

Submission in Response to NSF CI 2030 Request for Information

DATE AND TIME: 2017-04-05 13:36:26

PAGE 1

REFERENCE NO: 244

This contribution was submitted to the National Science Foundation as part of the NSF CI 2030 planning activity through an NSF Request for Information, https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf17031. Consideration of this contribution in NSF's planning process and any NSF-provided public accessibility of this document does not constitute approval of the content by NSF or the US Government. The opinions and views expressed herein are those of the author(s) and do not necessarily reflect those of the NSF or the US Government. The content of this submission is protected by the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (<https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode>).

Author Names & Affiliations

- Neil Heffernan - Worcester Polytechnic Institute
- Korinn Ostrow - Worcester Polytechnic Institute

Contact Email Address (for NSF use only)

(Hidden)

Research Domain, discipline, and sub-discipline

Education, Education Research, Learning Sciences, Science of Learning, Educational Data Mining, Learning Analytics

Title of Submission

Moving the Goalposts: Educational Research At Scale

Abstract (maximum ~200 words).

The gold standard in determining causality, the randomized controlled experiment, has been difficult and costly to conduct in real-world classrooms. Teacher- or school-level randomization is often complicated to achieve and maintain, and conventional "intervention" research may be perceived by participants as disruptive. However, online learning platforms have the potential to strengthen and scale the processes involved in educational research. These systems can automate randomization at the student-level, delivering different content to students within the same classroom (i.e., different types of feedback) while providing support for existing school policies and practices, thereby allowing intervention research to be conducted at scale without intrusion (i.e., through homework assignments). The ASSISTments TestBed, a shared tool for researchers conducting randomized controlled experiments within authentic learning environments, was recently realized through an NSF SI2 grant. With this letter, we call on colleagues in the field to similarly support and supplement educational technologies with the capacity for sound, collaborative science. Moving the goalposts for educational research will result in a broad range of benefits for students, researchers, platforms, and educational practice and policy. Much of what we present is condensed from our recent publication in the Teachers College Record (Vol. 119, Num. 3, p. 1-36), accessible at tiny.cc/TomorrowsEdTechToday.

Question 1 Research Challenge(s) (maximum ~1200 words): Describe current or emerging science or engineering research challenge(s), providing context in terms of recent research activities and standing questions in the field.

Large-scale randomized controlled experimentation has traditionally been difficult to achieve within educational contexts. Experiments conducted in authentic learning environments tend to carry high stakes, with extensive costs and lengthy commitments for "all or nothing" results amidst myriad potential obstacles. While a handful of traditional classroom experiments have led to significant implications for educational practice and policy, these explorations often include thousands of students and span multiple years but still fall short of

Submission in Response to NSF CI 2030 Request for Information

DATE AND TIME: 2017-04-05 13:36:26

PAGE 2

REFERENCE NO: 244

identifying learning interventions that reliably enhance student achievement. Although researchers spanning a variety of domains have grown accustomed to the complex nature of studying effective classroom practices, we argue that moving the goalposts for educational research is growing plausible in the context of modern technology.

Educational technologies have already shown great promise for extending the accessibility of educational materials and improving learning outcomes across diverse populations. Popular learning platforms harbor an untapped potential to provide researchers with access to extensive and diverse subject pools of students interacting with educational materials in authentic ways. These systems log extensive data on student performance that can be used to identify and leverage best practices in education and guide systemic policy change. Entire fields of research are growing alongside educational technologies in hopes of better understanding how these tools and their data can be used to improve education (e.g., Learning Analytics, Educational Data Mining). However, despite this significant growth, few currently available learning platforms allow real-time hypothesis testing. Examining the causal effects of specific learning interventions through “Big Experimentation” would allow researchers to begin answering the three driving questions behind personalized education: “What works best? For whom? When?” By determining the interventions that work best for particular students and the optimal time to deliver those interventions, controlled experimentation conducted within educational technologies could revolutionize the future of education.

Through a mix of methods spanning the fields of education, psychology, human computer interaction, and data science, we have started to move the goalposts for educational research by leveraging ASSISTments, an online learning platform that is provided as a free service of Worcester Polytechnic Institute. Teachers already use ASSISTments to assign classwork and homework to over 50,000 students around the world. Over 10 million problems were solved in the 2013-2014 school year, making the platform a valuable tool for learner analytics, especially when considering its capabilities for embedded experimental research. These capabilities were recently scaled through the creation of the ASSISTments TestBed (www.ASSISTmentsTestBed.org), a project that parallels and leverages ASSISTments to enhance educational research by making it easy for researchers to design and implement low cost, high power, noninvasive randomized controlled experiments that feature student level randomization and access ASSISTments' pre-existing content and user population. The ASSISTments TestBed is a unique collaborative funded by an NSF SI2 grant (SI2-SSE&SSI: 1440753) that brings researchers together with students and teachers to study effective learning interventions while iteratively improving ASSISTments content and the user experience. The TestBed is currently hosting over 130 randomized controlled experiments. In parallel, data is being collected to assess and improve how researchers and participants external to the ASSISTments team access and leverage the TestBed.

Recent revelations of a failure to reproduce the findings presented in most scientific papers (<http://www.nature.com/news/over-half-of-psychology-studies-fail-reproducibility-test-1.18248>) has led to a crisis of faith that is quickly spreading across domains. These observations have led to a movement toward open science, with researchers subscribing to the idea that all studies should be pre-registered (<https://osf.io/scayl/>) and that results should be transparent, anonymized, and freely accessible (see the Open Data badges <https://osf.io/tvyxz/wiki/home/>). Educational research is following suit and we agree that researchers should not be able to hide their errors behind a cloak of privacy concerns. Alongside this movement toward open science, school districts are battling companies to make sure marketing profiles are not built using student data for popular learning applications. These battles consider student privacy as the primary goal while turning a blind eye to the progress that could be made by legitimate scientific study. While open science and student privacy both carry extreme value, they clearly conflict. Grantees in education working with K-12 schools will face this dichotomy moving forward in coming years. High-level leadership will need to recognize this challenge and work to protect both open science and student privacy through powerful calls to the community.

With this letter, we call on colleagues in the field to infuse educational technologies and popular learning platforms with the cyberinfrastructure required for sound, collaborative research at scale. Those responsible for designing learning systems often focus on the user experience but fail to consider how randomized controlled experimentation could inform best practices within their systems while simultaneously providing a broader impact on the field. Infusing popular learning platforms with the capacity to support collaborative research environments has the potential to lower the stakes of educational research by drastically reducing costs, promoting validated universal measures of achievement, and assisting researchers through the process of designing, implementing, and analyzing experiments conducted at scale within real-world classrooms. Moving the goalposts for in this manner will result in a broad range of benefits for students, researchers, platforms, and educational practice and policy.

Question 2 Cyberinfrastructure Needed to Address the Research Challenge(s) (maximum ~1200 words): Describe any limitations or absence of existing cyberinfrastructure, and/or specific technical advancements in cyberinfrastructure (e.g. advanced computing, data infrastructure, software infrastructure, applications, networking, cybersecurity), that must be addressed to accomplish the identified

Submission in Response to NSF CI 2030 Request for Information

DATE AND TIME: 2017-04-05 13:36:26

PAGE 3

REFERENCE NO: 244

research challenge(s).

While most learning platforms evidence in-house research, ASSISTments is alone in its promotion as a tool for open science. The ASSISTments TestBed is unique in allowing researchers to tap into a learning platform to design and conduct minimally invasive RCEs within easily accessible and highly used educational content. Further, researchers can access various compilations of data through the TestBed's data analysis and reporting tool, the Assessment of Learning Infrastructure. These reports detail student performance across granularities with the goal of streamlining the analysis of learning interventions. Other popular learning platforms do not share the cyberinfrastructure required to tackle the challenge of research at scale and they do not promote collaborative research environments.

Randomized controlled experimentation within most modern technology tends to begin and end with marketing, most commonly through A/B testing meant to optimize user experience or prolong user interaction. In non-educational realms, these practices are quite common. For instance, Google experiments with advertisement location to maximize ad traffic without diminishing the user experience. Similarly, gaming application creators like Zynga conduct A/B testing to optimize their games in a way that will retain users while promoting ad space.

Commercialized EdTech products also lack open and easily accessible avenues for empirical research. For instance, the popular Khan Academy provides resources and support for select researchers to work through a process requiring substantial time and effort to understand the dynamics of the system. Creating and running an experiment within Khan Academy requires knowledge of the platform's open-source code, the coding skills necessary to make modifications to implement experimentation, and progression through a standard code review process working alongside Khan Academy developers. Obtaining data files following an experiment is also heavily reliant on system programmers. To our knowledge, none of the A/B experiments that researchers have patiently conducted on Khan Academy have been formally published. Work that has been published has held less regard for the power of specific learning interventions and more for overall system efficacy and predictive modeling. Similarly, education behemoths like Kaplan and Pearson could surely use their stature to promote learning technologies as powerful tools for advancing research in the field. Large-scale EdTech platforms with less of a monetary focus still show little outward interest in examining learning interactions to optimize learning gains. Massive Open Online Course (MOOC) platforms and large scale learning tools like Coursera, EdX, Udacity, openHPI, and Google's "Course Builder" focus on delivering content, while spending little time or money thoroughly examining the effects of what they deliver. This argument is not intended to suggest a complete deficit of sound research, but instead to point out that few researchers have access to course data from these platforms to isolate and improve best practices in the field. We argue that in the next decade, designers of learning platforms should consider the cyberinfrastructure necessary to broaden the field's focus on open educational research at scale, or should at least support the open collection of anonymized data through APIs to inform EdTech policy.

We argue that to get the most out of educational technologies, learning platforms must be revolutionized into shared scientific instruments. Unlike a static piece of equipment, learning platforms can be used to run multiple experiments simultaneously and research serves to iteratively improve the instrument while enhancing learning and informing the field. While these studies help researchers to identify evidence-based instructional improvements, findings also lead to the generation of new hypotheses that expand investigation or reroute postulated theories. Early results inspire collaborative idea expansion through replications and extensions of studies that serve to enhance system content and content delivery, while improving student learning and advancing the state of knowledge in the field through peer reviewed publication. New hypotheses form and grow as results are observed, naturally evolving until pushing the boundaries of the platform's infrastructure. In response, scientifically validated infrastructure improvements can be tailored to research demand, allowing researchers to start the cycle anew with novel hypotheses. Thus, promoting collaborative and open research infrastructures will support perpetual evolution locally within these systems and broadly across research communities.

By focusing on the cyberinfrastructure improvements that would support such collaborative scientific tools, grant sources like the NSF and the IES would lower the overall cost of funding educational research. For instance, the Institute of Education Sciences (IES) currently funds Efficacy Trials for promising interventions, averaging \$3M and involving more than 50 schools. Larger and more stringent Effectiveness Trials carry a median funding cost of \$6M. In the math and science domains, the IES has funded 22 Efficacy Trials and five Effectiveness Trials. Despite the high cost of funding this work, reliable positive implications for educational practice have rarely been observed. Learning platforms geared toward research could expedite at-scale research at a fraction of the cost. While low cost procedures may not hold for all educational investigations (i.e., the design of full learning programs or platforms that require significant funding), there are many benefits to cost-effective, efficient, and rigorous experimentation that can be conducted using educational technologies.

Many unique features make ASSISTments capable of serving researchers as a shared scientific tool. However, ASSISTments is not the only platform with access to implementing the cyberinfrastructure required to drive a collaborative research environment like the TestBed. The majority of learning applications have the capacity for data collection, and many could be restructured to offer the flexibility required for experimental content manipulation. Platforms may also be capable of establishing an API to deliver preprocessed data, de-identified for

Submission in Response to NSF CI 2030 Request for Information

DATE AND TIME: 2017-04-05 13:36:26

PAGE 4

REFERENCE NO: 244

student protection, to researchers conducting experiments or even wishing to mine data.

Systemic change will not stem from a small number of large-scale RCEs funded by government grants, but instead from a revolution in thought surrounding the value of technology based learning applications. Infusing pre-existing learning technologies with the cyberinfrastructure required to support randomized controlled experimentation is the first step in kick starting this revolution. Research infused platforms have the potential to drive inquiry for a diverse community of researchers through the low-cost, rapid iteration of valid, generalizable, and noninvasive investigations within authentic learning environments. Systems like ASSISTments can provide researchers with access to an extensive and diverse subject pool, an automated fine-grained logging of educational data, validated measures of student learning and affect, and automated data reporting and analysis to tackle the high stakes nature of typical education research. With similar research-focused platforms in the field, it would also be possible for researchers to compare learning interventions across platforms to better measure the reliability and generalizability of results. With this letter, we call on colleagues in the field to similarly support and supplement educational technologies with the capacity for sound, collaborative science. Moving the goalposts for educational research will result in a broad range of benefits for students, researchers, platforms, and educational practice and policy.

Consent Statement

- "I hereby agree to give the National Science Foundation (NSF) the right to use this information for the purposes stated above and to display it on a publically available website, consistent with the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (<https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode>)."
-