Model-Based Systems Engineering Applied to Engineering Learning Analytic Systems (ELAS) to Enhance Student's Learning and Performance

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***Abstract*—Engineering education is a complex that involves multiple stakeholders, including students, educators, administrators, and industry partners. It is continuously evolving to meet the demands of modern industry and society. The traditional teaching and learning methodologies are being replaced by a more integrated skillset that focuses on developing students' cognitive, social, and emotional skills. The shift towards this integrated approach is gaining momentum, and it is important to have a framework that has been proven to solve complex systems. The usage of systems engineering tools to model engineering education systems is not often seen.**

In this paper, a novel application of Model-Based Systems Engineering using Systems Modeling Language (SysML) to develop an Engineering Learning Analytic System (ELAS) framework that consists of multi-dimensional elements related to educational systems. The core of this study involves a rigorous Requirements Verification and Validation (V&V) process to ensure stakeholder needs which systematically were map with system capabilities. ELAS model simulations provided predictive insights into soft skill development, enabling decision-making via targeted interventions that could significantly enhance students' skill sets. ELAS highlights that a data-driven approach, enabled by SysML, significantly enhances the ability to enact timely by relevant interventions at various levels of the educational management process. The proposed ELAS model offers a strategic blueprint for continuous improvement within educational institutions, demonstrating a pathway toward a responsive and self-improving educational system. The refining of the ELAS model, for broadening simulation scopes, and further integrating predictive analytics into administrative decision-making processes is an ongoing endeavor.

***Index Terms*—Model-Based Systems Engineering, Systems Modeling Language (SysML), Educational Management, Engineering Learning Analytic System (ELAS), Requirements Verification and Validation (V&V), Soft Skill Development, Automation Pyramid, Engineering Education**

I. Introduction

Engineering education is the process of preparing students to become competent and creative engineers who can contribute to the advancement of technology and to the benefit of society. Engineering education involves not only teaching technical knowledge and skills, but also developing students' abilities to think critically, communicate effectively, collaborate with others, and adapt to changing environments. To achieve these goals, engineering education needs to be modeled as a system that can be analyzed, designed, and improved using a system approach.

A system approach is a way of thinking and acting that considers the whole system, rather than its parts and focuses on the interactions and interdependencies among the system elements. The system approach can help engineering educators to identify and understand the needs and expectations of various stakeholders, such as students, faculty, administrators, and industry partners, and to align the different stakeholder requirements with learning objectives and program outcomes of the engineering curricula. In addition, it can also help engineering educators to select and implement appropriate teaching methods and technologies that can enhance the learning process and the learning environment. A system approach can also help engineering educators to evaluate and monitor the performance and effectiveness of the engineering education system, and to make necessary adjustments and improvements based on feedback and data.

In the literature, Model-Based Systems Engineering (MBSE) which is a key component of the system approach has been successfully used in several complex systems, in areas such as aerospace [1], defense [2], automotive [3], and healthcare [4] among others. One example of a successful implementation of MBSE is the NASA Jet Propulsion Laboratory's (JPL) Mars Science Laboratory (MSL) mission [5]. In the MSL mission, MBSE was very effective in managing the design of complex systems by creating a model of the system and analyzing its components and interactions.

The contributions of this work can be outlined as follows: First, a framework for ELAS was developed including defining stakeholder requirements and Measures of Effectiveness (MOE). Second, structure and behavior diagrams were constructed in Cameo Systems Modeler by Dassault Systèmes using Systems Modeling Language (SysML). Third, requirement verification & validation were simulated. Lastly,

This material is based upon work supported by the National Science Foundation under Grant No. 2022299

the advantages of MBSE in the engineering education system were discussed.

This paper is structured in the following manner. In Section II, a comprehensive overview of Model-Based Systems Engineering and System Engineering that form the basis of this study is provided. Additionally, this section defines the principal objectives of our work. Section III, the Model-Based Systems Engineering (MBSE) approach employed to develop the ELAS framework is presented. In Section IV, the system architecture, and subsystem functionality are demonstrated along with the verification and validation of stakeholder's requirements. Finally, in Section V, conclusions based on the research findings and contributions are presented.

II. Overview of Model-Based Systems Engineering and System Engineering

A. Model-Based Systems Engineering Methodology

In recent years various approaches have been proposed to address complex systems effectively. Model-Based Systems Engineering (MBSE) represents a paradigm shift from traditional methodologies that relied heavily on word-processed documents to a model-centric approach [6] [7]. This new approach transforms requirements development into a collaborative effort, moving away from the isolated work of subject matter experts in conference rooms or cubicles. Unlike the previous paradigm where each expert might have had an individual vision of the system model, MBSE places the system model at the forefront, accessible to all stakeholders. The value of a Model in systems engineering is aptly demonstrated by the allegory of blind men examining an elephant, where each describes only their limited perspective. However, with a Model of an elephant, these individual perspectives can align more closely with reality. Similarly, in MBSE, each stakeholder's view is integrated into a coherent model representing the desired system outcome [8]. Modeling, a core aspect of systems engineering, involves envisaging the system before its actual construction. Modern tools enable the creation of high-level system models, facilitating sharing a vision within stakeholders, including the customers. This process brings system validation to the early stages of a project, addressing the critical question, "Are we building the right system?". Once this is established, the focus shifts to verification in every phase of the design cycle, ensuring the system is built correctly. Customers' visions, although crucial, are often unclear at the beginning. The system's nature emerges through iterative analyses and requirements implementation, accommodating the dynamic nature of requirements [9]. These requirement changes are influenced by various factors like politics, budgets, and technology. A fast-adaptable systems engineering methodology is required to keep pace with these changes. While building a model may initially require extra time, the investment pays off by facilitating easier management of changes. Engineers might argue that Models have always been used. However, the novelty in MBSE lies in making the model the central focus of all systems engineering activities, contrasting with the document-centric approach of the past that resembled a "Victorian novel" of requirements.

B. System Engineering

Systems Engineering Vision 2020 report [10], published by the International Council on Systems Engineering (INCOSE) in 2007 and authored by Crisp, highlights a significant shift in systems engineering from a document-focused to a model-centric approach. According to this report, the model-centric approach is anticipated to supersede the traditional document-centric method, integrating fully into the systems engineering process.

Additionally, INCOSE conducted a survey, detailed by Estefan in 2008, on various Model-Based Systems Engineering (MBSE) methodologies. This survey categorizes a methodology as a set of interconnected processes, methods, and tools, essentially serving as a structured approach to address a range of problems sharing common features.

The survey provides a concise overview of several MBSE methodologies [11], including Harmony SE by IBM/Telelogic/iLogix [12], the Object-Oriented Systems Engineering Method (OOSEM) of INCOSE [13], the Rational Unified Process for Systems Engineering (RUP SE) by IBM [14], the Model-Based System Engineering Methodology by Vitech [15], and the State Analysis (SA) method by JPL. Each methodology presents a model-based strategy for executing the key stages of the systems engineering process: requirements analysis, system functional analysis, and architectural design.

One of the most widely used system engineering frameworks is the Vee model, which is a graphical representation of the system development process [16] [17] [18]. The Vee model shows the relationship between the system requirements, the system design, the system implementation, and the system verification and validation. The Vee model also illustrates the feedback loops and the risk and opportunity management that are essential for successfully designing a complex system following a system engineering approach. The Vee model for the engineering education system has been used limited for the design, development, and evaluation of engineering courses and curricula. The Vee model illustrated in Fig. 1 shows the relationship between the learning objectives, the teaching and learning activities, and the assessment methods at different levels of the engineering education system. It also shows the feedback loops and the verification and validation processes that ensure the quality and effectiveness of the engineering education system. It ensures that the system meets the needs and expectations of the stakeholders.

To understand the engineering university operation, an automation pyramid model [19] that shows the hierarchical structure and the interactions among the various components of the educational system is shown Figure 2

At the control level: Student Performance (SP) is evaluated in terms of the following variables: Academic Performance, Practical Skills, Capstone Projects & Research, Internships & Co-op Experiences, Technical Competence, Communication

& Presentation Skills, Problem-Solving Abilities, Teamwork & Collaboration, Professionalism, Ethical Behavior, and Extracurricular Activities.

At the planning level: Department Performance (DP) is evaluated in terms of the following variables: Faculty Qualifications, Curricula & Courses, Infrastructure & Facilities, Research & Innovation, Student Performance, Accreditation & Rankings, Alumni Success, Student Feedback, and Continuous Improvement Initiatives.

At the supervisory level: College Performance (CP) is evaluated in terms of the following variables: Strategic Vision and Planning, Academic Program Development, Faculty Recruitment and Development, Budget and Resource Management, Industry Engagement and Partnership, Research and Funding, Student Success and Engagement, Diversity, Equity, and Inclusion, External Relations and Fundraising, Leadership and Management Skills.

At the Management Level: At this level the University Performance (UP) is evaluated in terms of the following variables: Strategic Vision and Planning, Academic Excellence and Program Development, Financial Management and Resource Allocation, Faculty Recruitment and Development, Student Success and Engagement, External Relations and Partnerships, Diversity, Equity, and Inclusion, Research and Innovation, Community Engagement and Public Service, Leadership and Management Skills.

This paper, explores the complex interplay at the control level/Faculty, specifically focusing on Student Performance (SP). This is achieved by the development of a well-rounded engineer by following the ELAS framework. Under this level, there are multiple variables including Communication, Presentation Skills, Problem-Solving Abilities, Teamwork, and Collaboration. Using Model-Based Systems Engineering (MBSE) methodology, the current requirements given by Education Stakeholders, including government, ABET, Industry, and society are presented. Following this groundwork, the development of an Engineering Learning Analytics System Framework was designed. This framework advances teaching strategies, improves student outcomes, and designs efficient/adaptable learning systems. By integrating MBSE, the aim is to construct a systematic approach that not only captures the multi-variable nature of student performance metrics but also facilitates the continuous improvement of educational outcomes through data-driven insights and actionable feedback mechanisms.

III. Methodology

1) ELAS Framework Development: This paper employs Model-Based Systems Engineering (MBSE) in the development of the ELAS framework. MBSE provides a formalized methodology to support the requirements, design, analysis, verification, and validation associated with complex systems. MBSE places models at the core of system design. By doing so, it ensures a structured and holistic perspective of the framework, taking into account all interconnected components as part of a comprehensive system.

Problem Domain: The framework development begins by identifying the problem domain, which includes aligning with the requirements derived from various stakeholders such as government, industry, and the Accreditation Board for Engineering and Technology (ABET). These requirements ensure that the ELAS addresses the necessary technical competencies, complex problem-solving abilities, and professional skills needed in the current engineering landscape.

Solution Domain: The development of the system architecture is driven by the requirements of the problem domain. The architecture, as depicted in the figure 3, consists of several curricular tracks that are developed by department chairs and faculty. This structure is designed to be flexible, allowing for the creation or adjustment of course tracks in response to changing requirements.

The system architecture outlines the various controllable variables within the framework, such as faculty workload, teaching methods, and support services. This closely reflects

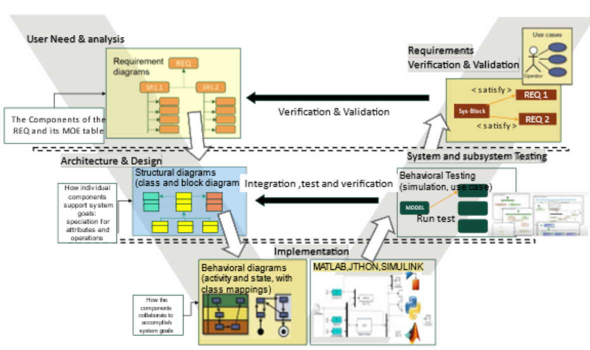

Fig. 1: Vee Mode - Overview of the SysML Modeling Process, Showing the progression from user needs and requirements through architecture and design to implementation and verification, with integration of behavioral simulations and system testing.

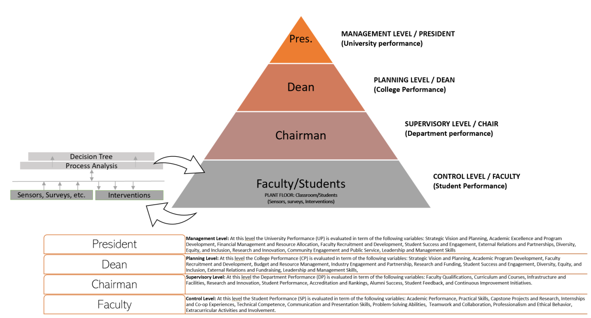

Fig. 2: Automation Pyramid in Educational Management, Showing the hierarchical decision-making process from faculty and student levels up to the president, integrating data-driven interventions for performance enhancement at each level

the application of SE principles, where each subsystem's role and interplay are meticulously planned. The architecture also considers uncontrollable variables that might affect student transition, such as family or health issues, and designs interventions to mitigate their impact.

The student body interacts with the implementation of the curriculum through various tracks and courses. Their satisfaction and course outcome data feedback into the system for verification, aligning with SE principles of iterative development and continuous improvement. If there is dissatisfaction or undesirable outcomes, the Course curricula are adjusted.

The final components of the diagram show the processes of Validation & Verification (V&V) of the requirements through engineering education system reports. These processes are integral to SE, ensuring that the system meets its objectives and stakeholder needs. The feedback loop in V&V ensures that the system can adapt and respond to new data, completing the holistic approach of the SE principles.

This details the systems engineering principles directly to the framework shown in figure 3, showing a clear line from the problem domain through to the implementation and the iterative feedback loops of verification and validation. It showcases how MBSE is applied to structure an engineering education system that is responsive, adaptable, and aligned with both academic and industry standards.

2) Defining System Requirements: The ELAS framework development process begins with detailed stakeholder requirements outlined in the tableI. Each requirement is considered a building block for the system, ensuring the final product aligns with the specific needs of each stakeholder group.

Government Requirements ($SH_R1 - SH_R2$): For government stakeholders, the system must adhere to performance-based funding models, ensure graduate earnings meet expected averages, maintain eligibility for financial aid, and achieve a certain job placement rate. These requirements are translated into system specifications that track and report on these metrics.

Educational Institution Requirements ($SH_R3 - SH_R4$): The institution's needs, including maintaining ABET accreditation and demonstrating a progression in technical skill and responsibility, are incorporated into the curriculum development

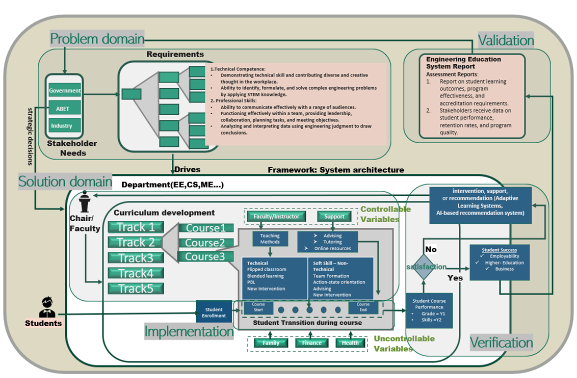

Fig. 3: ELAS op-down Framework from a Model-Base System Engineering Prospective.

ID	Stakeholder Requirement	Stakeholder Requirements Description
SHR_1	**GOVERNMENT -State University** system of Florida (Performance Based Funding Model)	
$SHR_1.0$	Bachelor's Graduates Earning	Average Bachelor's Graduates Employed Earning (Full-time) must be>= $\$60,000$
$SHR_1.1$	Eligibility for financial assistance	students must maintain a completion rate of 67% or higher to remain eligible for financial assistance
$SHR_1.2$	Pell-grant Financial assistance	student must complete graduation in six-year for receiving Pell-grant
$SHR_1.3$	job placement rate or continue education	each year students job placements rate should be $> 50\%$ or continue education
SHR_2	**ABET accreditation**	
$SHR_2.0$	Demonstrate a progression in technical competence and increasing responsibility in the practice of engineering	(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.(2) an ability to apply engineering design to produce solutions that meet specified needs
SHR_3	**Industry**	
$SHR_3.0$	Essential 21st century soft skills for engineer	1)Problem Solving:The ability to identify, analyze, and solve complex problems, 2)Communication: Effective exchange of information and ideas, 3)Collaboration:Working effectively with others towards a common goal, 4)Leadership: Guiding and inspiring others to achieve goals, 5)Critical Thinking: Objective analysis and evaluation of information, 6)Teamwork: Collaboration within a group to achieve objectives, 7)Adaptability Ability to adjust and thrive in changing environments.
SHR_4	**Society**	
$SHR_4.0$	Student Wellness Support	The institution must provide comprehensive support and resources to promote the physical, mental, and emotional well-being of students, fostering a healthy and balanced campus environment

TABLE I: Stakeholder Requirements

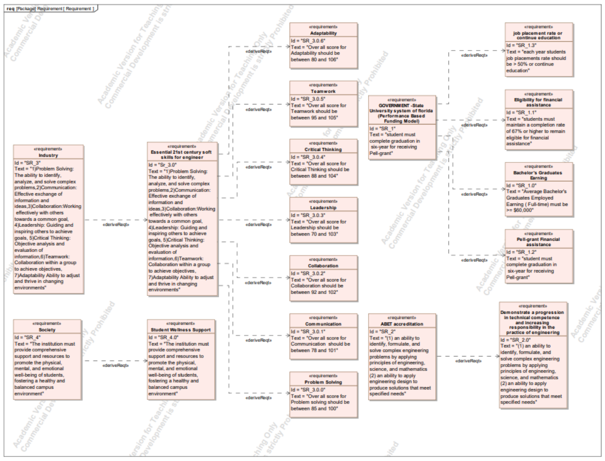

Fig. 4: SysML Requirement Diagram illustrating the hierarchical structure and interrelationships of system requirements for the ELAS Model

process. This includes defining learning outcomes that map to ABET criteria and creating assessment tools to measure progression in the practice of engineering.

Industry Requirements ($SH_R5 - SH_R6$): Industry requirements emphasize problem-solving abilities and essential 21st-century soft skills for engineers. The framework must include mechanisms to evaluate and enhance these skills, with a particular focus on collaboration, leadership, and adaptability.

Society Requirements (SH_R7): The broader societal impact is addressed by ensuring the ELAS framework supports the institution's role in fostering a healthy and supportive student environment. This might involve integrating wellness resources and support structures within the system.

Translation into System Features: Each requirement is translated into specific features and functionalities within the ELAS framework See Figure 4. For example, SH_R1 might result in a feature that allows tracking of graduate employment outcomes, while SH_R2 could lead to the development of a financial aid eligibility tracking system within the ELAS.

Requirements Validation: Finally, the defined system requirements are validated with stakeholders to ensure accuracy and completeness. This step may involve reviewing the requirements with government bodies, industry partners, faculty, and students to confirm that they reflect the stakeholders' true needs and expectations.

Measurement of Effectiveness (MOE): The system requirements for ELAS are directly informed by industry needs, as indicated by the Measurement of Effectiveness (MOE). The table provides clear benchmarks for soft skills that are critical in the industry, such as Problem Solving, Communication, and Teamwork, with specified target scores representing the desired level of competency. Detailed in Table II

The ELAS is designed to integrate a soft skills evaluation matrix that reflects industry-relevant competencies. The system needs to have mechanisms for assessing these skills against

Soft Skill	Evaluation Matrix	Target Score
Problem Solving	- Ability to identify and define complex problems - Analytical thinking and logical reasoning - Creativity and innovative solutions	> 85
Communication	- Ability to identify and define complex problems - Analytical thinking and logical reasoning - Creativity and innovative solutions	> 78
Collaboration	- Ability to identify and define complex problems - Analytical thinking and logical reasoning - Creativity and innovative solutions	> 92
Leadership	- Ability to identify and define complex problems - Analytical thinking and logical reasoning - Creativity and innovative solutions	> 70
Critical Thinking	- Ability to identify and define complex problems - Analytical thinking and logical reasoning - Creativity and innovative solutions	> 88
Teamwork	- Ability to identify and define complex problems - Analytical thinking and logical reasoning - Creativity and innovative solutions	> 95
Adaptability	- Ability to identify and define complex problems - Analytical thinking and logical reasoning - Creativity and innovative solutions	> 80

TABLE II: MOE for Stakeholder Requirements (SHR 3.0)

the set targets—such as ¿85 for Problem Solving, > 78 for Communication.

Assessment tools within the ELAS are tailored to measure the specific attributes listed in the MOE, such as analytical thinking and creativity. These tools must be capable of providing a nuanced evaluation that aligns with industry expectations for each soft skill.

Continuous Performance Monitoring: To ensure that the system effectively measures student development in line with industry requirements, ELAS is equipped with features for continuous performance monitoring. This allows for the tracking of student's scores against the MOE targets, facilitating timely interventions when targets are not being met.

Data-Driven Feedback Loops: The ELAS framework incorporates data-driven feedback loops that leverage the soft skills scores to inform both students and educators about areas of strength and those needing improvement. This feedback is crucial for adjusting teaching methods and learning strategies to better meet industry standards.

Reporting and Analytics: Advanced reporting and analytics capabilities are built into the ELAS to aggregate and analyze soft skill development data. These reports are aligned with the MOE targets and provide actionable insights to stakeholders on the efficacy of the educational programs in meeting industry needs.

Stakeholder Communication: The framework provisions for regular communication with industry stakeholders, using the

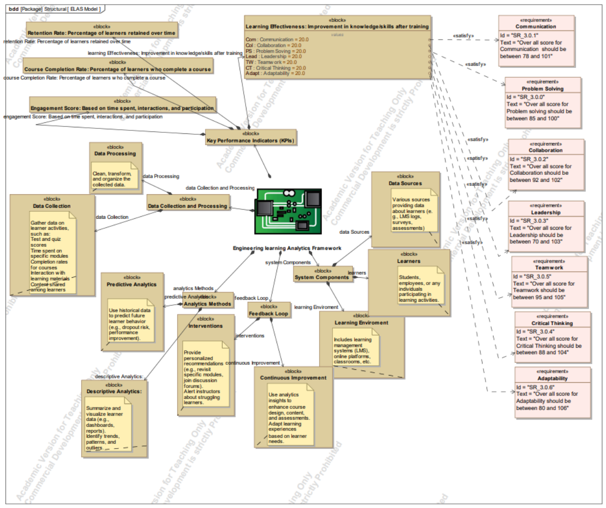

Fig. 5: SysML Block Definition Diagram (BDD) showcasing the modular architecture and component composition of the ELAS framework

data gathered to ensure the alignment of educational outcomes with evolving industry standards and to validate the effectiveness of the ELAS.

Iterative Refinement: Recognizing the dynamic nature of industry requirements, the ELAS framework is designed for iterative refinement. The system will regularly update the evaluation matrices and target scores in response to feedback from industry stakeholders and changes in the job market. See Figure 5 for the structural diagram of ELAS.

3) Modeling System Interactions: Figure 6 provides a visual representation Use Case diagram of the system interactions within the ELAS Block. It identifies the main actors involved, including the Department Chair, Students, Research Analyst, and Faculty/Instructor, as well as the primary use cases that they interact.

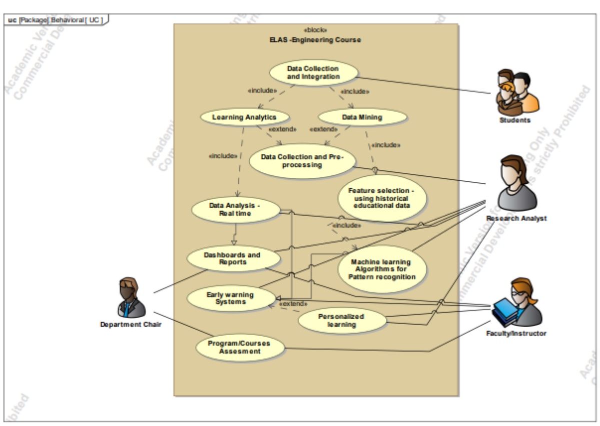

Fig. 6: SysML Use Case Diagram depicting the interactions between various actors and the ELAS system to fulfill key educational functions

Data Collection and Integration: This use case is central to ELAS, where data is collected from various academic and learning sources(LMS). This comprehensive data from the LMS is then fed into the learning analytics and data mining components of the system.

Learning Analytics and Data Mining: Students, Research Analysts, and Faculty interact with the system through these modules. Learning Analytics is focused on interpreting the data collected to derive insights into student learning patterns, while Data Mining is used to uncover deeper patterns and relationships within the data.

Data Collection and Pre-processing: This use case ensures that raw data is transformed into a format suitable for analysis. This step is crucial as it serves as the foundation for accurate and reliable subsequent analysis.

Feature Selection Using Historical Educational Data: This interaction involves selecting the most relevant features from historical data to predict or identify current student learning outcomes. Machine learning algorithms are applied for pattern recognition to facilitate this process.

Data Analysis - Real-time: The system is modeled to perform real-time data analysis, providing immediate insights that can be acted upon in real time. This interaction is key for adaptive learning environments where immediate feedback is essential.

Dashboards and Reports: The data analysis feeds into dashboards and reports, which are tools for the Department Chair and other stakeholders to monitor and assess the system's outputs. This interaction is designed to provide user-friendly and actionable insights.

Early Warning Systems: As a part of the interaction model, the system identifies students at risk based on predefined criteria and triggers alerts. This module extends to provide support mechanisms for those students.

Personalized Learning: This use case extends from the data analysis and machine learning components, modeling an interaction that delivers tailored educational experiences to students based on their unique learning patterns and needs.

Program/Courses Assessment: This final use case involves assessing the entire program or specific courses to ensure they meet the educational objectives. It models an interaction where the system's outputs are used to make informed decisions about curriculum design and instructional strategies.

Interactions with the Academic Community: Throughout the model, the interactions between the system and the academic community are structured to support a continuous feedback loop. This ensures that ELAS is dynamic and responsive to the needs of both students and educators.

IV. Result

The Result synthesizes the findings from the model- -requirement verification & validation simulation and compares them to the predefined bounds set by the system Measure of Effectiveness(MOE), as outlined in the table 7. Each soft skill has a specified range,i.e. the "Bounds" column, which is considered the acceptable target for student performance. The ”Value” column indicates the actual performance as measured by the system, and the ”Margin” column shows the difference between the actual value and the lower bound of the target range.

In the context of ELAS, the simulation of the system would involve creating scenarios where students engage in learning activities designed to develop and assess these soft skills. The simulation would generate predicted values for each skill, which would then be compared to the target bounds.

A. Model Simulation

The model simulation would involve running a series of tests where virtual student agents interact within the ELAS. The interactions would be based on algorithms that incorporate learning theories and pedagogical methods aimed at enhancing the soft skills outlined in the table.

For Problem Solving, a simulation might involve complex problem scenarios where students must navigate through problem identification to solution implementation. In the Communication skill area, simulated interactions may include various communication channels and content creation tasks. The simulation results would provide predictive data i.e. the ”Value” column in the table for each soft skill. For instance, the system might predict an average score of 70 for Problem Solving, which is 15 points below the lower bound of the target range.

Example of Model Simulation for Problem Solving:

Setup:

- Initial Parameters: The simulation begins by setting initial skill levels for a cohort of virtual student agents. For instance, the baseline problem-solving score might be set according to incoming student data or an assumed average.
- Learning Activities: The students are engaged in a series of problem-solving activities, such as case studies, puzzles, and real-world problem scenarios relevant to engineering.

Simulation Process:

#	Id	Name	Property	Bounds	Value	Margin
1	Sr_3.0	Sr_3.0 Essential 21st				
2	SR_1.0	SR_1.0 Bachelor's G				
3	SR_1.1	SR_1.1 Eligibility fo				
4	SR_1.2	SR_1.2 Pell-grant Fi				
5	SR_1.3	SR_1.3 job placeme				
6	SR_1	SR_1 GOVERNMEN				
7	SR_2.0	SR_2.0 Demonstrat				
8	SR_2	SR_2 ABET accredit				
9	SR_3.0.	SR_3.0.0 Problem S	PS : Problem Soving	[85;100]	70	-15
10	SR_3.0.	SR_3.0.1 Communic	Com : Communication	[78;101]	90	11
11	SR_3.0.	SR_3.0.2 Collaborat	Col : Collaboration	[92;102]	80	-12
12	SR_3.0.	SR_3.0.3 Leadership	Lead : Leadership	[70;103]	85	15
13	SR_3.0.	SR_3.0.4 Critical Thi	CT : Critical Thinking	[88;104]	95	7
14	SR_3.0.	SR_3.0.5 Teamwork	TW : Teamwork	[95;105]	60	-35
15	SR_3.0.	SR_3.0.6 Adaptabili	Adapt : Adaptability	[80;106]	70	-10
16	SR_3	SR_3 Industry				
17	SR_4.0	SR_4.0 Student Wel				
18	SR_4	SR_4 Society				

Fig. 7: Requirements Verification and Validation (V&V) Matrix for the ELAS Model, mapping the target performance metrics against actual outcomes to evaluate system efficacy

- Engagement and Interaction: The virtual students interact with these activities in the simulated ELAS environment, with each interaction contributing data points to the model.
- Adaptive Learning Pathways: Based on initial responses, the ELAS dynamically adjusts the complexity and type of problems presented to the students, aiming to gradually increase their problem-solving skills within the target bounds.

Data Collection:

- Performance Metrics: The simulation tracks various metrics such as time taken to solve problems, correctness of solutions, and the strategies used by the students.
- Feedback and Iteration: The system provides feedback to the students, which is also simulated, and allows for repeated attempts or scaffolding as needed to improve their problem-solving scores.

Predictive Analytics:

- Skill Growth Forecasting: Using the data collected, the simulation predicts growth in problem-solving skills over time, generating a forecasted score. Comparison to Target Bounds: The predicted scores are then compared to the target bounds specified for Problem Solving ([85,100]).
- Performance Metrics: The simulation tracks various metrics such as time taken to solve problems, correctness of solutions, and the strategies used by the students. Feedback and Iteration: The system provides feedback to the students, which is also simulated, and allows for repeated attempts or scaffolding as needed to improve their problem-solving scores.

Outcome Analysis:

- Evaluation of Effectiveness: The simulation evaluates the effectiveness of the ELAS in enhancing problem-solving skills by observing whether the virtual students' scores approach or enter the target bounds.
- Margin Analysis: It calculates the margins by which the predicted scores fall short of or exceed the lower bound of the target range.

Results:

- Successes and Shortfalls: If the forecasted score for Problem Solving after the simulation is, say, 70, this would indicate a shortfall of -15 from the lower bound of the target score, highlighting areas for improvement.
- Refinement Suggestions: Based on these results, recommendations are made to adjust the learning activities, provide additional resources, or enhance the feedback mechanisms within the ELAS to better support the development of the problem-solving skill.

Post-Simulation Actions:

- Following the simulation, the ELAS would be updated to incorporate the insights gained. This could involve:
- Enhancing Learning Materials: Introducing more complex or diverse problems to challenge the students.

- Personalizing Learning: Further personalizing the learning experience based on the student's demonstrated problem-solving ability.
- Instructor Interventions: Providing opportunities for instructors to intervene when students are not meeting the expected improvement trajectory.
- Through iterative simulations, adjustments, and re-simulations, the ELAS framework can be finely tuned to ensure that it effectively supports the development of problem-solving skills, ultimately aiming to bring all students within or above the desired performance bounds.

B. Requirements V&V

The Verification and Validation process would then assess the predictive accuracy of the model and the effectiveness of the system in developing the desired soft skills within the student population.

Verification would check whether the model accurately reflects the design and requirements, ensuring that the system measures what it is supposed to measure. Validation would assess how well the predicted values match actual student performance. If students are indeed achieving the skills within the target bounds, the system is considered valid. For example, if the model predicts a score of 60 for Teamwork, and the actual observed score after implementing the system is within the [95,105] range, the system would need significant adjustments. The negative margin of -35 indicates that the system is not currently effective at developing the Teamwork skill to the desired level.

C. Margins and Adjustments

The "Margin" column indicates how far off the predicted or actual values are from meeting the minimum requirement. A positive margin suggests that the system exceeds the minimum requirement, while a negative margin indicates a shortfall.

Where the margins are positive, that is Communication and Leadership, the system is likely effective as it is, though it could potentially be optimized further. Where the margins are negative that is Problem Solving, Collaboration, Teamwork, and Adaptability, this points to areas where the system needs improvement. Based on these results, the ELAS would be adjusted—perhaps by modifying the learning activities, enhancing feedback mechanisms, or providing additional resources.

The Results section concludes that ELAS model is designed to execute various scenarios, offering a robust platform to validate whether stakeholder requirements are being met effectively. As the model simulates different educational interventions and their impact on soft skill development, it generates critical data that can be used to refine and enhance the system. This iterative process of simulation, validation, and refinement ensures that the ELAS remains adept at fostering the key competencies that engineering students need to fulfill industry expectations. Upon analyzing simulation outcomes, the system can be meticulously adjusted to align more closely with the desired performance benchmarks. Reassessment strategies will be integral to this cyclical process, ensuring continuous improvement and the sustained relevance of the ELAS in the evolving educational landscape.

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V. DISCUSSION

The integration of Modal-Base System Engineering within the educational management framework, as demonstrated in this study, represents a paradigm shift toward a more systematic approach to academic performance enhancement. Through the careful application of SysML, from requirements diagrams to structural and behavioral models, a clear pathway for addressing the multifaceted nature of educational systems has been identified in this study. The Requirements Verification and Validation (V&V) process, anchored by the detailed matrix provided in Table II, ensured that each stakeholder's expectations were meticulously mapped and assessed against actual system performance. This rigorous approach has provided valuable insights into the efficacy of the model and highlighted areas requiring attention.

The Automation Pyramid shown in Figure 2, serves as a conceptual map for understanding the flow of information and decision-making across various tiers of educational administration. At the base, the study have the faculty and students, where the control level is most granular, focusing on direct student performance metrics. While ascending the pyramid, the scope of management broadens, moving through departmental chairpersons, deans, and ultimately to the university president, each level synthesizing information from below to inform broader institutional strategies.

ELAS model simulation exercises, which ran various scenarios through the ELAS framework, have been particularly revealing. For example, in simulating soft skill development scenarios, study noted a consistent shortfall in the area of Teamwork, as indicated by a -35 margin from the target performance score. This suggests a need for enhanced collaborative activities or revised pedagogical strategies within our system to boost this critical skill sets. Conversely, the area of Leadership exceeded expectations, suggesting that current methodologies are effectively nurturing this attribute among students.

Furthermore, the simulation revealed the impact of interventions fed by surveys and online forms, as depicted by the decision tree and process analysis tools in the model. These interventions are crucial for real-time course correction and represent a feedback loop that is pivotal for continuous improvement.

It is through the lens of the Automation Pyramid that the flow of such interventions is recognized. For instance, faculty can directly implement remedial measures based on real-time student performance data. At higher levels, the dean and department chair can use aggregated data to plan and execute strategic initiatives, such as curriculum adjustments or faculty development programs, to address systemic issues identified by the ELAS model.

Ultimately, the discussion of our findings underscores the importance of a systemic, data-driven approach in educational administration. The SysML framework, coupled with the insights gleaned from our simulations, provides a blueprint for decision-making that is both responsive and strategic. By bridging the gap between granular student performance data and high-level administrative actions, the study showcases an educational system that is not only self-aware but also self-improving.

To conclude, this study highlights the impact of the Model-Base Systems Engineering methodologies integrated with tools such as Cameo system modular, SysML, Data mining,Learning analytics tools which bring great promise for advancing the field of educational education /education management. Future work will focus on refining the ELAS model, expanding the scope of simulations, and further integrating the model's predictive capabilities into the decision-making processes at all levels of the educational hierarchy.

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