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Undergraduate Research as a System: Mapping the Institutional Landscape of a High-Impact Practice

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Abstract: This study examines the written and visual results of a participatory systems-mapping process used to explore undergraduate research at a large, public research university in the United States. With the university's transition to a high-impact practice model, the institutional value of undergraduate research has increased, but challenges remain in implementing the practice equitably and inclusively, especially in the complex environment of higher education. The systems-mapping process reveals the subtle, often conflicting dynamics that underlie the undergraduate research enterprise, while simultaneously supporting the emergence of a shared vision, or story, of what the undergraduate research experience could be.

Keywords: high-impact practice (HIP), undergraduate research, systems thinking, systems mapping, research universities, organizational change

The blind men and the elephant is an Eastern parable that provides an enduring lesson on how perception may be limited by context, as well as a fitting metaphor for systems thinking. If there is a complex system (the elephant) that one wishes to understand, in other words, then it is an injustice to visualize it from only a single perspective, or even a group of single, isolated perspectives (the blind men). In some versions of the tale, the varied interpretations lead to conflict, in others, consensus. For the purposes of this study, our "elephant in the room" is the practice of undergraduate research, captured as it emerges from a limited set of individual experiences into a multifaceted system that touches nearly all parts of university culture.

Overview and Literature Review

The history of undergraduate research has been well chronicled by others, but a major turning point in its development occurred in the 2000s, when George Kuh (and others) first identified it as one of several high-impact practices (HIPs; Kuh & Schneider, 2008). From that point onward, undergraduate research would no longer be limited to individual partnerships. Rather, the HIP model has served to extend the scope of targeted activities to the institutional level (Kuh, 2013). This wider lens has, in turn, extended the conceptual frameworks for many HIPs to encompass a broader range of practice

across disciplines, roles, and academic units. In the case of undergraduate research, this bird's-eye view has engendered constructive conversations about the differentiated participation across disciplines (and super disciplines, e.g., the STEM [science, technology, engineering, and mathematics] fields; Ishiyama, 2002), which has led to the emergence of more nuanced definitions of the essential components of an undergraduate research learning experience that can be integrated into multiple contexts via a range of modalities (Beckman & Hensel, 2009; Healey &Jenkins, 2009; Hensel, 2012; Hu, Scheuch, Schwartz, Gayles, , & Li, 2008; Jansen et al., 2015; Kinkead, 2003; Mumford, Hill, & Kieffer, 2017; Zimbardi & Myatt, 2014).

To date, these emerging frameworks for undergraduate research have been driven by the need to assess (and, by extension, to enhance) their institutional impact, largely by collecting and aggregating the work being done by individual student, faculty, and academic units across a campus or campuses (DeAngelo, Mason, & Winters, 2016; Elgin et al., 2016; Fitzsimmons et al., 1990; Hensley, Shreeves, &Davis-Kahl, 2014; Kuh, 2003; Lopatto, 2004; MacDonald, Brown, & Swaby, 2019; Malachowski, Osborn, Karukstis, & Ambos, 2015; McDevitt, Patel, & Ellison, 2020; Nelson Laird, BrckaLorenz, Zilvinskis, & Lambert, 2014; Rogers & McDowell, 2015; Webber, Nelson Laird, & BrckaLorenz, 2013). Because of its HIP status, undergraduate research has been scrutinized especially heavily by researchers interested in its influence on student success, in the form of equity, access, persistence, and/or graduation (e.g., Eby et al., 2012; Jacobi, 1991; McLean & Howarth, 2008; Miller, Barnes, Miller, & McKinnon, 2013; Rogers &McDowell, 2015; Santos & Reigadas, 2004). A summary of the research indicates that the practice does indeed live up to its high-impact status, with gains noted across the board (Carter, Ro, Alcott, & Lattuca, 2016; Gilmore, Vieyra, Timmerman, Feldon, & Maher, 2015), yet scholars have also pointed out that these gains may or may not accrue at the same rate across different populations, disciplines, or institutions (Bangerra & Brownell, 2014; Y. K. Kim & Sax, 2009).

The consensus on the benefits of undergraduate research has allowed the focus of research to shift from questioning whether undergraduate research "works" to exploring instead how to make the practice more inclusive and equitable. A corollary to this shift in emphasis is an interest in identifying barriers to participation, whether these stem from (lack of) student motivation, faculty investment, disciplinary value, or institutional support (Bauman, Bustillos, Bensimon, Brown, & Bartee, 2005; Milem Chang, & Antonio, 2005). The majority of such studies, however, have continued to focus on the viewpoints of individuals, or groups of individuals, rather than examining the relationships between and among various stakeholders (Myers, Sawyer, Dredger, Barnes, & Wilson, 2018; Webber et al., 2013). Possible exceptions to this are the studies that have examined the intensive mentoring relationship between students and faculty, often a characteristic of undergraduate research projects, but even these studies have tended to focus on student outcomes, delineating psychosocial as well as cognitive benefits (Hu & Ma, 2010; Wallace, Abel, & Ropers-Huilman, 2000).

One of the barriers limiting comparative, interdisciplinary, multidisciplinary, and cross-institutional studies of undergraduate research is the emerging realization that the practice can take on different attributes relative to its context. Beckman and Hensel (2009) identified no less than eight axes along which beliefs about undergraduate research can range, including differences on who does what, for whom, when, how, and why (Figure 1).

Outcome	Origination	Participants	Position	Number	Research question	Disciplinary perspective	Audience
Process	Student-initiated	All students	Curricular	Collaborative	Original to students	Multi- or inter-disciplinary	Campus/community audience
↕	↕	↕	↕	↕	↕	↕	↕
Product	Faculty-initiated	Honors students	Co-curricular	Individual	Original to the discipline	Discipline based	Professional audience

Figure 1. Continua of beliefs regarding undergraduate research (adapted from Beckman & Hensel, 2009). Figure modified from figure in Mary Beckman and Nancy Hensel, "Making Explicit the Implicit: Defining Undergraduate Research," *CUR Quarterly*, 2009, 29(4): 40. Reproduced by permission of the Council on Undergraduate Research.

Researchers at McMaster University recently posited a ninth axis, curricular integration, ranging from the scaffold (across the curriculum) to the bookend (capstone) models (Perrella, Dam, Martin, MacLachlan, & Fenton, 2020). New categories continue to be added as different stakeholders emerge. These beliefs can be highly varied, with consensus unlikely to be found even within (much less between) disciplinary departments or programs, sometimes even within the same individual. As an HIP, undergraduate research has expanded to become a large umbrella encompassing a broad range of attitudes, values, and practices that often cut across formal roles and hierarchies.

As that umbrella expands, it may be an opportune time to consider new conceptual frameworks that shift the locus of analysis from individual engagement to institutional culture, with attention to how this multiplicity of views can be directed toward shared goals and the advancement of inquiry-based teaching and learning. Leveraging teaching transformation at the institutional level is a topic receiving much attention within the STEM disciplines, practitioners of which have articulated a number of theories of change intended to foster changes within both teaching practice and the broader context of institutional culture (Beach, Henderson, & Finkelstein, 2012). A seminal meta-analysis of these theories suggested that much attention has been paid to prescriptive (e.g., curriculum, policy) and emergent (e.g., intrinsically motivated faculty) approaches to change; but comparatively little attention has been paid to effecting change that is both emergent and institutional, what one set of researchers calls "developing a shared vision" (Henderson, Beach & Finkelstein, 2011). Part of the reason for the under-representation of this approach to change, however, is that it can be challenging both to effect change on such a broad (and deep) scale and to measure its impact.

Fortunately, systems thinking has emerged as a promising tool for understanding organizational culture, particularly in the case of phenomena that work outside of formal hierarchies or institutional silos. Within higher education, the application of systems thinking has been fueled by growing interest in recreating universities as teaching and learning communities, including an emphasis on interdisciplinary collaboration, shared governance, and collective decision making (Bui & Baruch, 2010; H. Kim & Rehg, 2018). In the systems framework, rather than viewing undergraduate research as a relatively static set of activities or stakeholders, it can be seen as a dynamic and evolving set of connected and interdependent elements that interact within the boundaries of the institution (Acaroglu, 2017a). When complex organizations such as universities and colleges are viewed through

the lens of systems thinking, the object of analysis becomes the delineation of those lines of interdependence (or lack thereof), a process referred to as systems mapping (Meadows, 2008).

Systems mapping should not be confused with similar terms used in other contexts. It does not refer to multicampus university systems, for example, nor other forms of mapping, whether cartographic, social network, or concept/mind mapping. Rather, systems mapping is a strategic analytical tool that is often applied as a prelude to change, allowing researchers to frame challenges in ways that deepen understanding as well as illuminate pathways and bottlenecks which then, in turn, inform the development of potential solutions and new opportunities (Acaroglu, 2017a).

Participatory systems mapping, in which multiple stakeholders engage in systems mapping simultaneously through a process of individual and collective reflection, has been shown to foster a shared commitment to collective change in addition to the insights provided by the maps themselves (Király, Köves, Pataki, & Kiss, 2016). There is considerable promise, in other words, for the approach to serve two purposes: to simultaneously measure and develop a shared organizational culture across disparate stakeholders. This participatory systems-mapping process has recently showed considerable promise in taming other so-called "wicked" or highly complex problems in higher education (Király, Géring, Köves, Csillag, & Kováts, 2016), including student success in STEM disciplines (Chan-Hilton, 2019), long-term change in a college of engineering (Morelock, Walther, & Sochacka, 2019), the role of centers for teaching and learning (Chan-Hilton & Cruz, 2019), and developing a shared vision for the future of higher education (Géring et al., 2018). For the purposes of this study, we engaged in a participatory systems-mapping process in which 56 stakeholders came together to consider our "elephant"—the emerging culture of undergraduate research across our campus.

The Study

Context

The study took place at The Pennsylvania State University (commonly known as Penn State) a large, public university classified as doctoral with very high research activity, located in the northeastern part of the United States. Penn State also has 19 primarily undergraduate branch campuses that serve roughly 40% of the total number of undergraduate students (approximately 80,000). At this time, STEM majors on the main campus had long benefitted from sustained opportunities to assist with research as part of externally funded projects, including high-profile partnerships with the medical campus. Other units and campuses generally had less consistent engagement with externally funded projects (though it was prevalent in niche areas).

With the transition to the HIP model starting around 2012, undergraduate research at Penn State received more widespread support through the division of undergraduate education, including the provision of research and travel grants, an undergraduate research exhibition (with awards), and a competitive grant program to support undergraduates in independent summer research projects supervised by a faculty mentor. For the 2017–2018 academic year, the institution awarded 72 summer research grants and 297 grants for 352 students to travel to conferences for presentations and showcased 348 projects at the centralized research exhibition and over 250 at individual campus exhibitions. After an initial surge in activity, efforts to expand the practice beyond these levels, particularly across disciplines and campuses, appeared largely to have plateaued and it became increasingly apparent that a new approach would be required to advance the practice further. Before that could occur, there needed to be a greater understanding of all the factors enabling and inhibiting the growth and development of undergraduate research as a HIP.

Developing a shared vision of undergraduate research at Penn State has been an especially complex task, as the practice developed primarily through individual units within the organization.

Colleges, located on the largest campus of the university, and smaller individual campuses established independent practices and procedures to best support their unique faculty, students, and circumstances. University-wide programs and supports formed later in response to shared needs, leadership initiatives, and interest in centralized investment. Initiatives such as those listed above, for example, the all-university undergraduate research exhibition, were responsive to the efforts begun within the units. Consequently, colleges and campuses developed independent norms, beliefs, and practices prior to programs being generated from the central administration of the university.

Because of the autonomy granted to the colleges and campuses in the decentralized model of practice at Penn State, it is not uncommon for these units to have unique cultural identities. Identities are built around fundamental differences between units in terms of disciplinary expertise, location, community context, and resources. For example, while all tenure-track faculty are required to actively participate in a productive research agenda, those who are located at the largest campus routinely have significantly reduced teaching responsibilities and greater access to appropriate physical and material resources. Faculty who are involved with undergraduate research frequently mention the need to reward supervision and mentoring, which is not currently articulated in the university standards, and reporting standards vary widely. This research project serves as an effort to begin to discern the range of current views, as a precursor for strengthening a shared vision and identifying desired directions for change related to the practice of undergraduate research throughout the university.

The Participatory Systems-Mapping Process

In the spring semester of 2020, the senior leader who oversees undergraduate research at Penn State issued a university-wide invitation asking for volunteers (from faculty members, students, and administrative staff) to engage in "collaborative conversations" via a participatory systems-mapping session (Acaroglu, 2017b; Chan-Hilton, 2019; The Omidyar Group, 2019). The invitation was sent via email to previously established distribution lists for participants in undergraduate research activities across the university (including all campuses and colleges). Unit leaders were enjoined to share the invitation with others who might be interested. In addition, printed flyers were distributed at known gathering places for students and faculty on the main campus. Sixty-three faculty, staff, and students volunteered to take part in the first three systems-mapping sessions.[1] During each of the three sessions, the process was guided by two questions, "What impacts undergraduate research?" and "How might contributing factors be connected and interrelated?"

The process was designed to be generative, providing participants from a variety of disciplines and roles with opportunities to develop their ideas organically while providing guidance to facilitate systems thinking. During a 2-hr session, participants worked through two primary stages: developing a systems map and creating a more focused feedback loop for one identified theme, with each activity scaffolded by a combination of ideation, consensus building, and reflective activities (Table 1).[2]

Table 1. The systems-mapping process (by stage, description, modality, and artifact).

Stage	Description	Modality	Labels	Specific Artifact
1. Systems map	Node generation	Individual	Inhibitors/enablers	Sticky notes
	Clustering	Small group discussion	Themes/arrows	Systems map (visual diagram)
	Reflection	Individual and small group		Stories

[1] Two additional planned sessions were postponed because of the university's response to the COVID-19 pandemic in March.

[2] For those wishing to fully replicate this version of the participatory systems-mapping process, a detailed facilitators' guide is available upon request to the authors.

Stage	Description	Modality	Labels	Specific Artifact
	Whole group reflection	Gallery walk	Missing voices	I wonder… statements
2. Feedback loop	Node generation	Small group discussion	Structural, attitudinal, or transactional	Sticky notes
	Directionality	Small group discussion	Arrows	Feedback loop (visual diagram)
	Reflection	Individual and small group		Stories

This participatory systems-mapping process was designed specifically for these sessions, taking into account time constraints, audience, and plurality of disciplines and roles. In addition to generating a systems map, the first stage was intended to prepare participants for the more focused, deeper dive in the second activity, a feedback loop. The facilitators chose not to provide participants with a pre-established definition of undergraduate research, and they emphasized throughout the process that the intended goal was to get a better of understanding of the current culture of undergraduate research at Penn State, not to identify potential solutions or articulate next steps, tasks that would need to be addressed by future forums. The design also included attention to the composition of the small groups, which were engineered to include as broad a representation of roles (e.g., student, faculty, staff) and disciplines as possible, given the characteristics of those present at each session.

Participants

Participation in the sessions was voluntary; thus it is presumed that those willing to dedicate time to the process likely were supporters, even advocates, of undergraduate research. As a biased sample population, then, these results are likely not representative of the university as a whole. Participants noted an under-representation of students, advanced graduate students, senior administrators, and detractors or nonengagers, though at least one representative from each of these groups was present for each of the three sessions. The session demographics could, however, serve as a rough proxy for which roles or disciplines consider themselves stakeholders in undergraduate research at Penn State.

Of the 56 participating and consenting participants in the systems-mapping process, faculty, especially tenured faculty, were slightly over-represented (56%), which is consistent with emerging trends of tenured faculty taking on stronger advocacy roles in undergraduate research (Figure 2A). Given the history of undergraduate research, it is not surprising to see STEM disciplines (faculty and students) heavily represented (50%), but the transition to the HIP model is evident from the participation of a range of other disciplines, collectively constituting nearly 50% of the total (Figure 2B). All major academic colleges had at least one representative (faculty, staff, and/or student) present in the sessions, with the exception of Business and Education.

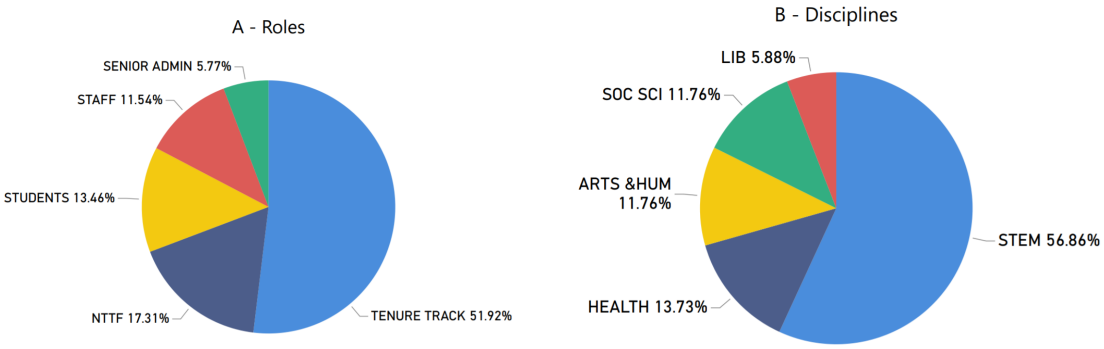

Figure 2. Participatory systems-mapping participants by (A) role and (B) by discipline. Senior Admin = Administrators; NTTF=Non-tenure track faculty; HUM = humanities; STEM – science, technology, engineering, and mathematics; LIB=Libraries; SOC SCI=Social Sciences.

Because of the distinctive institutional structure of Penn State, the session facilitators hosted one session at a campus located several hours east of the main campus. Altogether, session participants included representatives from eight different campuses, and constituents (faculty, staff, and students) from the main campus made up just over half of all participants. This latter representation would likely have decreased with the inclusion of the two postponed sessions, both of which were scheduled to be held on campuses other than the main campus.

Methods of Analysis

As Figure 1 demonstrates, the participatory systems-mapping process produced seven artifacts for each group of 3–5 participants. Those artifacts included a systems map (visual diagram), a worksheet (text with questions, stories, and structured reflections), a feedback loop (visual diagram), and a final story (text). For the purposes of analysis, the researchers transcribed the elements in each of the visual artifacts into a spreadsheet, including text entries for the stories and "I wonder" statements.

Analysis of the artifacts took place in three stages. First, the research team aggregated evidence from across all artifacts generated and individually analyzed evidence from each artifact type (e.g., systems map, story) separately. In Stage 2, the themes and outcomes identified by the individual researchers (inductively) were integrated and a consistent coding scheme developed, which was then applied to all artifacts included in the study (deductively). The final stage involved an additional round of thematic coding, in which the research team looked at changes that occurred both within and across groups, as the participants engaged more deeply from the first map (undergraduate research system) to the second visualization (the feedback loop, focused on a theme). Formal analysis was supplemented by observational data recorded by the event facilitators. The components of the systems maps (n = 14), including nodes, clusters, and connections (see Figure 3), were thematically coded, counted, and then analyzed using descriptive statistics. The components of the feedback loops (nodes, directionality, attributes) were similarly thematically coded, counted, and then analyzed using descriptive statistics (Figure 4).

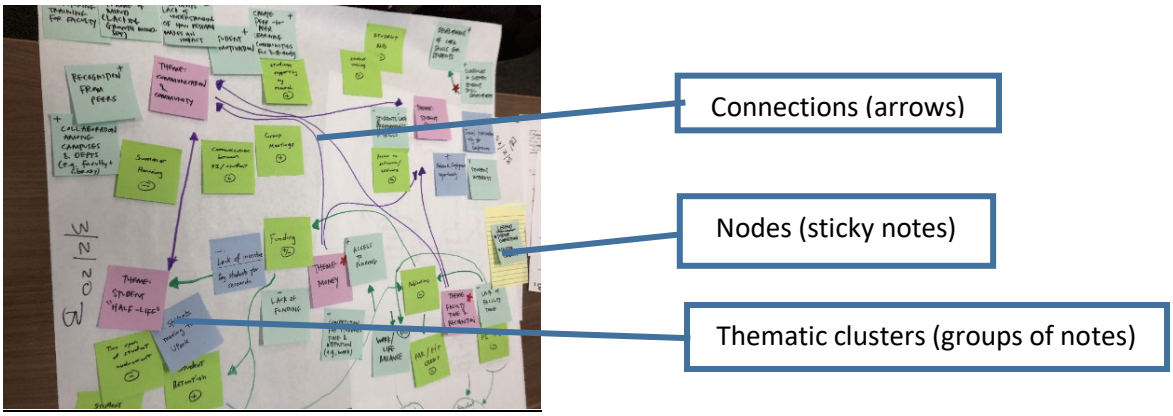

Figure 3. Example of an undergraduate research systems map.

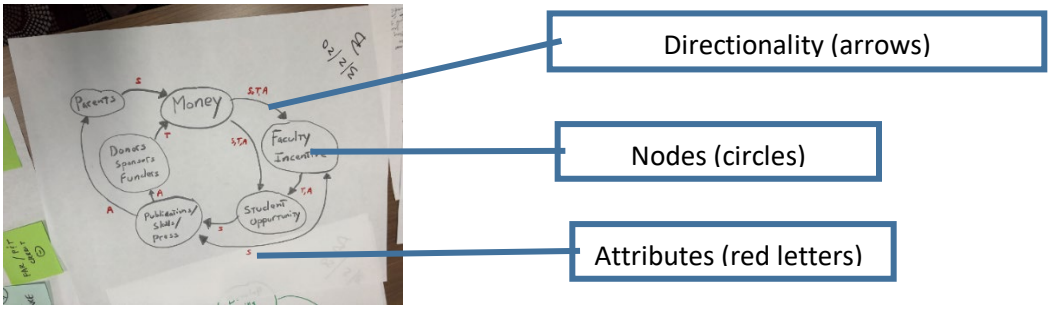

Figure 4. Example of an undergraduate research feedback loop.

The stories and questions on the worksheet were analyzed using a combination of discourse analysis and emergent coding, described in more detail below. Artifacts and themes were tracked using Excel spreadsheets.

Results

Part 1: Plurality

Our analysis of the visual artifacts that the participants generated through these systems-mapping sessions (e.g., systems maps, feedback loops) serves to illuminate the intersections and interconnectedness between programs, people, and ideas. Rather than focusing on a relatively narrow set of best practices at a single place along the continua of undergraduate research beliefs and practices, our findings affirm that the culture of undergraduate research can be viewed as a dynamic, interconnected, and pluralistic system.

Attitude clusters. The variability in definitions of research across disciplines has been identified as a significant factor in prior studies of undergraduate research as an HIP but our results suggest that additional patterns of variability regarding participation and purpose may also be present (Beckman & Hensel, 2009). These patterns resulted in attitudinal clusters, drawn by connecting factors identified in Beckman and Hensel's continua (Table 2). Note that evidence from the maps did not provide sufficient data to include the remaining two continua—individual/collaborative and disciplinary/multidisciplinary—from Beckman and Hensel's original model. The clusters are listed in order of prevalence.

Table 2. Attitude clusters regarding undergraduate research features (from nodes on systems map).

Cluster	Value	Initiator	Participants	Integration	Origins	Audience	Priorities
1	Product	Faculty	Honors students	Cocurricular	Discipline	Professional	Resources, especially funding
2	Process	Student	All students	Cocurricular	Student	Campus/community	Time, faculty and student
3	Process	Faculty	All students	Curricular	Both	Campus/community	Communication, especially outside the discipline
4	Both	Both	All students	Cocurricular	Discipline	Both	Definitions and boundaries

A fifth cluster, embracing perspectives absent from the systems-mapping sessions, could perhaps be posited and added to this emerging typology. Further analysis suggests that each attitude cluster can be correlated with the perception of inhibitors and enablers, which, in turn, reveal what the participants perceive to be institutional priorities in supporting undergraduate research (column 8, Table 2). It should be noted that these clusters were generated primarily from the experiences of the individual participants prior to the systems-mapping sessions and significantly shaped the dynamics of the subsequent activities.

Undergraduate research as an institutional commodity. After completing their feedback loops, participants were asked to consider and label factors that are primarily structural, attitudinal, or transactional in nature (as time permitted; Table 3). Our analysis of these factors indicates a prominence of attitudinal factors (e.g., beliefs, values, and norms) over structural (resource environment) or transactional (process and policy) factors.

Table 3. Feedback loops: Structural, attitudinal, and transactional factors.

Factor type	Administration	Communication	Culture	Faculty	Resources	Students	Total no. of factors (without and with double coded items)
Structural	1	2	6	8	18	7	37/4242
Attitudinal	1	1	23	7	5	14	40/5151
Transactional	—	5	10	12	11	9	33/4747
Total	2	8	39	27	34	30	110/140

Note. Structural factors relate to the physical, institutional, or social environment; attitudinal factors are beliefs, values, or norms that affect how groups behave; and transactional factors are processes and interactions (The Omidyar Group, 2019). These definitions were provided to participants. Totals are inclusive of factors that were double-coded.

This shift was particularly evident in how both faculty and students perceived the value of research as an institutional commodity, a new continuum we propose should be added to the growing

list. For those stakeholders who fell in the first attitudinal cluster (see Table 2), research is faculty initiated and students are engaged as assistants (e.g., *students supporting my research*)[3], often in laboratory-based work that requires skilled labor. For those in this group, student motivation to participate was not a central issue; rather the impetus was on students to take the initiative and get involved (e.g., *lack of initiative by student to contact professor*). In this view, research is treated as a scarce commodity, both rivalrous, for example, access to research by one person prevents access by another (*we get lots of inquiries but we can only take a few)* and excludable, for example, it is desirable to limit participation (*it takes longer to train an undergraduate than to do it myself).* Questions of expanding undergraduate research then focus on changes to both supply and demand (e.g., *professors lack the need to have an undergraduate researcher, especially freshmen and sophomores*).

For those who viewed undergraduate research primarily as an extension of teaching (Cluster 2 in Table 2), on the other hand, research functions more like a club good, meaning that access to research by one person does not preclude access by another; but participation is limited by the capacity of the institution and the bandwidth of faculty to support such intensive teaching practices at scale. This perspective is frequently reflected in the articulation of trade-offs such as this one: *[How do we determine] which students to invest time into (strong students take less work but weak students benefit most)?*

For stakeholders in this cluster, the goal is to expand membership in the club (e.g., *the goal [is] to include more people*), so to speak, which leads, in turn, to addressing questions of equity and access, for example, *how might we as faculty increase exposure and access to research*? *I wonder how to better "sell" research to students to overcome barriers*? Expanding membership requires a shift toward a more nuanced and wide-ranging understanding of what factors influence student participation. These factors range from attitudes (*how [do students'] interests and career goals influence their desire to engage?*), beliefs (*who "does" research*), self-concept (*student frame of mind/growth mindset*), belonging (*peer learning communities, organizations, events*), and motivation (*curiosity fulfilled*) to resources (*I wonder how programs like the grant affect attitudes from students*). The prevailing attitude from this cluster is, as one respondent put it quite eloquently, *if you don't already fit the model, we have to figure out how to include you.*

Part 2: Shared Culture

In the second section of our findings, the focus shifts from the nodes and labels generated in both stages of the mapping process to the connections and the stories. Because of the nature of our subject matter, the methods applied for this section are more reflective of norms associated with the humanities and could be characterized as a quasiethnography of the culture of undergraduate research at a large and highly complex public university.

Shared agency. The initial analysis of the nodes in the systems maps depicted faculty participation in undergraduate research as weighed primarily through opportunity costs (e.g., other activities, such as teaching and research that would have to be given up to participate in mentoring undergraduate students), and student participation by a lack of knowledge, whether of the value of undergraduate research or of opportunities in which to engage. What emerged through the reflective processes was a growing sense of shared calculus, in which the perspectives of both parties (e.g., faculty and students) were taken into consideration, for example, *What can we do to prepare and motivate students to participate without sinking disproportionate time/resources [into the process]?; there is a gap between attitudes towards undergraduate research and the faculty which affects the knowledge the students have of the opportunities*; *engaged faculty who understand undergraduate research attract interested students.*

That calculus also reflected a shift in the locus of agency. Initial inputs tended to focus on levers external to the individuals, most often the university, the main campus, or its representatives

[3] Quotations from the systems mapping artifacts appear in italicized text throughout the remainder of the document.

(e.g., *the key is administrative buy-in; it all comes down to leadership; how can [the main campus] support us?*) or at times an unnamed actor, hidden by the passive voice (e.g., *faculty efforts need to be recognized and their time needs to be rewarded*). By the end of the session, the rhetoric shifted toward both active voice and first person plural (e.g,. we) and reflected a growing awareness of collective agency (e.g., *How do we change perceptions, expectations, and culture at [Penn State] (without money)?*) and responsibility (e.g., *if only one factor could be changed, which would have the biggest ripple effect?*"; *will we settle for a series of small victories for some or are we interested in changing the landscape for all?).*

Developing systems thinkers. One of the last actions the participants took was to turn their feedback loops into a story, or narrative account, that captures the inherent dynamism of the visual process. This was not, however, their first story of the day. Earlier, they had worked together to write the story of their shared systems maps. Participation in the second story was not as consistent, as the exercise likely fell victim to being at the end of a long session, but a comparison of the insights gained from the first to the second story reveals a rather profound shift toward collective systems thinking.

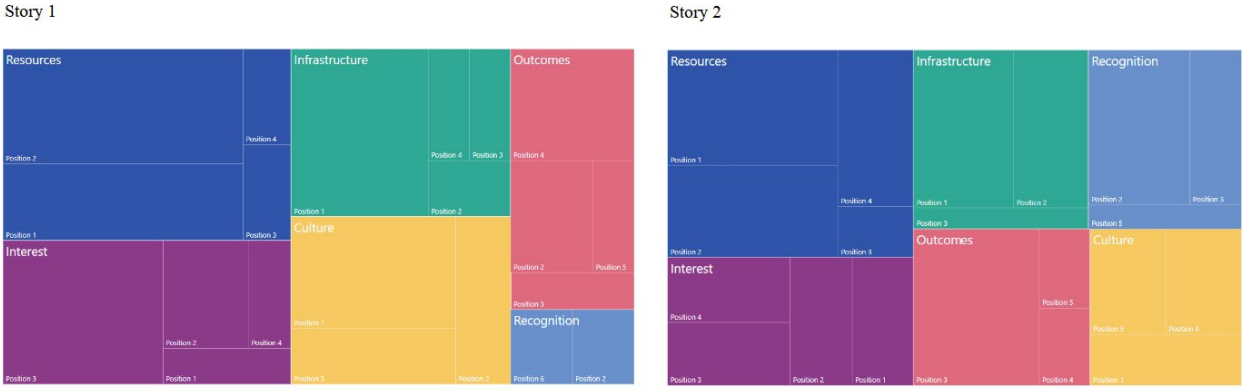

Figure 5. Systems-mapping exercise: Story themes (with positionality).Note: These figures show the categories and the order in which the groups organized the categories (position) within stories one and two. The size of each category's box represents the proportion of times the category was presented in the aggregate data for each of the two stories.

After coding the first and second stories, six categorical descriptors emerged: resources, infrastructure, outcomes, interest, culture, and recognition (see Table 4 for coding details). These six categories were consistently represented across groups and stories. However, the first and second stories differed in composition, number of categories represented, and directionality. In the first story (based on the overall systems map), the groups constructed stories with fewer categories; half the groups had stories with only two to three categories (see Figures 5, 6, and 7). While all coded categories were present in the aggregate of the first stories, the number of categories varied within groups, between two and six. Further, the links between categories was unidirectional (e.g., Category 1 affects Category 2, Category 2 affects Category 3; Figures 6 and 7). Across all the groups, there were only two instances of arrows originating from a later category and looping back to a previous category.

Table 4. Examples of coding scheme for Stories 1 and 2.

Participant descriptors	Coded category
University website, recruitment efforts, programming, undergraduate research office, advertising	Infrastructure
Funding, time, space	Resources

Participant descriptors	Coded category
Inclusion in promotion and tenure, increase in prestige, increase in visibility	Recognition
Increased productivity, published papers, presentations, job training, job opportunities, increase professionalism	Outcomes
Faculty and student interest	Interest
Value of undergraduate research at the university, administration support and buy in	Culture

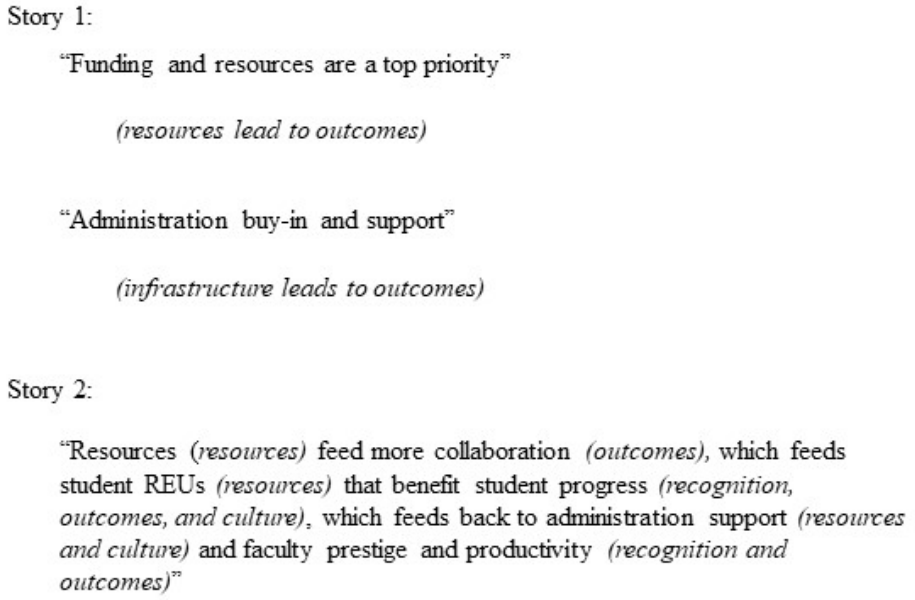

Figure 6. Example of one group's first and second stories; categories in parentheses and italics exemplify how the components of the stories were coded in the study. The first story exemplifies the inclusion of three categories: resources, infrastructure, and outcomes. However, there are two siloed responses, with only one category unidirectionally linked to another. In Story 2, the group included four categories: resources, outcomes, recognition, and culture. In this story, the links among categories were more intertwined, categories were linked back to other categories, and there is not a clear linearity to the story, demonstrating a systems-thinking approach to Story 2. REUs = Research experiences for undergraduates.

By the second story (based on the feedback loop of one theme in the overall systems map), the perspectives of the groups seemed to coalesce into a shared vision of the system. The most noticeable shift occurred as groups moved from siloed, unidirectional association between categories to tighter, interconnected relationships between the categories, demonstrating a transition from a collection of disparate connections between categories to an interconnected, systems view of the factors that affect undergraduate research (e.g., Figures 6 and 7). Further, while all six categories were again represented across stories, the composition was far more similar among groups. All the groups tended to have three or more categories and all but one group presented resources and infrastructure as either their first and second categories (not all groups used the same order). Many groups then presented recognition, followed by outcomes and culture. Finally, there were many more instances of arrows originating from a later category and linking back to other categories (Figure 7B),

demonstrating the interdependence of the variables, a key component of systems thinking (D. H. Kim, 1999). Remarkably, it would appear that what emerged from these three independent sessions was a shared vision of a pluralistic, integrated system of undergraduate research at Penn State.

The results from the first story confirm the attitudinal clusters identified previously in this study. The groups would typically form unidirectional links between two categories (e.g., resources affect outcomes; Figure 7A). While the second stories integrated the same number of categories, these now were joined by more complex linkages between them. For instance, resources are instrumental in setting the stage for successful participation in undergraduate research. These resources support students and mentors during the research experience, increasing the probability of publications and presentations. These outcomes lead to recognition and prestige at the local, national, and international level, which sets the stage for acquiring more resources in the form of external funding (recognition feeding back on resources). Publications, presentations, and recognition gained from participating in undergraduate research contribute to a culture of the importance of undergraduate research at Penn State. As the culture evolves and grows, the likelihood of more resources and infrastructure devoted to undergraduate research grows as well, beginning the cycle anew.

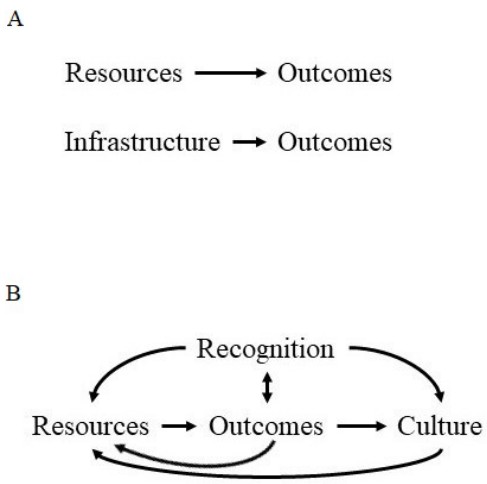

Figure 7. The institutional cycle of the undergraduate research system as depicted in the first (A) and second (B) story.

Telling our story. This glimmer of a shared vision is affirmed by the increasingly sophisticated representational strategies used by the participants. A system is a large, complex, intangible, and dynamic thing that can be challenging to convey, whether in words or pictures, so many of the participants used metaphors. In several cases (n = 4), there was reference to awareness of a shifting systemic paradigm (e.g., *traditional implementation* (as an inhibitor) or the need to subvert a perceived dominant paradigm (e.g., *break out of STEM as the only legitimate undergraduate research*; *I wonder how undergraduate research can be inverted*).

Others (n = 3) evoked or depicted a spoke or wheel model (e.g., *everything radiates from and goes back into the values*), with one particularly memorable extended metaphor: *There are different moving parts in undergraduate research—like a wagon with wheels; all the parts need to be properly "oiled" maintained with a continued pipeline of supplies. And the overall system should be driven by the motivation/impact/purpose fuel that in the end makes all the involved parties happy/content.* Other less common visual and written metaphors included webs, spirals, ecosystems, and landscapes. Whatever the metaphor, it was evident that undergraduate research at Penn State was no longer perceived as just a collection of stakeholders, a

list of participants, a description of programs, a discipline-based practice, or an administrative problem; rather it was all of these, part of a flawed, yet vibrant, community in which we all participate.

Discussion and Implications

One of the primary goals of this systems-mapping process was to get a clearer sense of the current ecosystem of undergraduate research at Penn State. This leads to the question, if we were to take each of the systems maps that the participants created and overlay them, would we find our elephant? Taken as a whole, the culture of undergraduate research took shape in several ways through the mapping process. First, the process provided evidentiary support for previous assumptions held by the stakeholders closest to the process; second, the maps illuminated key areas of intersections (or lack thereof) that were previously unknown; and finally, the stories enriched the complexity of the tasks that lie ahead.

In many ways, it could be argued that our findings have made it more, rather than less, difficult to foster a shared vision of undergraduate research at Penn State. By viewing the practice through an institutional rather than an individual or disciplinary lens, we found that our vision became further refracted, like a prism, increasing rather than simplifying the plurality of policy, practice, and people involved. After all, our findings suggest at least two new continua to add to Beckman and Hensel's (2009) initial list—institutional priority and commodity value---with the open possibility for more. That said, this plurality should not necessarily be viewed as a problem to be solved but rather as a means for ensuring the development of a shared vision that is fully inclusive.

These findings also reflect the intentional blending of approaches used in the presentation of this research. We hope that those looking for the signposts of a conventional social science approach may find meaning in the mixed methods analysis of the visual artifacts; and those from the arts and humanities may appreciate the emphasis on storytelling (whether as evidence or in the presentation). One of our implicit findings is the need for raised levels of awareness and tolerance for multiple pathways for constructing legitimate research, including that on undergraduate research as an HIP. Those pathways include various ideas of the purpose of research. In the case of this study, the outcome is not primarily direct applications or solutions but rather greater insight into the complex, ambiguous, indeed, arguably wicked challenge of transforming culture.

We may be getting ahead of ourselves and of the evidence from our study. As was emphasized during the sessions, the initial systems-mapping process was not intended to identify or provide solutions, though participants found themselves often tempted to do so. Rather, the purpose was to capture a more robust understanding of how the current system works across multiple modalities, disciplines, and campuses, and for this to serve as a baseline for future action. Our goal was to take the first steps toward developing that shared vision, knowing that this would be just one small part of a larger process of transformation, one that will need to embrace a robust and multifaceted theory of change as it moves forward.

From the perspective of the senior administrator who sponsored this process, there were several key takeaways that emerged:

- A need to intentionally focus on cultivating *a shared vision of undergraduate research*, including the need to define the practice in such a way to include the plurality of voices, embrace the complexity of processes, and reflect the distinctive identity of the institution. And that culture may include other forms of symbolic meaning making, including the creation of a hub at the spokes of the wheel, for example, a centralized undergraduate research office.

- A strong need to foster *community (or communities) of undergraduate research*, whether within stakeholder groups (e.g., student organizations), across groups (e.g., networking events), or with other campuses, including those outside of the institution. And these communities need to embrace a wide range of stakeholders, allowing many more members to "join the club," which necessitates addressing existing inequities.
- A need to recognize how the layers of the institution (university, campus, college, department) are intricately woven together. To change a culture will require *active participation at each level* with attention to the ways that decisions impact all aspects of the university. The process has empowered senior leadership to address issues more effectively, having identified the general desire for cohesive community and the interconnections between the layers of institutional governance.
- A need for this culture, these communities, and this shared vision to have a more *visible presence*, from celebrating successes to, as one participant put it, bringing both our deliverables and our stories to the table. And part of that will stem from sharing the story of these systems-mapping sessions.

There may be questions about whether this process served as a sufficiently robust basis for such actions. As noted above, participants were self-selected, leading to a positive bias as well as the absence of voices of opposition or indifference. And while efforts were made to be as inclusive as possible, the fact remains that Penn State is an extremely large, heterogeneous system, and the data presented in the current study do not have the resolution to finely discern if different patterns emerge from, for instance, different campuses, disciplines, or stakeholder positions (e.g., administration, faculty, students). More work needs to be done to refine our understanding, enrich our database of perspectives, and seek out those who may not be intrinsically motivated to add their voice. As one participant asked, *I wonder how to include everyone's voice that has something to share?*

It remains an open question, too, whether these goals and action items could have been achieved using a different process, perhaps one that is more efficient (each session took 2 hr) or more expansive (the process included 56 stakeholders, the majority of whom were faculty from the main campus). A survey, for example, would reach more people and require less of a time commitment to complete. When we analyzed the initial, individual responses from our participants in the mapping process, however, we did not learn anything especially new, which suggests that we might not learn a great deal from a survey either. Other scholars have noted the challenges and opportunities faced by faculty, staff, and students in expanding undergraduate research elsewhere, and many of those same challenges and opportunities apply to current conditions at Penn State. A survey or other conventional needs assessment tool, such as a SWOT (strengths, weaknesses, opportunities, and threats) analysis, would likely have brought us to a similar place to an analysis of the nodes that our participants indicated on their systems maps.

The value of the systems mapping did not come from identifying challenges and opportunities—that is the point from which the process started. Rather, the value came in illuminating the interconnections or interconnectedness of these challenges and opportunities through multiple disciplinary lenses. You could say that the value came not from the nouns but from the verbs, i.e., not the nodes themselves but the arrows that connected the nodes or the stages in the feedback loops. By enhancing our understanding of how each aspect effects the other, we can become more effective levers of change, even in an organizational environment as complex as Penn State.

It is well known that an effective strategy for breaking down silos is to get stakeholders in the same room and talking to each other; so we did expect similarly positive benefits to come from having faculty, staff, and students from different disciplines and campuses discuss undergraduate research,

regardless of the method used to facilitate that conversation. The structure of the systems-mapping process, too, was intended to develop the ability of these stakeholders to visualize undergraduate research at Penn State as a system. What was less expected was the degree to which a shared vision of that system emerged, even from groups acting independently of one another, and how the ability of our stakeholders to tell the story of the systems of undergraduate research at Penn State has the potential to serve as a basis for more profound cultural change in the future. It could be said that the systems-mapping process acted on two levels, the first as the basis of strategic planning (as well as a research project), and the second as the basis of changing how we perceive (and think about) the values, beliefs, and behaviors of all of the stakeholders who make up our undergraduate research—even our university—community. In other words, not only did we find our elephant, but we may also have found a path through the jungle.

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