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Essentials of the Nurse + Engineer: Integrating Systems Engineering Modeling

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Sarah Oerther

Essentials of the Nurse+Engineer: Integrating Systems Engineering Modeling

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Abstract

Previously, we reported on the development and pilot testing of a course to teach principles of systems engineering to students of environmental engineering at the Missouri University of Science and Technology. The prior publication included quantitative feedback from students collected through anonymous end-of-semester surveys. Recently, we explored the interface of public environmental health nursing and additional disciplines of engineering (i.e., architectural and civil engineering) as further subject matter for the application of systems engineering, particularly in the area of sustainable development. According to the United Nations, the Sustainable Development Goals support the five pillars of people, planet, prosperity, partnerships, and peace, which are known as the 5 Ps of sustainable development. Here within, we share: 1) background on the development of the nurse+engineer, which is a newly described V-shaped professional; 2) content of two course modules that may be used to teach partnership between engineers and nurses to address the challenges of sustainable development using systems engineering; and 3) initial qualitative feedback from students collected through anonymous end-of-semester surveys. Our results suggest that the integration of systems engineering across a range of engineering disciplines (e.g., architectural, civil, and environmental engineering) with the profession of nursing (e.g., public environmental health nursing) offers an opportunity to promote interprofessional education to advance sustainable development, including areas such as life-cycle assessment.

Introduction

The practice of engineering benefits both from the concept of sustainable development (e.g., meeting the needs of the present without compromising the ability of future generations to meet their own needs) and life-cycle principles (e.g., qualitative and quantitative tools to assess the environmental impacts associated with all stages of a product, service, or policy) [1]. In parallel to the profession of engineering, the profession of nursing also has identified that sustainable development and economic concepts, including areas such as life cycle understanding, are important to the practice of nursing [2, 3]. Authors have suggested that there is potential benefit to exploring the interface of engineering and nursing to achieve a better future for humanity [4, 5, 6, 7], and this includes work on convergence research where multiple disciplines collaborate to achieve new solutions to “wicked problems” [8, 9].

A recent scoping review identified 60 published studies in the peer-reviewed literature that included both nursing and engineering research, education, and practice [10]. The analysis of these 60 studies yielded five areas of interdisciplinary collaboration among nurses and engineers [10]. Briefly, these five areas included:

1) patient safety;
2) symptom monitoring and health management;
3) information systems and human resources;
4) education; and
5) communication [10].

This scoping review is an example of the type of systematic approach being used to assess the emergence of the nurse+engineer where the professions of engineering and nursing collaborate to create a better future for humanity and the planet [11, 12, 13, 14].

Although engineering and nursing are distinct professions, the individual researchers, educators, and practitioners who work at the interface among these professions (i.e., the nurse+engineer) represent an example of a what has been termed a V-shaped professional [15]. In contrast to an I-shaped professional who continues to drill deeper and deeper into a single discipline, or a T-shaped professional who balances depth in one discipline with breadth in multiple disciplines, the V-shaped professional is created from a "bending" of two disciplines (e.g., engineering and nursing) to achieve a shared aspiration for the future (i.e., the convergence point where humans may flourish) [8, 11].

Technology available at the interface of engineering and nursing provides a common conceptual framework to advances both disciplines [16]. Interesting, while nursing is clear a profession that employs science, technology, and math, it is not considered a STEM field [17, 18]. While this lack of recognition of nursing as a STEM profession may create barriers to collaboration, professional growth, and research funding [19], the similarities among the professions of environmental public health nursing and environmental engineering offer an opportunity for collaboration in the area of STEMpathy – of the integration of STEM with empathetic, or caring, professions [20, 21, 22].

According to the United States Bureau of Labor Statistics (US BLS), job code 29-1141 describes that, "Registered nurses [RNs] assess patient health problems and needs, develop and implement nursing care plans, and maintain medical records. [They] administer nursing care to ill, injured, convalescent, or disabled patients. [They] may advise patients on health maintenance and disease prevention or provide case management," [23]. The ABET EAC program criteria [24] for systems and similarly named programs states that, "the structure of the curriculum must provide both breadth and depth across the range of engineering topics implied by the title of the program, [including] engineering topics necessary to define, synthesize, analyze, design, and evaluate complex systems containing hardware and software, and human elements (where appropriate), in a holistic manner across the lifecycles [as well as] systems design and analysis topics, such as decision analysis, risk analysis (cost, schedule and performance), trade-off analysis, optimization, modeling based engineering, simulation, sensitivity analysis techniques, or requirements engineering," [24]. From the USBLS definition of nursing and the ABET EAC program criteria of systems engineer, one may surmise that nurses and engineers share some areas of professional practice. For example, nurses collect data, assemble plans, and implement holistic care. Systems engineers follow a similar approach of collecting data, creating and evaluating models, and offering suggestions based in the learning from the models. Therefore, based upon this background description of nursing and engineering, the guiding hypothesis for the work conducted as part of this current study is the belief that systems engineering is an appropriate framework to empower nurses and engineers to work together to promote sustainable development, which includes aspects of people, planet, prosperity, partnerships, and peace (also known as the five Ps).

To begin to explore this hypothesis, we modified an existing systems engineering course to include modules that introduced problems that could be addressed through the integration of engineering and nursing approaches. The existing course taught principles of systems engineering to students of environmental engineering [25]. To modify the course, students from additional disciplines of engineering were invited to participate in the course, and examples of sustainable development were incorporated into the course. Specifically, students of architectural and civil engineering joined students of environmental engineering, and course modules examining sustainably providing food security in Central America and throughout the Caribbean were included. The topics for these additional modules were selected because of their value both as examples for system engineering as well as for public environmental health nursing.

Here within we provide further detail of the course content at the interface of public environmental health nursing, architectural engineering, and civil engineering as a further example of systems engineering advancing principles of sustainable development. In particular, we present two course modules, specifically:

1) constructing a model that relates bad weather in Central America with poverty and poor food security contributing to northward migration to the U.S. southern border [26, 27, 28] (see Appendix A); and
2) constructing a model that relates bad weather in the Caribbean with poverty and poor food security contributing to illegal drug trafficking from Central and South American to the U.S. [29, 30, 31, 32] (see Appendix B).

Through these two course modules, students of architectural, civil, and environmental engineering engaged with the concept of sustainable development in the context of the practice of nursing and engineering as caring professions employing holistic, life-cycle approaches to decision making. Public environmental health nursing helps to provide some of the solutions to the underlying problems of poverty and poor food security such as supporting healthy communities [33, 34], while architectural, civil, and environmental engineering help to provide some of the solutions to the underlying problems associated with bad weather such as resilient technologies [35, 36, 37]. Together, engineering and nursing offer a V-shaped solution to a better future which supports the economic success and health of local communities. Students in the course are exposed to the additional policy benefit of improving conditions of immigration and drug trafficking that impact the U.S., which is an example of a systems engineering conceptualization of sustainable development and life-cycle assessment.

Methods

<u>Institutional context.</u> Founded in 1870 in Rolla, Missouri, the Missouri University of Science and Technology, or S&T, is a technological research university offering 100 degrees – primarily focused on science, technology, engineering, and math (STEM) – to 7,500 students – including 6,000 undergraduate and 1,500 graduates students.

Course description. The course, 5605 Environmental Systems Modeling is described as, "Introductory course in modeling environmental systems. Course will focus on contaminant fate and transport in the environment. Models will be developed that will include physical, chemical and biological reactions and processes that impact this fate. Prerequisites: Fundamentals/Introduction to Environmental Engineering; Biological Principles of Environmental Engineering; Chemical Principles of Environmental Engineering." As a 5xxx-level, this course is available to upper level undergraduate students (i.e., juniors and seniors) as well as graduate students (including both students pursuing a master's degree or a Doctorate). As an online course, this material is available to students at S&T as well as the three other universities in the Missouri System (Mizzou, University of Missouri Kansas City, and University of Missouri St. Louis) as well as others across the country. This online offering includes students enrolled in programs of nursing.

Module Details. The course was described previously [25]. In brief, students complete required assignments using a flipped classroom format before meeting with the instructor to work on optional, active learning. Models are constructed for different subject matter, including drinking water pollution, air pollution, and sustainability. Details of the module on the subject of Central America/Guatemala and northward migration in response to changes in weather and loss of income/food security due to failing agriculture is provided in Appendix A. Details on the module on the subject of the Caribbean and drug trafficking in response to changes in weather and loss of income/food security due to loss of fishing infrastructure damaged by hurricanes is provided in Appendix B. The authors may be contacted to share further details of the course modules if readers wish to explore modification and adoption to their own teaching.

Results and Discussion

As adopted by the United Nations General Assembly in 2015, the Sustainable Development Goals include 17 specific goals, which are intended to provide a roadmap for human development and planetary health between 2015 and 2030. One way that engineers can contribute to achieving sustainable development is through creating system models to facilitate when decision makers need to explore alternative policies and actions. As part of an existing course on systems engineering [25], two modules were developed, which focus on "systems engineering for sustainable development". As described in Appendix A and Appendix B, a key aspect of both modules was to ask students to consider, "how should the government of the United States balance investments promoting economic development in Central America or the Caribbean versus investments in building additional border security to reduce (illegal) immigration or drug trafficking?"

Concepts from public environmental health nursing were included in the modules, particularly to address the 5 Ps of people, planet, prosperity, peace, and partnerships. While engineers often are comfortable with prosperity (i.e., engineering economics) and planet (i.e., impacts on nature), often engineers are less comfortable with people. Public environmental health nurses work directly with people as patients, where a nurse defines a patient as an individual, family, population, or community. Exploring the interface of public environmental health nursing and systems engineering is an example of partnership. And these modules center the importance of peace as students are asked to consider the broader context of U.S. national security.

As described previously [25], each of the modeling exercises included in these modules requires students to complete six activities, namely:

1) Provide a narrative of the overall problem and identifying important states and relationships;
2) Include the ranges and typical values of states;
3) Include a pictorial representation of the system with explicit notation for states and relationships;
4) List assumptions;
5) Use the assumptions to reduce the model to a solvable sub-model; and
6) Describe the lesson/s learned in the overall exercise [25].

As part of optional work, students may develop and conduct a sensitivity analysis on a mathematical model built from their simplified concept model [25].

Appendix C includes a representative example of the type of response provided by students as part of their answers to these two modules. The structural model developed in Appendix C links environmental issues, such as diarrheal illness in water and toxin contamination in food, with the health of children as well as the cultural history experienced by Mayan-speaking indigenous people living in the Western Highlands of Guatemala. As noted in section "10 Lesson Learned" included in Appendix C, the representative student noted,

> *"My lesson learned from learning about the children in Guatemala is how blessed I have been to have been born into a middle class family in America and how strange the human body can be. …*
> *The strangest thing I learned is that the height of a population is not always tied to genetics. …*
> *Humans are a lot more similar than we give each other credit for and the barriers of race, genetics, or even politics are very thin.* ***At the end of the day, everybody is just human*** *[emphasis added]."*

What a powerful statement from a student growing in understanding of people, planet, prosperity, partnerships, and peace, or the 5 Ps.

This example reflects an approach to people that is atypical for many students of engineering who often focus on the technical and economic aspects of engineering design and problem solving. By engaging with aspects of public environmental health nursing, such as understanding people as individuals, families, populations, and communities, this student of engineering learned an important lesson: namely that people are connected to a much greater extent that may be considered in typical engineering design.

The approach from nursing that has been integrated into this course is known as, "Emancipatory Nursing Praxis," [38, 39]. ENP was developed through an international grounded-theory study, which identified critical factors impacting nursing participation in social justice. Particularly, ENP expands the traditional nursing role of "advocate" to also include the role of "ally", which is achieved through personal-professional growth that includes: becoming, awakening, engaging, and transforming [38, 39]. ENP was selected as the nursing approach most appropriate to integrate with systems engineering, because ENP is a mid-range theory that connects grand theories (i.e., above) and nursing practice (i.e., below). As a mid-range theory, ENP is similar to the practical systems engineering models being developed in this course.

Table 1. Selected Comments From Students Submitted Anonymously Via End-of-semester Surveys (Edited to Enhance Readability).

Response No.	**With regards to teaching, what are the strengths of the instructor?**
1	Passionate about helping improve the world. This rubbed off on us and motivated us to think about solving big problems, not just graduating and getting a job.
2	I couldn't have more good things to say about instruction. Excellent teaching style, course organization, and commitment to expectations of adult learning applied to real world problems.
3	We've done many project assignments related to every topic in environmental engineering like air pollution, water pollution, etc., so this is a strong benefit and aspect of the course for students.
4	Without getting into the weeds of computer models, this course teaches us a great overall understanding of the fundamentals of modeling and the key elements. I never felt like we got bogged down with the non-material problems, such as learning programs or software.
5	I obtained more out of this course than almost any other course I have taken. It provided me with new skill set, expanded my ability to solve problems, and exposed me to the complexity of issues
6	I had previously thought cut and dry and formed an ignorant opinion on. This course taught me much about complexity, reducing complexity, and finding solutions by balancing the 5 P's (people, planet, prosperity, partnerships and peace) and determine motivating factors to drive people to solve problems.
Response No.	**What suggestions do you have for improving the quality of instruction?**
7	I would suggest swapping the Guatemala and the Caribbean models. The Caribbean model was solvable and particularly interesting. The Guatemala model was more abstract and would be better suited for the term project.
8	Maybe going over one example model to solve a real life problem during the initial weeks of class would help us to understand better how to approach the rest of the models.
9	Modeling is relevant and an interesting way to think about students future careers and can be applied to just about any situation if not all. The course should be available to younger students so they can use it to help to find out what type of career they want to pursue.
10	The statement, "all models are wrong, some models are useful" gets kind of repetitive. I know why you use it, but maybe you can find a different way of saying the same thing from time to time. Just a suggestion.
11	Showing examples of calculations needed for each model in optional lectures.
12	Specific comments for improvement should be included on graded models when they are returned – this would help us to get better.

As described previously, the existing course was offered in person, via online synchronous, and via online asynchronous modality to upper level undergraduate and graduate students of environmental engineering [25]. Recently, additional student populations were invited to participate, including students of architectural engineering and civil engineering. And two additional course modules were included, which emphasized food security and climate resilience in Central American and throughout the Caribbean. Representative qualitative comments from students participating in the updated course in 2021, 2022, and 2023 are included in Table 1.

In response to an open-ended opportunity to mention comments about the strengths of the instructor, a point raised by students relates to the power of authenticity in the classroom. Students can sense when faculty are sharing a passion, and comments from the students support two important conclusions, namely:

1) teaching content that is important to the instructor comes through to the students and influences their attitudes towards the material; and
2) a pedagogical approach that emphasizes "thinking over programming" as an approach to systems engineering invites diverse students to engage in modeling.

In response to an open-ended opportunity to suggest ways to improve the course, students offered concrete, actionable suggestions. While not all of these need to be implemented, the fact that students offered concrete, actionable suggestions strongly suggests that they hold the belief that the instructor will listen and incorporate feedback. An important conclusion from this is that adult learning (e.g., struggling together, student and instructor) creates a level of mutual respect, which can benefit instruction for future students.

Collectively, the qualitative data collected from students recently enrolled in the course points towards a positive benefit of using systems engineering coupled with public environmental health nursing as a platform to teach sustainable development. Future research should further explore how students of nursing would perceive the course content, and how students of engineering and students of nursing would benefit from interprofessional teams.

Conclusion

Based upon a previously described course in environmental modeling [25], here within we share how working on challenging problems of sustainable development may be facilitated through an approach that leverages systems engineering and modeling. In this article, we shared background information on the nurse+engineer, details of the course and modules on sustainable development, and feedback from students. To solve the persistent, intractable problems facing humanity (e.g., poverty, lack of access to clean drinking water, food insecurity, and the impacts of a changing climate) platforms such as systems engineering offer a viable approach to work to promote V-shaped professionals at the interface of existing disciplines, such as engineering and nursing. Authentic content and a pedagogical approach leveraging adult learning offers an opportunity for the emergence of new V-shaped professionals, such as the nurse+engineer, to integrate systems engineering modeling as an essential professional skill.

References

[1] D.B. Oerther, "Using Modified Mastery Learning to Teach Sustainability and Life-Cycle Principles as Part of Modeling and Design," *Environmental Engineering Science,* vol. 39, pp. 784-795, 2022.

[2] K.W. Dion, D.B. Oerther, and P.M. Davidson, "Nurse Leaders and Financial Literacy: Learning to Become CFO of Me," *Nursing Economic$,* vol. 39, pp. 151-155, 2021.

[3] A. Squires, F.S. Chavez, D.K.H. Messias, G.L. Narsavage, D.B. Oerther, et al, "Sustainable Development & The Year of the Nurse & Midwife – 2020," *Int. J. Nurs. Stud.*, vol. 94, pp. A3-A4, 2019.

[4] M.F. Hendrickson, "The Nurse Engineer: A Way to Better Nursing Information Systems," *Computers in Nursing*, vol. 11, pp. 67-71, 1993.
[5] W. Eisenhauer, "The Time Has Come for Nursing Engineering," *Industrial Engineer*, vol. 47, p. 24, 2015.
[6] R. McMaster, "Is the Fourth Industrial Revolution Relevant to You?" *Nursing and Health Sciences*, vol. 20, pp. 139-141, 2018.
[7] M.E.S. Glasgow, A. Colbert, J. Viator, and S. Cavanagh, "The Nurse-Engineer: A New Role to Improve Nurse Technology Interface and Patient Care Device Innovations," *J. Nurs. Scholarsh.*, vol. 50, pp. 601-611, 2018.
[8] D.B. Oerther, and S. Oerther, "From Interprofessional to Convergence: Nurses Educating V-Shaped Professionals," *Nurse Educ. Pract.,* vol. 53, no. 103047, 2021.
[9] D.B. Oerther, and S. Oerther, "Improving Interprofessional Environmental Health Education Using the Leave No One Behind Framework," *AJPH,* vol. 112, pp. S250-S252, 2022.
[10] Y. Zhou, Z. Li, and Y. Li, "Interdisciplinary Collaboration Between Nursing and Engineering in Health Care: A Scoping Review," *International Journal of Nursing Studies*, vol. 117, no. 103900, 2021.
[11] D.B. Oerther, and M.E. Glasgow, "The Nurse+Engineer as the Prototype V-Shaped Professional," *Nursing Outlook*, vol. 70, pp. 280-291, 2022.
[12] Z. Wang, Y. Zhou, Y.D. Wang, and Z. Li, "The Training System and Characteristics of Graduate Education in Nursing Engineering and Nursing Informatics in the United States," *Chinese Journal of Nursing Education*, vol. 19, pp. 414-410, 2022.
[13] K. Landsman, and K.K. Giuliano, "Nurse-Engineer Partnerships in Academia," *American Journal of Nursing*, vol. 123, pp. 44-46, 2023.
[14] M. Sguanci, S. Mancin, M. Piredda, F. Cordella, N.L. Tagliamonte, et al, "Nursing-Engineering Interdisciplinary Research: A Synthesis of Methodological Approach to Perform Healthcare-Technology Integration Projects," *MethodsX*, vol. 12, no. 102525, 2024.
[15] D.B. Oerther, and S. Oerther, "Comparing Oranges Versus Grapes as a Metaphor of the Nurse+Engineer," *J. Clin. Nurs.*, vol. 31(11-12), pp. e14-e15, 2022.
[16] J. Bayuo, H. Abu-Odah, J.J. Su, and L. Aziato, "Technology: A Metaparadigm Concept of Nursing," *Nursing Inquiry*, vol. 30, no. e12592, 2023.
[17] P.M. Davidson, "Is Nursing a STEM Discipline – Does It Matter and What Can We Do About It?" *Journal of Advanced Nursing*, vol. 76, p. 1-3, 2019.
[18] C. Green, and L. John, "Should Nursing be Considered a STEM Profession?" *Nurs. Forum*, vol. 55, pp. 205-210, 2020.
[19] C. Dreisbach, M.L. Wright, R.K. Walker, H.D. Byon, and J. Keim-Malpass, "Nursing Science as a Federally-Recognized STEM Degree: A Call to Action for the United States With Global Implications," *International Journal of Nursing Studies Advances*, vol. 4, no. 100084, 2022.
[20] P.S. Yoder-Wise, "From STEM to STEAM," *Journal of Continuing Education in Nursing*, vol. 49, pp. 443-444, 2018.
[21] D.B. Oerther, and C.A. Peters, "Educating Heads, Hands, and Hearts in the COVID-19 Classroom," *Environ. Eng. Sci.*, vol. 37, pp. 303, 2020.
[22] D.B. Oerther, L. Gautham, and N. Folbre, "Environmental Engineering as Care for Human Welfare and Planetary Health," *J. Environ. Eng.*, vol. 148, no. 04022029, 2022.
[23] USBLS, *Occupational Employment and Wages, May 2022: 29-1141: Registered Nurses*. Washington, DC: United States Bureau of Labor Statistics, 2022. https://www.bls.gov/oes/current/oes291141.htm.
[24] ABET, *Criteria for Accrediting Engineering Programs, 2022-2023*. Baltimore, MD: ABET Inc, 2022. [Online] Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/.
[25] D.B. Oerther, "Introduction to Environmental Modeling: Results from a Three-Year Pilot," in *ASEE Annual Conference & Exposition, Tampa, Florida, DATE, 2019*. [Online] Available: https://www.doi.org/10.18260/1-2--33020.
[26] A. Linke, S. Leutert, J. Busby, M. Duque, M. Shawcroft, and S. Brewer, "Dry Growing Seasons Predicted Central America Migration to the US From 2012 to 2018," *Scientific Reports*, vol. 12, no. 18400. [Online] Available: https://www.undp.org/sites/g/files/zskgke326/files/migration/oslo_governance_centre/d8dca416c204cc6fdbe409ce38b45533a2b454e6657bca1a6368daefa5f5d96b.pdf.

[27] D.B. Oerther, "An Example of Convergence: Guatemala Research on WaSH (GRoW)," *Journal of Advanced Nursing,* vol. 75, pp. 2264-2266, 2019.
[28] D.B. Oerther, L.E. Voth-Gaeddert, and D.D. Divelbiss, "Improving Environmental Health Practice and Policy Through Convergence Research: A Case Study of Linked Food Water Systems Enhancing Child Health," *Environmental Engineering Science,* vol. 36, pp. 820-832, 2019.
[29] K. Bolaji, "Climate-related Security Risks and Violent Crime in Caribbean 'Frontier' Coastal Communities: Issues, Challenges, and Policy Options," United Nations Development Program, No. 15. [Online] Available: https://www.undp.org/sites/g/files/zskgke326/files/migration/oslo_governance_centre/d8dca416c204cc6fdbe409ce38b45533a2b454e6657bca1a6368daefa5f5d96b.pdf.
[30] D.B. Oerther, "From Disaster to Development: Finance Provides a Platform to Empower Technology for Resilience to Climate Change," *Procedia Engineering,* vol. 159, pp. 267-271, 2016.
[31] D.B. Oerther, "Using Science-in-Diplomacy to Develop COAST: The Caribbean Ocean and Aquaculture Sustainability faciliTy, and Reflections on Parametric Insurance Inspired by COVID-19," *Science & Diplomacy,* vol. 9, 2020. [Online] Available: https://www.sciencediplomacy.org/in-field/2020/using-science-in-diplomacy-develop-coast.
[32] D.B. Oerther, "A Case Study of Community Engaged Design: Creating Parametric Insurance to Meet the Safety Needs of Fisherfolk in the Caribbean," *Journal of Environmental Engineering,* vol. 148, no. 05021008, 2022.
[33] S.E. Oerther, "Gender Data Gaps: Structural Equation Modeling Offers an Alternative to Collecting More Data," *Procedia Engineering*, vol. 107, pp. 494-497, 2015.
[34] D.B. Oerther, and S. Oerther, "Nightingale's Legacy as a Nurse Theorist Promotes Healthful Food Systems," *Perspectives in Public Health,* vol. 140, pp. 141-143, 2020.
[35] D.W. Divelbiss, D.L. Boccelli, P.A. Succop, and D.B. Oerther, "Environmental Health and Household Demographics Impacting Biosand Filter Maintenance and Diarrhea in Guatemala: An Application of Structural Equation Modeling," *Environmental Science & Technology,* vol. 47, pp. 1638-1645, 2013.
[36] L.E. Voth-Gaeddert, M. Stoker, D. Cornell, and D.B. Oerther, "What Causes Childhood Stunting Among Children of San Vicente, Guatemala: Employing Complimentary, System-Analysis Approaches," *International Journal of Hygiene and Environmental Health,* vol. 221, pp. 391-399, 2018.
[37] L.E. Voth-Gaeddert, M. Fikru, and D.B. Oerther, "Limited Benefits and High Costs are Associated with Low Monetary Returns for Guatemalan Household Investment in Water, Sanitation, and Hygiene," *World Development,* vol. 154, no. 105855, 2022.
[38] R.R. Walter, "Emancipatory Nursing Praxis: A Theory of Social Justice in Nursing," *ANS Adv. Nurs. Sci.*, vol. 40, no. 3, pp. 223-242, 2017.
[39] R.R. Walter, *Emancipatory Nursing Praxis*. Nursology [blog], 2020. [Online] Available: https://nursology.net/nurse-theories/emancipatory-nursing-praxis/.

Appendix A.

Missouri University of Science and Technology

Course: CArE 5605

Title: Application of System Science for Sustainable Development

Missouri University of Science and Technology

Questions, Announcements, Other

- **IF you have a question, you can be sure that at least one other person has the same question**
  - **SO PLEASE ASK!!!!**
- Any questions from prior lecture or in general (syllabus, assignments, schedule, etc)
- Announcements
  - When's the next REQUIRED class meeting?
  - When's the next REQUIRED assignment due?
- Other – ANYTHING?

Missouri University of Science and Technology

Reminder about unit objectives

- By the end of this unit, students should:
  - describe the application of system thinking to international development
  - define the paradigm of sustainable development meeting the needs of the present without compromising the ability of future generations to meet their own needs
  - recognize the use of systems of systems to describe the five-F diagram – fingers, flies, floors, food, and feces
  - appreciate the application of systems thinking to the development of holistic interventions to promote international development as an approach to national security

Missouri University of Science and Technology

Review online lecture vocab

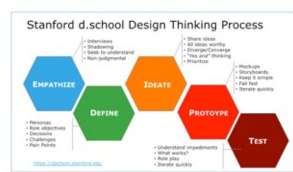
- Vocabulary:
  - Satisficing
  - Reflection in action
  - Biosoma
  - Cartesian view

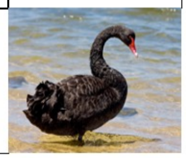
Missouri University of Science and Technology

Systems Thinking

- What's the difference between breaking-down and building-up?
  - How do we approach the world?
- What's the difference among simple, complicated, complex, and chaotic?
  - How do we model these systems?
- What's the meaning of open boundary and system emergence?
  - How do we get the details right?

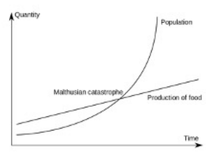
Missouri University of Science and Technology



know the knowns	know the UNknowns
DON'T know the UNknowns	

World$_3$

- "The World3 model is a system dynamics model for computer simulation of interactions between population, industrial growth, food production and limits in the ecosystems of the earth. It was originally produced and used by a Club of Rome study that produced the model and the book The Limits to Growth (1972). The creators of the model were Dennis Meadows, project manager, and a team of 16 researchers." from Wikipedia

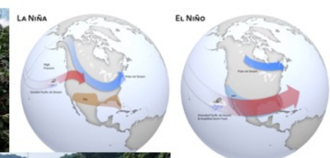


Stunting in Guatemala

Nine-year-old Guatemalan Maya children born in Guatemala (left) and in the United States (right): from ABC News

WaSH + Food and Nutrition Security

Weather, livelihoods, immigration



In the upcoming optional lectures…

- Construct a model linking the behaviors of families in Guatemala to promote health and wellness and prevent diarrheal illness and prevent the consumption of contaminated food in rural villages throughout the mountains of the Western Highlands.

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Let's check out an example…

- Ses:
  - https://youtu.be/jUN4JHEhsJ8

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What exactly does this 'optional assignment' include?

1. Providing a narrative of the overall problem and identifying important states and relationships
2. Including the ranges and typical values of states
3. Including a pictorial representation of the system with explicit notation for states and relationships
4. Listing assumptions
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Stunting in Guatemala (International Journal for Equity in Health)

Abstract

Background: Guatemala has the highest prevalence of stunting among under-five children in Latin America. We aimed to compare indigenous and non-indigenous under-five child populations in relation to stunting, as well as to explore the intersectionality of ethnicity by wealth and by place of residence. We also studied how the ethnic inequalities changed over time, using five ENSMI surveys from 1995 to 2014.

Methods: Five national health surveys carried out between 1995 and 2014 were analysed. World Health Organization (WHO) 2006 growth standards were used to calculate stunting prevalence. Self-reported ethnicity was classified as indigenous or nonindigenous. Wealth was measured through an asset-based index, and households were classified into quintiles (for analyses of the whole populations) or tertiles (for analyses of intersectionality with ethnicity). Area of residence was recorded as urban or rural, according to country definition.

Results: Overall stunting prevalence declined by 9.8 percentage points (95% CI −16.4 to − 3.3) from 1995 to 2014. The slope index for absolute inequalities in stunting - which corresponds to the difference in prevalence between the wealthiest and poorest households - ranged from − 52.9 to − 60.4 percentage points, with no significant change over time. Children in rural areas were consistently more stunted than those in urban areas, but rural indigenous children were significantly worse than any other group. Indigenous children in the poorest tertile of family wealth consistently presented the highest stunting prevalence, compared to all other groups. Time trends in stunting were assessed through the average annual absolute change (AAAC). The fastest decline was observed among indigenous children from the middle wealth tertile (AAAC = − 1.21 percentage points per year (pp/y); 95% CI − 1.45 to − 0.96) followed by nonindigenous children also from the middle tertile (AAAC = − 0.80 pp./y; 95% CI − 0.99 to − 0.60). Stunting prevalence in the two poorest tertiles of indigenous children in 2015 was similar to what nonindigenous children presented in 1995, 20 years earlier. In the wealthiest tertile, indigenous children were far worse off than nonindigenous children 20 years earlier.

Conclusions: In terms of stunting prevalence, poor and rural indigenous children are twenty years behind nonindigenous children with similar characteristics.

Keywords: Stunting, Health equity, Health status disparities, Ethnic groups, Guatemala

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Stunting in Guatemala (Maternal and Child Nutrition)

This review summarizes the impact of stunting, highlights recent research findings, discusses policy and programme implications and identifies research priorities. There is growing evidence of the connections between slow growth in height early in life and impaired health and educational and economic performance later in life. Recent research findings, including follow-up of an intervention trial in Guatemala, indicate that stunting can have long-term effects on cognitive development, school achievement, economic productivity in adulthood and maternal reproductive outcomes. This evidence has contributed to the growing scientific consensus that tackling childhood stunting is a high priority for reducing the global burden of disease and for fostering economic development. Follow-up of randomized intervention trials is needed in other regions to add to the findings of the Guatemala trial. Further research is also needed to: understand the pathways by which prevention of stunting can have long-term effects; identify the pathways through which the non-genetic transmission of nutritional effects is mediated in future generations; and determine the impact of interventions focused on linear growth in early life on chronic disease risk in adulthood.

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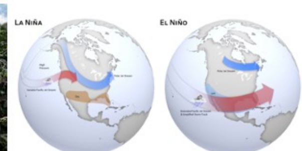
The Problem

Subsistence farming

Changing weather



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The Source

CO_2 emission

Colonial rule

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The Solution

Capacity, Technology, Finance

Appendix B.

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Course: CArE 5605
Title: Term Project

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What is Diplomacy Lab?

- See: http://blogs.state.gov/stories/2014/03/18/state-60-seconds-video-diplomacy-lab
- See: http://www.ou.edu/diplomacylab/

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What is Diplomacy Lab? Part Deux

- U.S. Department of State Partners with America's Universities
- Helping Solve the World's Biggest Challenges with Diplomacy Lab Program
- Diplomacy Lab is designed to address two priorities: first, Secretary Kerry's determination to engage the American people in the work of diplomacy. And second, the imperative to broaden the State Department's research base in response to a proliferation of complex global challenges. The initiative enables the State Department to "course-source" research and innovation related to foreign policy by harnessing the efforts of students and faculty experts at universities across the country. Students participating in Diplomacy Lab explore real-world challenges identified by the Department and work under the guidance of faculty members who are authorities in their fields. This initiative allows students to contribute directly to the policymaking process while helping the State Department tap into an underutilized reservoir of intellectual capital. Teams that develop exceptional results and ideas are recognized for their work and may be invited to brief senior State Department officials on their findings.

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The optional term project

- Construct a model linking the behaviors of fishers in the Caribbean to pre-storm and post-storm behaviors that reduce vulnerability to storms and improve management of fisheries to protect livelihoods and food security leveraging parametric insurance.

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Let's check out an example…

- Ses:
  - https://www.youtube.com/watch?v=4iYzU2Poh1Q
  - https://www.youtube.com/watch?v=n1xlYXblXrk

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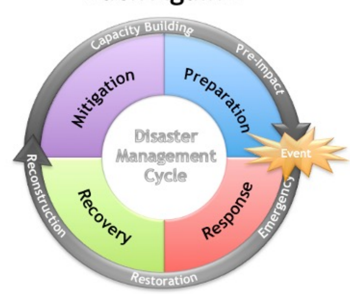
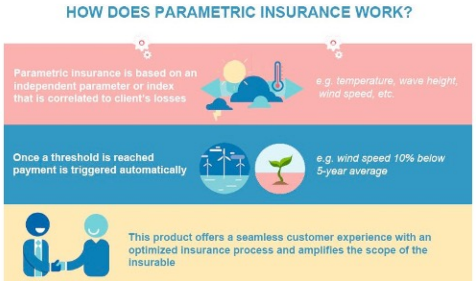
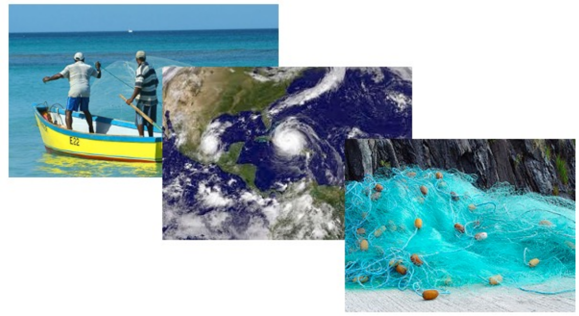
From Development to Disaster and Back Again…



Parametric Insurance to Manage and Transfer Risk



Weather, livelihoods, food security



Weather risk for Caribbean fisherfolk (1/2)

- The challenges of climate change and variability faced by fishermen and women in four Caribbean countries are to be addressed through early warning and emergency response tools being developed under the Caribbean Regional Track of the Pilot Programme for Climate Resilience (PPCR).
- The information, communication and technology (ICT) solution, which is being developed by the ICT4Fisheries Consortium in collaboration with the Caribbean Regional Fisheries Mechanism (CRFM), will work to reduce risks to fishers' lives and livelihoods posed by climate change and climate variability. The ICT4Fisheries Consortium is a multidisciplinary team comprising members from The University of the West Indies (UWI), the University of Cape Town and the Caribbean Network of Fisherfolk Organizations.
- Possible impacts of long term climate change trends and short term extreme weather events on Caribbean fisheries include damage to fishing and aquaculture community infrastructure, including roads, harbours, farms and houses caused by sea level rise and stronger storms, as well as unsafe fishing conditions and loss of life at sea as a result of strong storms and hurricanes, according to a 2015 study published by the Food and Agricultural Organisation (FAO).

Weather risk for Caribbean fisherfolk (2/2)

- Other hazards influenced by climate, such as sargassum seaweed, are also of deep concern to fishers.
- The ICT-based early warning system is expected to reduce fisher folks' vulnerability to the impacts of climate change. Using an application for mobile phones, fishers will be able to receive early warnings of risky weather and sea conditions.
- The mobile application will also be used to encourage fishers to share their local knowledge to support and improve climate-smart fisheries planning, management and decision-making. The system will be integrated within existing national disaster risk management and emergency response frameworks, and its main focus will be on communications.
- From: http://www.caribbeanclimate.bz/caribbean-early-warning-system-to-help-caribbean-fishermen-deal-with-climatefishermen-who-depend-on-fishing-for-a-living-need-an-early-warning-system-change/

The Problem

Artisanal fisheries

Bad weather

The Source

CO2 emission

Colonial rule

The Solution

Capacity, Technology, Finance

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Appendix C.

An excerpt from a student response to the term project examining the problems of poverty, food security, and northward immigration towards the US southern border from individuals living in Guatemala.

1. Providing a narrative of the overall problem and identifying important states and relationships

Nutrition is extremely important in the foundation of a child's health, especially when moving into adulthood, and without nutrition a child's growth is stunted. Currently in Guatemala, children are not getting enough nutrition due to not having access to clean drinking water and fungi that can be found in their diet. First, many children do not have access to clean drinking water because this area of the planet's water system has been contaminated. This causes the children to get diarrhea and this sanitary problem causes children to be stunted. Another reason that children are being stunted is fungi that is being grown on their corn due to cultural farming methods. The fungi aspergillus is commonly found on food that is consumed by Guatemalan children, this fungus creates aflatoxins which consume the nutrition that the children should be receiving from their food. Without the nutrition from their food and frequently getting diarrhea from their water, Guatemalan children are growing underdeveloped.

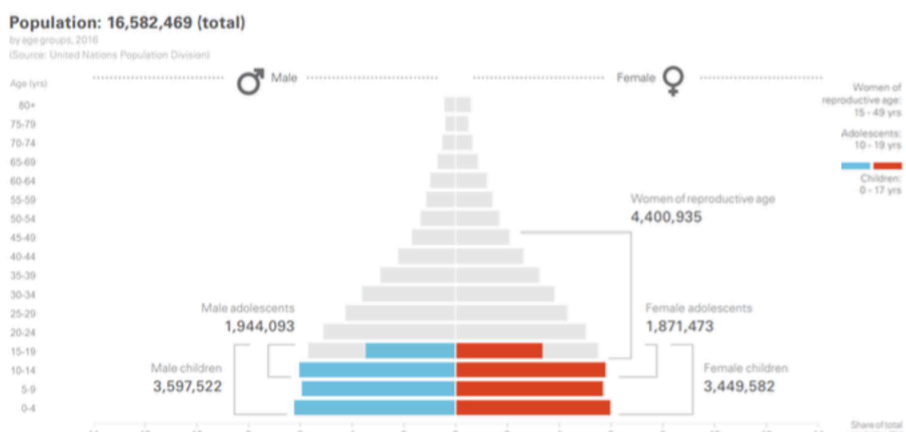
The people of Guatemala have a responsibility to allow their children to grow healthy. It has been shown that children from Guatemala can grow without being stunted, so it is not natural for a Guatemalan child to be stunted. With this knowledge it should be a simple fix of moving families to areas that have access to better water and food, but many people want to stay in the location of their culture and where they have friends and family. Another reason for not relocating is the lack of prosperity for many families in Guatemala. If all families had the means to drink clean water or immigrate to a different country then this problem would not exist. It also would not be a smart political move for one group to force these children away from their families and culture.

The different relationships between the states of children, their families, location, and what causes stunting are noted below:

1. Children need to eat and drink to survive
2. Children are being stunted by what they eat and drink
3. The location of a child's development can cause a child to be stunted
4. A child's household has a responsibility to take care of the child
5. A child's household control the location and culture that the child is raised in

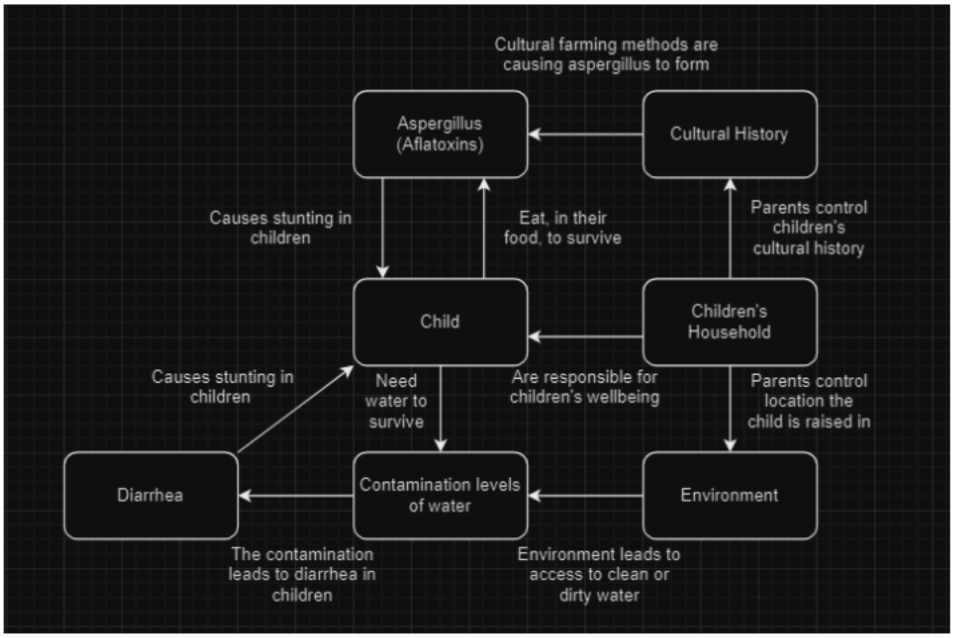
2. Including the ranges and typical values of states

States	Values
Children	According to unicef (see image below this table), there are roughly 7 million children under the age of 19 with roughly 3.3 million of those being under the age of 9 in Guatemala.
Children's Household	Children's household control raising the children. This includes access to clean water and edible food.
Location of childhood development	The value of the location of a child's development can be considered binary in this case. Either the child will be in an environment with agents that can cause stunting or they will not be.
Causation of stunting	According to the optional reading provided, J Env Health 82(1) 20 2019, the 2 week diarrhea prevalence for children was 33%. For this homework it was requested to focus on diarrhea stunting children, so I will not specifically talk about numbers for aspergillus stunting children. However: I thought it was prevalent for this model to mention it.



3. Including a pictorial representation of the system with explicit notation for states and relationships

Arrows point from one state to another with text that describes the relationship between them.



4. Listing assumptions

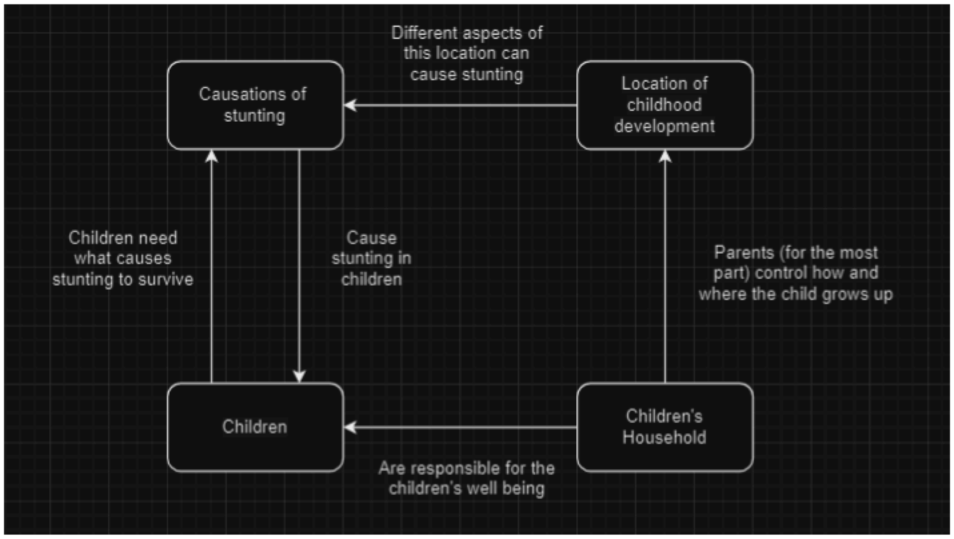
My assumptions for this system are noted below in bullet point form.

- A child’s household controls the culture and location that a child will be exposed to, so I lumped environment and culture into one category

- Since both the condition of the food and water that a child ingests can both causes stunting they have also been grouped together.

5. Using the assumptions to reduce the model to a solvable sub-model

With the values in question 2 and the assumptions in question 4 the problem has been reduced to a solvable sub-model.



10. Describing the lesson/s learned in the overall exercise

My lessons learned from learning about children in Guatemala is how blessed I have been to have been born to a middle class family in America and also how strange the human body can be.

My first lesson learned is people can have a lot of problems when they are born in a part of the planet that does not have access to clean drinking water and food due to prosperity issues, a concern that I have never had to worry about. If I was desperate enough for hydration I can go to a disgusting public bathroom and drink straight from the tap (or toilet if it has been cleaned) and be hydrated, a luxury that many people do not have. I can also get food that has not been contaminated by fungus by simply going to a grocery store. It's always a strange thing to learn a new fact about the world that has been taken for granted.

The strangest thing I learned is that the height of a population is not always tied to genetics. The Guatemalan people have a history of being short. It would be assumed that the reason for this would be the genetics of the people that lead to this commonality, but when these people were raised in a country with proper nutrition they grew to the average height of the population they were raised in. Humans are a lot more similar than we give each other credit for and the barriers of race, genetics, or even politics are very thin. At the end of the day, everybody is just human.