A System Approach to Instructional Change in Academia

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Abstract

The objective of this literature review (theory) paper is to present and describe a framework that illustrates factors in the academic system that drive or hinder the adoption of Research-Based Instructional Strategies (RBIS) in engineering education.

Numerous initiatives to promote instructional change in engineering education have had low to moderate success. Such lack of success can be attributed to the fact that the academic system has numerous elements, which leads to a complexity that needs to be properly understood. We suggest that the low success rates from previous instructional change initiatives are due to a viewpoint of the academic system that does not account for the dynamic and detailed complexity of academia. By using a system perspective, this paper illustrates the internal elements of the complex academic system that have been shown to ultimately influence faculty to enact instructional change.

To determine what factors are currently known to affect the success of such change initiatives, we reviewed the literature on instructional change in engineering and higher education. The refined search yielded 19 documents that were analyzed following several steps of constant comparative analysis.

This review suggests the existence of at least 31 factors that can potentially impact the successful implementation of RBIS in the classroom. Hence, they could be barriers or drivers to instructional change in higher education. These 31 factors were classified and organized into six categories: 1) culture, 2) change management, 3) institutional support, 4) pedagogical knowledge and skills, 5) students´ experience, and 6) faculty motivation.

Background

Several reports on engineering education make the call to change pedagogical approaches in engineering by increasingly embedding research on learning into teaching practices [1-3]. This type of change, that involves a transformation in instructional practices and adoption of RBIS, is called instructional change [4]. Facilitating instructional change in engineering education requires a different approach, one that understands academia as a complex system [5] and uses systems thinking to understand how everything is connected to everything else [6] instead of the traditional approach that is based only on faculty reflection and intuition drawn from their teaching experiences [2]

Academia is a complex system, and as such, it does not have isolated drivers or root causes that are individually capable of generating change [6]. Instead, multiple interactions and feedback loops exist that reinforce or balance decisions, motivators, and actions of agents in the system [7]. Academia is a system with strong historical roots but loose coupling within its parts [8], with stated “rules of engagement” but unseen or hidden agendas [9] and struggles of power [10]. It has defined structures yet diverse values and beliefs [11], published statements of mission and vision to educate students but with varied willingness to fulfill those statements [12], and three clear yet unequally distributed pillars that sustain it (i.e., teaching, research, and service) [13, 14]. The effectiveness of change within a complex system diminishes if we consider change as a linear process and we use designs that aim to solve simple and static problems instead of using a non-linear approach designed to deal with complexity [6, 7].

Universities, and particularly colleges/schools of science and engineering, have taken different strategies to promote instructional change but with low or moderate success [12, 13]. There are different reasons found in the literature that explain the success (or the lack of) in science and engineering education change initiatives. The purpose of this study was to review the literature to understand better these reasons. We argue that these different reasons suggest that success in change initiatives depends on the integration of several factors and change agents' actions. This paper shows the review of the literature aimed to answer the following research question:

> **What are the factors in the academic system that affect instructional change in engineering education?**

Methods

Sources of information

We followed multiple steps to search and select literature. First, to gather initial articles, we used broader search criteria with terms like "instructional change AND STEM," "STEM AND evidence-based instructional practices," "Higher education AND RBIS," "faculty AND instructional change." We read the abstracts to determine if the references discussed practices, barriers, or drivers to instructional change in STEM or higher education and excluded those oriented exclusively toward the methods of such practices (e.g., articles dedicated to describe or establish the effectiveness of certain RBIS). We refined the search by browsing the articles and looking for language related to barriers, drivers, adoption, or implementation of instructional change. Such references were registered in a spreadsheet to later read in detail. This process also assisted us in identifying new search terms and start establishing important authors in the particular field. The refined search ended with 19 documents (11 journal papers, two books, one book chapter, one report, and four conference papers).

Analysis

In summary, we conducted a content analysis [15] of the 19 documents. To analyze each document, we selected the factors described in each document. We defined factors as any resource, structure, or other content that was described as driving or hindering change from occurring. Factors were understood as barriers if they inhibit change, or they were understood as drivers if their presence supports or promotes change. However, some elements were not clearly defined as barriers or drivers.

The process of organizing, analyzing, and coding the information from the literature consisted of several steps of content analysis. Open coding [16] was initially used to designate the name of a factor represented in the selected literature. We extracted and coded all the factors from the selected references which we organized, classified in related groups, and categorized using axial coding [16]. As we refined these codes, we created definitions to appropriately understand what the classifications represented. Categorical axial codes were further refined by comparing the codes to literature related to change in higher education [12] or organizational change [7, 9, 17-21]. This study resulted in 31 factors that affect instructional change organized in six categories: faculty motivation, students' experience, faculty knowledge and skills, institutional support, change management, and culture.

Factors that influence Instructional Change

A summary of such factors, categories and brief definitions is shown in Table 1.

Table 1 Summary of the factors that influences instructional change in academia

Categories	Factors		Description
<u>Cultural</u>: Factors related to the cultural elements constructed and shared among members of an organization that inform the meanings that people assign to different situations.	**Symbols and artifacts**		Rituals, traditions, events or historical representations of the organizational culture.
	Attitudes		The perceived institutional attitudes towards faculty and the faculty attitudes toward change.
	Beliefs		The mental models that faculty share about teaching.
	Assumptions		The predefined interpretations or meanings towards academic activities.
	Values		The different collective importance or reputation that faculty and administrators attribute to the academic activities.
<u>Change Management</u>: Factors related to the design and management of the change process itself.	**Process Design**		The planned steps to enact instructional change.
	Vision		A picture of the future communicated to stakeholders that helps clarify the direction in which an organization wants to move.
	Goals		The milestones to fulfill the vision.
	Evaluation		The assessment and interpretations of the instructional change process.
<u>Institutional Support</u>: Factors related to the formal institutional support to the change initiative.	**Structures and Procedures**	Institutional Policies	The norms and rules of the institution about tenure, promotion, service and teaching.
		Available Resources and infrastructure	The Institutional resources, the allocation of those resources and the physical infrastructure.
		Instructional training	The support resources directed to enhance the faculty´s pedagogical knowledge.
		Flexibility of Curriculum	The flexibility of timing, content and sequence of the instruction.
		Time Allotted	The time allotted and dedicated to adopting the change initiative

	Networking and Community	Emergent	Conditions for networking and community development which naturally arise from faculty.
		Prescribed	conditions for networking and community development which are designated by administrators and leaders.
		Coordination of activities	The coordination of change initiative activities among change agents, faculty, administrators and staff.
<u>Pedagogical Knowledge and Skills</u>: Factors related to the level of knowledge or skills that faculty have about RBIS.	**Awareness**		The consciousness that faculty have about the existence and characteristics of different RBIS.
	Familiarity		The understanding of the educational concepts behind RBIS and those concepts´ effect on students´ learning.
	Expertise		The accumulated knowledge of the RBIS that effectively improves faculty teaching methods.
<u>Students´ Experience:</u> Factors related to how students perceive their academic experience in classrooms where RBIS are implemented.	**Improvement on students´ learning**		The perception of the improvement that RBIS has on student´s learning.
	Evaluation of student´s learning		The assessment of the students´ performance.
	Students´ resistance		The students´ resistance to engage in classrooms where RBIS are implemented.
	Students´ evaluation of teaching		The feedback and evaluation that students provide to the instructors and their instruction.
<u>Faculty motivation:</u> Factors related to the faculty´s willingness to adopt RBIS in their classes	**Empowerment**		The perception that faculty have some control over their learning process and a sense of autonomy to make their own choices.
	Usefulness	Value	The perception that adopting RBIS is useful or beneficial for faculty´s short or long-term goals
		External motivation	The external incentives, rewards, recognition or benefits of implementing RBIS.
		Cost Benefit Balance	The perception that the benefits of adopting RBIS outweigh its costs or risks.
	Success	Assessment Self-Efficacy	The faculty´s belief that they can succeed if they have the knowledge, skills, and put forth the proper effort.
	Interest		The value or importance that faculty put on their teaching.

a. Cultural Factors

The factors associated with this category are related to the cultural elements (i.e., symbols and artifacts, attitudes, beliefs, assumptions, and values) constructed and shared among members of an organization. Such cultural elements inform the meanings that people assign to different situations.

Symbols and Artifacts entail rituals, traditions, events, or historical representations of the organizational culture [17]. Finelli, et al. [22] and Pembridge and Jordan [23] found that one of the traditions of the academic culture is the necessity of having a permanent heavy workload, which reflects the importance of being highly busy most of the time. This factor could be a barrier to instructional change because any innovation adds to the current heavy workload sustained by faculty.

Attitudes reflect the importance of both the perceived institutional attitudes toward faculty and the faculty attitudes toward change. One barrier to change as described by Finelli, et al. [22] and Litzinger and Lattuca [24] is that faculty consider many change initiatives demanded or led by the administrators usually ignore the reality of the faculty's environment. Whereas administrators, and many faculty members, consider faculty to be, by nature, resistant to almost any change initiative [22, 25].

Beliefs represent the mental models that faculty share. Matusovich, et al. [26] illustrate that focusing on faculty beliefs can support change in practice. These beliefs hinder the motivation to change because any time a teaching innovation is suggested it challenges traditional practices with the consequence of causing feelings of incompetence on faculty accustomed to lectures in their classes [24].

Assumptions refer to the predefined interpretations or meanings toward academic activities. Such attitudes become a barrier to change when there is a negative assumption toward the RBIS. As Handelsman, et al. [27] noted, many faculty assumed such a conclusion because the current educational systems still generate many successful new scientists.

Values denote the collective importance or reputation that faculty and administrators attribute to academic activities. Researchers have found that cultural values could be barriers or drivers to adoption of RBIS depending on certain elements: the faculty's collective value put on traditional teaching methods [12], the value placed on innovations by administrators [26], and the importance that both faculty and administrators put on students' deep approach to learning [24]. Of high importance in this category is the balance between the collective value given to teaching and to scholarship [28], and which tends to favor scholarship. Another element is the higher value that both faculty and journal editors have put on the creation of new pedagogical methods versus the transferability of instructional strategies to practice [24], which discourages faculty from searching the literature about pedagogy in order to apply what has been done in the past.

b. Change Management Factors

The factors associated with this category are related to the design and management of the change process itself (i.e., process design, vision, goals and evaluation). These elements are managed by change agents or leaders in typically top-down approaches. Because change can be planned, it should be directed by a clear vision and goals [18]. Furthermore, change can be managed, therefore its success has to be constantly evaluated and measured [19].

Process design refers to the planned steps to enact instructional change. Kezar, et al. [29] illustrated how one of the biggest barriers to change occurs during its design phase, not only when designing for implementation but in the failure to include characteristics aimed to sustain the initiative [30]. Dancy and Henderson [31] support this idea by highlighting that successful change occurs when its design includes how change agents will articulate and coordinate activities.

Vision entails a picture of the future communicated to stakeholders that helps clarify the direction in which an organization wants to move [18]. Such vision would be a driver of instructional change if instead of imposing it, the vision is shared by administrators and faculty [24].

Goals are the milestones to fulfill the vision; they become drivers of instructional change if they are clearly stated and shared by the community [12], and if they advocate for multiple instructional strategies rather than a single practice (e.g., promoting only the implementation of PBL) [13, 24].

Evaluation in this context denotes the importance of assessment and interpretations of the instructional change process [32]. A driver to change is the existence of processes that facilitate both the documentation and evaluation of the instructors' implementation of their practices, especially when such processes show evidence that teaching has been undertaken in an effective and scholarly manner [33].

c. Institutional Support Factors

The factors associated with this category are related to the formal and informal institutional support to the change initiative (i.e., structures and procedures, and networking and community). These factors illustrate that instructional change is influenced by features of the organization (i.e., the particular academic institution) [12], and show that keys to enacting change are the modification of elements in the institutional structures and procedures [4], the creation of conditions for exercising networking and developing a community [28], and the consistency between all of these elements [31].

a. Structures and Procedures

Institutional policies vary depending on the institution type and the emphasis put on research [22, 29]. The institutional policies related to tenure and promotion influence the adoption of RBIS [22, 28] predominantly by the weight the policies put on both teaching evaluations and teaching performance as a condition for decisions of advancement and continuation in the academy. Nonetheless, decisions for tenure and promotion are also influenced by departmental norms [29, 34, 35].

The **available resources and infrastructure** are also potential drivers or barriers to instructional change. The lack of sufficient institutional resources and appropriate facilities reduces the likelihood of instructional change [23, 24] because they impact the expectancy of success of implementation of RBIS [26]. Similarly, allocation of institutional resources can be barriers to change because they are often allocated in ways that can be detrimental to teaching quality or that emphasize productivity over teaching quality [32].

Instructional training is a special case of support resources directed to enhance the faculty's pedagogical knowledge. It is common in universities to offer faculty development programs of varied characteristics and durations [28, 30, 32, 36, 37]. Researchers have found that to increase positive impact on adoption of innovations, instructional training should include a clear description of the rationale of the innovation [26, 37], the procedures for its implementation [26, 32], the opportunities for practice and simulation of the class activities [29, 32], and delivery in at least semester-long interventions [13, 36].

Flexibility of curriculum is another factor that promotes or hinders adoption of RBIS. Instructors are expected to cover all the content of the course syllabi [35, 38] and to follow the defined content sequence with a specific timing [22, 34]. Typically, content, sequence, and timing were established for lecture-based instructions. Several studies have found that a salient barrier to change is the perceived difficulty in covering all the content when using RBIS [30, 31, 38, 39] because RBIS usually require different timing than direct instruction.

Time allotted and dedicated to adopting the change initiative could be one of the substantial barriers to RBIS adoption. As with many activities within academia, adopting RBIS is also a process that requires time to learn its pedagogical principles [24, 31], time for preparation of class activities [23, 30] and, as mentioned before, class time for its implementation [23, 26, 30-32, 35].

b. Networking and community

The conditions for **networking and community** are also factors that influence instructional change. They combine both the emergent or bottom-up development of self-organized groups and the top-down or prescribed opportunities for faculty interacting with peers and administrators around innovations in academia [32].

The **emergent** conditions for networking and community development usually involve participation in self-organized groups that offer opportunities to engage with peers who share common issues [22, 30] and to learn about the practical concerns of adopting RBIS [34]. Research strongly indicates the positive effect of such communities of practice on the adoption of instructional innovations [28, 30, 35, 40].

The **prescribed** conditions for networking and community are manifested in the support from institutional leadership that explicitly value the teaching innovations, their diffusion, and their implementation [28]. Such prescribed conditions become drivers to change depending on the commitment of the department head [26, 29] and other community leaders [32].

Both emergent and prescribed conditions require the **coordination of activities** [31] to support the change initiative, especially during the trial stage when the community is learning and experimenting with the change process [32, 38]. Research suggests that such coordination shows the commitment from colleagues and administrators toward the change initiative [22, 28].

d. Faculty´s Pedagogical Knowledge and Skills Factors

The factors related to this category refer to the different levels of knowledge or skill that faculty have about RBIS. Research has shown that as a learning process, pedagogical knowledge has at least three levels (awareness, familiarity, and expertise) that must be fulfilled in order to sustain the adoption of RBIS [22, 41].

The first level, **awareness**, embodies the consciousness that faculty have about the existence and characteristics of different RBIS [22, 31]. The sheer number of RBIS represents a barrier to adoption [24, 41] because it makes RBIS more difficult to access and discern the research that validates such strategies [31, 41].

The second level, **familiarity**, represents the understanding of the educational concepts behind RBIS [41, 42] and its effect on students' learning [22, 41]. A common barrier to adoption of RBIS is that their implementation requires an adaptation of the strategies to the faculty's particular context [24]. At times the adaptation does not follow all of the details that make RBIS effective [43, 44] or are altered in ways that err on the side of a more traditional approach [31].

The third level, **expertise**, implies the development of practical knowledge of the RBIS that effectively improves faculty teaching methods [32]. Expertise denotes experience in the RBIS implementation, which suggests the effective adoption of the strategy [31, 41].

e. Students´ Experience Factors

The factors associated with this category are related to how students perceive their academic experience in classrooms where RBIS are implemented. Barriers and drivers to adoption of RBIS also occur at the students´ level because even though RBIS are intended to improve their learning and provide better evaluation processes, students could resist the instructional change through their evaluations of teaching or by disengaging in the classes. The **improvement on student´s learning** is a driver to motivate the adoption of RBIS [22, 29] because, as their name indicates, implementing RBIS is aligned with what is known about how learning occurs [41]. Another driver to instructional change is the multiple opportunities that RBIS offer to transform the **evaluation of students´ learning** [38]. By providing clear ways to assess the actual performance of students, faculty modify their perception of teaching effectiveness [45].

Students´ resistance is a barrier to adoption of RBIS [29, 31, 35] because it is common that students are not accustomed to these practices [46]. Faculty also fear that by attempting innovation in practices, the student´s resistance could prompt negative feedback in **students´ evaluation of their teaching** [22].

f. Faculty Motivation Factors

The factors related to this category are related to faculty´s willingness to adopt RBIS in their classes. The following paragraphs show characteristics of the empowerment, usefulness, success and interest elements of faculty motivation that the literature suggest could be drivers to instructional change.

Empowerment: To enact instructional change, faculty should feel empowered to adopt RBIS. This implies that faculty should feel autonomy or agency to make adjustments to implement RBIS in the classroom [30, 34, 42] and feel some control over how to integrate their service, teaching, and research activities [34].

Usefulness: To enact instructional change, faculty´s perception of the balance between the costs and benefits should err on the benefits side. The benefits are not only referred to as having financial incentives [22, 29] or reward systems [12, 22, 28], but in the perception that adopting RBIS increases value in students [29-31, 38, 41, 47] and the certainty that such practices help faculty to become better teachers [40].

Success: To sustain instructional change, faculty should perceive they can succeed with the implementation of RBIS. It starts with attention to faculty´s self-confidence in their professional abilities [22] and their beliefs on their pedagogical competence [24, 26, 40]. It continues with attention to faculty´s self-confidence of knowing how they could effectively use RBIS [23, 41, 47].

Interest: To enact and sustain change, the adoption of RBIS must be part of the interests and value that faculty give to their own abilities [22]. Change is enacted by developing or creating awareness and interest in the use of teaching innovations [26, 32] and making them compatible with faculty´s past experiences and needs [24].

Discussion and conclusion

Many of the resources found in this review of the literature attempted to explain some of the factors that affect change, defining them as either drivers or barriers to change, and providing suggestions for generating the desired outcomes. However, the literature reviewed is narrow in its approach for promoting change because it is evading the implications that the complexity of academia has on change initiatives. Few references used systems science to study change in academia - with the noted exceptions of Borrego and Henderson [32], Kezar [12] and Lattuca and Stark [48]- limiting the discussion to linear models focused on strategies to either reduce barriers or increase drivers with expected change outcomes [12]. Although these models seem logical, their extent has been proven largely unsuccessful [12, 13, 29, 49], since increasing certain drivers can lead to increasing barriers and, similarly, reducing certain barriers can lead to reducing other drivers [6, 7].

In addition, many of the reviewed literature resources rightfully use theories of change as their framework (see for example Finelli, et al. [22] or Litzinger and Lattuca [24]); however, even if used properly, isolated theories of change are limited to fit specific problems or ignore other aspects that impede change [12]. Some have tried to combine them [32], but others suggest that it is impossible [9] because either they are focused on different aspects of the system, consider the system from different perspectives, or could be contradicting to each other. The difficulty of combining perspectives is characteristic of the nonlinearity of a complex system [6].

From a complex system perspective, such non-linearity explains that there are factors that could be both barriers and drivers depending on the context and timing. For example, one factor that seems to be a driver, dedication of faculty's time, could become a barrier. Indeed, there is evidence of potential time savings when faculty adopt RBIS [22, 23] but, at first, the adoption of RBIS will likely increase the faculty's time commitments [38]. Moreover, complex systems do not have a right answer or root causes; they have, in its place, causal relationships [6].

In the academic system these causal relationships (e.g. the interactions of its numerous components) lead to a complexity that needs to be understood using a process that accounts for the interrelations of the elements of the academic system [5]. We believe that such approach can be the creation of System Dynamics Models (SDM) [6]. To explain the effects of the interactions, SDM uses the particular causal relationships between the components of the system to understand their dynamic complexity. Although it seems consistent to apply the lessons of SDM into instructional change because SDM has been heavily used to model problems in complex organizations and to understand their dynamic complexity in change efforts [6, 50], very few studies have used SDM to understand change in academia (as a notable exception see [51]).

Together, the outcomes of this study will contribute to the current body of knowledge on instructional change in higher education in at least two ways. First, the list and description of factors that affect change will provide a synthesis of the current research on instructional change. Second, the review will provide insights into those effects on faculty motivation, hence offering additional insights to the calls for change towards increasing the pedagogical quality of our learning environments.

Summary

In summary, this study suggests the existence of at least 31 factors that can potentially impact the successful implementation of RBIS in the classroom, hence they could be barriers or drivers to instructional change in engineering education. These 31 factors were classified and organized into six categories: culture, change management, institutional support, pedagogical knowledge and skills, students´ experience, and faculty motivation. The latter is key to understanding instructional change in academia because systemic change in teaching practices would be ultimately enacted by faculty. Hence, for future research it is important to study how the other factors influence faculty´s willingness to adopt such change.

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