# NSF's I-Cubed Initiative: Site Accomplishments and Lessons for the Field

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# Contents



## Figures

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## Background

The NSF's *Innovation Through Institutional Integration* (I-Cubed) initiative was developed in 2008 to incentivize changes in how institutions of higher education (IHEs) approach science, technology, engineering, and mathematics (STEM) education and research by supporting integration across diverse efforts. Aimed at institutions with multiple grants supporting STEM education, the I-Cubed initiative provided funds and collegial support to transition from silos of activities to integrated, cross-cutting structures. The I-Cubed initiative focused on the culture within IHEs to overcome barriers to cross-fertilization and collaboration that appear to be inherent in the traditional organizational and reward systems of academe. NSF allowed considerable flexibility to I-Cubed grantees to address five goals within their institution:

- Increase synergy and collaboration across NSF-funded projects and within/between institutions. Emphasis is placed on (1) breaking down silos and creating new interactions among academic units to address STEM educational change, (2) expanding and deepening the impact of existing STEM programs, and (3) enhancing their sustainability through institutional integration.
- Broaden STEM participation at both the faculty and student levels, with special attention to critical educational junctures such as gateway disciplinary courses. Grantees are also encouraged to permeate boundaries and provide for a more globally engaged workforce.
- Promote innovative programming, policies, and practices to encourage integration of STEM research and education.
- Encourage research on intra- or inter-institutional integration and broader impacts. Grantees are encouraged to be reflective about their own work and make contributions to the knowledge base.

The solicitation also included a staffing requirement that was somewhat unusual. The principal investigator (PI) was required to be someone at the level of a provost or higher. This was done deliberately and explicitly to send the message that support and engagement of top-level leadership was expected. From what we have learned, it appears to have been a very wise move.

NSF awarded I-Cubed integration grants to 30 colleges and universities, both 2 and 4 year, as well as a small number of support and research grants. Our I-Cubed research grant, *Investigating Institutional*

*Integration and Innovation in NSF's I-Cubed Activity*, was designed to study the changes occurring at a sample of grantee institutions and develop an understanding of factors influencing the change process and its outcomes. Our research was intended to describe the changes that occurred in the name of the I-Cubed program and what these changes can tell us about effective educational reform. Our research was aimed at developing an understanding of how culture affects the change process and documenting how different dimensions of context can facilitate or hinder it.

The central element in our research was a sample of six cases. To select this sample, we reviewed program documents and conducted interviews with grantees that had expressed an interest in the study and then identified six that provided "interesting" cases for study. Because of the nature of our sampling methodology—a purposeful sample—we cannot claim that these grantees are representative of all the other 24 I-Cubed awardees much less the entire universe of postsecondary institutions. Nonetheless, these six sites afforded us the opportunity to examine how the I-Cubed initiative played out under a range of conditions that reflect real differences among the institutions that make up the national postsecondary pool. While these six sites all share the status of having received multiple grants from NSF and other federal agencies, they differ in other potentially important ways.

This report presents a summary of what we found about out how our cases operationalized the NSF goal of bringing about the "innovation through institutional integration," the factors that influenced the pathways they chose, and what they accomplished by the end of their grant periods. Most important, the work has led us to develop a framework or logic model that describes factors that influence the change process and how local context influences not only what the change is but also what needs to be considered in attempting to bring change about. We also relate our findings to other work on change in IHEs that has taken place as our own work evolved, looking at similarities and differences in the conclusions reached. Taken together, the picture that emerges suggests a renewed focus on approaching IHE change from a complex systems approach, one that acknowledges the multiple levels and dimensions that must be taken into account, including an institutions history, as well as present considerations. We believe that our findings are important not only to the institutions themselves, but to funders, like the NSF, that see transforming these institutions as critical to STEM education both nationally and globally.

## Methodology

Our research used multiple methodologies to study the change process in the six IHEs. These included

- Document review—we reviewed initial proposals, annual and final reports, websites, other documents as available.
- Site visits—we visited five of the six programs[1] twice during our study, once in year 1 and a second time in years 4 and 5. These visits were conducted by the PI and co-PIs and tailored to each site. At these site visits we interviewed a project leaders (including Provosts, Deans, etc.) and faculty, and, where possible, viewed campus activities.
- Surveys to gather information on relationships and changes in relationships—we collected data for social network analysis (SNA). Specifically, data collection began in the summer of 2012 (preceded by a snowball sampling technique initiated in 2011 to determine the initial population). Time 2 data were concluded in 2014, providing a second snapshot 3 years later.
- Dialogics—Finally, we explored our findings from the above using the three different perspectives brought by the PI and Co-PIs. Although dialogics is not typically considered a methodology, in this case we considered the application of interdisciplinary perspectives to the same data to set a methodology that leads to a transdisciplinary understanding of the phenomenon being examined.

Use these data sources as a basis, we developed working summaries of each site and the work they undertook. In the remainder of this document, we discuss two related areas of thought: what the I-Cubed initiatives did and accomplished and how the findings relate to emergent theories of change in IHEs.

[1] One program received only a single site visit.

# Findings

## What the I-Cubed Initiatives Did and Accomplished

**Overview of the six case sites.** In this section, we present an overview of our six case study sites and the logic model or theory of change that emerged from the study. We also offer comments` on the extent to which these efforts resulted in innovation and transformation.

Presented below are brief summaries of each case, including characteristics of the institution, focus of the I-Cubed and strategies adopted to implement it, sources of leadership, and the nature of the "innovation" that resulted.

### Case A

Case A is a major research university that sees itself as a player in the local, national, and global arena. Serving approximately 75,000 students—the majority of whom are undergraduates—Case A is seeking to established itself as "A New American University." Case A approached its I-Cubed mission by extending its outreach activities, specifically with regard to in-service professional development for middle school teachers in the surrounding school districts. The focus of I-Cubed was on the expansion to middle school science of a successful modeling instruction program for teaching physics developed by David Hestenes, combined with other efforts to engage the community. Five, loosely integrated elements were originally part of the project:

1. A Content-Focused, Master of Natural Science (MNS) degree program for middle school STEM teachers
2. A middle school STEM Summer College-for-Kids
3. STEMnet—a professional development network of STEM secondary educators
4. Ask-a-Scientist—an expansion of the popular Ask-a-Biologist web presence
5. Creation of a middle school STEM endorsement to the state teacher certification

Led by faculty in the College of Education, the program was designed as an outreach program, offering a collaborative degree between math, physics, engineering, sustainability, biology, and education. At the point of initial proposal development, this approach aligned with both perceived priorities of the College

of Education and the institution's legacy of investments in outreach through in-service training. However, early in the program, institutional upheavals challenged and eventually derailed the effort. The reasons for the upheavals are complex. In part, budget problems led to restructuring and staff reassignment. At the same time, political forces played a role. Specifically, in reaction to challenges raised by some education faculty to the state's conservative education agenda, education budgets were cut, and organizational structures (with regard to education) drastically modified.

In order to keep the project alive, the original developer of the program resigned from her tenured faculty position and transferred leadership of the project to a nationally recognized STEM researcher who, after some side trips, established himself in the engineering department. The original developer remained significantly involved and clearly provided project leadership, but from a less stable and prestigious position. Eventually, the I-Cubed ended early due to program cost and lack of the necessary enrollment to support its continuation, as well as weak institutional support.

The integration in Case A as initially designed focused more on integration of existing outreach efforts, rather than a broader attempt to integrate faculty or integrate STEM-related work across institutional units. It was "programmatic" rather than "institutional."

When asked about the innovation resulting from this grant, the project director stated that the innovation was in the relationships that had been formed. And it does appear that a small cadre of STEM faculty, not initially working together, continue to collaborate to make changes in educational offerings at the university. At this point, however, it does not appear that the I-Cubed has served as a driver of integration across major STEM investments in any significant way. While the faculty involved have done some good things and appear on track to do more, and some of the program components ( primarily the components initiated before the grant and adopted into it) will outlive the grant, the transformational purpose of the I-Cubed initiative does not seem to have been met

## Case B

Case B is also a research 1 university that has regional, national, and global interests. It is one of 34 U.S. public institutions belonging to the Association of American Universities (AAU). The University has a strong research tradition, proudly acknowledging recognitions received by the faculty. Although part of the state system, tuition support is very modest and decreasing. Attracting and retaining enrollees from outside the state and even outside of the US is important.

The I-Cubed integrated three existing lines of work supported by NSF: (1) efforts in course transformation in STEM, particularly at the undergraduate and graduate levels; (2) programs in teacher preparation and professional development, for K–12 and college (Learning Assistants, Noyce); and (3) discipline-based education research among faculty, students, and postdoctoral scholars. In addition to continuing historical lines of work, these efforts focus, to varying degrees, on the institutional priority of student retention, especially in STEM-related subjects. Key to the approach is the creation of a center (currently a virtual center that unites and supports STEM activities and the place of the university as a national leader in STEM education and learning). The center was established in 2014 and is a key accomplishment of the I-Cubed. The Physics Department was core in the initial days of the I-Cubed effort, gaining strong support from the Biology, Chemistry, Computer Science, Math, Physiology, and Education Departments.

The I-Cubed also included a number of features designed to continue efforts to change the culture of teaching and learning—efforts preceding the grant—such as creating a different norm for how courses are planned, changing how instruction is delivered, and enhancing the extent to which expectations and goals are made explicit. A key part of the work on courses is explicitly defining learning outcomes at the department level, rather than allowing each faculty member to independently determine expected outcomes. This requires a different way of thinking not only about courses, but about the coherence and structure of a program, as well as the obligations of faculty.

Going beyond programs and courses redesign, the center also serves as a vehicle for convenings to share research, as well as discuss local and national issues. The leadership also hopes to create the capacity to respond quickly to requests for support of university initiatives, including efforts to enhance student persistence and work in the surrounding communities.

The I-Cubed has made substantial use of incentives to engage faculty and move their work forward. The incentives are of two types: small grants to faculty to engage in interdisciplinary research and an Annual Fall Symposium that provides a venue for showcasing faculty research and accomplishments. This symposium is well publicized and billed as a high-profile, high-prestige event.

The innovation in Case B is the establishment of the center, with its broad mandate for supporting STEM researchers, programs, and course reform. That said, there remain nearly 100 STEM programs at the university that are not actively integrated into the center. Further, at the time our research was completed, the center was still struggling to become self-supporting, with time-delimited funds from the university supporting its administration and management. Its more permanent shape and place in the organizational structure is still evolving.

## Case C

Case C is a community college. It is the second largest of 10 public universities and colleges in the state university system. With a focus on liberal arts and 21st century career programs, student enrollment has grown dramatically over time. Led by the Office of Institutional Effectiveness and the Mathematics Department, the I-Cubed at Case C focused on building a formal STEM program of study, building bridges to the major 4-year institution, and better serving Native Hawaiian and other underrepresented local students. The I-Cubed largely extends work previously undertaken to provide a strong STEM career path for first-generation college goers.

Activities include summer institutes for faculty, new online hybrid STEM courses, increased numbers of STEM faculty, new research experiences for students, increased service learning, and the creation of a new Associate of Science in Natural Sciences (ANS) degree. It is the fastest growing program on campus. It started with two concentrations and has since grown to five, which are specific preprograms designed for transfer.

The College has the largest liberal arts transfer program in the state system. The College has a deferred enrollment agreement with the major 4-year institution, including its College of Engineering, in which students can co-enroll at the College and then matriculate after graduation. A "Degree Pathways" joint agreement allows accepted students to begin their undergraduate experience at the College and seamlessly transfer to the University.

The major "innovation" associated with this I-Cubed grant is the ANS degree and, to a lesser extent, the embedding of research experiences in existing courses. Like Case A, these accomplishments are more like programmatic expansions than transformations. They are what Kezar (2014) refers to as "first order changes" and do not reflect the characteristics of second order changes, whose defining feature is the simultaneous manifestation of attitudinal change in an organization's structure (Kezar, 2014.p 63). That said, Case C used the I-Cubed opportunity to add value to the college's STEM offerings, leaving behind a sustainable artifact that will benefit the community.

## Case D

Case D, founded in 1870, is one of the oldest public colleges in the country. Currently, over 22,000 students attend, pursuing both undergraduate and graduate degrees in more than 170 different programs of study. The College is recognized for the diversity of its student body. It is attended primarily by a

commuting population with a significant proportion of students being first-generation college goers. Since 2007–08, Case D has had an initiative to improve student graduation rates. A second thrust is to increase student satisfaction.

The purpose of the I-Cubed was to integrate opportunities for students to participate in STEM enrichment activities through a single web portal that provides information about the programs, as well as support in applying to them. The I-Cubed thus built on the college's investment in STEM research experiences, while at the same time trying to increase student satisfaction with supports and experiences. The work focused on three primary areas: student recruitment and identification, student engagement, and the creation of an information infrastructure for student tracking, reporting, and assessment. Phased in over time, these activities were accompanied by efforts to engage the leaders of previously independently operated enrichment programs in joint work.

Originally focused on STEM enrichment activities, the I-Cubed broadened over time to include a wider range of disciplines offering enrichment opportunities. Key in the evolution of the I-Cubed was the establishment of the Office of Undergraduate Research, which over time came to house not only the I-Cubed, but a broad range of student enrichment opportunities. This office was established by the Provost, who also served as PI for the grant, working closely with faculty and colleagues in the psychology department. A champion for the grant, the Provost provided not only visible leadership, but also supplemental funds to support implementation and initial steps toward institutionalization.

The innovation in Case D was the unified portal for identification and application to undergraduate enrichment opportunities, as well as the Office of Undergraduate Research. However, in addition to these tangible structures, the I-Cubed also tried to change attitudes and create a more integrated approach to enrichment program implementation and monitoring. New opportunities for collaboration among previously isolated efforts were put in place with the goal on enhancing the experiences of students, as well as supporting the work of program leaders.

At the time our research ended, this innovation was still a work in progress, and the sustainability of the effort is unknown. A clear challenge for long-term endurance is the departure of key leadership. Promotion of the Provost and departure of staff to a higher position in the university system as the grant was ending left the college without its most visible defender. It is unclear whether the portal is sufficiently established to be continued by others in the absence of these key players.

## Case E

Case E presents itself as a regional institution, dedicated to supporting first-generation college students. Unique among cases, Case E has had the privilege of consistent leadership at the top, with the University President being a stable force for nearly 30 years. Case E, part of a state University System, is an open enrollment university that serves both American and Mexican citizens. Many students enter Case E with insufficient academic preparation, with 49 percent requiring some developmental supports. Only 1 in 10 students graduates within 4 years, and graduation rates remain very low. Using data and data mining to track student progress and support students' academic success are high priorities for the institutional research office.

Building on the university's investment in cyber-related activities (including projects addressing immigration and border security) the I-Cubed focused on use of technology for knowledge sharing, creation of new organization practices and social interactions to support interdisciplinary research teams, and promotion of student success. The cybernetwork is explicitly designed to celebrate the accomplishments of faculty, provide bios and other background information, and support communities of practice around topics selected and supported by the faculty themselves. Additionally, in line with the university's goal of increasing its research presence, a mapping capacity available through technology tools has been developed to create concept maps or logic models to provide information on data sources and human capacity resources around specific topics or research areas. This tool, under development at the time our research ended, is intended to be a resource to identify what is being learned about student success, as well as provide a resource for those developing new research initiatives.

To complement the virtual community developed through the cybernetwork, Case E is creating a real space for interaction by redesigning an area in the library. The department-neutral space is created to further reinforce cross collaborative experiences and create spaces where sharing is encouraged.

The lead for this I-Cubed is in the Computer Science Department, along with substantive engagement by the Office of Institutional Research and the Provost's Office. It is notable that the lead faculty member for the I-Cubed clearly qualifies as a "boundary crosser," having worked in both organizational units, as well as in a disciplinary department. She has the respect of both disciplinary faculty and the institutional administrative staff.

In Case E, the cybernetwork with its various functionalities and supports for interdisciplinary sharing and communication is the innovation. At the time our research ended, this network was continuing to be expanded, both at the university and, potentially, statewide.

## Case F

Case F is a public research university that is part of the state university system. The university offers degrees in more than 150 courses of study through 13 colleges and hosts 60 research centers and institutes. The university is moving toward becoming a Hispanic-serving institution, with the goal of having 25 percent of the students being of Hispanic background by fall 2017.

With a history of valuing outreach activities, Case F focuses on putting in place activities to raise the profile and stature of outreach activities, including creating the infrastructure to track outreach efforts and support their coordination, expand outreach services, foster interdisciplinary work, and encourage policy changes that reward faculty time and interest in outreach. With regard to the latter, a goal was to increase the visibility of outreach as an activity to be valued and seen as scholarly work.

Included in the I-Cubed were a number of efforts to support K–12 education, especially for high school students, as well as postsecondary-oriented activities such as student mentoring. Like many others of our six case studies, offering opportunities for faculty from different departments to meet around STEM issues of common interest was a strategy used to incentivize engagement. Opportunities to form new networks and share ideas broadened faculty engagement and extended participation across schools and colleges.

Central to the success of the effort was the close relationship between the leader of the I-Cubed (from the Mathematics Department) and institutional leaders, such as the Provost and the Chancellor. The trust/comfort level between disciplinary faculty and several key members of the administration helped to provide a smooth transition when the Chancellor who was the original PI left. Over time, wider departmental support was also gleaned. While the mathematics/arts and sciences/administration was critical at project startup and remained important over time, as the grant evolved, other schools were drawn into the work. This includes Agriculture, Education, Engineering, and The Graduate School and Human Sciences.

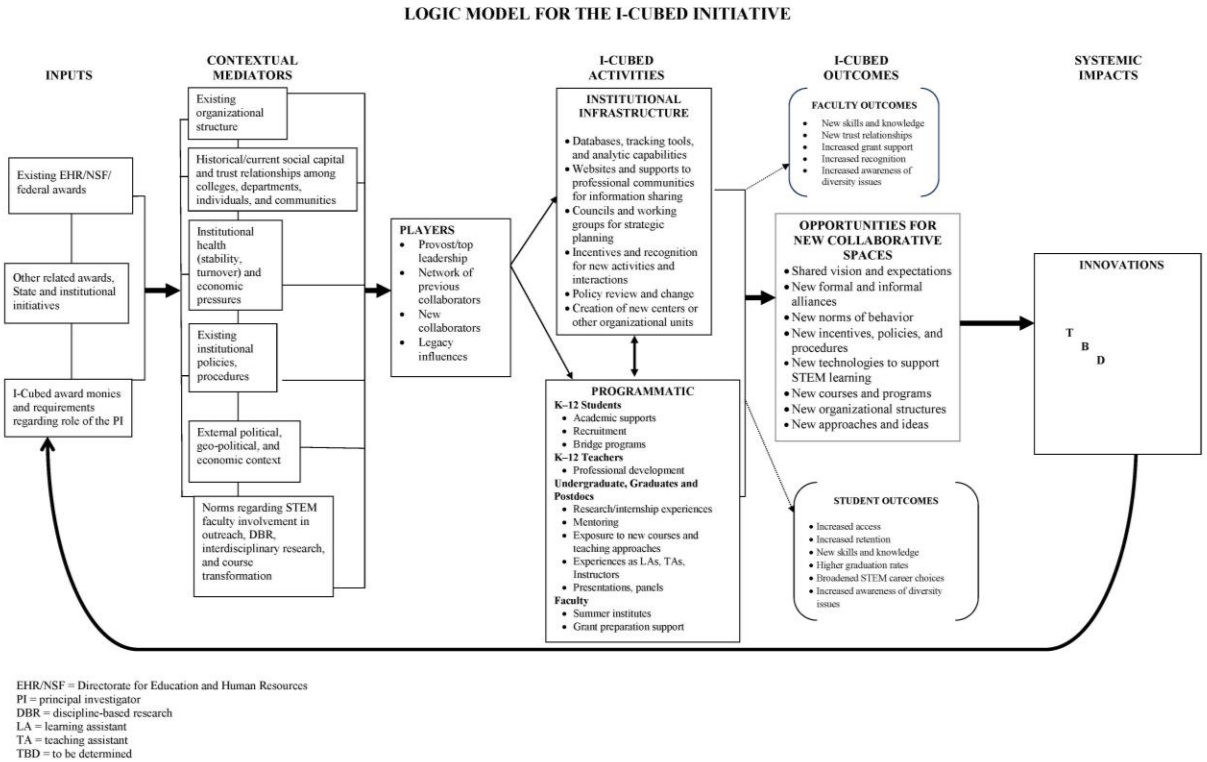
The various activities of Case F were brought together formally at the university through the creation of a STEM Center overseen by a committee of Deans. The leader of the I-Cubed from the Mathematics Department served as the center director until his departure to a position at another university in the fall of 2015. The STEM Center continues with a mission of identifying and supporting new opportunities for interdisciplinary research, as well continuing to serve as a gathering place for STEM faculty from different departments and schools.

The STEM Center, along with policy changes related to the treatment of outreach as a scholarly activity, is the innovation fostered by the I-Cubed. At the time of the last visit to Case F, administrative leadership was continuing to focus on shaping and refining its outreach plans, with outreach efforts remaining high on the strategic priorities agenda.

**The framework emerging from our current work.** The focus of our work was primarily on understanding the changes our case study sites made and the factors that drove these changes. The NSF solicitation left ample room for the grantees to pick a path for transformation and did not prescribe a target or best practice for meeting program goals. As described briefly above, our cases chose different pathways for responding to NSF's call. Why did these different pathways emerge and what do their choices have to say for others starting down the road to change?

We approached the task of describing the evolution of the I-Cubed sites through the development of a cross-cutting Logic Model showing the factors at work across our six cases. The Logic Model, shown in Figure 1, evolved over time, starting from a simple model that reflected the original NSF solicitation to a far more complex model, built from what we read, saw, and heard.

**Figure 1. Logic model for the I-Cubed initiative**



This model identifies major components or classifications of components traditionally found in logic models—inputs, activities, and outcomes—as well as some components that are not typical. We start by describing the more traditional elements.

- *Inputs* are the resources brought to the intervention. In this case, we have identified three—existing STEM awards received from EHR/NSF, existing STEM awards received from other sources, and the new I-Cubed awards. These resources represent not only financial resources but also the intellectual capital and experience that have been accrued through them.

- *Activities* are what is done within the grant to reach its goals. Activities encompass the range of interventions or actions that are carried out to meet the grant's goals. Our logic model divides activities into two general categories: changes in infrastructure and changes in programs. These are not presented as an "either or." While the balance between the two sets of activities may differ from grant to grant, most would be expected to incorporate changes of both types.

- *Outcomes* are the last category of concepts. In this theory of change, we identified three classes of targeted outcomes: outcomes for faculty, outcomes for students—both reflecting outcomes for groups of individuals—and outcomes for institutions—called here "opportunities for new collaborative spaces." This multi-dimensional classification reflects our belief that institutional change needs to be thought of from both the institutional and the individual level.

The columns "contextual mediators" and the associated "players box" are not a part of standard logic models, although context is frequently acknowledged as a kind of background consideration. In our work, however, as hinted to above in our case summaries, we found that context was a critical factor in defining the pathways our case studies chose. We define contextual mediators as local factors that influence how an activity or objective is viewed in a specific IHE. Contextual mediators include a range of dimensions, both internal and external, that affect all institutions, but may do so differently, and within institutions may have different effects over time. These mediators are not limited to what is happening currently, during the time in which the change process is initiated and developed, but also include earlier experiences and the sum of the institution's history. Indeed, we found that a critical component of the contextual mediation process is its history of evolution and the footprint left by what has come before. In stressing history in addition to current enablers (or challenges), our work is reflective of institutional theorists such as Scott (2008). He asserts that too much of the work in social science concentrates on structures and processes of the here and now. In contrast, the institutionalist position is that "institutionalists accord more attention to types of effects occurring over longer time periods" (p. 213).

Our proposed contextual mediators, why they are important, and how they manifested themselves in our case study sites are described below.

- Existing organizational structures—Organizational structures provide both opportunities and barriers with regard to change pathways. They create gathering places, power relationships, and territories. Departments are typically the most prominent organizational unit considered in bringing about change in IHEs, but do not work in isolation. Both actual and virtual cross-cutting organizational structures play important roles.

  – In all our cases, existing organizational structures initially played a role in creating distance among STEM researchers. Distance was both actual, with departments being located in different buildings, and cultural, with departments having differing norms of behavior. Key in moving the work forward was crossing these institutional boundaries to create new, shared spaces. In Cases B and F, this was done by creating STEM Centers, virtual organizational units that fostered interaction among STEM researchers and provided services to support their work. In Cases D and E, this was done by creating cyber structures that brought together diverse programs and researchers in a single web-based location. In Case E, in addition, virtual communities on the shared portal were formed around topics defined by the members themselves. Case E also took boundary crossing further by creating a new space for interaction in an existing building. They established a "Collaboration Hub," a neutral space in the library where faculty and students from different departments and schools can gather to share ideas and explore ideas. Creating this space in the library is symbolic in that it provides a space that doesn't belong to any one department or organizational unit. It is a concrete artifact that attests to integration.

- Institutional health—The health of an organization may be influenced by many things, including funding for research, tuition coverage, stability of faculty, and support of its alumni. An important determiner of the health of state institutions is the strength of state funding streams.

  – A driving force in many of the case study sites was institutional health, which includes features such as availability of resources, issues with regard to student recruitment and retention in the STEM fields, and opportunities for faculty development. Case B was experiencing a dramatic decrease in state funding, and a primary concern was finding ways to make up for expected future shortfalls. There was great emphasis on student retention, retention at the university overall, but also retention in STEM majors, where the extent of dropout raised concerns. The I-Cubed was developing at the same time that new strategies were being sought for bringing in funds and retaining students. Some of the I-Cubed activities were aimed at course redesign that would, hopefully, moderate this pattern of students leaving the STEM field. At Case C, leadership identified faculty skills and knowledge in STEM-related subjects as inadequate and a barrier to successfully implementing a new associate's degree in the natural sciences. One key feature of the I-Cubed was, therefore, summer institutes aimed at increasing faculty competence in the STEM areas.

    At Case A, the impact of institutional health was singularly dramatic. The College of Education in which the grant was housed was eliminated shortly after the grant began. Education-focused centers also were closed. Tenured and untentured faculty were displaced. This left the project with no home and no higher level support. In varying degrees, I-Cubed researchers were left to scramble to find a home and a champion. While the researchers did their best to salvage the work, in the long run, the organizational disruption greatly handicapped the work, and it ended early.

- Social capital and trust relationships—Another mediator of importance is established coalitions among individuals and organizational units and the nature of the trust relationships that have been established. This includes the extent to which faculty from different departments or colleges interact with each other (formally and informally), whether the incentive system reinforces collaboration or competition, and how risk taking may be viewed by those in power positions. Trust relationships are one of the more important areas requiring a historical perspective, a look at where individuals have come from and where previous experiences have created bonds or barriers.

  Our evaluation had a special focus on social capital and trust relationships, not only through the information gathered during our site visits, but also through our two rounds of SNA. These analyses showed how pre-established relationships among departments and between departments and the administration shaped their strategies.

  – The six I-Cubed sites have a singular feature in common—that of early, small group formation. The power of the small group galvanizes individuals to stick together when embarking on institutional change and to stick together when under attack should outside events and market forces derail their efforts. Some groups start out as a simple form of camaraderie between like-minded friends who are steeped in shared disciplinary knowledge and/or hold a similar world view. Cases C and D would be examples of this approach. Other groups share a vision of changing higher education and organize to recruit others across departments to join in the movement. Cases E, B, and A were examples of this approach. This trust galvanizes small group formation by creating highly charged key connectors who in turn are highly catalytic for network growth. This factor was strongly upheld in four of the six sites: Cases E, F, B, D.

  – The organizational units that led the I-cubed initiative or eventually became a part of it differed substantially across cases, reflecting both STEM leadership at the institutions and where ties with NSF were the closest and most well established. At Case D, the administration was key in moving the work forward from start to finish. A close working relationship existed, however, between the Administration and the Psychology Department, and these two units combined to move the work forward over time. Interestingly, however, by the end of the grant, while similar individuals were involved, the role of the Psychology Department was diminished as staff moved into administration. In Case B, the work was led by the Physics Department with strong support from Education. While these two departments had a history of cooperation, the fact that key players in the I-Cubed—leaders from the two units—had a history of working together was very important. This history and the established trust that pre-existed the I-Cubed shaped both the programs that were integrated and the faculty who were brought into the work. In Case E, the grant leader was a boundary crosser with strong ties to key administrative units that supported the I-Cubed work.

  – SNA also showed that over time the I-Cubed initiatives were successful in building on initial relationships, with the proportion of engaged faculty generally (albeit marginally) increasing over time. Two other trends are worth noting. First, regardless of the intervention, high-level administrators played a central role is fostering or hindering the potential transformation. Second, females appeared to play a singularly

important role in fostering innovation.[2] Regardless of their role (faculty, staff, administration) the proportion of females in central positions increased over time when activities related to innovation were considered.[3]

- Institutional policies and practices—Business rules, as established through institutional policies, can also affect the path toward institutional change. Policies related to tenure and promotion or allocation of faculty slots and resources can be both hindrances and facilitators to the change process. For example, in our I-Cubed sites where integration and interdisciplinary interaction were major goals, promotion and tenure policies that reward individual, scholarly activity posed challenges across the board.

  – By and large, in this study we found that policies typically were not innovation friendly, serving to promote the status quo and functioning as inhibitors. Indeed, they needed to be overcome or worked around. The policy most discussed across our sites, and least effectively addressed, was that related to tenure and promotion. There was tension between major activities promoted by the I-Cubed and the types of activities typically valued in promotional decisions. Tenure and promotion policies put the emphasis on the individual, what the individual has achieved and published, whereas the I-Cubed generally promoted team work, work that is interdisciplinary in nature. We repeatedly heard in Case E, for example, of problems faced by young faculty who chose an interdisciplinary research route and even received small grants from the I-Cubed for engaging in interdisciplinary pilots, but feared that these activities would not serve them well when it was time for them to be considered for promotion.

    A second problem related to existing tenure and promotion policies was how outreach activities are viewed in tenure and promotion decisions. While in theory tenure and promotion consider research, teaching, and outreach, the latter is usually considered of lesser importance. At Case F, where outreach was a critical component of the institution's self-identify, as well as the I-Cubed, the I-Cubed leadership was able to get changes in the promotion and tenure policy in place that increased importance on outreach and considered publications on outreach to be a scholarly activity. This change in policy was a facilitator for the development of the I-Cubed and also enhanced its stature as an effective change agent.

    In addition to tenure and promotion, funds allocation policies presented a challenge. At Case B and other sites, course enrollments helped to determine resource allocations. This policy led to course duplication across departments and reduced the likelihood of interdisciplinary offerings because only one department could receive "credit" for the students' participation.

- Norms of behaviors and beliefs—Institutions develop a set of routines and expectations, that include assumptions about what is allowed and what isn't, as well as standards of behavior. These norms are durable because "group members tend to behave in ways that teach these practices to new members, rewarding those who fit in and sanctioning those who do not" (Kotter, 1996, p. 148). The norms and beliefs provide a comfort zone, defining safe space and boundaries not to be crossed. Whether change requires stepping outside of established

[2] The SNA analysis examined networks and network change related to five types of relationship: informal, work, innovation, expertise, and improvement. The life cycle of improve theory on which our approach is based posits that work and informal relationships provide the foundation for the emergence of innovation, which is filtered by expertise, and, ultimately, results in improvement.

[3] Greater detail on our approach SNA can be found in Stephenson, 2015.

boundaries or adopting different behaviors will influence the strength of the resistance that occurs.

- We found many examples of how norms of behavior or beliefs in what is the "right way" of doing things posed challenges and needed to be addressed. For example, in Case D, there were expectations on the part of some programs offering research opportunities that only a program-specific application would suffice for their program, rather than the joint application being promoted by the initiative. Such programs felt that *their* information needs were too specialized to be covered adequately in a joint application. In many cases, programs holding this belief were ones that had been around for quite a while, whereas newer programs more readily saw the benefits of accommodating. In some cases, these hold outs could be persuaded to participate in the integrated application process, in other cases not. Also in Case D, attempts to create a uniform system for tracking students and collecting data on their enrichment experiences were met with resistance, as program leaders were loath to give up the program-specific systems already in place. In Case B, where one of the I-Cubed-sponsored activities focused on creating joint goals for student learning at the department level, resistance was felt from faculty who felt that the goals should be course specific and saw the department-wide approach as somehow diminishing their particular domain. Here the change agents began their work with departments that were more open to the collaborative approach, hoping that less enthusiastic departments would become more amenable to the process once its efficacy was established elsewhere.

- External factors—In addition to the internal moderators discussed above, a number of external moderators shape the direction of change. One such moderator is state funding streams that may provide incentives for moving in one direction or another. A second is research opportunities offered by foundations and agencies. Policy making boards like Boards of Education or Boards of Governors may push an institution in one direction or another. Another factor is the position of the institution in the community, how it is perceived, and how it perceives its role. Research has also found that what is occurring in institutions seen by peers may stimulate emulation.

  - We have already mentioned one external factor, state funding in the discussion above that concerns institutional health. State funding was not, however, the only external factor that helped shape the focus on activities in our I-Cubed sites. Opportunities for research funds were a critical driver in a number of cases. Of course, the most obvious of these is the I-Cubed grant itself. In Cases B-F, the existence of the NSF grant, although relatively modest in size, gave a boost to nascent ideas and a status to the I-Cubed activities as they evolved that would not have been attained without the NSF imprimatur. In Case B, however, we also saw other funding opportunities, local and national, helping to define the shape of the effort. Both the emphasis on course redesign and the attractiveness of creating a STEM center, were certainly influenced by activities being undertaken in what were perceived to be peer institutions.

  - In Case E, the geographical location of the university and the nature of the community provided an impetus to increase sharing of information and engagement in extensive analysis of existing data to develop better ways of serving first-generation college goers. In Cases F and A, there was also evidence of responsiveness to community

needs and the focus of the I-Cubed was clearly influenced by a historical attention to serving the local K–12 educational community.

In addition to these contextual mediators, our logic model also identifies "players" as another type of contextual mediator that should be considered. While the idea of players overlaps somewhat with the dimensions described above, it is different in that it addresses the influence of an individual rather than position. It calls out the contributions of specific persons who have had a significant and long-term impact on a department, college, or institution's evolution. This players mediator is composed of several types of people and their interactions—networks of previous collaborators, new collaborators, and legacy influences from researchers/faculty who are no longer active. At Case B, for example, the imprint of previous faculty, those associated with the Science and the Initiative an the Learning Assistant program was very clear in the work being conducted.

Finally, we have included a column called "systemic impacts." This column refers to profound and lasting changes that may occur as a result of the I-Cubed, the innovations or transformations that NSF in its solicitation hoped to support. Our review of the six cases suggests that in the initiatives studied we saw a range of results that could be placed along a continuum from adjustment, defined as programmatic enhancement, to far reaching, defined as having the *potential* for innovation and transformation. We say *potential* at this point because it is too soon to say whether innovations will be sustained and in what form. Figure 2 describes the type of integration vehicle and transformation status of the sites at the time our data collection ended.

Figure 2. Integration vehicle and transformation status

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| **Integration vehicle** | New degree program | Virtual center | New degree program | Database | HUB (space/ place) | Policy & virtual center |
| **Transformation status** | Failed | Far reaching | Adjustment | Adjustment | Far reaching | Far reaching |

As can be seen, in five out of the six cases, the I-Cubed resulted in some kind of change. Two of these, however, appear to be more of an adjustment, a modification of a program or service that already existed, rather than something that held the promise of making major changes in how the business of STEM teaching and learning is implemented. And in two of these cases where we do see the potential for transformation, the assessment may be a bit generous as there clearly remain aspects of STEM teaching and learning in the institutions that have not been included. That said, these sites have taken significant steps toward actualizing the I-Cubed vision, and their efforts should be recognized and celebrated.

## How Our Findings Relate to Emergent Theories of Change in Institutions of Higher Education

Given the increased focus on IHEs over the last 5 years and the repeated call for educational change at the postsecondary level, it is not surprising that during the time in which we were undertaking our research, there was a significant increase discussions and theory development in this area. The call for reform at the IHE level has led to the exploration and development of a number of analyses of the change literature, individual and multi-site projects aimed at bringing about change, and the development of new theoretical frameworks for understanding the change process and how it can be influenced. Like our own work, these go beyond describing changes in courses and teaching to examining the complex, multi-level factors that may be in play, even in somewhat targeted reforms. Further, rather than starting from the perspective of best practices in instruction, course design, or faculty development, they start from the point of view that change is a complex process and rather than thinking about a "magic bullet" they acknowledge that multiple institutional, interpersonal, cultural and socio-political factors need to be considered in making change work. It is useful to examine these emergent theories and how our theory of change and logic model align with and differ from them.

The research and the frameworks that have emerged from this recent work themselves build on somewhat different perspectives, with some drawing on organizational theories and conceptualizations of leadership in general, and others looking more narrowly at educational institutions, and within institutions' STEM programs. Not surprisingly, given the increasing recognition of the importance of team science, much recent work has been targeted at changes whose goal is increasing interdisciplinary research and teaching.

**Various Lens.** Although these frameworks have a number of similarities in dimensions highlighted, they differ in their focus. We have grouped the frameworks into three categories :

- Strategies for change—strategies for affecting change
- Evidence that change has occurred—where to look for evidence of change
- Steps in bringing about change

### Strategies for Change

Several different researchers have framed the change process from the perspective of aspects of the institution and its environment that need to be considered when trying to enact a change. These

researchers do not look so much at why an approach or change target is selected, but rather the strategies used for actuating the change once a starting point has been identified.

One area that has received considerable focus is that of leadership or agency and the extent to which the location of the leadership affects what is or is not accomplished. Frequently, the discussion focused on whether top-down or bottom-up leadership is the more successful. May, Susskind, and Shapiro (2013) address the top-down bottom-up questions drawing on data from IHE partnerships created for NSF's Math and Science Partnership program. Assessing questions related to leadership and the relative efficacy of top-down vs. bottom-up strategies they conclude that "it depends." They consider the roles of grassroots leadership, traditional leadership, and their interactions. They describe how leadership structures emerged in four different partner institutions, emphasizing the importance of local context in the extent to which bottom-up or top-down leadership structures led the changes.

Kezar (2014) also examines leadership as one of four components to consider in the fostering of change. She presents a macro framework describing the context of change that, in addition to agency/leadership, includes type of change, context for change and approach to change in discussing which strategies are most effective in implementation. In discussing agency or leadership, in addition to the top-down/bottom-up dimension focused on by May, Susskind, and Shapiro, she includes consideration of two other approaches to leadership: collective leadership and shared leadership. Collective leadership involves a group of people, but does not necessarily include those who are in positions of authority, as well as those who are not. Shared leadership intentionally brings together both those in and outside of positions of authority (p. 110). Reflecting on findings from the efforts she examines, she suggests that too often change agents depend too much on individual leadership and do not adequately consider the advantages of the group approach. She also points out the value of one or another types of leadership will depend on the conditions, thus supporting and broadening the work of May et al. in emphasizing how local factors that come into play.

Scott (2008) takes a broader approach, focusing not on leadership per se, but on aspects of organizational function that need to be addressed. He posits three pillars of institutions to consider. These are

- Rules—"how institutions constrain and regularize behavior" (p. 52).
- Norms—what should be done and how it should be done
- Cultural-cognitive assumptions—"shared conceptions about what constitutes the nature of social reality and the frames through which meaning is made" (p. 57).

According to Scott, it is important to consider each of the pillars in designing and implementing a change strategy and that their alignment or lack of alignment has important consequences for an effort's ultimate success.

Borrego, Bowden, and Newswander (2014) adopted these pillars as a frame for studying how higher education organizations change to support *interdisciplinary graduate education*, using NSF's Integrative Graduate Education and Research Traineeship program. Extending Scott's work, they hypothesize that bringing about lasting change or institutionalization also requires attending to these three pillars simultaneously.

Roth and Elrod (2015) build on the four frames of how organizations work developed by Bolman and Deal (2008) in the context of efforts to increase interdisciplinarity in STEM programs. Like Bolman and Deal, they see the four frames not as alternatives, but as an integrated and complementary set of dimensions of an institution's operation that need to be addressed. Aligning the four frames is seen as essential for creating lasting change. The four frames are

- Human resources
- Structural
- Political
- Symbolic

They suggest that unpacking these four frames results in addressing the following questions

**Do you have the right people?**

1) People with expertise in the initiative
2) The incentives to promote participation in the program
3) Opportunities for faculty development in the program's focus

**Are necessary structures in place to enable the program?**

1) Workload policies
2) Review, promotion, and tenure policies
3) Spaces for the work to happen (informal and formal)

4) Funding (immediate and sustainable)

5) Networks for communication

**Are strategies aligned with campus policies and politics?**

1) Engaging conversations about vision

2) Including faculty in the decision making

3) Establishing review policies aligned with program

**Have symbolic needs been attended to?**

1) Are there plans to highlight and celebrate the work by faculty and students toward the initiative's goals?

Kezar (2014) examines change in IHEs through the lens of the organizational change literature. She suggests that six perspectives or logistical approaches should be considered when change is undertaken. These perspectives are

- Scientific management—using incentives and rewards to influence behavior
- Evolutionary—looking at the university as a holistic system, influenced by external as well as internal factors
- Social cognition—attending to the underlying beliefs that influence decision making, understanding how a change may influence the individual
- Cultural—understanding and shifting cultural norms
- Political—working through strategic coalitions and internal power structures
- Institutional—leveraging existing external structures that influence universities, includes receipt of grants from prestigious funders

Unlike some of the frameworks described above, these perspectives are offered not as dimensions that need to be aligned, but as a series of lens that help to define appropriate strategies under different conditions and may be more or less useful depending on who needs to be engaged and brought on board. Kezar writes

> "Most changes play out across multiple levels of the system, so the key for change agents is to understand and use several theories that help them see the ways the change operates at different levels. *Cognitive theories* help to

> articulate strategies for altering individual behavior; *cultural* and *political theories* shape knowledge of group interactions; *scientific management* and *institutional theories* provide important information about organizations; *evolutionary* and *institutional theories* provide insight into the system or enterprise level. (p. 53)

Corbo, Reinholz, Dancy, Doetz, and Finkelstein (in press) draw on Kezar's work to describe various efforts at reform that have been carried out at the University of Colorado at Boulder. They start by positing that IHEs should be considered "multi-leveled, interconnected systems." While they see the department as being the key unit of change and through their review of research find that most efforts have focused on departments, they suggest that successful change requires also considering the administrative and faculty levels at the same time. They describe several multi-level change efforts focused on STEM education, through Kezar's six perspectives. Further, they suggest that successful change requires considering what role each of these perspectives can play as the process moves forward.

## Evidence That Change Has Occurred

Eckels and Kezar (2003) approach the subject somewhat differently and discuss the types of evidence that could be examined to confirm or disconfirm that change has taken place. Like the theorists and researchers discussed above, they posit that there are different dimensions to consider, identifying both structural and attitudinal/cultural dimension of IHEs. These include

- Structural evidence of transformation
  - Changes in curriculum
  - Changes in pedagogies
  - Changes in student learning and assessment practices
  - Changes in policies
  - Changes in budgets
  - New departments and institutional structures
  - New decision-making structures

- Attitudinal and cultural evidence
  - Changes in the ways groups or individuals interact with one another
  - Changes in the language the campus uses to talk about itself
  - Changes in the types of conversations (who is at the table and the substance of conversations)
  - Old arguments abandoned
  - New relationships with stakeholders (trustees, alumni, donor, community)
  - New relationships with stakeholders (trustees, alumni, donors, community groups, local businesses, and foundations)

## Steps in Bringing About Change

Finally, researchers have addressed effective ways of sequencing the steps in the change process. Elrod and Kezar (2015) discuss the Keck/Project Kaleidoscope (PKAL) model for effective institutional change. This model is based on work 11 eleven California-based colleges and universities, addressing issues in undergraduate education, particularly STEM undergraduate education. Stating that "New research demonstrates the importance of a broader vision of STEM reform for student success—moving away from programs and departments to an institution wide effort," they offer the following steps for successful institutional change.

- Establish a vision—identify the direction for altering the STEM experience to support student success. Important is a vision that is clear, shared, and *aligned with institutional priorities.*
- Examine the landscape and conduct capacity analysis—inform your vision through the examination of existing data, as well as the readiness for change that may reflect the history of reform, leadership, and buy-in and ownership of faculty.
- Identify challenges and opportunities—based on the environmental scan, identify challenges and opportunities; this phase often brings in considerations of a political and cultural nature.
- Choose strategies/interventions and leverage opportunities—acknowledging opportunities and challenges, weigh alternative strategies for addressing them.
- Determine readiness for action—consider issues related to resources, workload, institutional commitment, facilities, and timelines that may affect readiness to move ahead with a particular strategy.

- Begin implementation—based on all of the above, develop a plan, which may include a pilot phase to test out hypotheses.

- Measure results—include an assessment plan that can determine what is working and what is not and how to make substantive improvements.

- Disseminate results and plan next steps—in order to avoid "siloization" of the work, develop strategies for dissemination that may be regional, statewide, or national, while at the same time planning where to go next.

Reflecting on their experiences, they also point out some common challenges and barriers. High on the list was moving ahead to implement a strategy read about in a report or publication, without assessing its fit with the local context. Another barrier cited is that individuals sometimes hold implicit theories of how change happens that are in conflict with the identified vision and goals. An example of this is faculty believing that change can only happen in departments when the vision posits broader institutional cooperation and integration.

**Similarities and differences in the emergent frameworks.** Looking across these frameworks, as well as our own research, we see several similar themes emerging.

First, almost all approach the problem from a multi-dimensional orientation. Successful change does not emerge from a focus on a single aspect of the institution but must address multiple aspects of the institution at the same time. These multiple aspects may be units or levels within the institution and/or characteristics of institutions and of the individuals within them. This suggests that if a goal of the change is to reform undergraduate education, merely changing course content and suggesting the adoption of new pedagogical practices is not likely to be successful. New norms and new trust relationships need to be established to scaffold these changes, as well as new incentives to entice faculty out of ingrained comfort zones.

Second, to understand institutional change, attention needs to be paid to external pressures or norms as well as to internal ones. The impetus for change may be a reaction to external demands as well as to internal conditions. These external pressures can take a number of forms, including state policies or budget decisions, as well as standards set by perceived institutional peer groups. A key external pressure found in our work is the NSF grant itself. This grant, although modest in size, was found to legitimize and add status to the change process.

Third, the history of the particular institution must be considered. It is not only the current context that shapes the change process, but also its past. History includes how the institution has evolved to its current

status, how STEM reform has been successfully (or unsuccessfully) approached in the past, which individuals and units have been in the forefront of change, and what mistakes have posed barriers to previous efforts.

Fourth, relationships are critical mediators in the change process. These may be formal relationships in the institutional structure, as well as less formal relationships that may often fly below the radar. Our SNA provides rich illustrations of the importance of such relationships.

Fifth, leadership is essential, but where the leadership comes from may vary. Further, both actual and symbolic leadership need to be considered. We found in our work that symbolic leadership, i.e., having the Provost, Dean, or university President on the banner as the project's leader contributed significantly to the seriousness with which the reform effort was taken. Our work also showed, however, that multiple forms of leadership are important to shepherding an effort toward maturity. Our SNA highlighted the important of boundary crossers, hubs, and gatekeepers to the development of successful efforts.

Sixth, there is no one size fits all. What is effective in one situation may not be an effective in another situation. The path to successful reform is not as simple as choosing a "best practice" and putting it in place. How and whether a change can be put in place must consider local conditions.

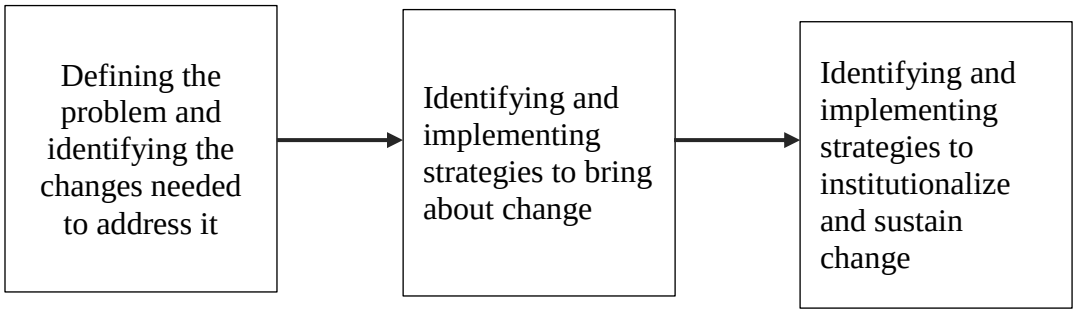
We believe that our work thus provides complementary insights to that of other researchers studying the process of change in IHEs and, importantly, affirms the criticality of considering local context in its multiple dimensions.

There is, however, a major difference between the emphasis in many of these frameworks and the route to innovation that we posit from our work. That difference is in the emphasis we put on *identifying what is to be changed.* Here we distinguish between two meanings of the term *change strategy.* First is the determination of a target or what the change will be. By "target" we mean whether the goal will be sought by creating infrastructure changes, course changes, policy changes, etc., The second is a determination of the way the hoped-for change will be introduced and put in place. To use Kezar's terminology, will the change be enacted drawing on scientific management, evolutionary, cultural, etc. strategies? Most of the work described above talks about how to successfully bring about change *after a target is selected.* Our work recognizes the importance of the process of change, but also suggests that more attention needs to be paid to the strategic identification of *the target of change and what new structure/process to put in place.* This is where we feel it is important to re-emphasize the consideration of context and the need to be deliberative about understanding one's own context before moving forward. Before deciding whether the path to change is through a new organizational unit, a new information sharing tool, or a new

approach to course design and instruction, change agents must also consider institutional context, past and present, if they are to be maximally effective. Given the flexibility in the NSF solicitation, our case study sites were encouraged to do this. Such flexibility is not always present, however, especially where the focus is on spreading some practices found to be effective or encouraging the adoption of an intervention believed to be a silver bullet.

We suggest that it is useful to break the change process into three steps (Figure 3) each of which is well served by considering local context

**Figure 3. The three-step strategy**




This assertion of the importance of local context stands in contrast to many approaches to reform that focus on "best practices." This is not to say that studies of best practices should be discounted. Rather we recommend that more emphasis be placed in thinking through how and whether a practice that has been successful elsewhere will work at a specific IHE. And, if adopted, what adaptations might be needed to align it more fully with the local context.

This assertation echoes the observation made by Elrod and Kezar (2015)

> "During our work with campuses, we discovered common challenges and barriers they encountered. The most common obstacle was that campus leaders wanted to start by immediately implementing a strategy that they read about in a report or publication. While news of a successful program may motivate change, it is important to check with campus vision and landscape analysis before jumping into implementation of the latest published student success strategy. It may or may not fit your campus situation, student population, faculty expertise, or resources. Campuses that jumped right into a strategy found that, while they made some progress, they struggled with defining purpose, specifying outcomes, implementation, and measuring impact. They ended up going back to their vision, refining it and doing more landscape analyses, which ultimately slowed progress but improved success in the long run." (p. 6)

Here, we want to call attention to what has been offered by those who work in "dynamic systems theory." This theory hypothesizes that the nature of the changes that occur depends on both the status of the organism and that of an outside agent; what emerges through similar outside stimuli will differ depending on an organisms' own status at the time the process is initiated (Thelen and Smith, 2005).

## Implications of Our Research

We see several implications of the research we have undertaken. First, we present the implications for those wanting to change their IHEs. We believe that those seeking to transform IHEs would be well served by recognizing the complexity of the system in which they are operating and the need to consider multiple levels, processes, and strategies in developing a plan to make major changes. As they do so, careful consideration should be given to contextual factors, such as those described earlier, in determining both the best opportunities for change and the most effective strategies for actualizing them. It should also be recognized that understanding context requires looking beyond the current status to taking a more historical vision. Our work provides a strong argument for starting by understanding "who we are and where we have come from" before holistically embracing practices that worked elsewhere. Relatedly, research on "best practices" should also be more deliberate in examining how context may or may not influence how well practices work in different environments. Closer examination of the interaction between proven practices and potential contextual characteristics would be useful to moving the field forward.

Second, we present the implications for external agents wishing to change IHEs. Policymakers and funders should also place more emphasis on understanding context and promote consideration of contextual variables in both developing their policies and programs and determining who will be funded when funding opportunities arise. It is not enough to justify a program or intervention based on the evidence of its effectiveness elsewhere. Rather, the argument needs to include consideration of whether and how it will work in the proposed environment and what kinds of adjustments might need to be made to make the adaptation maximally beneficial.

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