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Linked Course Communities Can Increase Student Success: Lessons Learned from a Randomized Control Trial

Summary: microCOSM (small Communities Of Science and Mathematics) created linked-course learning communities for first-year STEM majors that aimed to create a more communal view of STEM in two ways. First, the hub of each community was a first-year seminar that utilized one or more UN Sustainable Development Goal to emphasize how STEM can be utilized to address complex social problems. Second, students took two or more classes together as part of the communities, so that they were able to see familiar faces in multiple classes during their first semester. Importantly, microCOSM randomly assigned students to a community or a control group of appropriate but unlinked courses. This rigorous methodology is testing the impact of linked-course learning communities on student success, eliminating the selection effects found in previous research.

Broader Impact: Previous research has consistently shown that groups that are underrepresented in STEM fields (e.g., women, Black and Brown students, people from working-class backgrounds) tend to hold communal values, goals, and preferences. Therefore, creating a communal culture of STEM can make STEM fields more compatible with underserved groups. Results from the randomized controlled trial show that these communities boosted STEM retention into the second semester, especially among students of color, first-generation students, and underprepared students. If these findings persist throughout students' undergraduate years, microCOSM has the potential for broad impacts on the full participation of women and underrepresented racial minorities in STEM and thus the development of a globally competitive STEM workforce by creating conditions under which project participants may thrive as scientists and mathematicians.

Intellectual Merit: While linked-course models have been implemented at various universities, no previous studies have tested the effectiveness of linked-course communities in a randomized controlled trial. Therefore, reported effects of similar communities at other universities may be due to selection biases (i.e., pre-existing differences in which students volunteer to be part of the communities). MicroCOSM addresses this critical gap by utilizing a strong experimental design to test the impact of linked-course communities. The third cohort is still in progress, but analyses on the first two cohorts show increased retention in STEM for students in the communities compared to the control group. Results from the RCT will be included in a future manuscript, but we did publish a paper showing that, in a sample of students prior to microCOSM, the degree to which students are connected with one another by taking classes together is associated with better grades and higher STEM retention (Ramsey et al., 2023).

Institutional Context: BSU is a medium-sized, public, Master's comprehensive institution with 8,172 undergraduate students and 1,002 enrolled in the College of Science and Math. Underrepresented students of color comprise 35% of the College compared to 28% of the university. University-wide, 33% of students receive Pell Aid (low-income) and 48% of students are first generation (neither parent attained a 4-year degree).

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Study Design: After completing placement testing, first-year students are divided into two groups: community members and a control group. Students are assigned to community / control in pairs, accounting for major, gender, race, income, and whether the student is ready to take the 1st course in their science or mathematics major. Partial schedules are then built for all students that include recommendations of specific sections of the first mathematics course needed for the student's major and appropriate courses in their major pathway. Students opt into the study by registering for the recommended courses.

<table>
<tr><th colspan="2">Recommended Course Section Listing</th></tr>
<tr><th>Community Members (Linked Courses)</th><th>Control Group (Unlinked Courses)</th></tr>
<tr><td>1. Common First Year Seminar on UN Sustainable Development Goal in STEM
2. Appropriate Mathematics Course
3. First Course in Major (if ready)
  a. Lab Section, if required
  b. Small Group (recitation) sections, if required
4. Public Speaking (if not ready for major)</td><td>1. Appropriate Mathematics Course
2. First Course in Major (if ready)
  a. Lab Section, if required
  b. Small Group (recitation) sections, if required
3. A general education requirement class (if not ready)</td></tr>
</table>

All members of a given community take a common First Year Seminar. Students in that community with the same major enroll in the same first course of their major, same lab section, and same small group section if needed. Students in control groups are recommended specific sections intended to equally spread students across different classes.

Study Participants: Cohorts ran in Fall 2021, Fall 2022, and Fall 2023. Our first cohort was smaller than anticipated due to challenges with enrolling students post-pandemic.

	First Cohort (2021)	**Second Cohort (2022)**	**Third Cohort (2023)**
Total Number of First-Year CoSM Students	176	226	218
Number of Students in the Study	76	125	115
Community Group	30	56	51
Control Group	46	69	64
STEM-Ready	46	83	92
STEM-Not-Ready	30	42	23
Additional Students in the College	100	101	103
Did not consent	34	71	70
Did not answer	36	16	18
Not invited	30	14	15
Acceptance Rate into the Study	52%	59%	57%

Registration and Enrollment Process: A very big part of our study was to randomly assign students into communities and get them to accept this schedule. Moving forward, we want to make sure that we achieve equity in the participation rates in the communities of underserved students. We found that first generation students were substantially more likely to delay placement testing, reducing their ability to make good schedules. By saving seats for students in the communities, we achieved a population balance of under-represented students in the communities. In follow-up work, we are planning to study how to best accomplish this equity goal. Steps in enrollment were as follows.

1. Students complete placement testing.
2. Assign students to control or community groups.
3. Build partial schedules for students that specify exact course *sections*.
4. Email all students a welcome email with instructions on how to register, including the recommended course schedules.
5. Encourage students to watch a video explaining how to register (also briefly describing the goals of the study): https://youtu.be/JeHsGabRqbs .
6. Follow-up with all students through Academic Achievement Center one-on-one advising appointments throughout the summer.

Class sizes: Important to our study is that our class sizes are relatively small. Introductory mathematics classes are capped at 25 students. Most intro science courses are capped between 24 and 32 students. Labs are capped at 16 students, with small group (peer-led recitations) at 8 students.

Data Collected: From institutional data, we acquire self-reported demographic information, grades, credits earned, major, and academic course history. We request that students complete pre- and post-semester surveys that measure STEM belonging, self-efficacy, and their understanding of STEM as a communal or individual exercise.

From the registration history, we construct social network variables. We are interested in how often a student is in class with another student they have previously been in class with. A study of student performance for students starting in fall 2015 and fall 2016 (Ramsey et al., 2023, *Journal of College Student Retention*) found that two social network variables are interesting:

1. the degree, or the number of different peers a particular student has had class with
2. the total number of repeated connections, which measures the number of times a student had class *again* with the same peer added up across all peers.

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Preliminary Results: For the first two cohorts studied in microCOSM, students who participated in the community were retained at the university into the spring semester and retained within STEM in the spring semester at higher rates across all groups. We see statistically significant differences in spring STEM retention for multiple groups, including for traditionally underserved students of color, first-generation students, and students whose mathematics placement was too low to take the first course in their major (Not STEM Ready). Community members seemed to earn higher overall grades with a higher percentage of their credits resulting in A or B grades (Fall AB Rate) and a lower percentage of their credits resulting in D, F, or W grades (Fall DFW Rate) in the fall semester; these differences did not reach statistical significance, but they may when the third cohort is added to the dataset.

	Spring Retention	Spring STEM Retention	Fall AB Rate	Fall DFW Rate
Overall				
Community	93.9%	**91.5%**	.67(.35)	.18(.27)
Control	87.9%	**78.5%**	.59(.35)	.25(.35)
Students of Color				
Community	97.1%	**97.1%**	.64(.34)	.22(.29)
Control	86.0%	**67.4%**	.57(.33)	.29(.36)
First Gen Students				
Community	96.9%	**90.6%**	.65(.35)	.17(.23)
Control	83.0%	**67.9%**	.56(.35)	.31(.39)
Low Income Students				
Community	92.3%	88.5%	.58(.34)	.28(.30)
Control	87.9%	69.7%	.56(.32)	.27(.33)
Not STEM Ready				
Community	97.0%	**93.9%**	.61(.33)	.20(.25)
Control	87.9%	**75.8%**	.49(.33)	.33(.39)
Commuter Students				
Community	92.9%	92.9%	**.77(.33)**	.14(.30)
Control	85.0%	80.0%	**.55(.38)**	.27(.37)
Women				
Community	96.9%	93.8%	.77(.31)	.09(.22)
Control	88.9%	82.2%	.66(.31)	.20(.31)

Table 1: Student success outcomes in the first two cohorts of microCOSM students, comparing success for students randomly assigned to community or control group schedules. Statistically significant differences at the $p<0.05$ level are marked in bold print. AB Rate and DFW Rate refers to the percentage of credits attempted that resulted in grades of A or B and D, F, or W. The standard deviation of the grade rates are provided in parentheses.

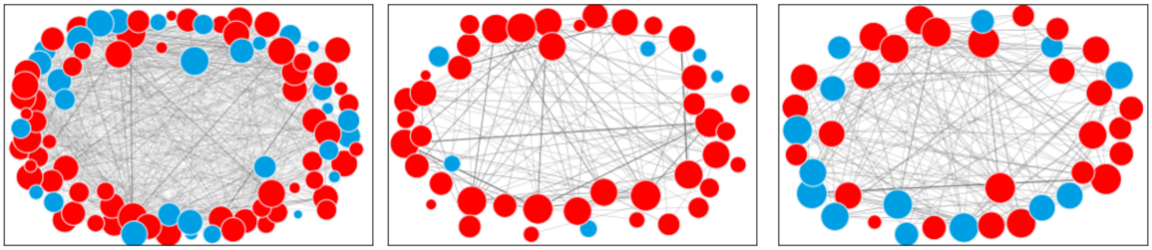
By placing students in communities, we significantly increased their connections with peers as measured by the social network variables.

	Fall Degree	Fall Total Repeated Connections
Community	**26.3(8.0)**	**16.3(8.7)**
Control	**18.0(5.8)**	**7.52(5.2)**

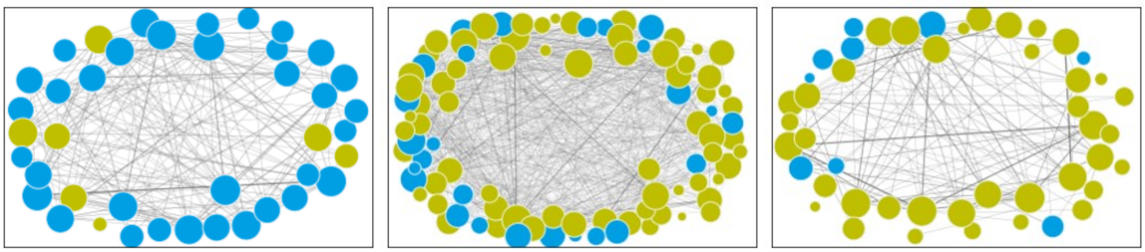
Table 2: The social network variables Degree and Total Repeated Connections in the fall semesters for the community and control groups under microCOSM. The differences in both variables are statistically significant at the $p<0.05$ level, showing that the creation of linked-course communities increased both the connections (degree) and number of times a student was in multiple classes with the same peers (total repeated connections).

Summary from Study of Social Network Analysis: Classroom Connections: A Social Network Analysis of STEM Students at a Regional University https://doi.org/10.1177/15210251231215787

Visualization of Social Network Analysis of 2015 Students by Race and Gender



(a) Computer Science Biological Science Mathematics



(b) Computer Science Biological Science Mathematics

Note. In (a) blue circle = students of color, red circle = White; In (b) blue circle = men, yellow circle = women.

Logistic Regression Analyses Predicting Overall Graduation

	Factor	Estimate	z-value	P-value	Odds Ratio
Model 1	Standardized TRC	0.529	2.64	0.008*	1.70
	Standardized TC	3.23	3.05	0.002*	25.2
	Race	-0.503	-1.45	0.148	0.605
	Gender	-1.40	-4.43	<0.001*	0.248
	Commuter Status	0.233	0.709	0.478	1.26
	First Generation	-0884	-2.84	0.004*	0.413
	Pell Eligibility	-0.637	-1.95	0.052	0.529
Model 2	Standardized MC	0.465	2.12	0.034 *	1.59
	Standardized TC	3.88	3.98	<0.001*	48.3
	Race	-0.494	-1.43	0.152	0.610
	Gender	-1.34	-4.27	<0.001*	0.262
	Commuter Status	0.239	0.73	0.465	1.27
	First Generation	-0.878	-2.85	0.004*	0.416
	Pell Eligibility	-0.656	-0.656	0.044*	0.519

Students with a higher number of total repeated connections and total connections were more likely to graduate as shown in Model 1. Specifically, given other variables fixed, on average, students with one larger standardized total repeated connection are 1.70 times more likely to graduate. Students with one larger standardized total connection are 25 times more likely to graduate, all else being equal. Note that because the standardized total connection variable ranges from 0 to 1, this particular odds ratio is a comparison between students with the very lowest number of connections and those with the very highest, hence the greater magnitude of the odds ratio value.

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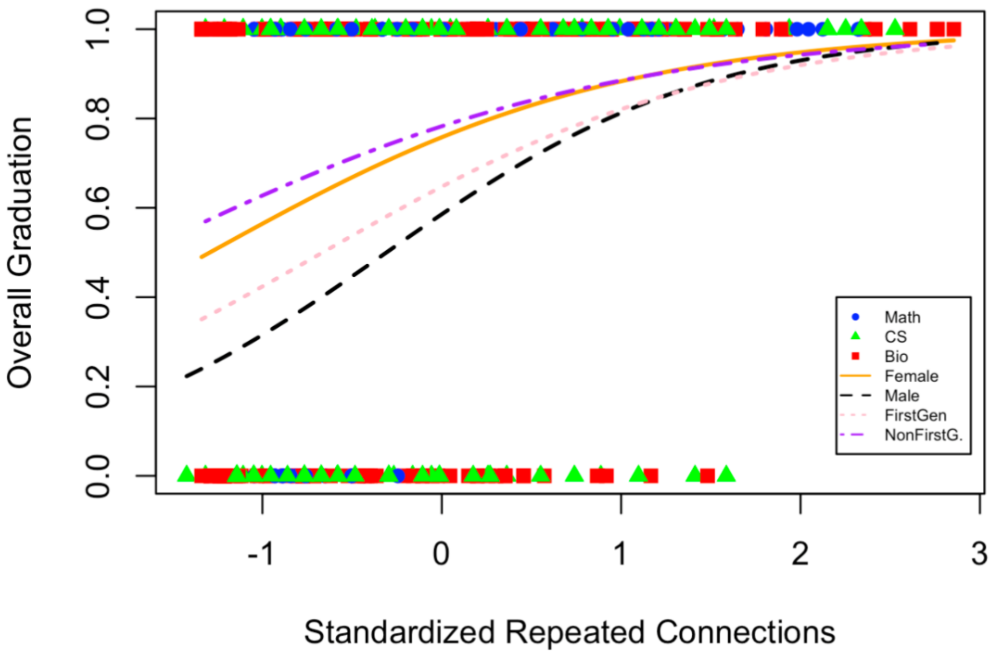
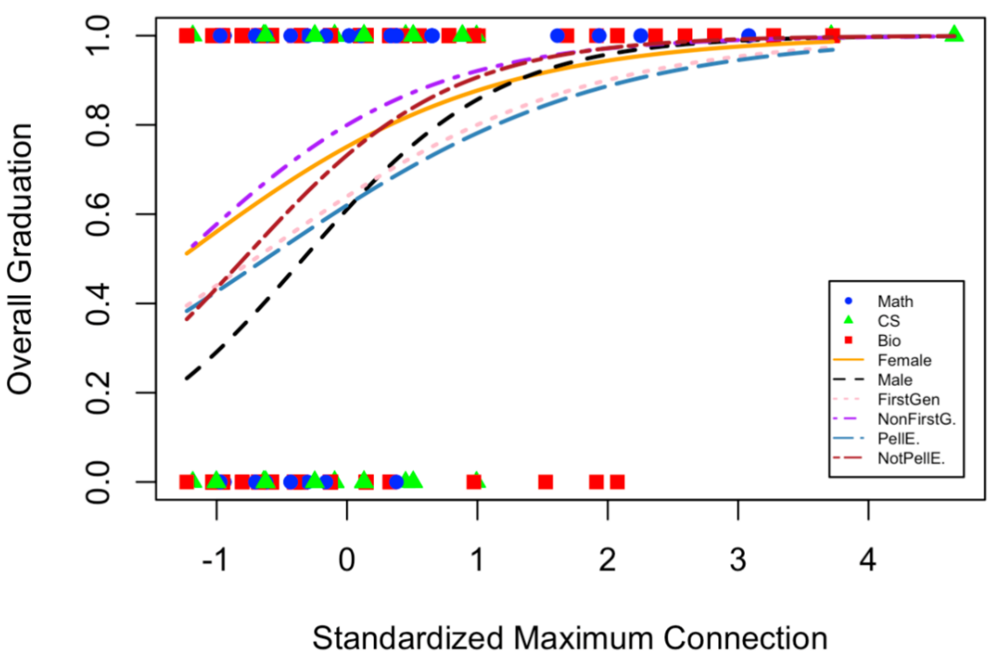
Model 2 results showed that students with a higher number of maximum repeated connections and total connections were more likely to graduate. More precisely, if other variables are held constant, on average, students with one larger standardized maximum repeated connection are 1.59 times more likely to graduate.





Utilizing the UN Sustainable Development Goals in First-Year Seminar Courses for STEM-Linking Course Learning Communities

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Abstract: Four writing-intensive, inquiry-based, three-credits seminars were created to serve as the hub for linked learning communities for first-year students in STEM. Based on United Nations Sustainable Development Goals (UN SDGs), the seminars engaged students in socially-relevant modeling, lab work, and public presentations. The seminars were designed to foster a communal view of science and mathematics, both in terms of the importance of collaboration to STEM success and the application of STEM to real-world problems. Course structures and sample materials will be shared, along with preliminary analysis from a randomized control trial comparing students in the seminars to a control group of peers. In fall 2021, students who participated in the seminars reported increased awareness of the UN SDGs, valued teamwork more highly, and earned more credits and higher grades than control group students. Supported by NSF 2020765, these seminars are part of a study of the effectiveness of learning communities.

MATH 199: Math for Social Dynamics

This seminar, on mathematical modeling, social dynamics, and social justice, aims to provide students with concrete examples of how mathematics can be used to study critical societal issues such as segregation and social injustice.

Modules are built around a central thematic question: **"Is Computational Modeling useful in studying complete social systems and phenomena?"** Three modules (social systems and modeling, economy, and segregation) are guided by

- A literature review
- Class discussions
- Guided computational experiments

UN SDG 1: End poverty in all its forms everywhere.
UN SDG 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

BIOL 199: Clean Water, A Basic Human Right

This seminar integrates biological lab work and public health by understanding water, water sanitation, and water-borne illness. While many people have gained access to improve water sanitation in the past three decades, water borne diseases continue to cause 500,000 deaths per year.

Students read and keep reflective journals on topics that include "What Water is Safe?" and "What does Female Involvement in Water and Sanitation Mean and Why Do We Care?" **The seminar culminates in "Surviving a Zombie Apocalypse"** where students must deliver clean water to a population somewhere in the world by

- Researching current infrastructure
- Identifying materials and labor available
- Planning for scale, building a water filtration system, and testing it

UN SDG 6: Ensure availability & sustainable management of water & sanitation for all.

BIOL 199: HIV: Knowing is Everything

This seminar integrates basic concepts from biology, public health and social sciences to examine the impact of HIV on our society. Discussions focus on HIV biology, public health aspects of HIV management and disease prevention.

After gaining a basic understanding of the world of HIV, **students work collaboratively to create a campus-wide campaign for World HIV/AIDS Day** (December 1). Course activities building to this event include

- Information literacy skills built through digesting documentaries, popular media, and scientific articles
- Class discussions
- Individual research papers and group public campaign work

UN SDG 3: Ensure healthy lives and promote well-being for all at all ages
UN SDG 10: Reduce inequality within and among countries

CHEM 199: Sustainable Nanotechnologies

This seminar helps students discover how unique material properties unlocked at the nanoscale allow us to grow more food, provide clean water, and protect the environment.

"How can the tiniest technologies solve some of the world's largest problems?" Student teams consider one of four UN SDGs, then research, design solutions and educate their classmates through

- Blog posts
- Oral presentations
- Applying nanomaterials to solve world challenges

UN SDG 2: End hunger, achieve food security and improved nutrition & promote sustainable agriculture
UN SDG 6: Ensure availability & sustainable management of water & sanitation for all
UN SDG 7: Ensure access to affordable, reliable, sustainable & modern energy for all
UN SDG 13: Take urgent action to combat change & its impacts

More info: Click the QR codes for class materials or email tkling@bridgew.edu & lramsey@bridgew.edu

Faculty & Course Development

Emphasis placed on

* project- or inquiry-based learning
* group- or team-based assignments
* social relevance
* scaffolding writing & oral assignments

Nilson's *Teaching at its Best*
Bean's *Engaging Ideas*

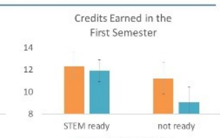
We love these books!

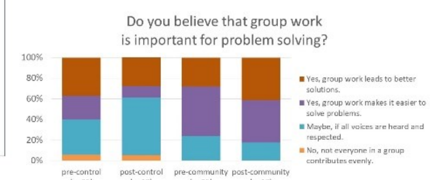
Study Methodology and Aims

UN SDG Seminars are the central hub in linked course communities for first semester students that includes

- A UN SDG-themed Seminar
- An appropriate mathematics course
- Either the 1st course in the students major or a communications course

Using **matched random assignment**, all incoming first-year science and mathematics majors participated in either a linked course community or a randomly created schedule. We then tested the impact of participation on GPA, retention, social belonging, and attitudes about science and mathematics.





Summary of Take-Home Points

- Linked-course communities for first-semester students increased classroom-based peer connections and STEM retention from fall to spring
- Effective first-semester curricular interventions need to attend closely to equity issues in the enrollment and registration process (e.g., timing of placement tests)
- A correlational study of student social networks demonstrated that increased classroom-based peer connections are related to better grades and higher STEM graduation rates

Discussion Questions

- What linked-course learning communities are possible on your campus?
- How else might you increase peer connections in the classroom or via the curriculum?
- How might you use a randomized controlled trial to assess the effectiveness of a curricular intervention on your campus?
    - What challenges could arise?
- For STEM educators, how can you create a more communal culture of STEM at your institution?