Enhancing Undergraduate Systems Thinking and Collaboration through a Sustainable Development focused Team Project

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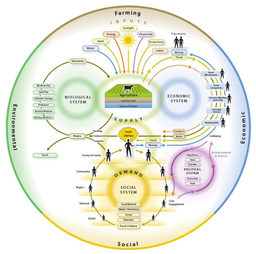
BACKGROUND & MOTIVATION



As the complexity and interdisciplinarity of challenges within agricultural and biological systems increases, it is critical that biological engineering students develop effective **systems thinking** and **collaboration skills**.

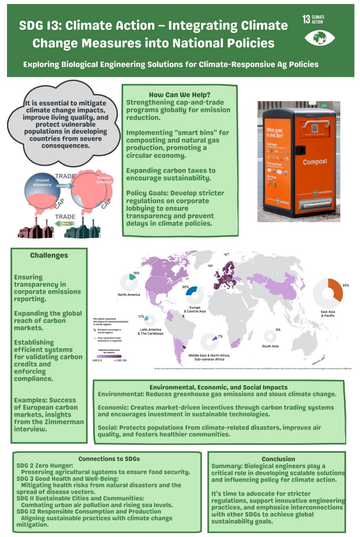
This is echoed by two of the engineering accreditation student learning outcomes, which state students should have:

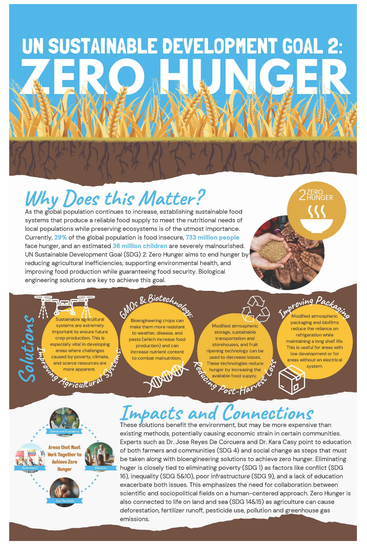
- ❑ *An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must **consider the impact of engineering solutions in global, economic, environmental, and societal contexts***
- ❑ *An ability to **function effectively on a team** whose members together provide leadership, create a collaborative environment, establish goals, plan tasks, and meet objectives.*

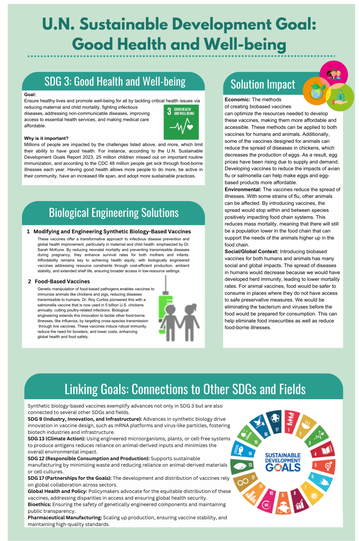
The U.N. Sustainable Development Goals (SDGs) can provide a lens to draw connections between engineering design and broader social and global contexts.

The aim of this study was to investigate the effectiveness of a U.N. Sustainable Development Goal (SDG) focused team research project on enhancing undergraduate BEs' system thinking and teamwork skills.

TEAM PROJECT INFOGRAPHIC EXAMPLES







METHODS

Implemented in **ABE2012C: Introduction to Biological Engineering**

- 30 students, mostly sophomore biological engineering students
- Benefits of teamwork were introduced through a reading assignment
- Systems thinking and sustainability concepts were introduced via:

Lectures:
- What is Biological Engineering
- Systems Thinking
- Sustainable Development Goals

Activities:
- Concept Mapping
- Team Research Project

(1) Concept Mapping Activity

Prompt: **How does my major impact the world?**

Scoring modified from Novak & Gowin (1984):

- Propositions
- Nodes
- Cross-links

(2) Team Project

1. Students ranked SDGs by interest
2. Worked in teams of 3-4, over 10 weeks
3. Developed a team contract, conducted literature review and interviewed 2 experts
4. Prepared and presented an infographic *(team)* and essay *(individual):*
   - Why is the SDG important?
   - How are biological engineers addressing SDG?
   - What are environmental, economic, social, global implications?
   - How does chosen SDG connect to other SDGs?

(3) Pre/Post Surveys

Individual teamwork skills were assessed using the TeamUp rubric (Vaughan et al., 2019) consisting of 28 items across 5 domains: (a) project planning, (b) fostering a team climate, (c) facilitating the contribution of others, (d) managing conflict, and (e) contributing to team project.

Sustainability Attitudes, Behavior and Awareness were assessed via:
- The Sustainability Attitudes Scale (Zwickle & Jones, 2018)
- United Nations ActNow campaign (UN, 2024)
- Awareness Survey (Kirby & Zwickle, 2021)

RESULTS

Students demonstrated an **increase in concept map complexity,** indicating a greater degree of system thinking after the team projects:

Course	PRE Nodes	PRE Props	PRE Cross-Links	PRE Ave. Score	POST Nodes	POST Props	POST Cross-Links	POST Ave. Score	Score Change
Leadership (9)	23	7	21	103	18	6	14	73	-30
Engineering (19)	22	6	18	89	23	6	21	103	14
Env't Science (4)	25	6	34	147	19	4	32	130	-17
Overall (32)	23	5	21	100	21	6	20	98	-2

Students demonstrated **positive change in the majority of teamwork skills** evaluated. The greatest positive change was seen in the domain of fostering a team climate.

Domain	Precent Change	How well do you demonstrate each of the following skills?
Fostering Climate	12.85	Cooperating with others to achieve project goals.
Fostering Climate	12.12	Showing respect for the contributions of others (Even if in disagreement).
Facilitating Others	10.87	Ensuring that decisions are made in a a timely manner.
Managing Conflict	10.76	Assisting the team to stay focused on the overall team goal.
Project Planning	9.28	Willingly taking on a team role that can be completed on time to a quality standard.
Fostering Climate	9.18	Expressing genuine gratitude and praise generously.
Fostering Climate	6.58	Demonstrating self-awareness and emotional regulation.
Facilitating Others	6.50	Establishing and honoring team ground rules.
Managing Conflict	5.53	Participating in the team conflict transformation processes.
Managing Conflict	5.53	Expressing concerns with team/team members in a constructive manner.
Managing Conflict	4.10	Approaching conflict with the aim to de-escalate.
Facilitating Others	3.91	Leading and/or participating in team building processes.
Managing Conflict	3.31	Being open to receiving and reflecting upon criticism of self.
Project Planning	2.67	Defining and agreeing on team goals and objectives.
Project Planning	2.44	Participating in role allocation based on individual skills and learning needs.
Project Planning	1.77	Contributing to the development of the plan.
Contributing to Project	1.20	Adhering to academic standards for writing.
Contributing to Project	1.20	Demonstrating relevant content knowledge.
Facilitating Others	1.11	Participating in consensus-building decision making.
Managing Conflict	-0.52	Minimizing unnecessary conflict by project planning and management.
Fostering Climate	-1.04	Following up with others when there is concern about their feelings or contribution.
Fostering Climate	-1.21	Exhibiting an open, gentle, polite, and friendly manner.
Fostering Climate	-1.73	Actively contributing to team discussions.
Fostering Climate	-2.27	Demonstrating sensitive awareness of the feelings of others (Including interpreting body language).
Project Planning	-2.78	Setting and agreeing to realistic timeframes for each part of the plan.
Project Planning	-3.33	Defining and agreeing on quality standards for each part of the plan.
Contributing to Project	-5.59	Demonstating sufficient technological skills.
Managing Conflict	-6.11	Challenging team processes not conducive to the achievement of team goals.

Some significant positive change was observed in students' attitudes, behaviors and awareness around sustainability. More emphasis can be given to global sustainability issues in the course.

Sustainabilty Attitudes Scales Change

Statement	Pre	Post	Change	P value
The well-being of others affects me.	5.17	5.83	0.66	0.004
Generally speaking, consumerism is not sustainable.	4.79	5.3	0.51	0.046
An unsustainable economy values personal wealth at the costs of others.	5.17	5.61	0.44	0.083
Clean air is part of a good life.	5.75	5.91	0.16	0.201
Equal rights for all people strengthen a community.	5.75	5.91	0.16	0.250
I am willing to put forth a little more effort in my daily life to reduce my environmental impact.	5.46	5.65	0.19	0.314
Biological diversity in itself is good.	5.67	5.83	0.16	0.343
Access to clean water is a universal human right.	5.75	5.87	0.12	0.452
Community cooperation is necessary to solve social problems.	5.75	5.83	0.08	0.579
I believe that many people can work together to solve global problems.	5.67	5.61	-0.06	0.772
Our present consumption of natural resources will result in serious environmental challenges.	5.79	5.83	0.04	0.796

Changes in Internt Towards Sustainabilty Behaviors

Statement	Pre	Post	Change	P-value
Use a reusable water bottle or mug	4.375	5.04	0.665	0.030
Eat a plant-based meal	2.67	3.2	0.53	0.147
Buy second-hand clothes rather than new	2.88	3.44	0.56	0.152
Take a 5-minute or less shower	2.25	2.72	0.47	0.223
Recycle waste (plastic, organic, etc.)	3.83	2.28	-1.55	0.255
Buy local produce and/or meats	2.96	3.28	0.32	0.453
Turn off your lights when leaving the room	4.5	4.68	0.18	0.596
Use reusable bags when shopping	3.25	3.44	0.19	0.648
Use the stairs instead of the elevator	3.79	3.88	0.09	0.796
Unplug electronics or small appliances when not in use	3.04	3.16	0.12	0.803
Walk, bike, or take public transit to a location instead of driving	3.71	3.76	0.05	0.887

Changes is Awareness

Topics	Pre	Post	Change	P-value
United Nations Sustainable Development Goals	2.52	4.36	1.84	0.000
Systems Thinking	2.2	3.8	1.6	0.000
Systems Mapping	2.28	3.68	1.4	0.000
Disciplinary Impacts on Global Challenges	2.4	4.04	1.64	0.000
Global Agricultural Challenges	3.56	4.08	0.52	0.078
Global Environmental Challenges	3.84	4.48	0.64	0.012
Global Economic Challenges	3.16	3.48	0.32	0.290
Global Political Challenges	3.08	3.4	0.32	0.272
Global Social Challenges	3.56	3.92	0.36	0.180
Global Health Challenges	3.6	3.96	0.36	0.214

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