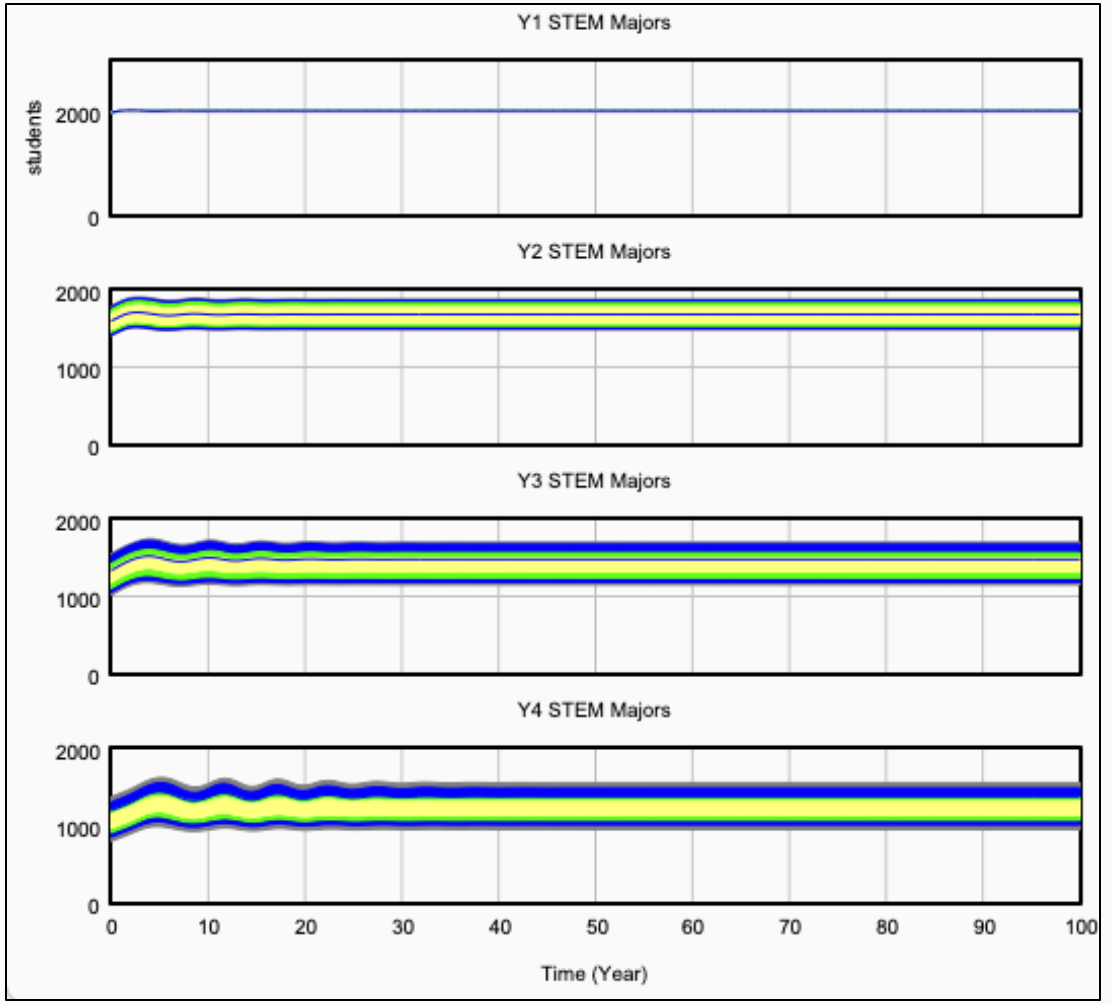
# Functionality – mean and variance analysis (no policy intervention)

## Baseline STEM retention numbers, no variance




- Mean no. of STEM majors **decreases** from Y1 to graduation due to attrition
- Variance propagates through STEM pipeline and **increases uncertainty** from Y1 to Y4

## Baseline STEM retention numbers, uniform distribution, Monte Carlo analysis

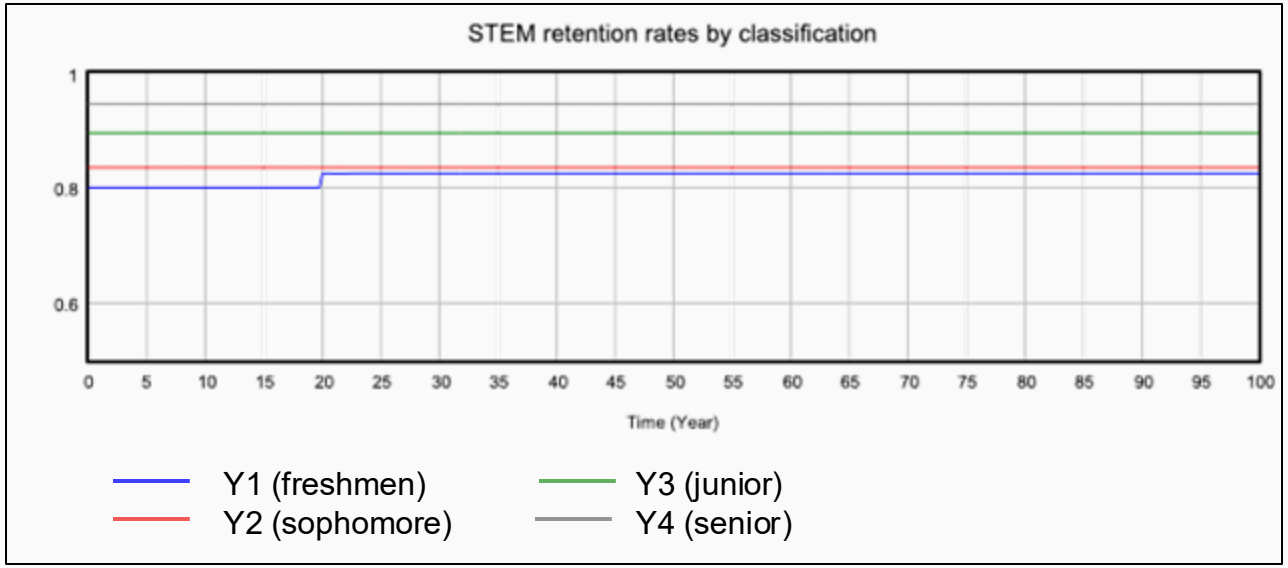


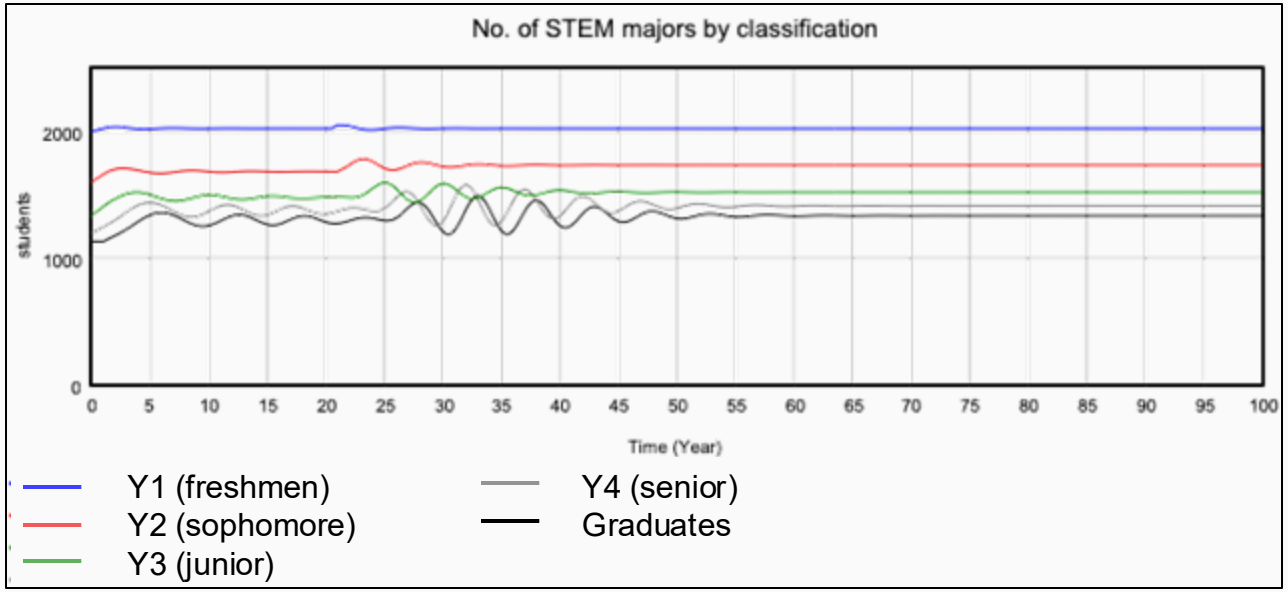
# Functionality – policy impact analysis (workshops)

- Scenario: 500 workshop places for STEM-oriented freshmen (from t=20)

- Workshops → **support for college transition / STEM coursework** → sustained STEM interest
- **Y1 overall retention rate increases** at t = 20
- Equilibrium no. of STEM majors increase proportionately at every level, starting from t = 20
- Similar analyses can be applied to other policy interventions

Y1 (freshmen)
Y2 (sophomore)
Y3 (junior)
Y4 (senior)
Graduates

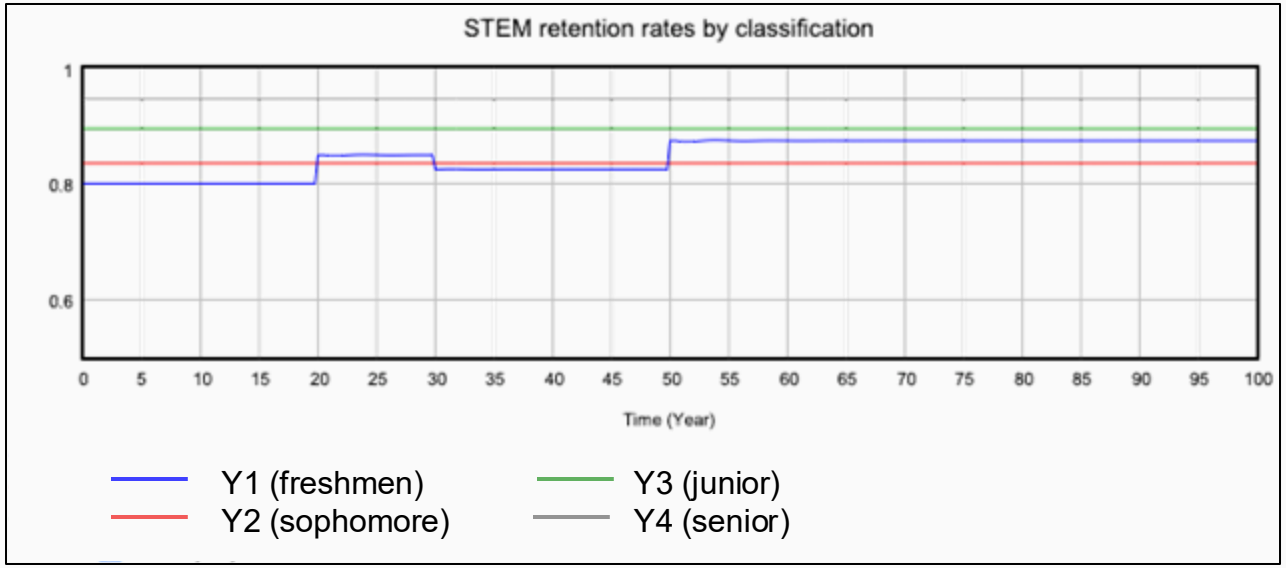


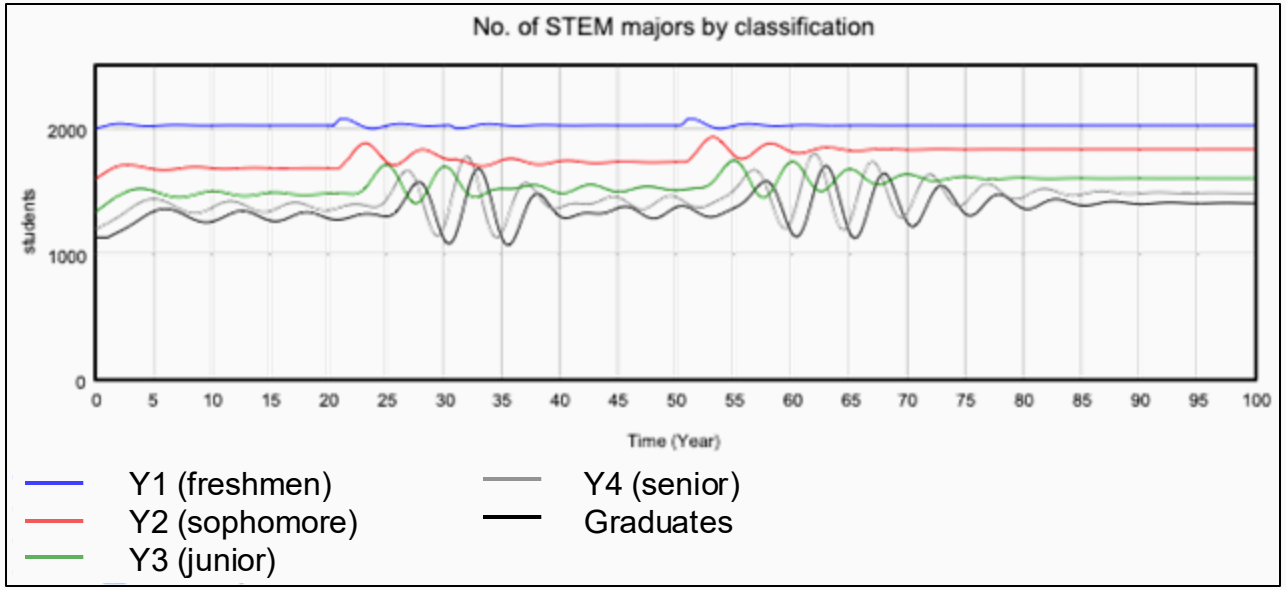



# Functionality – variable policy parameter impact analysis (mentorships)

- Scenario: no. of STEM-oriented freshmen mentees changes from 1000 to 500 to 1500 at t=20, 30, 50

- Mentorship → **academic support** + **personalized guidance** + **student engagement** → strengthened STEM persistence
- **Y1 overall retention rate changes accordingly** at t = 20, 30, 50
- No. of STEM majors at every level also changes accordingly
- Similar analyses can be applied to other policy interventions



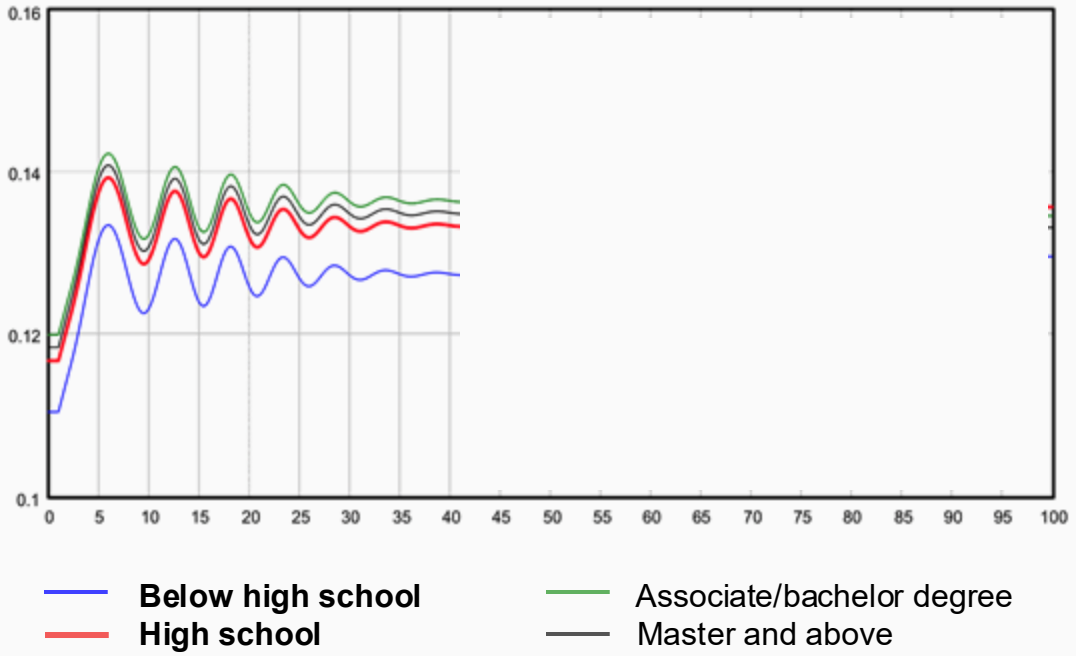



# Functionality – policy impact analysis with cost (scholarships)

- Scenario: 1000 freshmen & sophomore scholarships for first-generation students (from t=40)

- Scholarships → **boost sense of achievement** + **alleviate financial burden** → higher motivation and focus
- Cost assumptions
  - 50% of $2,000/person scholarship born by tuition increase
  - Higher tuition → lower college enrollment
- Y1 and Y2 STEM retention rates increase, but **effects across demographic groups differ**
  - Eligible groups: **slight increase in retention**
  - Non-eligible groups: no positive policy impact but higher tuition costs → **slight decrease in retention**
- Can be applied to other policies

STEM graduates as ratio of high school students
(by parents' education levels)




*Note: policy parameters exaggerated to show model functionality*

# Comments on model limitations

- Model focuses on **analyzing changes in equilibrium levels**
  - Tool to investigate relative changes (e.g., % change in STEM retention due to policy intervention)
  - Not to predict absolute numbers of STEM graduates at a given point in time
- Users should **track uncertainty propagation**
  - With more variables (e.g., in multi-policy scenarios), data uncertainties add up and propagate over time
  - Users should monitor uncertainty bands (e.g., using Monte Carlo) to ensure reasonableness of output
- STEM pipeline also affected by **market dynamics of workforce component**
  - E.g., students with STEM major parents more likely to pursue STEM major
  - Future work will consider closing the feedback loop from workforce factors to capture longer term trends (e.g., 20+ years)
- **Model validation** against historical trend data will improve model confidence
  - Currently limited by data availability

# Conclusions

- STEM retention is a complex problem. **Data is often qualitative**, and in general a **large amount of data is necessary** to properly understand the dynamics
- High school and universities have slightly different factors and incentives that impact the STEM pipeline (flow of students from K-12 to college to workforce)
- For high school, intensive literature review and data collection showed the **importance of interactivity and games**. A large database of relevant studies has been collected
- For college, we built a System Dynamics model to **aid decision-makers to design and prioritize effective interventions** to raise college STEM retention and bolster the U.S. STEM pipeline
  - Model can be calibrated with **multiple data sources** and is **reconfigurable** to suit different test scenarios
  - Test scenarios demonstrated the model's **multiple functionalities** to simulate various aspects of policy impact and identify optimal policy designs
    - Mean and variance analysis
    - Policy impact analysis
    - Variable policy parameters
    - Cost and benefit analysis
- Future work: expand the databases, and improve and validate the model to further enhance its modeling and simulation capabilities

# Thank you

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