Integrating Systems Approaches into Education Using Active Case Studies

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***Abstract*— The focus of this workshop is integrating systems approach principles and content into engineering courses of all disciplines using a case study pedagogy. Participants should leave with a clearer understanding of what a systems approach is, how to run active case studies, and how it can be integrated into existing engineering courses. To achieve these goals, our approach is to work through a systems case live with the participants… starting with the participants doing the case as students and then having them switch roles to be instructors working through creating, running, and assessing the case.**

Keywords—system approach, case study, workshop,

I. Learning Objectives for Workshop Participants

The participants should leave the workshop with a common language around which to discuss a systems approach and first-hand experience with strategies for integrating a systems approach into engineering classes. More specifically, participants should be able to explain core components of a systems approach, explain the context of the systems approach components (including developing an appreciation for the humility required in a systems approach), and demonstrate how cases can be used to integrate a systems approach into engineering courses.

Through focusing on enabling attendees to develop innovative classroom experiences for students, these learning objectives align with the Frontier in Education conference's "innovative practice" track.

II. Workshop Description

A. Systems Context

Systems thinking is a critical differentiator for engineering leaders. It is not owned by anyone or any discipline. Its power lies in its applicability to any problem; in particular, to the most complicated multiobjective, multi-stakeholder large scale problems facing society. In industry, the most influential engineers who rise to leadership invariably learn to view problems as systems. They are able to combine outstanding technical skills with a systems perspective.

The current state of engineer education, however, is famous for its focus and specialization. This focus is no accident – the requisite knowledge to be an engineer requires deep understanding. In this juxtaposition – a need for systems thinkers and a curriculum for specialists -- lies the problem, the challenge, and the opportunity.

We are not the first to recognize this need: in fact, it is a national focus. One can find the call for a systems approach in multiple National Academy of Engineering publications [1]–[3] and throughout most the Grand Challenges for Engineering [4]. The demand for systems engineering in both the Department of Defense [5] and NASA [6] is evident by the offices in each focused on systems engineering. Finally, the many calls for "T-shaped" engineers frequently focus on how to produce engineers with the top bar of the T, not just the vertical depth. Then-director of NSF's engineering education division, Marshall Lih captured the need for engineers who take a systems approach by saying that "**narrowly trained engineers in America tend to be subordinate to other professions… [and] are ill-equipped to fill top jobs in business or industry**" [7].

B. Systems Approach

As defined here, **a systems approach** is a "top-down, goal-oriented" method "to solve complex problems in the context of multiple stakeholders with competing and conflicting objectives where significant trade-offs are required to achieve acceptable outcomes under uncertain and changing conditions" [8].

> *In the systems approach, concentration is on the analysis and design of the whole, as distinct from ... the components or parts ... The systems approach relates the technology to the need, the social to the technological aspects; it starts by insisting on a clear understanding of exactly what the problem is and the goal ... It provides for simulation and modeling so as to make possible predicting the performance before the entire system is brought into being. And it makes feasible the selection of the best approach from the many alternatives.*
>
> Simon Ramo, Cure for Chaos, pp. 11, 12 [9]

The workshop focuses on a "systems approach" as a process that operationalizes the broader topic of systems thinking [10]. The overall systems approach has been turned into many specific systematic methodologies and tools using names such as systems analysis, systems life-cycle, systems integration, and systems dynamics modeling. The systems approach, as used in this workshop, however aims first to be *systemic* in its embodiment of systems thinking. This is in contrast to many systematic approaches, whose focus on process manifests in a mechanistic set of steps or reliance on a narrow set of tools.

Fundamentally, a systems approach is focused on improving systems performance. As such, the approach used in this

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workshop focuses on foundational questions related to this purpose such as:

- What is the system?
- How should performance of the systems be measured?
- How does the system perform now?
- What does a well-performing system look like?
- What trade-offs represent improvement?

C. Active Case Studies

Active case studies engage students in a real world or realistic situations. The realism of the situations means that there is not one right answer, but instead many approaches with different strengths and weaknesses. This is in contrast to cases where one right answer is sought. The "active" part of the case study puts students in the role of responding to a client question in the case. Instead of being a story of how someone else handled a situation where the students analyze what did happen, an active case asks students to commit to their own response… which could be a recommended course of action, policy, design, etc., depending on the case.

D. Example Case Topics

While there are many ways to integrate a systems approach into cases, we will target cases focused on problem and system definition. A real or realistic situation is posed followed by the motivating question "Is this an example of a success or failure?" This question has proven helpful in formulating problem definition cases for situations that, on the surface, appear to be a success or failure, but when you look at the broader context and system, that conclusion is less clear.

Examples of such situations include:

- The landing of US Airways Flight 1549 on the Hudson River. Appears to be and is a success in many ways, but that conclusion depends on what you consider "the system" to be.
- The building of waste incinerators to reduce the use of fossil fuel. Appears to be a success, but is also an incentive to create waste.
- Autonomous vehicles that hit, hurt, and even kill pedestrians. Appears to be and is a failure in many ways, yet autonomous vehicles on the whole are touted to be a success.

E. Workshop Schedule

Participants first experience systems cases as a student.

45 minutes	a systems approach through doing a case with the participants
20 minutes	Meta-discussion of student experience: synthesize the work done on the case; put names to what we just did
15 minutes	Generate case ideas

Participants then experience systems cases as faculty, seeing key elements of active case studies through examples and then working to develop case studies of their own.

20 minutes	Read through case ideas
30 minutes	Pair up and write cases, then switch and do a case that was just written
30 minutes'	Open discussion characteristics that make a case a "good" case based on experiences with writing and doing a case

III. Anticipated Audience

We are targeting a mix of engineering and computer science faculty who are currently teaching courses and want to envision how to integrate systems cases into their classrooms.

IV. Takeaway Skills, Knowledge, and Materials for Attendees

Attendees should leave with a prototype "sketch" of a case that they can integrate in one of their classes. That is , they should have identified one or more areas around which they could construct a systems case, and, through their direct experience doing a case and seeing multiple examples of other cases in the workshop, be prepared to take their rough idea and develop it fully. Each attendee with also leave with access to multiple existing cases that they can use as a reference.

V. Presenters and Qualifications

All of the authors integrate systems cases into their classes. With mechanical engineering degrees, Dr. Bailey has taught systems with active case studies for the past ten years. Drs. Will Guilford and Shawn Russell have each written and used systems approach cases in their biomedical and mechanical engineering classes, respectively, during the last year.

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