AC 2012-3717: RESULTS FROM A SURVEY OF NATIONAL SCIENCE FOUNDATION TRANSFORMING UNDERGRADUATE EDUCATION IN STEM (TUES) PROGRAM REVIEWERS

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Results from a Survey of National Science Foundation Transforming Undergraduate Education in STEM (TUES) Program Reviewers

Abstract

The purpose of this analysis is to understand the engineering education community's views on transformation and change. This is addressed by studying NSF's Transforming Undergraduate Education in STEM (TUES) program. TUES and its predecessor, Course, Curriculum and Laboratory Improvement (CCLI), have been an influential and substantial source of funding for U.S. undergraduate STEM education change since 1990.

A framework of institutionalization and transportability is used to understand evolution of the engineering education community's perceptions of change processes as demonstrated in NSF's CCLI-TUES program. We present the results of a peer review panelist survey organized by prior CCLI criteria and newer institutionalization and transportability TUES criteria.

In July 2011, 133 TUES engineering panelists were surveyed about characteristics of the Type 1 proposals they had just evaluated. Analysis of their responses indicates greater consensus regarding the weaknesses of proposals than of the strengths. Weaknesses tended to focus on local impacts which had been emphasized in CCLI, while strengths were more closely related to TUES emphases on transformation and broad impact at multiple institutions. Evaluation and assessment remain prominent weaknesses to be addressed, along with dissemination and institutionalization.

This paper informs prospective PIs of program expectations, provides baseline data for evaluating recent and future changes to the program, and allows program officers to reflect on program and policy needs. In the broader context of studies on change in engineering education, this study documents shifting values of peer reviewers and engineering educators to increasingly emphasize approaches that will broadly impact and transform how future engineers are educated.

Introduction

Increasingly, high profile organizations including ASEE[1], National Academy of Engineering[2-4], Association of American Universities[5], National Research Council[6-8], and the National Science Board[9, 10] are calling for widespread improvements in undergraduate STEM education. Tremendous investment and related efforts over the past few decades have built up a substantial knowledge base about STEM learning and many effective pedagogies and interventions[11, 12]. Yet these groups are increasingly expressing dissatisfaction with the rate of implementation, which draws attention to implicit assumptions and models of how change occurs in STEM higher education and how it might be accelerated. Broad scale changes to teaching practices and culture at the institutional level are currently being tested. The Science Education Initiative, facilitated by Carl Wieman, at the University of Colorado Boulder and the University of British Columbia[13] and efforts in the University System of Maryland[14] are concrete examples of efforts to change institutions. At their core, these projects emphasize evidence-based teaching and student engagement through active- and inquiry-based approaches. While these model initiatives address many disciplines within STEM education, engineering education leaders have similar aspirations for achieving excellence in undergraduate education. The TUES program solicitation explicitly supports such aims.

The purpose of this analysis is to study NSF's Transforming Undergraduate Education in STEM (TUES) program to understand the engineering education community's views on transformation and change. TUES and its predecessor, Course, Curriculum and Laboratory Improvement (CCLI), have been an influential and substantial source of funding for U.S. undergraduate STEM education change since 1990[15]. For example, CCLI's emphasis on project evaluation, coupled with outcomes-based assessment driven by ABET's EC2000 criteria, is a strong example of how policy can influence practice in engineering higher education. This paper also informs prospective PIs of program expectations, provides baseline data for evaluating recent and future changes to the program, and allows program officers to reflect on program and policy needs.

Literature Review

Prior analyses have demonstrated that the general change model implicitly taken by STEM faculty members[16, 17] and engineering educators[11] is to develop and perfect a curriculum or intervention and then attempt to convince others to use it. This is a diffusion model of change, which lends itself well to study using a diffusion of innovations perspective[18]. In STEM education, this approach is based on the assumption that typical faculty members have neither the time nor the expertise to read educational literature and develop their own innovative curricula. The relatively low levels of adoption[11, 19] demonstrate that this is not necessarily a productive approach or assumption. The limitations of a diffusion of innovations perspective, which have been identified in theory and research, are that well-packaged innovations don't address the breadth of engineering faculty desires to adapt, reinvent and make it their own.

A separate but related emphasis is on institutionalization of educational programs and changes after an initial grant funding period. Curry defines institutionalization as the final phase in a change process, "when an innovation or program is fully integrated into an organization's structure" [19]. For example, engineering education coalitions funded many curricular changes at institutions across the United States throughout the 1990s and 2000s, but only some of these, such as first-year projects, were institutionalized and continued beyond the initial funding period[20].

STEM education studies usually take either diffusion or an institutionalization perspective, rarely combining the two, so their relationship is not entirely clear. It seems logical that an innovation should be institutionalized on the home campus before attempting to convince others, but certainly counterexamples in which a practice was more successful at other institutions can be identified. For the purposes of this paper, we treat diffusion and institutionalization as separate (but clearly related) topics addressing the same goal of widespread change in STEM education.

Diffusion and institutionalization have been advanced by NSF's CCLI and TUES programs. In fact, they are closely related to the name change emphasizing transformation. Concerns about return on investment (which is minimal if CCLI only funds local, frequently unsustainable changes) motivated program changes to emphasize transformation. While a prior analysis explored myriad potential meanings of transformation in the TUES program[21], we focus on institutionalization and diffusion mechanisms for broad impact.

The first TUES program solicitation retained much of CCLI's language about curriculum, faculty development, evaluation, and building on prior knowledge of STEM learning. However, the program synopsis was rewritten to emphasize transformation, transferability, dissemination, and adaptation:

> This solicitation especially encourages projects that have the potential to transform undergraduate STEM education, for example, by bringing about widespread adoption of classroom practices that embody understanding of how students learn most effectively. Thus transferability and dissemination are critical aspects for projects developing instructional materials and methods and should be considered throughout the project's lifetime. More advanced projects should involve efforts to facilitate adaptation at other sites.[22]

Additional review criteria were also added: "Are the plans for institutionalizing the approach at the investigator's college or university appropriate?" under intellectual merit and "Does the project involve a significant effort to facilitate adaptation at other sites?" and "Does the project have the potential to contribute to a paradigm shift in undergraduate STEM education?" under broader impacts. The Intellectual merit review criterion on exemplary materials, processes, or models review criterion was modified to include the qualification "and easily adapted to other sites."[22]

In our TUES program outreach to the engineering education community[23, 24], we encourage prospective PIs to be proactive in designing their projects for sustainability and transportability. Sustainability refers to institutionalization at the colleges and universities receiving the NSF funding. The term transportability was intentionally chosen to expand the ideas of dissemination and diffusion to involve potential users in the process as early as possible. Rather than perfect an innovation at one type of institution with one population of students, prospective PIs are encouraged to involve others in the development and testing of the educational materials. This approach is consistent with diffusion theory, which does not necessarily emphasize co-development, but suggests that flexibility and adaptability increases the likelihood that an innovation will be adopted permanently.

This framework of institutionalization and transportability can be used to understand evolution of the engineering education community's perceptions of change processes as demonstrated in NSF's CCLI-TUES program. We present the results of a peer review panelist survey organized by prior CCLI criteria and newer institutionalization and transportability TUES criteria.

Methods

TUES Program Setting

To address the program goals described above, TUES has two review deadlines each year for three types of proposals. Type 1 proposals typically, but not necessarily, focus on advancing one project element that will enhance undergraduate STEM education in a specific institution and STEM discipline. (Recently, however, we have begun receiving more Type 1 proposals with multiple collaborating institutions.) Type 2 and 3 proposals generally have a wider focus, engaging multiple project elements and several institutions. Substantial effort to disseminate the material to other organizations is expected. In summer of 2011, a total of 395 engineering Type 1 TUES proposals, spanning seven engineering disciplines were reviewed (Figure 1). Like most solicited NSF proposals, these were peer reviewed by a panel of STEM education experts from academia and industry, many of whom were previous recipients of TUES grants.

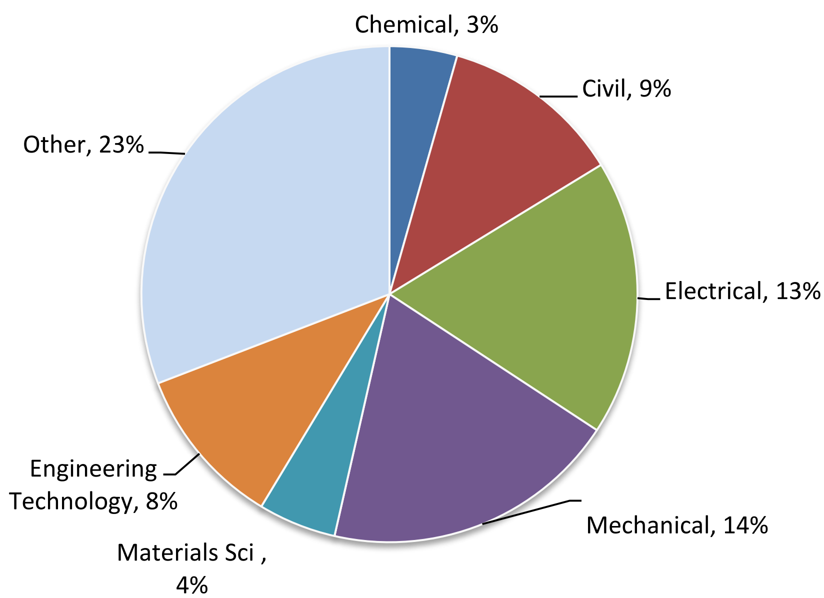

Figure 1. Distribution of engineering Type 1 proposals.

Sample and Data Collection

In July 2011, we administered a survey to 133 TUES Type 1 engineering panelists (peer reviewers immediately after they had completed reviews and deliberations on 10-15 proposals). To encourage a high response rate, participants were asked to provide their addresses if they wanted to be emailed a copy of the results. The response rate was excellent at 95%. Shortly after the panel meeting, we sent a variation of the aggregate results report generated by the survey software to these participants.

Instrument

The survey contained 18 questions. Two items collected information on respondents' prior experience with NSF review panels and NSF educational projects. Most of the items were multiple choice, using a five-point Likert-type scale ranking the quality of proposals on a variety of characteristics and criteria. Two additional two open-ended questions asked respondents to list the most common strengths and weaknesses of the proposals.

Data Analysis

In addition to basic descriptive counts of responses, a weighted average was calculated for the Likert scale items. Responses to the open-ended questions were thematically coded by one author, and the top five most common strengths and weaknesses are reported. In order to identify differences in the responses between new and experienced reviewers, we performed a two-tailed, paired t-test, with alpha ≤ 0.05.

Results

Respondent Characteristics

The initial questions assess the reviewers' previous experiences with panel review sessions and involvement in NSF funded educational experiences (Figure 2). In this set of reviewers, 44% of the respondents had no previous experience, while 56% had served on at least one panel. However, the majority of respondents have some experience with "NSF educational projects," as the question was worded. The majority of respondents, 72%, have been involved in at least one NSF education project. In other words, even if reviewers were new to TUES Type 1 panels, they were likely to have other experience with NSF education-related projects.

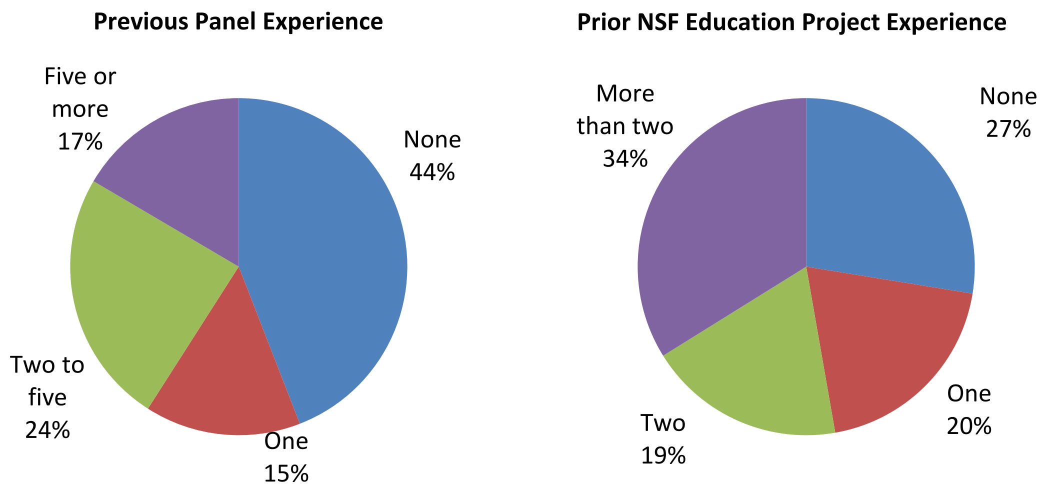

Figure 2. Respondents' prior NSF experiences.

In transitioning from CCLI to TUES, some of the criteria remained constant. These criteria would be the most familiar to the prospective PIs due to carry over from CCLI to TUES. We label these "local" criteria because they have little to do with dissemination or transportability to other institutions. Panelists indicated that "local" proposal aspects such as utilizing the existing literature base and planning project activities scored high, 2.23 and 2.15 respectively (Table 1). In contrast, non-local elements pertaining to advancing undergraduate STEM education and developing exemplary materials, received lower scores, 1.63 and 1.59 respectively (Table 1). These results indicate that activities that are more familiar and within the writer's direct control produced higher scores overall. Criteria that advance the field of STEM education either through material development or advancing knowledge were scored lower, but also may be more difficult to conceptualize.

Table 1. Panelists' perception of "local" effects in TUES Type 1 engineering proposals. Number of respondents for each answer listed below the percentage.

How many of the proposals that you reviewed in this panel had the following: N = 127						
	Almost none (0)	**About ¼ (1)**	**About ½ (2)**	**About ¾ (3)**	**Almost all (4)**	**Weighted Average**
A discussion building on existing knowledge about STEM education?	2% (2)	24% (30)	37% (46)	27% (34)	11% (14)	2.23
Contribute to the understanding of STEM education?	11% (14)	39% (49)	29% (37)	14% (18)	6% (8)	1.63
Well conceived and organized activities?	0% (0)	24% (30)	42% (53)	29% (37)	5% (6)	2.15
Activities to broaden the participation of underrepresented groups?	10% (12)	29% (36)	33% (41)	25% (31)	5% (10)	1.90
Produce exemplary material, processes, or models that would enhance student learning?	6% (7)	52% (65)	25% (31)	15% (19)	3% (4)	1.59

The TUES Program criteria also emphasize new elements, which we describe as non-local effects that emphasize broader dissemination, adoption and impact of TUES awards. Proposals received a high score of 2.09 for instituting changes at the home institution (Table 2). However, creating materials that are readily transferrable to new sites or making determined efforts to aid other sites in adopting the product received lower scores, 1.74 and 1.50 respectively (Table 2). Lastly, developing ideas that are creative or transformative of undergraduate STEM education received the lowest rated score of the survey (1.44, Table 2). Since these criteria were implemented with the change to TUES, prospective PIs have had less time to engage the ideas and develop ways to fully address the criteria. Considering the data in Table 1 and 2 together suggests that researchers are accessing the literature but still finding it difficult to develop ideas that contribute to the overall understanding of STEM education or are transformative in nature.

Table 2. Panelists' ratings of non-local effects in TUES Type 1 engineering proposals. Number of respondents for each answer is listed below the percentage.

How many of the proposals that you reviewed in this panel had the following: N = 127						
	Almost none (0)	**About ¼ (1)**	**About ½ (2)**	**About ¾ (3)**	**Almost all (4)**	**Weighted Average**
Plans for institutionalizing the approach at the investigator's college or university?	5% (6)	24% (30)	39% (49)	25% (31)	8% (10)	2.09
Produce adaptable material, processes, or models?	4% (5)	38% (48)	39% (49)	18% (23)	1% (1)	1.74
A significant effort to facilitate adaptation at other sites?	8% (10)	44% (55)	40% (50)	6% (8)	2% (3)	1.50
Creative, original, or potentially transformative concepts?	4% (5)	57% (71)	30% (38)	9% (11)	0% (0)	1.44

A major, longstanding emphasis in the CCLI and TUES Programs is strong project evaluation plans, including learning assessment. While incorporating newer technology and teaching methods can make improvements in student learning, assessment is required to effectively gauge the impact of the intervention. Two questions in the survey determined the perception of evaluation and assessment efforts and designing methods that facilitate measurable outcomes. Defining measurable outcomes was rated with a moderate score of 2.03 (Table 3), suggesting that researchers are designing educational interventions with measurable results. However, large-scale integration of evaluation and assessment methods remains incomplete in proposals, as indicated by the score of 1.88 (Table 3).

Table 3. Panelists' views of evaluation efforts in TUES Type 1 engineering proposals. Number of respondents for each percentage is listed beneath the percentage.

How many of the proposals that you reviewed in this panel had the following: N = 127						
	Almost none (0)	**About ¼ (1)**	**About ½ (2)**	**About ¾ (3)**	**Almost all (4)**	**Weighted Average**
Appropriate expected measureable outcomes?	4% (5)	19% (24)	51% (65)	22% (28)	4% (5)	2.03
An evaluation effort that would produce useful information?	4% (5)	27% (34)	48% (60)	19% (24)	2% (2)	1.88

Statistical tests indicated just three of these items were significantly different between new and experienced reviewers. Reviewers with no prior TUES Type 1 experience rated outcomes ($p = .035$), evaluation plans ($p = .025$), and institutionalization plans ($p = .001$) higher than experienced reviewers. All other quantitative items revealed no statistically significant differences between new and experienced reviewers.

Open-ended questions determining the most common strengths and weaknesses were also collected in the survey results. These data were analyzed and grouped according to common thematic components. Each panelist was able to write at length, and frequently made multiple comments. The percentages are based on the total number of comments tallied. The top five most common weaknesses and strengths are shown in Figures 3 and 4 respectively. Generally, the data corroborate the results from Tables 1 to 3 with some differences in ranking. For example, the most commonly cited weaknesses for Table 3 include difficulty with addressing the transformative aspects of the TUES Program criteria, dissemination, and producing exemplary products, while the most frequently cited weakness in the open-ended questions were lack of an evaluation and assessment plan. As open-ended questions allow reviewers to focus on specific critiques rather than the entire proposal pool, the difference in ratings may reflect the different wording of survey items. Since evaluation and measurable outcomes are rated moderately and appear in the top weaknesses, we can conclude that reviewers are strongly emphasizing these criteria in their proposal critiques.

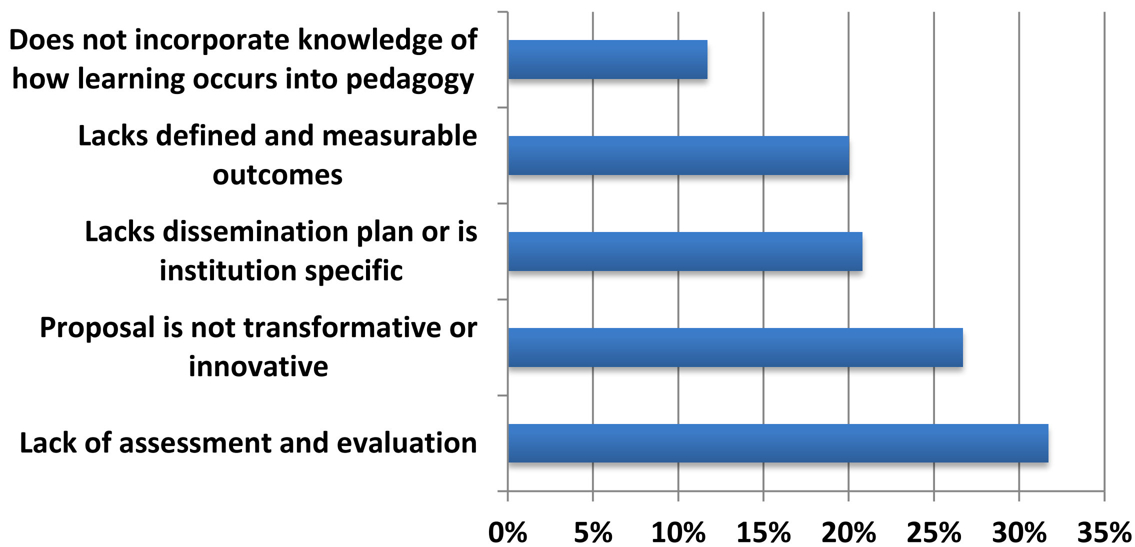

Figure 3. Top five weaknesses stated by reviewers in engineering TUES Type 1 proposals.

The most commonly cited strengths in Figure 4 also diverged from the survey results. As "transformative and innovative proposals" was the most commonly cited strength, clearly some proposals are achieving the quality and goals set forth by the TUES Program. However, as only 18.8% of responses identified this strength, further work remains for most proposals to achieve greater engagement of transformative ideas. Additionally, the second most commonly cited strength was the "commitment to undergraduate education reform." This category indicates the overall enthusiasm, energy, and commitment for improving STEM higher education.

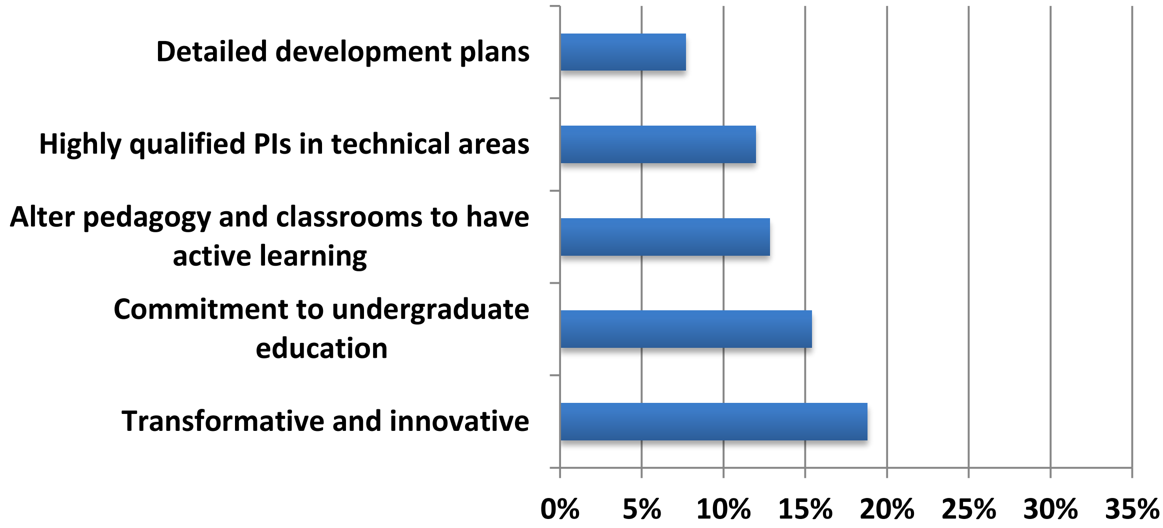

Figure 4. Top five strengths identified by reviewers in engineering TUES Type 1 proposals.

Discussion

In analyzing the multiple choice and open response survey items, we find that the weaknesses were more consistent than the strengths. Project evaluation and learning assessment remain the most prominent aspects lacking in weak proposals. Plans to disseminate project outcomes and effect lasting change at multiple institutions were also consistently found to be disappointing. On the other hand, strengths were less consistent. Panelists are rated some aspects of proposals highly (Tables 1-3), yet identified different strengths in their open-ended responses. Agreement on proposal strengths is expected to be more varied than weaknesses given the expectation for creative and transformative projects.

These data highlight key areas of the TUES solicitation where prospective PIs may be wise to focus their efforts. Project evaluation and learning assessment, outcomes dissemination, and the potential to transform engineering or STEM education were the most frequently mentioned by the reviewers. Without robust evaluation and assessment evidence, drawing conclusions about the effectiveness of interventions—and convincing others— is impossible. These data also indicate that the bar is rising for expanding TUES Type 1 engineering projects beyond one institution. Engineering proposals which do not demonstrate some forethought about transportability to other institutions are unlikely to be highly competitive. For example, proposals to purchase expensive, specialized equipment with no future plans to make it accessible to others (e.g., via the internet) would not easily transfer to other institutions. Increasingly, we are receiving collaborative Type 1 proposals, which may include partners in some aspects of development that would make the products more flexible and adaptable to different types of institutions (even if the primary intervention takes place at one institution). This is one way of addressing the concerns expressed by reviewers in this survey. NSF DUE engineering and computer science program officers actively engage proposal writers in exploring these concepts by hosting webinars on proposal preparation[23, 24].

Encouragingly, the survey results indicate that some proposals are meeting the TUES criteria described in the solicitation. The top strength identified is the transformative capacity of proposals, indicating that novel educational ideas are being proposed by engineering educators. Transformative projects are grounded in the literature but integrate some creativity or novelty in solving an important problem of broad appeal, so that it is clear that others may someday want to implement it. As noted in the top strengths, the technical engineering credentials and reputation of PIs indicates a high degree of interest from broader segments of the engineering education community.

There are several limitations to this study. These data only capture the perception of one set of TUES Type 1 reviewers evaluating one set of proposals. Readers may be surprised by the high percentage of new reviewers. This is one type of diversity that program officers consider when composing panels. Few differences were identified between the responses of new and experienced reviewers (new reviewers rated outcomes, evaluation and institutionalization higher). Reviewers had other experience with NSF-funded educational projects. For example, new TUES PIs are frequently called upon to serve as reviewers.

Higher education in general, and STEM education specifically, in the United States is under intense scrutiny. Persistent problems with the retention of students in STEM fields, including engineering, exist despite particular benefits of being a STEM field[25, 26]. Recent reports from the President's Council of Advisors on Science & Technology[27] and the Committee on Science, Technology, Engineering, and Math Education[28] both acknowledge challenges of undergraduate STEM recruitment and retention. Each recommends actions to address the shortfalls in STEM education. In accordance with these recommendations, NSF is developing a new program, Widening Implementation and Demonstration of Evidence-Based Reform (WIDER), that explicitly seeks to enable much more widespread reforms to undergraduate STEM education. Surveying the perspectives of panelists regarding TUES Type 1 proposals is important for understanding and communicating with the engineering education community so that we can work together to meet current and future challenges.

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