Work-in-Progress: Systems Thinking Applied to Higher Education Curricula Development

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***Abstract*—The educational landscape is a complex ecosystem consisting of interconnected systems, each serving distinct roles such as educators, students, administrators, digital resources, and educational objectives. Systems Thinking (ST) is a broad yet nuanced concept that describes an approach for understanding and managing complexity in real-world systems. The intricate interplay among the diverse components and functions makes the educational system particularly suited for the application of systems thinking principles. In this work-in-progress paper, we present a preliminary case study of the curriculum development process for the online M. S. in Systems Engineering program at Embry Riddle Aeronautical University Worldwide. In particular, we examine weaknesses and limits of the current instructional design practices and demonstrate the utilization of systems thinking method to enhance the outcomes of the university's curriculum development, and ultimately lead to a positive influence on student learning.**

***Index Terms*—Systems thinking, curriculum development, online education**

I. Introduction

Online education has witnessed remarkable growth in the past decade. According to a report from the Education Department's National Center for Education Statistics [1], there was a substantial 5.7% increase in the number and proportion of college and university students enrolled in online classes in 2017. This growth persisted even as overall post-secondary enrollments experienced a slight decline of 0.5%. The global COVID-19 pandemic, spanning from 2020 to 2023, propelled the adoption of online education to unprecedented levels. Initially implemented as an emergency measure to address school closures, online modalities have since been embraced by numerous higher education institutions for their inherent advantages [2], [3]. These include enhanced flexibility, increased interactivity, and the ability for students to pace their own learning.

The transition to online education necessitates a collaborative and concerted effort from various academic and administrative units. While numerous theories support good online teaching practices, the curriculum remains at the core of every well-established online program. The curriculum must maintain the required academic rigor while addressing the unique challenges facing both instructors and students in this new learning environment. These challenges include developing "time management skills, being technologically prepared and computer literate, possessing good work ethics, being effective communicators and goal-oriented learners, ensuring academic readiness, and fostering personal commitment, independence, and responsibility" [2].

Embry-Riddle Aeronautical University Worldwide (ERAU-WW) is one of the leading online universities in the country and had been ranked consistently either No. 1 or No. 2 overall, compared with all institutions — private and public — in the annual U. S. News and World Report from 2016 to 2023. Beginning as a school that offered distance education primarily to active service members and veterans, ERAU-WW was among the first universities to recognize the potential, and thus shift to online education. Through years of practice, a mature course design process has been established that serves our constituents. However, the university, academic units, and instructional support team continue to seek areas of improvement and integrate new approaches. One of the focuses has always been the need to regularly review and update curriculum and course content to add personalized learning materials and frequent and meaningful interaction between students and faculty members.

In [4], we presented systems thinking and its applications to higher education curricular development. Systems thinking aims to leverage the potential differences in the behavior of individual system elements when they are viewed in isolation versus when they are integrated into a larger system within a specific operating environment. The M. S. in Systems Engineering (MSSYSE) program at ERAU-WW is an online master's program with a current enrollment exceeding 200 students, many of whom are non-traditional students balanc-

ing full-time work. Recently, in response to feedback from students and alumni, the program has transitioned its name from Master of Systems Engineering to M. S. in Systems Engineering. This change has prompted a comprehensive review of the curriculum. Two courses, SYSE 515 Mathematical Applications in Systems Engineering and SYSE 610 System Architecture Design and Modeling, have been identified for redevelopment. Reflecting on feedback from instructors and students, the program faculty recognize the limitations of the current process for developing online graduate-level engineering courses. Collaborating with the university's instructional design staff, we made a concerted effort to leverage systems thinking principle in course development life cycle, given the expertise and research background of the program faculty.

The rest of the paper is organized as follows. In Section II, we review the general systems thinking principles and their applications to higher education. The course development process at Embry-Riddle Aeronautical University Worldwide is explained in Section III. The shortcomings in the existing process are summarized in Section IV, and two MSSE course redevelopments guided by systems thinking principles are previewed. We conclude in Section V by pointing to the future work of assessing the reception of new development by our stakeholders.

II. Systems Thinking

Systems Thinking covers a broad swath of concepts, some of which are of a general and "common-sense" nature whereas others are more pointedly focused on application within a system engineering context. Several commonly accepted principles of systems thinking include the following:

- Analysis of a system from the perspective of the entire system, and not as a generic assemblage of individual components or sub-system elements.
- Demarcation of system boundaries as framing the extent of the system under consideration and placing constraints upon such boundaries.
- Analysis of the interactions among various combinations of system elements and sub-system components, especially as such interactions can produce unforeseen and un-predicted behavior of the overall system.
- Consideration of influences and factors upon a system and its components, especially the effect of cross-boundary external influences that can adversely impact particular system elements.
- Evaluation of internal system feedback mechanisms (whether of a positive or negative nature) that can adversely affect the performance of the system even in the absence of clear external or internal factors or stressors upon the system.
- Review and mitigation of identified problems with a given system in such a manner that systems thinking principles are sufficiently addressed.
- Reflection upon the extent and type of complexity resident within a given system incarnation and how such complexity can complicate system analysis across the previously listed systems thinking principles.

Much of systems thinking is rightly focused on understanding the attributes of a whole system as related to the combined attributes of the component elements. Nevertheless, there is another aspect of systems thinking that is focused more on the approach to analyze and evaluate problems within a system and consideration of a logical and analysis-based process to understand the interrelated nature of issues that can arise within complex systems. We show in [4] that there is a connection of this problem identification and evaluation process to the environment of higher education curricula development that can provide proper feedback to the education system to improve higher education curricula development in a progressive and iterative fashion.

One way to represent higher education curricula development is to consider the interrelationships and interactions among various factors and influences that affect the persons and institutions seeking to develop such curricula. Fig. 1 shows a representative set of external influences (those outside of the educational institution) and internal factors (those within the educational institution) that can impact the curricula development process.

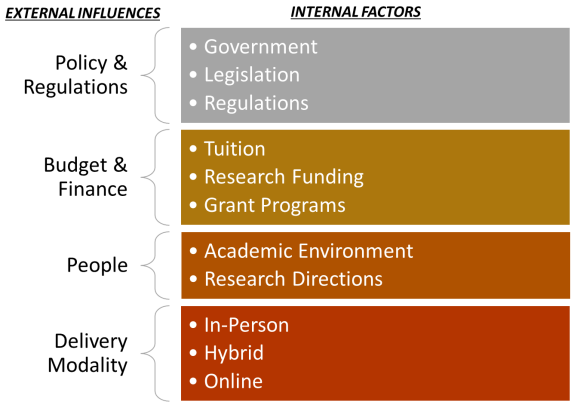


Fig. 1. Broad definition of external influences and internal factors related to a systems-thinking approach for higher education curricula development [4]

The consideration of these influences and factors forms the basis of treating education curricula development as a complex system and, therefore, one suitable for treatment within a systems thinking framework. Fig. 2 presents a representative example of a complex yet holistic higher education curricula development system that not only addresses external factors and internal influences to that system but also provides for problem identification and an iterative process for evaluating such problems and implementing solutions within the broader scope of the system boundaries.

The inclusion of the broad set of external influences and external factors (left hand side of the figure) enable the curricula management team to give a proper consideration to the interrelationships and impact among these elements and better identify issues that can be resolved using the identified systems thinking problem solution process (right

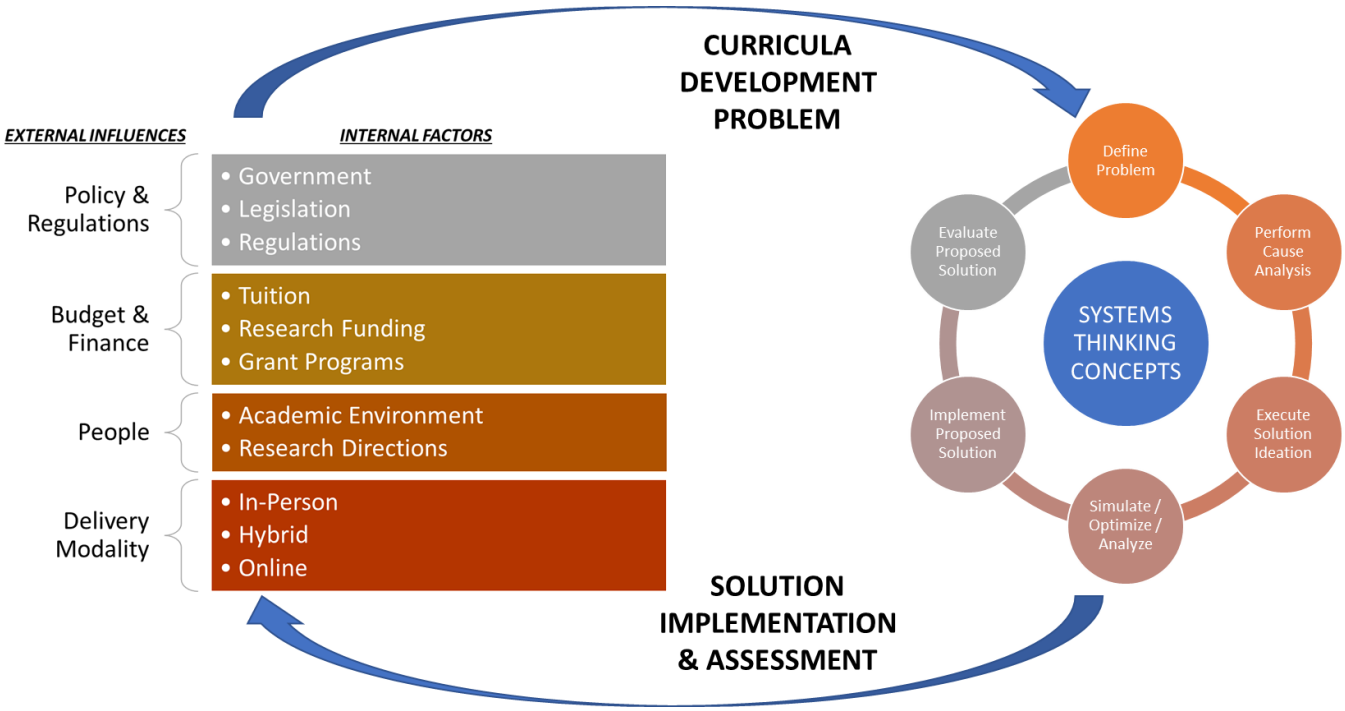


Fig. 2. Iterative evaluation process of higher education with systems-thinking principles [4]

hand side of the figure). The top process link ("curricula development problem" blue arrow) and bottom process link ("solution implementation & assessment" blue arrow) form the components of the problem identification and process solution feedback loop back to the educational system itself. We further note as an aside that the presence of system feedback loops is one of the identifying characteristics of a systems thinking approach as discussed in [5].

III. Curriculum Development Process at ERAU

Embry-Riddle Aeronautical University Worldwide offers most of its courses in the online, asynchronous modality. The university's academic calendar is different from that of the traditional brick-and-mortar institutions. We divide the year into terms instead of semester, trimester or quarter. Each term is nine weeks, and our courses are developed into nine modules with one module for a week. The idea behind the compact active learning period is to give non-traditional students the freedom to take courses that fit their work or life needs. Though the time is shorter, the rigor and coverage of each course has to be on par with what students will experience in on-campus classes. The workload therefore in each week is more intense because the students need to complete a regular 16-week course in brick and mortar school in nine weeks.

Another important factor that impacts the course development is that, to offer maximum course availability to students, the university employs significant number of adjunct faculty so that high-demand courses can be repeated in multiple terms and some times, multiple sessions in each term. To ensure uniformity in course delivery across sessions and by different instructors, a common template needs to be established.

Instructional Design & Development (IDD) department maintains and updates the procedures to keep up with the needs and demands of multiple stakeholders. The instructional designer works with the course developer/subject matter expert to develop the Master Production Template. Once the template is complete, the course is copied into the Builder template, which is used as the master template for all live sections.

Generally, the course developers and instructional designers follow the intricacies of authentic learning in the design and development of online courses. Authentic learning is built upon a number of tenets, including real-world relevance, sustained investigation by the learner, collaboration-based activities, and reflection. Given that ERAU's main mission is to teach the science, practice and business of aviation and aerospace, naturally the learning activities are centered around the aviation and aerospace industry where the learners are able to hone relevant and directly applicable knowledge and skills to meet rigorous academic standards and industry requirements.

IV. Systems Thinking for Improving Course Development

After examining current course development process, we have identified the following issues:

- Subject Matter Expert (SME) based development leverages the knowledge and expertise of domain specialists to develop courses. Although, SME involvement can offer valuable insights and domain-specific knowledge, there are some potential challenges associated with this approach:

  - Limited Domain Expertise: SMEs may lack technical knowledge or familiarity with subject development practices, leading to challenges in translating domain knowledge into actionable requirements or design specifications. This may cause misunderstandings, or unrealistic expectations between SMEs and instructional developers.
  - Biased Perspectives: SMEs may bring knowledge and perspectives based on their specific domain and experiences. This can result in a narrow focus on certain functionalities at the expense of students learning outcomes or system requirements.
  - Dependency on SME Availability: SME may not be available when needed for the course update/redevelopment. Dependence on SMEs for course development can lead to project delays or disruptions if SMEs are unavailable or inaccessible.
- External influences vs. internal factors. As shown in Fig. 1, external influences are those factors that originate outside of the educational institution and have a significant impact on curriculum design, while internal factors are those elements that are specific to the institution itself. Curricula shall be influenced by a combination of external factors and internal considerations.
  - External influences
    * Industry and Labor Market Needs: Industry trends, technological advancements, and changes in the labor market drive demand for specific knowledge, skills, and competencies. Curriculum must align with industry needs to ensure graduates are prepared for employment and contribute effectively to the workforce.
    * Advancements in Research and Pedagogy: Developments in educational research, teaching methodologies, and learning theories inform curriculum design and instructional practices. Curriculum developers may incorporate evidence-based strategies, such as active learning, project-based learning, or personalized learning, to enhance student engagement and achievement.
    * Technological Innovations: Advances in technology, digital tools, and educational resources present opportunities to enhance teaching and learning experiences. Curricula may integrate technology-enhanced learning environments, online resources, and digital literacy skills to prepare students for the digital age.
  - Internal Factors
    * Institutional Mission and Strategy: The mission, strategic initiatives, and values of the university govern curriculum goals, priorities, and educational outcomes. Curricula must synchronize with institutional objectives and reflect the institution's commitment to academic excellence, student success, and societal impact.

Student Survey					Grades		Faculty Feedback	
Overall Score	Course Experience	Delivery Mode	Instructor Experience	Response Rate.	Enrollment.	Avg. Student Grade	Q16 Courses Overall Rating	Overall Score.
4.25	4.23	4.23	4.27	76.47	17	3.88		
4.69	4.58	4.54	4.83	92.31	13	4.00		
4.56	4.43	4.36	4.76	70.00	10	4.00		
4.52	4.48	4.35	4.59	76.47	17	3.63	4.00	4.27
4.37	4.08	4.36	4.70	87.50	16	3.31	3.00	3.40
4.17	4.19	4.04	4.17	70.00	20	3.74		
3.69	3.44	3.14	4.08	87.50	8	4.00	4.00	4.07
4.50	4.22	4.40	4.83	83.33	18	3.78		

Fig. 3. SYSE 515 Student and Instructor Feedback Comparison Table

    * Faculty Expertise and Resources: The domain knowledge, qualifications, and interests of faculty members influence curriculum content, design, and students learning outcomes.
    * Student Needs and Expectations: Student demographics, backgrounds, learning styles, and career aspirations inform curriculum design and student support services. Curricula should be responsive to student needs, interests, and feedback to ensure relevance, engagement, and retention.

A. *Identify stakeholders*

The success of the systems thinking relies on active participation of stakeholders in the entire systems development lifecycle. Therefore, first step in assessing development process starts with identification of stakeholders, which we have shown in Table I. One stakeholder needs particular attention. The Education Department, using latest available statistics [6], found that 18% of military undergraduates took all of their courses online, compared with 12% of their nonmilitary peers. Among military graduate students, 41% attended fully online compared to 19% of nonmilitary graduate students. ERAU serves a vast student population in active duty service members and veterans. In the engineering and engineering technology programs of the Worldwide campus, active military and veterans account for 50% and 20% of enrollment, respectively. In addition to the difficulties facing traditional and other nontraditional students, military students have to endure confusions and overcome barriers in the online environment that are unique to their professional and private lives.

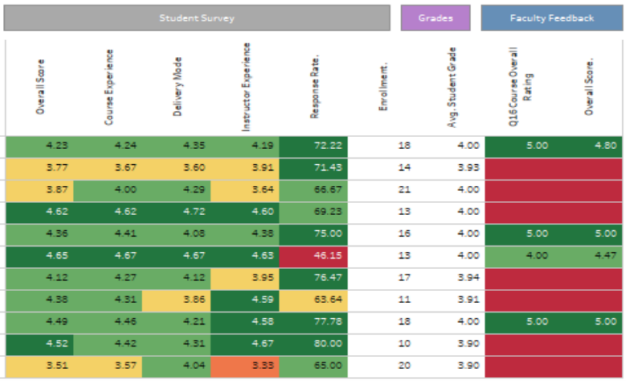
B. *Define needs and requirements*

Identifying and understanding the stakeholders' needs are essential to developing functional system. This process will deter issues involving process improvement that could occur when total program is not kept in mind in achieving the purpose and/or goals.

As aforementioned, most of the ERAU online courses are offered in multiple terms and potentially by full-time and adjust faculty members in parallel sessions. While students are only encouraged to offer end of course evaluations similar

TABLE I
MSSE PROGRAM STAKEHOLDERS

Stakeholder	Passive/Active Stakeholder?	Stakeholder Role/Description
Students	Active	Commitment to active participation. He or she should take their responsibilities seriously and participate in assigned/agreed activities
Instructor	Active	Leadership. He or She should share/transfer experience, knowledge, and wisdom. Be a model and set goals and objective
ERAU - COA	Active	Sponsor the program. Make it part of curriculum
ERAU IDD	Active	Assist course design, development and update.



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4.23	4.24	4.35	4.19	72.22	18	4.00	5.00	4.80
3.77	3.67	3.60	3.91	71.43	14	3.93		
3.87	4.00	4.29	3.64	66.67	21	4.00		
4.62	4.62	4.72	4.60	69.23	13	4.00		
4.36	4.41	4.08	4.38	75.00	16	4.00	5.00	5.00
4.65	4.67	4.67	4.63	46.15	13	4.00	4.00	4.47
4.12	4.27	4.12	3.95	76.47	17	3.94		
4.38	4.31	3.86	4.59	63.64	11	3.91		
4.49	4.46	4.21	4.58	77.78	18	4.00	5.00	5.00
4.52	4.42	4.31	4.67	80.00	10	3.90		
3.51	3.57	4.04	3.33	65.00	20	3.90		

Fig. 4. SYSE 610 Student and Instructor Feedback Comparison Table

to other universities, the instructors are mandated to provide feedback and assessment for the courses. This creates a valuable repository of input and gives us new data points for course updates or re-development. Fig. 3 and Fig. 4 show the combined students and instructor feedback for the two courses that are in the process of re-development.

The feedback and recommendations collected from these surveys can be summarized as follows:

- Tools/software selection and limitation
- Group project challenges
- Number of assignments
- Instruction for assignments
- Textbook/literature
- Practical applications
- Applicability of course
- The relationship between reading and assignments
- Frustration with the rubrics
- Workload
- Mini-projects
- Use of tutoring

C. Execute, simulate, and implement solution

Following the systems thinking concept cycle illustrated in Fig. 2, the course developer and instructional designer are to move on to the next phase by choosing the right learning materials, delivery method, and teaching pedagogy. The main goals are:

- On the marco-level: to increase coverage on engineering subject to support the program move to master of engineering degree
- On the micro-level: to address the needs and concerns raised by different stakeholders.

V. CONCLUSION

In this work-in-progress paper, we propose using systems thinking to enhance the course design process. This approach addresses weaknesses and limitations identified by program faculty in the current instructional design and development process. By applying systems thinking principles, we aim to guide the redevelopment of two key courses in ERAU's M.S. in Systems Engineering curriculum. The effects of these changes in course content and delivery methods will be evaluated through quantitative measures on pre- and post-course assessments when the new courses are implemented in the upcoming academic year.

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