AC 2011-2439: ANALYZING THE TRANSFORMATIVE NATURE OF ENGINEERING EDUCATION PROPOSALS

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Analyzing the Transformative Nature of
Engineering Education Proposals

Abstract

This study analyzed proposals submitted to the National Science Foundation's Course Curriculum and Laboratory Improvement (CCLI) program for the Phase/Type 1 deadlines of 2005 and 2009. The goal of this study was to characterize the nature of CCLI proposals in order to determine a baseline for examining the potential effect of the recent name change in the solicitation to Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics (TUES). The name change was made to emphasize interest in projects that have the potential to transform undergraduate education in STEM fields. Therefore, we were interested in how, prior to the name change, the community conceived of what is necessary to make educational improvements and how investigators operationalized this through their project's proposed activities.

We selected Phase/Type 1 engineering CCLI proposals, analyzing all funded proposals in 2005 and 2009, and selected a random sample of non-funded proposals for comparison purposes. The percentage of proposals analyzed each year was consistent and represents approximately 30% of submissions received that year. Furthermore, since our sample included approximately 200 proposals, we coded and analyzed data only from the Project Summary.

Results showed statistically significant differences between funded and non-funded proposals in line with several "transformative" categories taken from the literature as well as based on the TUES review criteria of intellectual merit and broader impact. In addition, we found statistically significant differences in several categories between proposals submitted in 2005 and 2009. This paper reports these findings and discusses how proposals submitted to the CCLI/TUES program align with various aspects of educational transformation discussed in the literature.

Introduction

In 2010 The National Science Foundation (NSF) changed the name of the Course Curriculum and Laboratory Improvement (CCLI) program to Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics (TUES). The name change was intended to emphasize the special interest in projects that have the potential to transform undergraduate STEM education[1]. Program specific NSF review criteria were modified to emphasize the desire for projects that (1) propose materials, processes, or models that have the potential to enhance student learning and to be adapted easily by other sites and (2) involve a significant effort to facilitate adaptation at other sites.

The word "transformation" has been described as a process that transmutes one form into another[2]. Within the STEM fields, there are various views about transforming the education system, and speculation about its new outcomes. Transformation can be defined as making the education system more open[3], enhancing learning and empowering the student[4, 5], as well as involving the human, organizational, cultural aspects of the institution[6,7,8,9]. Seymour[10] has

expressed a general and common theme of emphasizing a shift from teaching to learning and stresses that teachers should refocus classroom practices and restructure courses in a way such that students have the opportunity to learn the material. According to Reigeluth[11], transformation is a process of emergence in which the older processes and structures are replaced with new ones within the system. He states that transformation is not the same as piece-meal change. Piece-meal change is when one part of the system is changed without changing the other parts or their organization within the system. For the desirable transformation of an educational system, simultaneous change must occur in three different areas: 1) "core" work processes such as teaching and learning, 2) the "social" architecture of the system including culture and communication, and 3) the system's relationship with its "external" environment. The current project adopted this framework to code proposals along these major areas of educational transformation.

This study investigated the following research questions:
- Prior to the name change to TUES, how did investigators interpret, define, and operationalize educational change in terms of the three main transformative categories of "core," "social," and "external?"
- Did the transformative nature of CCLI proposals evolve from 2005 to 2009?
- Are there differences in the transformative characteristics of funded and non-funded proposals for those submitted in 2005 and 2009?

Method

The framework adopted from Reigeluth[11] uses the idea that transformation occurs only by simultaneous change in three different areas: core, social, and external. Using this framework we created a diagram that comprises elements of what would fall into the three areas, see Figure 1. Several of the elements fell into more than one category and this overlap is indicated in the diagram. The diagram shows a noticeable absence of elements included in all three areas. The intersection of all three areas would in essence be the "solution space" for how to achieve transformation, which is a focus of the current study.

In addition to creating a diagram based on suggestions from the literature we also created a similar framework based on criteria from the NSF TUES solicitation, see Figure 2. Both of these formed the basis for the rubric used to code the proposals' project summaries. During the time of this study co-author McKenna was serving as a Program Director in the Division of Undergraduate Education and co-author Gillespie was a summer undergraduate student intern. Since the study was performed while the authors were affiliated with NSF, all authors had full access to proposals for the purpose of this study.

We analyzed all funded proposals in 2005 and 2009. We selected 2009 since this represents proposal submissions immediately before the program name change, and 2005 data provides a longitudinal perspective on the nature of proposal submissions.

Key Components for the Transformation of Undergraduate STEM Education From Literature

Relationships with the Environment (External relations)

Core (Teaching and Learning)

Social (internal relations)

Focus on outreach

Program in comfort range

College/Institution level assessment

Department level assessment

Program/Style assessment

Focus on skill development

Interdisciplinary

Research   Industry   Able to be expanded upon

Integration of current trends

Based off of strengths   Based off of weaknesses

Course level assessment

Student level assessment

Physical environment

Hands-on activities   Use of technology

Teaching style/ Pedagogy

Minority involvement

Transparency

Shared decision making/ collaborating

Transition programs

Faculty incentives

Lifelong learning

Faculty development

Easily manipulated for others

Focus on core principles

Student retention

Student to student

Colleagues helping colleagues

Faculty beliefs concerning education
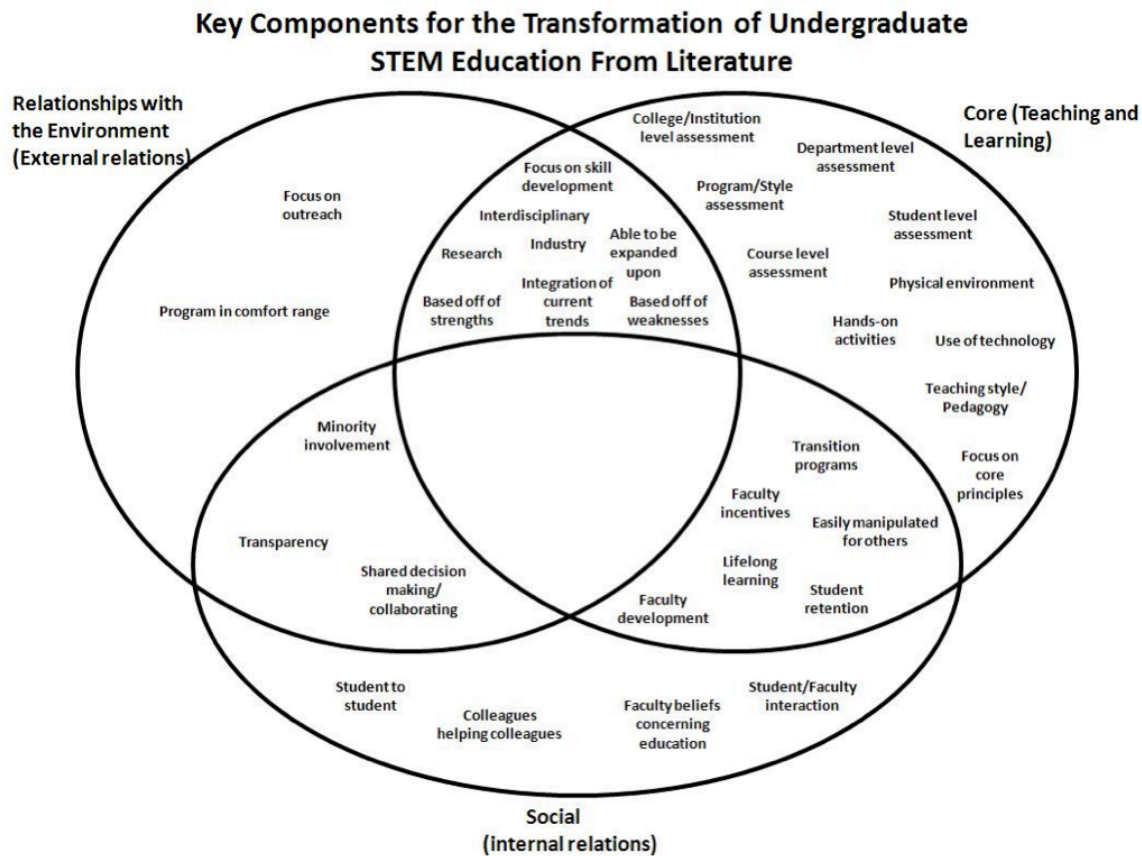
Student/Faculty interaction

Figure 1. Transformational characteristics in three areas: core, social, and external.

The total sample included 74 proposals from 2005 and 109 proposals from 2009. The slight variation in totals is due to the overall number of submissions received per year; however, the percentage of proposals analyzed each year was consistent and represents approximately 30% of submissions received that year. Furthermore, since our sample included approximately 200 proposals, we coded and analyzed data only from the Project Summary.
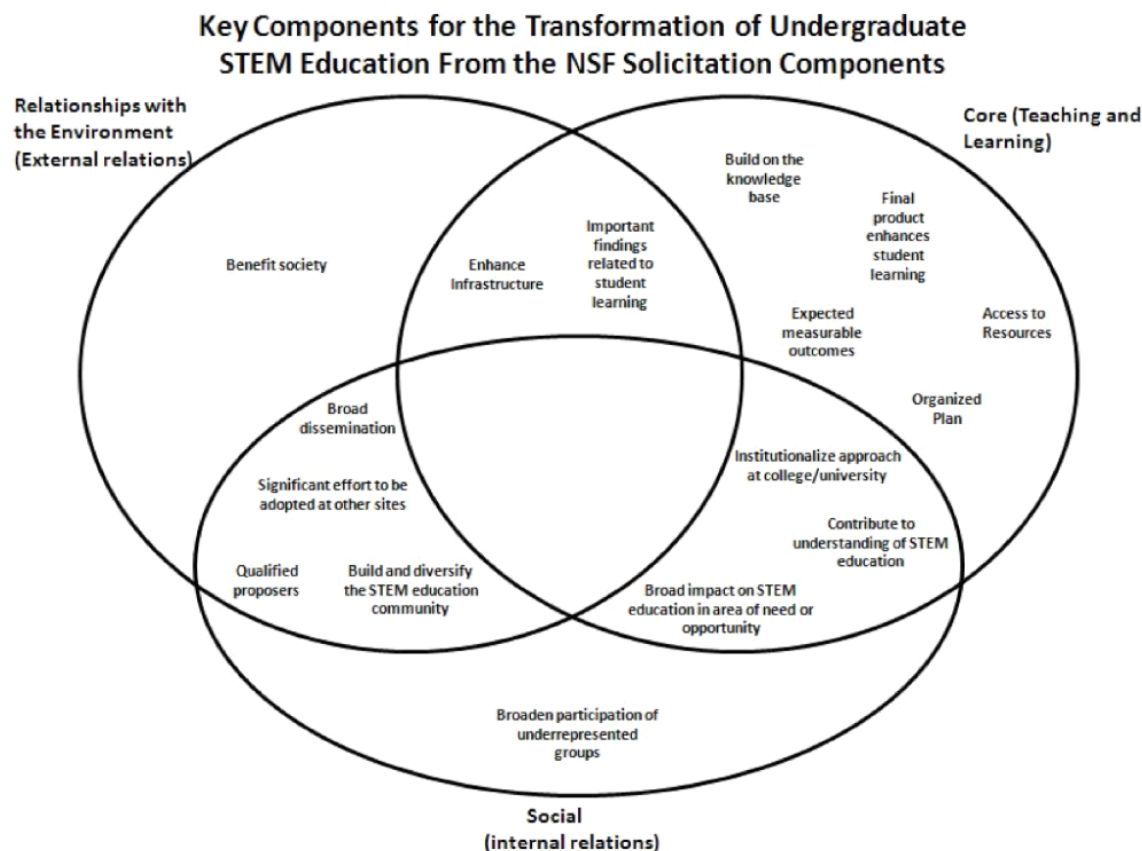
Key Components for the Transformation of Undergraduate
STEM Education From the NSF Solicitation Components

Relationships with
the Environment
(External relations)

Core (Teaching and
Learning)

Benefit society

Enhance
Infrastructure

Important
findings
related to
student
learning

Build on the
knowledge
base

Final
product
enhances
student
learning

Expected
measurable
outcomes

Access to
Resources

Broad
dissemination

Organized
Plan

Significant effort to be
adopted at other sites

Institutionalize approach
at college/university

Qualified
proposers

Build and diversify
the STEM education
community

Contribute to
understanding of STEM
education

Broad impact on STEM
education in area of need or
opportunity

Broaden participation of
underrepresented
groups

Social
(internal relations)

Figure 2. Transformational elements based on NSF TUES review criteria.

From 2005 to 2009 the Phase/Type 1 funding rates ranged from 11% to 32 % with an average around 20%. We also note that the 2005 proposals were submitted during fiscal year 2005 and funded in fiscal year 2006 and similarly, the 2009 proposals were submitted in fiscal year 2009 and funded in fiscal year 2010.

We analyzed the proposals based on a rubric consisting of items represented in Figures 1 and 2. To make the rubric manageable for coding purposes we grouped items according to aspects relating to 1) intellectual merit and broader impact, the two criteria used in reviewing NSF proposals, 2) "core" teaching and learning, 3) "social" aspects, and 4) "external" relationships. We coded the project summaries, including the intellectual merit and broader impact sections of each proposal. If the Project Summary included an item in the rubric, it was assigned a "1" for that item; if not, it received a "0." This analysis allowed us to examine to what extent proposals did, or did not, address different components related to transforming undergraduate STEM education. Upon completion of the coding, the data were analyzed by summing up the number of items for each proposal, as well as the number of proposals coded for each item. We used the t-test to compare the mean values for the proposal in 2005 and 2009 and for the funded and non-funded proposals. For this study, a p-value of 0.05 was used as the threshold for statistical significance.

Results

Identifying, Defining, and Operationalizing Transformation
According to Reigeluth[11], one would anticipate that if proposals combined individual items in the three different areas together, the outcome would result in the transformation of educational systems. To identify how investigators defined and operationalized educational change in terms of the three main transformative categories of "core," "social," and "external" we looked at what percentage of rubric items investigators included in proposals, what areas were included the most, and if there were specific items on the rubric that were always or rarely addressed.

Table 1 shows the percentage of proposals that included NSF criteria items for the funded and non-funded proposals for each of the two years. The items are grouped according to aspects of intellectual merit, broader impact, and dissemination methods. The most common items relating to the NSF criteria that were present in the project summary included a) having an organized plan for the project and b) that the final product would enhance student learning. These were both mentioned in over 80% of sampled proposals for all years. The item that was included the least was to "benefit society," where we defined society as outside of the STEM discipline. This item was coded in less than 20% of proposals sampled. The average numbers of NSF criteria items coded for 2005 and 2009 were 7.6 and 8.5 items out of 16. The data indicate that on average each project summary addressed approximately half of the NSF criteria items relating to transformation. Moreover, the total number of NSF review criteria items coded in proposals did not show any statistically significant differences between 2005 and 2009.

Table 1.Percentage of proposals that included specific NSF criteria items.

Rubric Item	Year	All Sampled	Funded	Non-Funded
Aspects of Intellectual Merit				
Organized plan	2005	90%	100%	86%
	2009	92%	100%	89%
Final product would enhance student learning	2005	96%	96%	96%
	2009	94%	100%	90%
Expected measurable outcome	2005	82%	100%	74%
	2009	80%	97%	72%
Build on knowledge base	2005	82%	100%	74%
	2009	76%	97%	66%
Important findings related to student learning	2005	55%	87%	40%
	2009	55%	77%	45%
Broaden participation of underrepresented groups	2005	53%	58%	50%
	2009	46%	43%	47%
Enhance infrastructure	2005	40%	62%	30%

	2009	50%	66%	43%
Qualified proposers	2005	31%	46%	24%
	2009	28%	37%	24%
Dissemination Methods				
Publish on web	2005	34%	25%	38%
	2009	49%	51%	47%
Conference proceeding	2005	31%	21%	36%
	2009	34%	34%	34%
Journals	2005	26%	21%	28%
	2009	29%	40%	24%
Share or partner with colleagues/other institutions	2005	26%	25%	26%
	2009	32%	34%	31%
Workshop	2005	15%	12%	16%
	2009	16%	11%	18%
Share with K-12	2005	19%	17%	20%
	2009	39%	43%	38%
Aspects of Broader Impact				
Significant effort to be adopted by other sites	2005	55%	71%	48%
	2009	53%	67%	46%
Contribute to understanding of STEM education	2005	43%	62%	34%
	2009	46%	74%	32%
Build and diversify the STEM education community	2005	31%	33%	30%
	2009	35%	37%	34%
Benefit society (outside of STEM discipline)	2005	5%	0%	8%
	2009	4%	11%	0%

Analysis of the core, social, and external categories showed that the items mentioned most include teaching style/pedagogy and a focus on core disciplines, such as fundamentals and traditional course materials; both of which were mentioned in over 75% of proposals sampled.

From the core, social, and external categories the least-mentioned items were:
   a) Student involvement with industry
   b) Assessment at the department level
   c) Assessment at the college/institution level
   d) Lifelong learning skills
   e) Transition programs from high school to college or 2 year to 4-year college
   f) Faculty beliefs concerning educational goals

These items were mentioned in less than 10% of proposals for all years. "Faculty incentives" was not mentioned once in any coded proposal but was mentioned numerous times in the literature[2, 6, 7, 8, 10, 12, 13].

We also analyzed each of the three areas necessary for transformation. Table 2 shows the average number and percentages of core, social, and external-based items that were coded in proposals for each of the areas. Our rubric contained more items that fell into the "Core" area since the literature tended to focus on this area. This focus on core was also reflected in proposals. Thus, the percentages of items coded from each area were similar, but the numbers were different.

Table 2. Averages and percentages for three main categories of transformation.

Year	External #	External %	Core #	Core %	Social #	Social %
2005	4.6	29%	7.3	27%	3.5	27%
2009	3.0	18%	7.8	29%	3.6	28%

We found that on average proposals included 25% to 30% of the items expected in a potentially transformative proposal with at least a few items in each of the three areas necessary for transformation. However, the focus for transformation is still on the core area, possibly because of the history of the CCLI/TUES program and its early emphasis on supporting course innovations. That is, many CCLI and its predecessors programs could be described as focusing at the classroom-level to develop course materials, implement new pedagogical approaches and assessment instruments. While these activities continue to be elements of TUES, the program has broadened its focused to include the "system" which is represented not only of "core" classroom-level activities but also the social and external relationships that are involved in transformation on a broader scale.

We analyzed potential differences for each of the three main areas and found a statistically significant increase in "external" items coded from 2005 and 2009. This finding suggests that the community may also be evolving such that investigators recognize the importance of and are interested in studying aspects of educational change that fall outside the "core" area.

Funded and Non-Funded
Figure 3 and Figure 4 both show that funded proposals tended to have larger numbers of NSF criteria items coded than non-funded proposals. The histograms display the percentage of proposals that included the indicated number of items; for example, in Figure 3, 22 % of the funded proposals included 10 items while 4 % of the non-funded include 10.
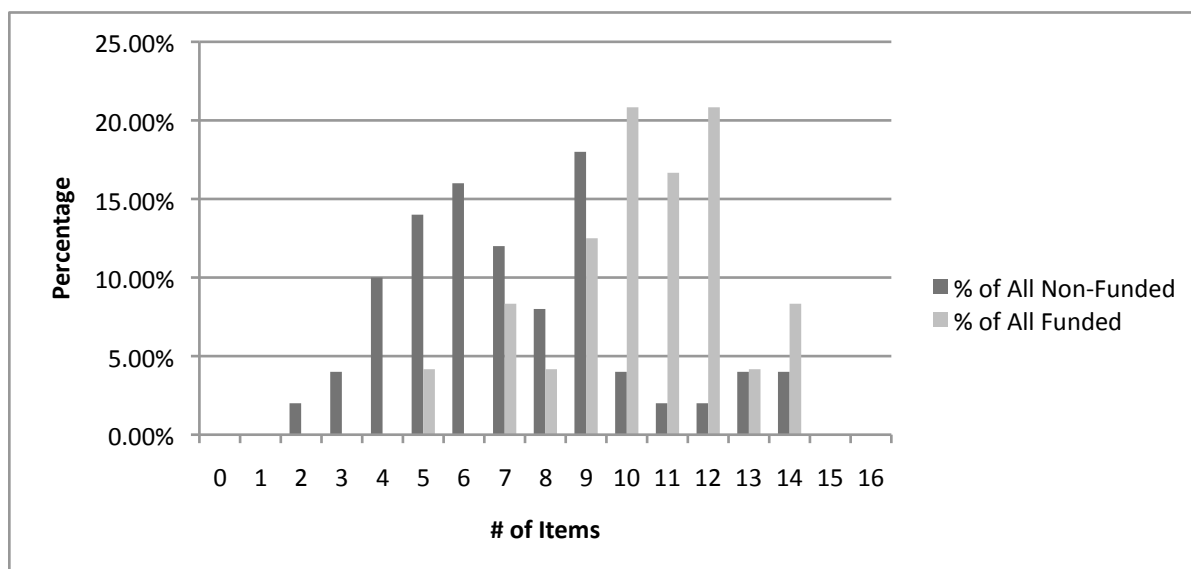
Figure 3. Number of NSF criteria items coded in proposals, 2005.
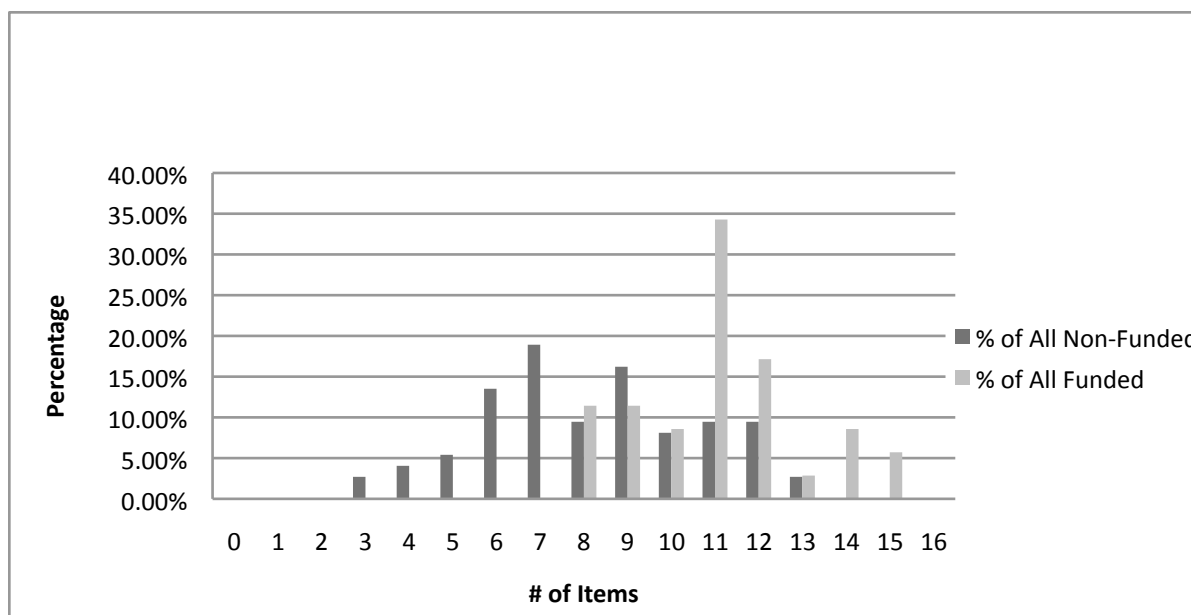

Figure 4. Number of NSF criteria items coded in proposals, 2009.

Similar graphs could be shown for the total number of transformation items as well as for each area of core, social, and external. For all categories, funded proposals tended to have more items coded than non-funded proposals. In addition, specific items were coded significantly more in funded proposals than in non-funded proposals as shown in Table 3.

Table 3. Statistically significant differences for funded and non-funded proposals.

Rubric Item	Year	% Non-funded	% Funded	p-value
Easily adapted (cheap, mobile, not specific to one program)	2005	38%	67%	p<0.05
	2009	46%	83%	p<0.001
Teaching Style/Pedagogy	2005	72%	96%	p<0.01
	2009	74%	100%	p<0.001
Interdisciplinary between engineering sub-disciplines	2009	14%	34%	p<0.05
Student level assessment	2009	30%	51%	p<0.05
Program in comfort range for others	2009	10%	40%	p<0.01
Able to be expanded	2009	31%	74%	p<0.001

Summary and Future Work

A review of the literature as well as the TUES review criteria provided a basis for defining "transformation" in the context of undergraduate STEM education. Based on our analysis of CCLI proposals we found that most proposals did address some of the three areas necessary for transformation, that is, core work processes (teaching and learning), the social architecture of the system (culture and communication), and the systems relationship with the environment (external). However, the main focus of proposals is primarily on the core area of teaching and learning which is not surprising given the history of the program. This study was conducted during the first year of the name change in order to establish a baseline for comparing potential differences in the nature of proposal submissions to the new TUES program. However, we also recognize that more than a name change may be necessary to impact the nature of proposal submissions. That is, one important and complementary activity is educating the community about the new expectations for proposals, and guidance to PIs on how to best prepare proposals to meet the new expectations.

Future work could examine the longitudinal effect of the name change not only on funded vs. non-funded proposals, but also if there is any impact of the funded work beyond the local institutions. Moreover, one limitation of the study was that we analyzed only the Project Summary. Additional research could examine the entire proposal to determine how the project embeds transformational qualities.

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