DBER as MidScale Infrastructure in Education

By Charles Henderson and Noah Finkelstein

In 2016, the National Science Foundation (NSF) announced its mid-scale infrastructure program to improve experimental research capabilities that "may include any combination of equipment, instrumentation, cyberinfrastructure, broadly used large scale datasets and the personnel needed to successfully commission the project." (NSF, n.d.) To date, no such project has been funded to support Discipline Based Education Research (DBER) work. In this blog post we argue that a mid-scale project could significantly amplify the impact of DBER and advance our collective efforts to broaden participation. We provide some starting points for discussions within the DBER community about how such a project might be framed. We welcome your thoughts or interest in contributing further, as we are far from set on what form of infrastructure is needed and possible for advancing equitable and inclusive STEM education.

In considering a mid-scale infrastructure project, there are at least two main things that need to be decided. What topic(s) should be the focus? And what infrastructure is needed to support this work? If education is the foundational infrastructure (R&D) for individuals' well-being and a key form of making an equitable and inclusive society (Finkelstein, 2022) we might ask ourselves what are the foundational forms of research that need to take place within and across the disciplines for realizing this promise? And how might we conduct this work?

In early efforts to build out the STEM DBER Alliance (e.g., Henderson et al., 2017), community members affiliated with AAAS, APLU/ NSEC, ASCN, AAU* and the span of DBER communities gathered over a series of discussions that concluded with a working meeting at HHMI in May 2017. One of the outcomes of this final meeting was to identify a set of challenges that will be transformative for society and the STEM DBER Alliance was well positioned to address. Notably there are areas of work within a given DBER community (i.e., the physics education community may be attending to different issues than the math or biology education communities); however, these challenges are designed to focus on the areas of greatest need and impact that span the breadth of education research communities in the STEM fields. What challenges might best be addressed through coordination and/or collaboration across the STEM DBER Alliance?

The top 6 Grand Challenges from these early meetings are summarized as: (in alphabetical order):

- Active Learning and How People Learn. All disciplines talk about active learning, yet no clear definition exists, and core principles are continually reinvented. How can we stop the reinvention cycle, advance research, and foster the increased adoption of active learning pedagogies? Need to 1) assess more than content, 2) determine generalizability of findings (e.g., attitudes and beliefs) and 3) assess cross-discipline skills (e.g., critical thinking, collaboration).
- Diversity, Equity, and Inclusion. Need to harness theory (e.g., implicit bias, stereotype threat, attribution theory, optimal distinctiveness theory), work at all types of institutions, and avoid deficit framings.
- Institutional Change. Most change is short lived and hard to sustain. The economic situation of higher education is changing rapidly. Need to determine what can be generalized and what is determined locally.
- Professional Development/Training. Need to incorporate research and perspectives on professional development from all DBER fields. Research on professional development must work in concert with implementation.
- Scientific and Mathematical Practices. Although there is some degree of consensus regarding the practices, integration, and articulation of practices in undergraduate curricula, such practices remain limited, even in practice-focused learning experiences such as Undergraduate Research Experiences (UREs).

In the past five years our fields and the educational landscape itself have all evolved, in some ways dramatically. For example, workforce development is far more prevalent as a goal (Finkelstein, 2022) that has implications for each of these challenges, possibly constituting its own challenge. Our emphasis on and thinking about issues of diversity, equity, inclusion, access, and justice have become far more robust, and stand not only as an area of focus, but more more strongly permeate each of these other areas of inquiry. So, given evolution in our worlds, which challenges would you add? emphasize? demote?

If the above are, indeed, grand research challenges across the DBER communities, we then turn to how these challenges might be addressed

Any midscale infrastructure initiative should consider the desired models of interdisciplinary DBER research that the infrastructure can support. Through community discussions, the STEM DBER Alliance coalesced around five basic types of interactions (A-E in Figure 1) that benefit individual DBER fields and advance the collective, cross-disciplinary work that needs to occur for the DBER movement to reach its full potential to improve STEM learning - including the Grand Challenges listed above and to-be-determined. A thriving DBER community requires work in all five types of interactions, and infrastructure is necessary to support these interactions. While all five types of interactions are important, we argue that work in Research Community Development (Column E) is particularly critical to advancing DBER as a field and is particularly in need of new infrastructure to support it. Developing the community's capacity to engage in Research Community Develop work must be built deliberately over time. Work in the other four types of interactions (Columns A-D) serves as scaffolds to develop the structures, evidence base, and relationships necessary to conduct work in Research Community Development. Thus, a midscale infrastructure initiative should promote these activities. Of the five basic interactions shown in Figure 1, the activities in columns A-C exist primarily at the interface between individual DBER fields. These are already occurring to some extent (e.g., the Introductory Physics for Life Sciences initiative, the Statistical Thinking in Undergraduate Biology network), and can be strengthened by a midscale infrastructure project. The work in Column D is occurring in small ways now but is critical and needs to be strengthened. Work on Column E is only just beginning.

Figure 1: Five interaction types between individual fields expected in the STEM DBER Alliance. (adapted from Henderson et al., 2017)

Facilitated by DBER-All ⟷ Situated in DBER-ALL

A: Develop Understanding of Other Contexts	B: Transfer of Research Ideas/Methods	C: Collaborative Research	D: Cross-Cutting Research	E: Research Community Development
-Discipline 2 requires understanding of Discipline 3 to improve work in Discipline 2. -**Example**: How to develop a physics course for biology majors	-Discipline 1 learns ideas and approaches from Discipline 2 to improve work within Discipline 1. -**Example**: How to study problem solving	-Disciplines 3 and 4 collaborate on cross-disciplinary research that improves work in both Disciplines. -**Example**: How the teaching of "energy" can be coordinated across multiple DBER disciplines	-Disciplines 4, 5, and 6 collaborate on research that spans and improves all STEM disciplines. Disciplines 1, 2, and 3 also benefit from this. -**Example**: Improving equity and inclusion	-Multiple Disciplines interact to set norms (implicit or explicit) for DBER research. DBER (and all Disciplines) benefit. -**Example**: How student learning gets reported

An important argument for the need for new infrastructure to support the DBER community is that the problems identified and solutions proposed are not new. A decade ago, in 2012, the National Academies DBER report (NRC, 2012, p. 194-202) identified similar problems and called for the type of cross-DBER work that we are proposing in Columns D and E. These included: interdisciplinary studies that examine cross-cutting concepts and cognitive processes; collaborations among the fields of DBER to result in shared methodology and shared insights into achieving instructional change and building students' understanding of science and engineering; and additional research on the translational role of DBER.

Yet, progress in these directions has been slow. So, what is the solution? **What if we conceive of infrastructure not as helicopters and large data sets, but rather as structures to connect researchers and research initiatives?** Perhaps there is cyberinfrastructure that can support DBER community development through improved interactions between researchers that can increase knowledge production. The Quantitative Undergraduate Biology Education & Synthesis (QUBES) project has provided one vision for how to do this in one DBER area by a single online gateway where people interested in QUBES topics can engage in many types of professional activities, from professional development to collaboration. An additional or alternative approach has been seeded by the Accelerating Systemic Change Network (ASCN). ASCN is an open online network designed to bring together people who are researching systemic change with people who are making systemic change happen. Infrastructure required to support such interactions includes electronic resources (e.g., online collaboration tools, private and public workspaces, dissemination mechanisms) as well as personnel resources (e.g., to support successful online interactions, to provide guidance to working groups, to ensure consistency and quality). Perhaps models incorporating some of these elements could be scaled up to the larger DBER community.

These are but two of the many effective approaches that could be built on to provide much needed infrastructure. There are many other networks and efforts, beyond these two (e.g., INCLUDES Alliances, APLU, AAU, SEMINAL, NSEC, NASEM, AACU, AAAS*, etc. - see Brenner et al. (2022) for more details). Effective infrastructure is needed to align and coordinate these existing efforts. To our knowledge there is not even a comprehensive public accounting of all those working in the STEM education space.

What’s your take? Are we ready for national infrastructure? Are these the right challenges for us to consider? Do we need or want a centralized or distributed infrastructure? What is our balance between material and human infrastructure? Who is interested in bringing this vision into practice?

References and Notes:

Brenner, Kerry, Schweingruber, Heidi, Redd, Kacy, Gobstein, Howard, and King, Tara (2022). Cultivating Data-Informed Leadership for Systemic Change: Insights from the Coalition for the Reform of Undergraduate STEM Education (CRUSE). Workshop presented at the 2022 IUSE PI Meeting, Washington, DC, June 2, 2022. Presentation slidest: https://www.aau.edu/sites/default/files/AAU-Files/STEM-Education-Initiative/CRUSE-IUSE-2022.pdf and Summary of Initiatives: https://goo.gl/rSuFGN

Henderson, Charles, Mark Connolly, Erin L. Dolan, Noah Finkelstein, Scott Franklin, Shirley Malcom, Chris Rasmussen, Kacy Redd, and Kristen St. John. (2017). "Towards the STEM DBER alliance: Why we need a discipline-based, STEM-education research community." Journal of Engineering Education 106, no. 3: 349-355.https://onlinelibrary.wiley.com/doi/full/10.1002/jee.20168

National Science Foundation (n.d.). “Mid-scale Research Infrastructure-1 (Mid-scale RI-1)”. Retrieved 11-21-22 from https://beta.nsf.gov/funding/opportunities/mid-scale-research-infrastructure-1-mid-scale-ri-1

National Research Council, (2012). Discipline-based education research: Understanding and improving learning in undergraduate science and engineering. Washington, DC: National Academies Press.

Finkelstein, Noah. (2022). DBER and Broadening Participation: Who and What is Education For? https://members.aaas.org/ofbp/discussion/dber-and-broadening-participation-who-and-what-is-education-for#bmdfcbdc2e-bf3e-4bfb-88ed-892ccbee1c91

*AAAS - American Association for the Advancement of Science,
AAC&U- American Association of Colleges and Universities
AAU- Association of American Universities
APLU - Association of Public and Land-grant Universities
HHMI- Howard Hughes Medical Institute
NASEM- National Academies of Sciences Engineering and Medicine
NSEC- Network of STEM Education Centers
SEMINAL - Student Engagement in Mathematics through an Institutional Network for Active Learning
SERC- Science Education Resource Center.