Development and evaluation of system dynamics education modules for socioenvironmental systems

R. Costello and <u>J.C. Little</u> 🆔

Department of Civil and Environmental Engineering, Virginia Tech, Blacksburg, Virginia, United States
Email: jcl@vt.edu

Abstract: The family of societal challenges of the Anthropocene (e.g., climate change and impacts, renewable energy, adaptive infrastructure, disasters, pandemics, food insecurity and biodiversity loss) are numerous and daunting. Addressing these problems requires an interdisciplinary systems-thinking approach that coordinates problem-solving between practitioners of varied disciplines including engineers, physical scientists, economists and other social scientists. Civil and environmental engineers have distinct technical skills necessary to help address these challenges as part of coordinated multidisciplinary efforts, but training for this multidisciplinary exchange requires incorporation of systems-thinking into academic curricula.

This research expands upon the existing literature regarding incorporation of systems-thinking into civil and environmental engineering coursework through development, implementation and subsequent evaluation of educational modules based on system dynamics models and modelling concepts. The modules consist of lecture materials, in-class exercises, homework assignments and a capstone course project based on several system dynamics models. Four educational modules were developed and deployed in the Sustainable Systems course (CEE 4134/5114) in the Civil and Environmental Engineering (CEE) department at Virginia Tech. The evaluation of module effectiveness was performed via surveys that were given pre and post module delivery and were used to determine whether there was a statistically significant change in learning outcomes. An established tool, the Lake Urmia Vignette (LUV), was used to determine the effectiveness of the modules as tools for educating CEE students in systems-thinking concepts.

The results suggest that the modules are effective in improving systems-thinking learning including student ability to identify cause-and-effect variables, causal links, and feedback loops. This outcome was associated primarily with domestic students and students that had higher initial scores on the LUV survey given at the beginning of each semester. These results are interesting and introduce new questions such as why the domestic students performed better than their international counterparts. A more detailed set of demographic questions may provide additional insight necessary to identify specific strengths and weaknesses within the educational modules. Questions regarding proficiency with English as a first or second language as well as familiarity with causal link and feedback loop concepts would likely improve the resolution of the data on student populations that are assessed using these educational and assessment tools.

The results also indicate some limitations with the modules that require further investigation. First, the education modules need some improvement with respect to stock and flow concepts. Students did not appear to increase learning outcomes on these topics. Second, although the results indicated a strong association of improved learning outcomes for domestic students, this was primarily noted for the 2021 cohort of students. No significant improvement in learning outcomes was noted for the 2022 cohort of students. Several items such as increased volume of materials provided as references, additional concept coverage and impacts from the COVID-19 pandemic were identified as potential causes of this finding. Furthermore, additional assessments of future implementations of the system dynamics educational modules could provide additional evidence to help validate the extent to which these education tools impact learning outcomes in CEE students. Finally, the results identified that students who had self-identified as having prior systems training performed worse on the LUV survey. This finding is consistent with prior research and leads to speculation as to why this occurred in two different studies with different experimental designs and student populations. Determining the cause of this occurrence may lead to improvements in the LUV survey demographic questions as well as the education modules.

REFERENCES

Costello, R., 2023. Development and Evaluation of System Dynamics Education Modules for Complex Socioenvironmental Systems. PhD Dissertation, Virginia Tech.

Keywords: *Anthropocene systems, causal structure, feedback loops, Lake Urmia Vignette*