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Board 118: Systems Engineering Initiative for Student Success (SEISS) Framework for Transforming Organizational Designs

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Systems Engineering Initiative for Student Success (SEISS) Framework for Transforming Organizational Designs

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Abstract
In this paper, we present the Systems Engineering Initiative for Student Success (SEISS) framework we are developing for enabling educational organizations to scan, evaluate and transform their operations to achieve their diversity, equity, and inclusion goals in student recruitment, retention, and graduation. The underlying structure and logic in our SEISS framework is that an organization such as a college of engineering is a *sociotechnical system (STS)* consisting of a social subsystem and a technical subsystem. The social subsystem consists of people, their roles and is a model of who talks to whom about what. The technical subsystem consists of all the activities, programs, policies, and operations that help the organization achieve its goals. In a sociotechnical system, the social and technical subsystems are interdependent in their functioning, and they must be jointly optimized from an organizational design perspective. Our SEISS framework which views a college or a similar organizational unit as a sociotechnical system lends the organizational designer a unique systems lens with which to view, analyze and design the operations and organize the capacities and resources in the college. The systems lens views an organizational unit, its sub-systems, components, and its corresponding capacities not in isolation, but as entities that interact with each other. With support from an NSF IUSE grant, we have been developing the SEISS framework and have piloted the framework in a predominantly white college of engineering to identify existing and potential technical and social system capacities for underrepresented minority (URM) students to succeed in the college. Preliminary results from our qualitative analyses of URM student interviews reveal the utility of the SEISS framework and the STS lens in unearthing the barriers and enablers for these students in the social and technical subsystems in the college. We also model the interactions between the social and technical subsystem elements in the SEISS framework, revealing latent opportunities for leveraging the connections between the social and technical subsystem capacities and resources.

1. Introduction
To assess and evaluate current capacities and identify catalysts that can bring about transformational change in an institution and promote student success, we argue that we need to view a college as a complex *sociotechnical organization*[1] with two subsystems at work – a *social subsystem* consisting of people including key stakeholders such as URM students, faculty, staff, and administrators, and a *technical subsystem* consisting of all elements that can impact capacity building, including goals, policies, processes, programs, data, technology, and knowhow. By conceptualizing the college as a sociotechnical organization with a social and a

technical subsystem, we gain a *sociotechnical systems lens*. This lens can reveal both existing but latent, and new, catalysts in the *social system* to enable *people capital* so we can leverage and connect these catalysts in the social system with the catalysts in the *technical system* to enable resources like *money and knowhow*. We can then strengthen the processes and structures either already in place or to be created anew for meeting expressed and latent unmet needs, and for delivering transformative experiences for students. Our rationale for our approach is that by using a *systems lens* to view and analyze the dynamics of the social and technical system catalysts in a college, we will generate views of the organization that *integrate* both structural resources, needs and constraints on capacity, and grassroots efforts, resources, needs and constraints on capacity. The social and the technical subsystems in an organization are interdependent – that is, one does not have a purpose without the other, so both will need to be examined and designed jointly.

To this end, we present the Systems Engineering Initiative for Student Success (SEISS) framework we are developing for enabling educational organizations to scan, evaluate and transform their operations to achieve their diversity, equity, and inclusion goals in student recruitment, retention, and graduation. Our SEISS framework which views a college or a similar organizational unit as a sociotechnical system lends the organizational designer a unique systems lens with which to view, analyze and design the operations and organize the capacities and resources in the college. The systems lens views an organizational unit, its sub-systems, components, and its corresponding capacities not in isolation, but as entities that interact with each other. We have piloted the framework in a predominantly white college of engineering to identify existing and potential technical and social system capacities for underrepresented minority (URM) students to succeed in the college. Preliminary results from our qualitative analyses of URM student interviews conducted by the primary author reveal the utility of the SEISS framework and the STS lens in unearthing the barriers and enablers for these students in the social and technical subsystems in the college.

2. Bases for SEISS Framework: Organizational and Systems Thinking

Systems theory advances a perspective that any organization is an open social system that interacts with its environment to perform its functions[2]. Systems approaches view an organization as composed of many interacting components including the people, technology, physical environment, policies and processes. Systems theory suggests that there are inputs and outputs in the system, and feedback loops between the system and the external environment to maintain the equilibrium of a system. The system processes the input, resulting in throughput and finally output, and checks against the feedback loop to calibrate its outputs. The sociotechnical systems methodology we use in our study is based on systems theory and has been developed from classical organizational design studies conducted by Emery and Trist[3]–[5], and the methods refined and adapted by Taylor and Felton[1].

Sociotechnical systems consider the social aspects, technical aspects, and the interactions between them. Sociotechnical systems approach argues for *jointly optimizing* the social and the technical elements, since optimizing them in isolation produces unexpected and undesirable non-linear relationships. The sociotechnical systems theory[5] was one of the first to use a group, instead of an individual as the unit of analysis. Some of the main characteristics of sociotechnical systems include responsible autonomy of the stakeholders involved, adaptability to changing external conditions, and aligning the performance of systems to meaningful goals and tasks. Sociotechnical systems approach has been used to understand many research problems[6] including in knowledge management[7], organizational learning[8]–[10], learning and teaching[11]–[13], innovation[14], process improvement in higher education[11], [15], and auto manufacturing[16] to name a few. In this study, we use the sociotechnical systems methodology developed by Taylor and Felton[1] to guide the development of our SEISS framework and to integrate tools for technical and social system analysis for capacity assessment.

2.1 SEISS Framework and Process

In this section, we present the main components of the SEISS framework and the different steps in the SEISS process. We begin with describing the skeletal structure of the sociotechnical system followed by the components involved in a technical system analysis and social system analysis. Finally, we discuss preliminary findings based on student interviews from the sociotechnical systems SEISS lens.

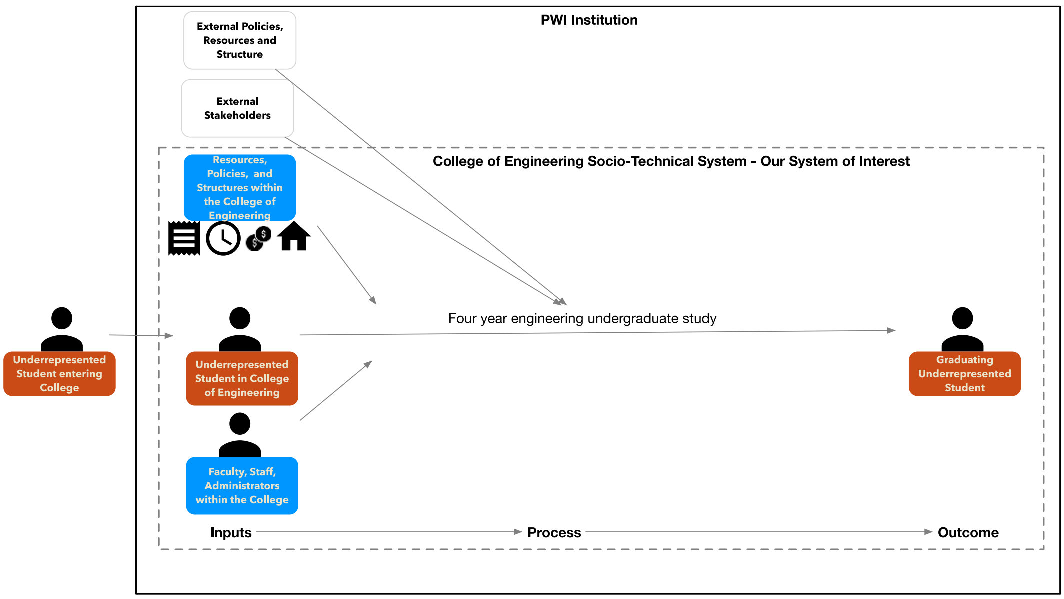

Figure 1. Technical System inputs, outputs and boundaries in relation to stakeholders

Key Operations											Key Attributes of Operations
Advising	1	1									Availability of courses to take this semester
	2		**2**								Amount of contact time with advisor
	3			**3**							Amount of availability of advisor
	4				4						Number of documents to fill for advising
	5			X		5					Time of last meeting with advisor
	6		X				6				Current student GPA
	7						X	7			Grades in prerequisite courses
	8	X			X	X			8		Completeness of documents in student files
	9	X	X							**9**	Clarity of degree requirements
	10	...									

Figure 2a. Example of a key operation Advising and possible attributes

Key Operations											Key Attributes of Operations
Recruiting	1	1									Number of staff dedicated to recruiting
	2		**2**								Extent of relationship with high schools
	3	X		**3**							Amount of money available for recruitment
	4		X		4						Frequency of contacts with high schools
	5				X	5					Amount of messaging to high schools
	6						6				Extent of variety of recruiting materials
	7	X	X					7			Extent of student spokespersons
	8						X		8		Quality of messaging to high schools
	9			X						**9**	Clarity of metrics for measuring recruiting
	10	...									

Figure 2b. Example of a key operation Recruitment and possible attributes

Technical system input, output and boundaries. The first step in the SEISS process is to understand the physical and time boundaries of the sociotechnical system of interest. Additionally, we identify the inputs to the system, the process and the resources within the sociotechnical system that transforms the inputs into the final output or outcomes from the system. Figure 1 shows a depiction of our sociotechnical system of interest. The inputs to our system consist of URM undergraduate students, faculty, staff, administrators, policies, resources, and infrastructure, which we liken to essential "raw materials" to recruit and retain students successfully. Our output from the technical system is the successful URM student. Our time boundary represents a typical 4-year undergraduate journey through an engineering program. Our territorial boundary is the College of Engineering.

Assessment of Purpose. The next step in the SEISS process is to have stakeholders articulate their understanding of the purpose of their efforts towards recruitment and retention of URMs and their understanding of the relationship between their activities and the purpose. Gaining perspectives from different system stakeholders helps us examine the degree of alignment and congruence of the purpose and goals of recruitment and retention activities between different stakeholders. Points of misalignment show that purpose of the organization is not calibrated for different stakeholders, and perhaps not clearly articulated and reveal opportunities for systems improvements.

Technical system analysis. The technical analysis captures the *work* done by stakeholders (including the URM students themselves) to make URM students successful. Given we want to understand *how* the stakeholders work in the system to achieve their goal of URM student success, the SEISS process gathers information on their know-how and expertise, the resources and programs they use, their awareness of policies, and their use of current infrastructure in the college. The goal is to identify the different activities in the college that significantly influence the recruitment and retention of URM students in some way – that is, any activity in the system that stakeholders undertake to make URM students successful; SEISS process labels these activities *key operations*.

Next, for each significant key operation, the SEISS process identifies potential barriers stakeholders report. For example, students might indicate *Amount of contact time with advisor* as a potential barrier or challenge they face in advising (a key operation). The SEISS process represents all these key operations together in a matrix form (see figure 2a and 2b) to: (1) provide a unified visual view across all key operations of all stakeholders; (2) identify any relationships between the attributes – for example, in figure 2a an x in the matrix indicates an interaction – the *number of documents to fill for advising is related to the completeness of documents in student files;* (3) identify key attributes.

Identification of key attributes. From the attribute matrix, the SEISS process helps identify the *key attributes* based on the following criteria: (1) does the attribute have an influence downstream on the success of the URM student? (2) does the attribute have many relationships with other attributes compounding the problem? (3) would these attributes by themselves significantly impact the URM student or the College? (4) were these attributes consistently identified as important by the stakeholder? These attributes are systematically ranked based on these criteria to identify the key attributes.

Social system analysis. *People, the stakeholders,* enable the college to reach short-term and long-term goals in diversifying the student body. People interact with each other in relationship structures based on their roles and responsibilities, so we need to understand how they interact within these structures if we are to leverage and align our social capital with our technical capacity, and if we are to empower the stakeholders to make changes. To model the social system's capacity, the SEISS process helps generate focal role network models and social system grids.

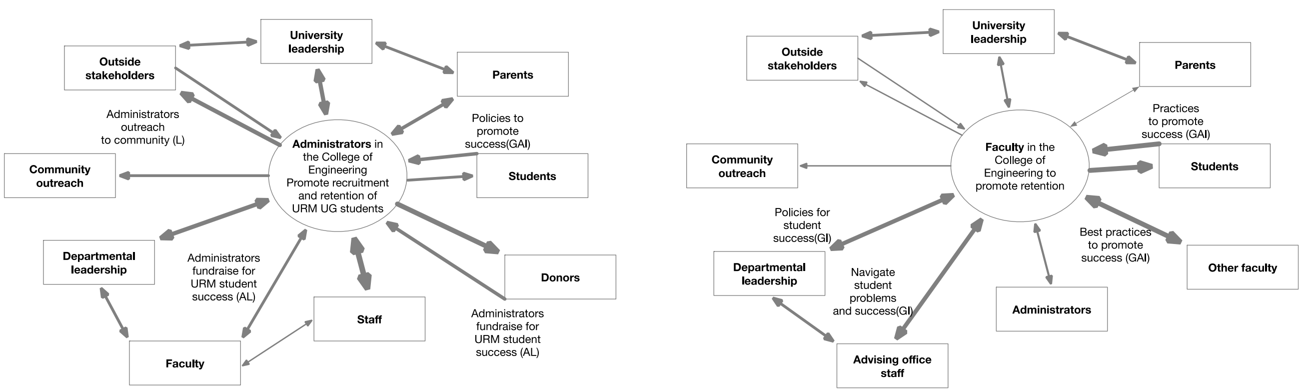

Figure 3. Focal role network with GAIL analyses

	Vertical Contact (supervisor to subordinate)	Equal contact (peers in the same workgroup)	Cross contact (between departments in the same college)	Outside contact (outside the college)	Non-social (employee work perceptions)
Goal attainment	-Staff coordinate with faculty for recruitment (+)		-Staff discuss future orientations for URM undergraduate students (0)		
Adaptation to external environment	-Administrators form partnerships with community colleges to increase recruitment (+)				
Integration of internal system	-Administrators resolve financial issues with staff assistance (-)	-Faculty discuss how best to advise students to prevent problems (-)		-URM professional organizations contact national organization to organize career workshops (+)	
Long-term development			-Faculty discuss curriculum changes to promote current state of the art(+)		-Administrators and staff conduct more outreach workshops for retention (+)

Figure 4. GAIL-VECON relationships

The social subsystem analysis phase of the SEISS framework focuses on : (1) identifying who the stakeholders regularly rely on to support the goals of recruitment and retention of URM students; (2) how the different stakeholders work toward GAIL, that is toward attaining goals (G), toward adapting to the external environment (A), toward integrating with their internal work environment to manage their conflicts (I) and toward developing their unit's long-term (L) capacity; (3) how the different stakeholders' relationships are structured – that is, whether the relationship is vertical/top down (V), horizontal/equal (E), cross-boundary across departments and programs within the College (C), outside the college of Engineering (O), and if the relationship is based on work-related perceptions that the different stakeholders carry (N); and (4) expectations of the stakeholders and the barriers or resources in leveraging the social capital in the system.

The social subsystem analysis helps identify all relevant stakeholders inside and outside the college who contribute in any capacity to make URM students successful. Each stakeholder could identify a distinct set of people based on their interactions and based on how much they rely on them for their work in supporting the success of URM students (figure 3). For example, a student may identify faculty, staff in the advising office, peers in a professional organization, and mentors in their internship as key stakeholders. A faculty, on the other hand, might identify administrators, and advising and tutoring staff as key in influencing the success of students. While there may be overlaps in the stakeholders identified by the participants, these also represent unique stakeholder views on social capacity. Systematically identifying what each stakeholder can contribute is an indication of their capacity – this can help in matching the technical system attributes we identified earlier with the capacity each stakeholder in the system brings.

In addition to the GAIL analyses, for each stakeholder, the SEISS process helps identify what type of relationship (please see figure 4) the participant has. For example, if a faculty identifies an administrator as a stakeholder, that indicates a vertical relationship, whereas if they identify other faculty, that indicates an equal/horizontal relationship. These relationships are crucial to identify – social capital can often address technical barriers without misaligning the goals that difficult vertical or cross-boundary authority relationships and power structures create in the system.

Bringing the technical analysis together with the social system analysis will help us identify which stakeholders can best address the technical barriers. For example, if a student mentions a lack of a particular resource as a barrier, and an administrator mentions that they know an alternative resource, we can identify the administrator as a "key stakeholder" in enabling this resource for the success of the student. A social system grid with these focal roles, their functions (GAIL), and types of relationships (VECON), helps integrate the technical system barriers and the social capital that we can leverage to address those barriers (see figure 4). The social system grid functions as the first step towards bridging the social and technical parts of the system, and the top-down and bottom-up approaches in the system.

3. Preliminary Findings from the SEISS Lens

We conducted interviews with 16 URM students in a college of engineering about social and emotional support structures, socioeconomics, and institutional structures they use; we sought information on their *social subsystem*, the different roles that constitute their social system, enablers and barriers they encounter in the social subsystem; and about their *technical subsystem*, the boundaries that make up their technical system including the college of engineering and related units, their goals, programs, policies, processes, technology, knowhow and other resources that serve as a significant part of their undergraduate study, and the barriers and enablers within the technical subsystem.

A deductive approach to data coding and qualitative analyses helped us elicit the social and technical system barriers and enablers, and linkages between barriers and enablers for URM students in the college.

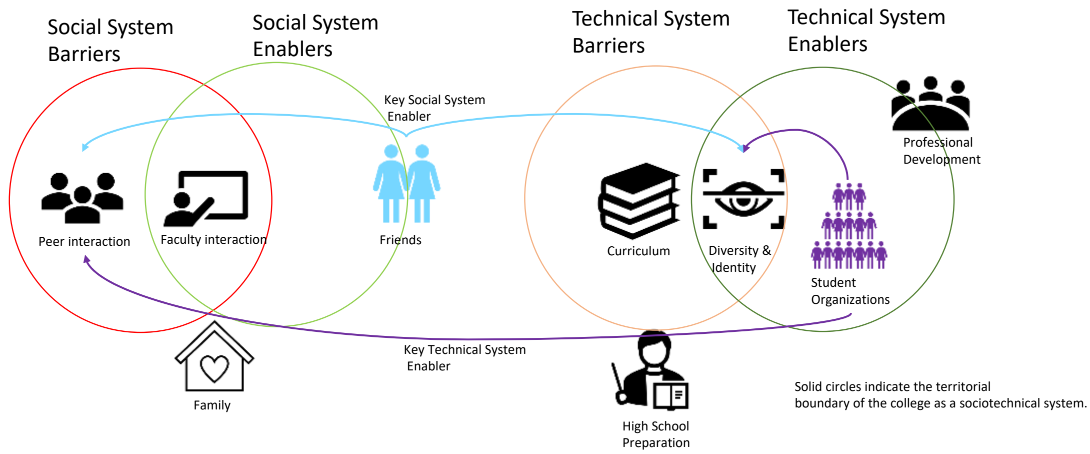

Figure 5. Technical and Social System Barriers and Enablers from a SEISS lens

We mapped the barriers and enablers that students reported in their social and technical sub-systems (see figure 5). The social sub-systems and technical sub-systems are shown as separate systems in the figure for clarity, but in reality, they are embedded within one another. The solid circles indicate the territorial boundary of the College of Engineering (our unit of analysis). Hence, family as part of the social sub-system is represented outside this boundary. Friends are embedded both within and outside this system boundary. Similarly, for the technical system, high school preparation is represented outside the technical system boundary. Professional development opportunities are present both within and outside the system boundary.

Our preliminary findings indicate that inadequate peer interaction, faculty interaction and family concerns emerge as barriers in the social system. Family support, faculty interaction and friends' support emerge as enablers in the social system. Lack of curriculum and instruction tailored to student needs and market trends, lack of diversity, and inadequate high school preparation emerge as technical system barriers. Professional development opportunities, diversity-based student organizations and efforts to improve diversity are seen as technical system enablers.

Viewing these barriers and enablers from a SEISS systems-based lens reveals a few important insights: (1) factors that were identified as barriers in either subsystem sometimes also serves as an enabler or at least has the potential to be an enabler. For example, lack of interaction with faculty was identified as a barrier, but when present and adequate was identified as an enabler. This indicates that such factors could be capitalized for system improvement opportunities given that they are already present to some degree in the system. (2) In both the social and technical sub-systems, barriers and enablers beyond the college of engineering system were identified. Students perceive their sociotechnical system to extend beyond the college of engineering – the barriers identified outside of the system significantly impacted their performance and success within the college of engineering; Similarly, the enablers identified helped them cope better with struggles they faced within the college of engineering system. This indicates that there are existing capacities not just within the College of Engineering, but outside and beyond that can be better utilized. But it also raises questions on whether the students resort to outside resources because they find the support within the system inadequate. (3) The social and the technical sub-systems have key enablers that address barriers across the sociotechnical system. The support from friends emerged as a key social system enabler that not only addressed barriers due to lack of peer interaction (social system barrier), but also helped cope with isolation because of lack of diversity (technical system barrier). Similarly, diversity based student organizations emerged as a key technical system enabler that helped students address isolation due to lack of diversity and identity (technical system barrier), and also lack of peer interaction (social system barrier). These key enablers and linkages between the social and technical sub-systems indicate that existing resources within either system can be used to address inadequacies in the other sub-system. Additionally, these key enablers need to be better supported and nurtured within the system so that students continue to be supported in their endeavors. For example, diversity-based student organizations could be better funded because of the important role it plays in how it shapes the URM student experiences. Similarly, colleges could better integrate other support structures such as friends or family into programs and activities they plan (4) Finally, one could argue that the barriers themselves could be directly addressed to improve student experiences. While this is true and needed for sustaining systems improvements over the long term, utilizing capacities and key enablers that already exists and works for the students might serve as a good first step to ignite the process of systems-based improvements.

The capabilities and deficiencies of the college in its goals, policies, processes, programs (the technical system), and how well the technical system in the college aligns with institutional goals and environments directly impact the college's success in recruiting and retaining URM students. We continue to develop the main components of the SEISS framework including the technical system analysis of key operations and attributes and the social system analysis with focal role networks, GAIL and VECON to contribute to our understanding of how to make systems level transformations to better align resources, needs and constraints on capacity to successfully recruit and retain URM students.

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