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Designing A Student Success Framework with Zachman Architecture

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WIP: Designing Student Success Framework with Zachman Architecture

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1. Introduction

In 2018, about six hundred thousand students were enrolled full-time in engineering programs in higher education in the United States [1]. Yet the American Society for Engineering Education (ASEE) found that engineering has a dropout rate of 40-50% [2]. ASEE also found that most engineering students do not complete the degree within the expected four years, with many needing closer to six years [2]. Poor advising, substandard teaching, difficulty of the curriculum, and lack of a sense of belonging in engineering are all significant contributing factors to the high dropout rate [3]. While understanding some of these reasons why students do not stay in engineering programs is important, an approach that focuses on barriers to success is fundamentally different from one that focuses on engineering students' holistic wellbeing [4,5]. Yet there is still a gap between talks and actionable support networks for students to succeed [6]. Thus, the guiding question for this paper is: *How can engineering programs in higher education better support holistic student development and overall well-being?*

In engineering, creating understanding of a problem often happens by creating conceptual models. This work proposes developing a Zachman architecture framework for student success modeling to provide additional perspectives and descriptions of the current literature (e.g., [5,7]). This architecture framework enables insight into six perspectives of student life, considered from six different viewpoints. This work-in-progress paper is a presentation of the framework, and the results of the study will be a follow-on effort. *By using a systems engineering architecture design framework to create an understanding of the metrics on student success, we can better understand ways to support students during their time in engineering programs and promote more holistic student growth and development.*

2. Background

2.1 Current Approaches to Assess Student Success

Since 1932, ABET, formerly the Engineers' Council for Professional Development, has provided evaluation criteria for engineering programs [8]. ABET has several different criteria available, but we focus on Criterion 3, Student Outcomes [9]. Criterion 3 was chosen due to its relevance to student performance, wellbeing, and development during an engineering program. Within this criterion, there are currently seven different statements that ABET expects engineering programs to meet:

1. Identify, formulate, and solve complex engineering problems
2. Apply engineering design to produce solutions that meet specified needs
3. Communicate effectively with a wide range of audiences
4. Recognize responsibilities in engineering situations and make informed judgements

5. Function effectively on a team
6. Develop and conduct experimentation, analyze and interpret data, and draw conclusions
7. Acquire and apply new knowledge as needed, using appropriate learning strategies

Along with ABET metrics, universities commonly have course learning outcomes that they expect their students to meet while taking classes. Yet both approaches focus heavily on the academic side of the student experience, and do not pay much attention to other areas of holistic growth or development. The course learning objectives provided by most classes focus primarily on obtaining and retaining information. Some examples of standard course learning outcomes are “Learners should be able to recall nutritional guidelines for planning meals” and “Learners should be able to develop solutions for networking problems, balancing business concerns, privacy and technical issues” [10]. While these course learning outcomes evaluate how well students are progressing in a class, they do not look at how much students have developed holistically.

2.2 Zachman Framework

The Zachman architecture framework, or the Zachman Framework for Enterprise Architecture, was developed by John Zachman at IBM in 1987 [11]. The Zachman framework is a 6x6 matrix that is used as a schema to assist in organizing complex information for large systems and is “a formal and structured way of viewing and defining an enterprise” [12]. By treating student success as part of the engineering education enterprise, the Zachman framework can be applied to some typical indicators of academic achievements, such as ABET metrics. The standard Zachman framework consists of six columns of primitive interrogatives to consider when analyzing a system. The six columns are what, how, when, who, where, and why. These columns explain the components and events that contribute to student success and thriving. The six rows of the Zachman framework are organized by perspectives, including scope, business model, system model, technology model, detailed representation, and functioning system [13]. Table 1 below shows an example of the Zachman framework.

Table 1. The Zachman Framework Adapted from [14] as Applied to a Business Enterprise

	What {Data}	**How {Function}**	**Where {Locations}**	**Who {People}**	**When {Time}**	**Why {Motivation}**
Scope {contextual} Planner	List of important items	List of processes	List of locations	List of important organizations	List of important events/cycles	List of business goals/strategies
Enterprise Model {conceptual} Business Owner	e.g., Semantic Model	e.g., Business Process Model	e.g., Business Logistics System	e.g., Workflow Model	e.g., Master Schedule	e.g., Business Plan
System Model {logical} Designer	e.g., Logical Data Model	e.g., Application Architecture	e.g., Distributed System Architecture	e.g., Human Interface Architecture	e.g., Process Structure	e.g., Business Rule Model
Technology Model {physical} Implementer	e.g., Physical Data Model	e.g., System Design	e.g., Technology Architecture	e.g., Presentation Architecture	e.g., Control Structure	e.g., Rule Design
Detailed Representation {out-of-context} Subcontractor	e.g., Data Definition	e.g., Program	e.g., Network Architecture	e.g., Security Architecture	e.g., Timing Definition	e.g., Rule Definition
Functioning System	e.g., Data	e.g., Function	e.g., Network	e.g., Organization	e.g., Schedule	e.g., Strategy

Zachman frameworks have been applied to a variety of domains in the past, from technology-based enterprise applications [15], to supply chain networks [16], and even sports [16]. While it is helpful to define what a Zachman framework is and how to apply it, the novelty of this project is the application of the framework to holistic student success in engineering programs. This project aims to develop a framework that captures both how a student is progressing academically, as is partially currently done with course learning outcomes, as well as how a student is progressing socially, mentally, and preparing for the time following graduation from their engineering program.

3. Methodology

This project focuses on incorporating ABET's seven metrics on student outcomes [12] into the framework. This will enable existing academic standards to be integrated alongside social, physical, and additional metrics of holistic student growth and development. These metrics are condensed into cognitive, affective, and psychomotor learning to develop six learning levels [18]. These levels include knowledge, comprehension, application, analysis, evaluation, and creation. This categorization is from ABET and was verified by previous literature from [19, 20, 21, 22]. The values from Criterion 3 were assigned to the various rows and columns by systems engineers with Zachman framework domain knowledge and was second checked by the coauthor on this paper. These six new levels are now used by the developed Zachman framework and correlate back to ABET's seven metrics, shown in Table 2 below to express clarity between the condensed metrics and the Zachman levels previously established.

Table 2. Relationship of the Condensed ABET Student Success Metrics onto the Zachman Architecture Levels

Learning	Condensed Metric	Zachman Level	ABET Metric Correlation
Cognitive	Knowledge	Scope	1, 4, 6, 7
Cognitive	Comprehension	Enterprise Model	1, 3, 4, 5, 6, 7
Affective	Application	Technology Model	1, 2, 5, 6
Psychomotor	Analysis	System Model	1, 2, 4, 6
Affective	Evaluation	Detailed Representation	2, 4, 5, 6
Psychomotor	Creation	Functioning System	1, 2, 5, 6

To design the Zachman framework, the elements of student success first needed to be mapped to the different cells of Zachman. All cells will be referred to as (row, column). ABET's Criterion 3 on Student Outcomes numbering is per Section 2.1. To map the seven student success metrics to the thirty-six cells in a complete Zachman Framework, a couple of rules needed to be established. The first of which is that each item in Criterion 3 must appear in the mapping. While this rule is basic, it does ensure that each item of Criterion 3 is being addressed by the developed framework. The next rule is that a column cannot have the same number for each row. Likewise, each row cannot have the same number in each column. This set of rules helps ensure that if a developed architecture were to be problematic or fail, that the entire framework would not miss a part of Criterion 3. An example of this is shown in Table 3 below, where bold, italicized numbers indicate a violation of this rule.

Table 3. Example Mapping with Rule Violations Bolded and Italicized. Numbers are ABET Criteria

	What	How	Where	Who	When	Why
Knowledge	***1***	***1***	***1***	***1***	***1***	***1***
Comprehension	***1***	2	7	2	3	5
Analysis	***1***	3	6	1	4	6
Application	***1***	4	5	5	6	7
Evaluation	***1***	5	4	6	7	2
Create	***1***	6	3	7	5	3

Once the different student success elements have been mapped to Zachman architecture cells, the development of the different architecture elements can begin. For the framework, there will be thirty-six unique elements developed. An example of these elements will be further discussed in the results section,

4. Results

To begin the development of the architecture, Criterion 3's elements had to each be mapped to one or more of the Zachman architecture's 36 cells. The result of this preliminary mapping is shown in Table 4 below.

Table 4. Preliminary Mapping of the Student Success Metrics on the New Zachman Framework with Numbers Corresponding to the ABET Criterion 3 Student Outcome

	What	How	Where	Who	When	Why
Knowledge	6	1	4	4	7	4
Comprehension	3	1	7	4	5	6
Analysis	6	1	4	4	2	2
Application	6	1	5	5	5	2
Evaluation	6	6	5	4	5	2
Create	6	1	5	2	5	2

The first of the architecture elements have been developed. This was developed to give an idea of how future models may look depending on student needs and inputs and is shown below in Figure 1.

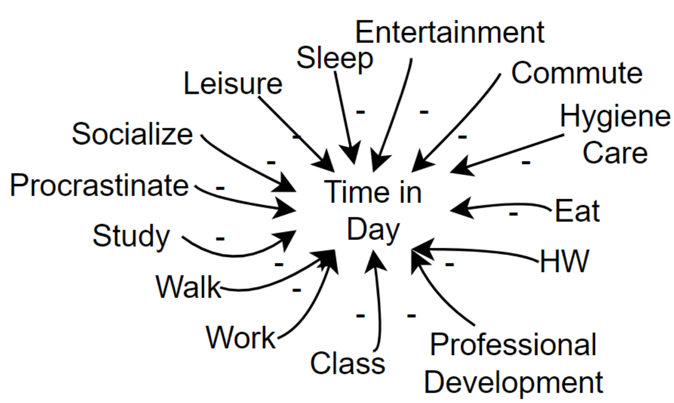

Figure 1. Functioning System Architecture for Student's Time Available in a Day via a Causal Diagram. Elements that Consume Time are Listed on Arrows with Minus Signs Showing the Diminishing of Time Left in a Student's Day (Functioning System, When)

5. Future Work

Once all thirty-six models are developed, they should first be validated through model testing. The eventual goal is that the framework will be distributed to students, and then there can be an evaluation of the impact on student well-being and success caused by students using and implementing this framework. It is necessary to evaluate these models for at least two years so that two cycles of students can use this developed framework to ensure less bias in the results. It is also necessary to evaluate the framework over a range of ages, class standings, and demographics to see how different elements do or do not impact the usefulness of the framework. Table 5 below highlights six of the proposed evaluation strategies.

Table 5. Proposed Evaluation Strategies for the Student Success Framework

Strategy	**Encoding**	**Weight**
Student Satisfaction Surveys	Quant	0.25
Faculty Satisfaction Survey	Quant	0.2
Enrollment Date Validation	Quant	0.05
Student Interviews	Qual	0.2
Academic Advisor Survey	Qual	0.1
End of Year Student Focus Group	Qual	0.2

To evaluate this framework, 261 of the students in a college of engineering at a large southeastern university should be surveyed. This sample size is based on an average of 6,045 undergraduate students in an engineering program from [2], a confidence level of 90% and a margin of error of 5%. This evaluation will be on a volunteer basis through an email call in the second week of the Fall semester. The participants will complete a pre-assessment, receive the student success tools, and receive monthly check-in emails to evaluate the perceived impact the framework tools have had on their success and well-being. They will complete a mid-cycle assessment in December before the winter break and an end-cycle assessment in May before graduation. The timeline for the recommended cycle of the framework can be found in Table 6 below.

Table 6. Proposed Evaluation Timeline for the Developing Zachman Architecture

Year 1		**Year 2**	
Pre-Assessment	September 2024	Pre-Assessment	September 2025
Monthly Emails	Sept-Dec 2024	Monthly Emails	Sept-Dec 2025
Mid-Cyle-Assessment	January 2025	Mid-Cyle-Assessment	January 2026
Monthly Emails	Jan-Apr 2025	Monthly Emails	Jan-Apr 2026
End-Cycle-Assessment	May 2025	End-Cycle-Assessment	May 2026

The questions used to evaluate the framework will consist of a combination of Likert style and demographic questions. The Likert questions seek to understand how confident a student is feeling on a specific competency of interest, such as the level of confidence that a student has for being prepared to enter industry in their chosen field. The demographic questions will largely aid in determining the factors which contribute to a student’s holistic development, for instance perhaps by their second year they were found to have increased confidence in industry readiness.

From the various questions asked to the students, the responses will help to drive the application and angle of the framework. For instance, if it is found that a particular group of students have a low confidence in a development area of interest, the framework can be molded to better provide resources to that group for aiding in their development. In terms of workforce development, this could include high level information for first year students from a business level perspective, and then narrowing down to a more detailed representation view for graduating seniors looking for a job or a student with more detailed career plans.

This framework is being developed from systems engineering principles. As such, systems engineering experts will be consulted throughout the development and design of the architectures to ensure they are sound from a theoretical standpoint and that the architectures follow architecture modeling standards.

Once the framework has passed verification and validation, it will be shared with the Engineering Fundamentals department and the Center for Teaching and Learning Excellence at Embry-Riddle Aeronautical University. These teams will be able to analyze the developed framework from the education space and provide input on any recommended changes for student implementation.

Before implementation, an Institutional Review Board will be contacted on the study to gain their approval before collecting the data involving the students. The review board will serve as the last validation point before implementing the first round of the framework for student success with the Fall 2024 incoming class.

Throughout each evaluation year, the framework data will be sorted, categorized, and analyzed with a mixed methods approach to observe and interpret the student perceptions of the framework from qualitative methods while measuring and evaluating the "scores" generated from the framework with quantitative methods. This approach will lead to a more accurate framework that can be expanded in future student cycles with larger data sets.

Since this project is still in its infancy, there is data to collect and evaluate. It is expected that data collection will begin in Fall 2024 and last until Spring 2026. Analysis for both project phases will occur over the summer, and the results will be shared with the ASEE community in Summer 2026. While two cycles of students are only the beginning of a comprehensive understanding of the usefulness of this proposed framework, it will provide a stable foundation to build off and help continue supporting student success through applied systems thinking and architecture-based developments. Thus, this work provides a key step toward supporting student success in engineering departments and is a step towards increasing retention, student learning, and support in these departments.

6. Conclusion

This work aims to examine the central question of *how engineering programs in higher education can better support holistic student development and overall well-being* using Zachman architecture, systems thinking, and mixed methods. In turn, this approach will evaluate the hypothesis: *Architecture can be used to create an understanding of how ABET metrics impact student success to better support students during their time in engineering programs and promote more holistic student growth and development*. The completed work provides the three contributions to the field of engineering education.

First, the framework developed in this paper will provide more insight into student success. With talks of thriving becoming commonplace, it is necessary to understand how students succeed in engineering programs, find ways to measure it, and have a framework to organize the results.

Next, the framework will provide engineering departments with a way to analyze their departments for student success. Once the process described in Section 5 has been completed, this framework will identify the components a department needs to have in place to support student success and thriving.

Lastly, the framework will expand on how architecture can be used in an educational research space to further student support. This framework will help identify the critical items of student success, and architecture can represent them so that people without domain knowledge can understand and apply knowledge of them to additional problems and challenges. This framework will help relate the ABET student success metrics to key elements of student well-being and success, and through an evaluation of the perceived usefulness of the framework, an understanding of the impact of each ABET student success metric on well-being and success can be further developed.

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