Draft Concept Paper for the
STEM Research and Modeling Network

The Case for Predictive Methods in STEM Education Research & Policy Analysis

Concern that the U.S. education system is failing to keep pace in the global talent race has resulted in a surge of actions aimed at improving science, technology, engineering and mathematics (STEM) education in this country—disciplines responsible, in part, for cultivating and supplying our nation's system of innovation with top talent that can keep the U.S. and its economy competitive. The America Competes Act signed by President Bush in 2007 is one notable example of an attempt to strengthen STEM education.

Major corporations and private foundations are investing significant resources to address this challenge. State and federal government agencies are trying mightily to catalyze improvements, while grappling simultaneously with looming shortages of teachers and shifting policy mandates. All of these players wish they had some way to forecast how their initiative might play out: will it produce the intended change? What side-effects will occur? Does it intervene at the highest-leverage point? Does a faster or more cost-effective pathway to a similar outcome exist? Unfortunately, today's education researchers do not have access to tools to aid in answering these important questions.

In this paper, we suggest that we must bring new tools to bear on this challenge. Specifically, we argue that the time has come to add rigorous predictive research and modeling techniques to the educational research and policy analysis toolkit.

Challenges and Opportunities in Education Research

The federal government has the leading role in funding education research and promoting the effective use of research and development (R&D); however, its effort is severely under funded, especially when compared to other fields[1]. While state funding accounts for the bulk of education expenditures, states have little capacity to fund education research. And while private and corporate foundations, as well as a handful of wealthy philanthropists, have invested significant resources in education innovations, they tend to allocate only a fraction of those resources for education research and evaluation (Greene 2005). This relative paucity of funding, combined with limited coordination among the major groups of funders, constrains the extent to which the education research community can develop a forward-looking, coordinated research agenda that addresses key national priorities.

These challenges notwithstanding, the field of education research has made some important gains in understanding key education problems, such as how students learn and the impact of teachers on student achievement. The field of education, however, continues to face significant challenges in connecting research with the practitioners and policymakers who need it. This is due in part to the fact that most education research is *descriptive* in nature, rather than *predictve*.

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[1] Even though the nation spends nearly $1 trillion annually on K-12 and postsecondary education, the Department of Education spent only $1 billion on education innovation in 2008. In contrast, we spend $2.6 trillion on healthcare and $28 billion on biomedical innovation.

As Clayton Christensen points out in *Disrupting Class*, while descriptive research relies upon inductive techniques (e.g., observation, categorization and association) to help understand *why* something happened, predictive research, when built upon high-quality descriptive research, can be used to study future scenarios to better understand what *might* happen given a particular circumstance (2008). For example, if an intervention found to improve student achievement were to be adopted statewide, would it produce the intended change? Over how long? With which students? And what unintended consequences would occur? Practitioners and policymakers need this type of forward-looking analysis to craft the most effective approaches to our education challenges.

Advances in the field of education and in the quality of descriptive research have paved the way for the development of predictive research methods and tools like those that have been used in other fields. For example, economists, urban planners, international development specialists and global security experts often use computer-based modeling to help them study possible future outcomes in the complex-adaptive systems on which they focus. They use a variety of techniques, each suited to systems with different properties and problems at different scales. Communities of researchers have developed over years in these fields, and their collective work has driven continuous improvements that allow model results to be applied with significant confidence. We propose adding research methods and tools like these to the educational research toolkit.

Predictive Research and Modeling Tools for STEM Education

One of the Business-Higher Education Forum's (BHEF) members has given this effort a significant jump-start. The Raytheon Company has produced a model using system dynamics techniques that represents how students move through STEM education and into teaching or the workforce. Raytheon is working with the research community on further testing and refinement of the model. The intent is to launch a new collaborative research network that will continually improve the model and apply it to the pressing issues of STEM education.

Raytheon's groundbreaking work of applying systems engineering methods and system dynamics modeling to the U.S. education system has shown that with further testing and validation, modeling activity has the potential to assist and guide policymakers and practitioners. Specifically, the model offers the following potential benefits:

1. Provides a robust tool to simulate and assess the impact of STEM-related policy and programmatic interventions over time

    - Tracks the effect of interventions introduced in one part of the system on other parts of the system

    - Provides an organized approach to estimate the future effects, both intended and unintended, of policy and programmatic changes

    - Allows policymakers and researchers to examine a more complete array of interactions and to evaluate the consequences of various policy and program changes

    - Informs the decisions of policymakers, educators, and funders in prioritizing those interventions that have the highest potential for maximizing STEM participation and outcomes

2. Provides an organized and comprehensive approach to viewing and understanding the complex, multi-level nature of the U.S. and STEM education pipeline

    - Breaks the P-20 system down into interrelated components and identifies, in an organized manner, the specific capacities and problems at each education level that influence the production of STEM graduates

    - Provides a framework that maintains cohesion of the system's components allowing for the analysis of system capacity to increase the number of STEM graduates

3. Provides a common platform for analysis, research, and dialogue among the often disconnected STEM education community, including policymakers, practitioners, funders, and researchers

    - Provides a common approach, language and framework to stakeholders at all levels of the system who are involved in efforts to strengthen STEM capabilities

    - Promotes the interaction of these stakeholders through model development, refinement, testing, validation, implementation, and beyond

    - Offers a broad community of researchers and policymakers a valuable open source resource

4. Identifies and informs the development of a more coherent education research agenda

    - Promotes the identification of appropriate research/data necessary for thorough analysis and understanding of the system

    - Focuses researchers on identifying gaps in the research that are related to high-leverage aspects of the system

    - Aids researchers and funders in prioritizing a national research agenda to support the testing of program and policies with the potential for strengthening the STEM pipeline

Advancing STEM Education Research and Modeling

To fully realize the potential benefits of predictive modeling tools such as the Raytheon STEM education model, Raytheon, and BHEF and its members recognize the need for additional model enhancement, testing, validation, and analysis prior to the transition of the model to open source use by the public. In order to accomplish this aim, they have formed a collaborative partnership to manage the project and engage strategic partners and the broader STEM education community. This will be achieved through the nascent STEM Research and Modeling Network (SRMN), the development of a Configuration Control Board (CCB), and the development of a robust user community. The SRMN will also work with researchers, practitioners, and policymakers as they use modeling in their efforts to improve student outcomes.

The STEM Research and Modeling Network. Raytheon has partnered with the Business-Higher Education Forum and BHEF member organization The Ohio State University (OSU) to establish the STEM Research and Modeling Network (SRMN), a collaborative partnership to foster the development and use of the Raytheon STEM education model and other predictive modeling tools in order to make them available in an open-source environment to researchers nation-wide.

BHEF has offered to take the lead in managing the SRMN, which includes a diverse array of organizations and individuals from across K-12 education, academe, business and industry, foundations, non-profits and government agencies. It includes researchers across a wide range of disciplinary fields including education and the STEM disciplines as well as system modeling experts, practitioners, and administrators from all levels of the education spectrum.

The SRMN plays a central role in testing, evaluating, and suggesting proposed changes to the existing Raytheon model prior to the transition to open source. The SRMN will also participate in developing the research agenda required for model enhancement. In addition to the Raytheon model, the SRMN plans to add discrete event and agent-based methods and tools in due course.

The SMRN will provide the technical talent needed to maintain each model, such as configuration control, resolution of coding and other technical errors, and maintenance of open-source licenses and access. It will also foster the growth of a user community that includes researchers, practitioners, policymakers and funders by providing technical support, deploying collaborative network tools (e.g. Wikis) and convening symposia and workshops.

The Configuration Control Board. In keeping with open source conventions, the SRMN will establish a STEM Modeling Configuration Control Board (CCB) that will judge proposed changes to the baseline model to determine if they have utility. Changes with broad utility will be incorporated. The CCB's first assignment will be to make final decisions on the initial model that will transition to open source. After the CCB finalizes the K-12 and undergraduate components of the model, the SRMN will launch the model on the Web for use by the general public.

Public/Open Source Use. By making the Raytheon model available as an open source tool, a broad community of users and developers will be able to download official versions of model files from the Web site. This community will also be able to make improvements to the model and submit model change requests to the CCB, which will evaluate and comment on the proposed changes. The CCB will make the final decision on which proposed model changes will be incorporated into the baseline model. OSU, as lead technical partner, will then commit the approved changes to the official version of the model on the Web.

Conclusion

The STEM Research and Modeling Network and the education model are exciting additions to the education community. We hope that together they will provide **researchers** with opportunities to bring theory to practice, **policymakers** with a means to assess the potential impact of legislation, **practitioners** with guides to what may produce results, and **funders** with a gauge of effective and successful education investments. Most importantly, we look forward to using these new tools as a means of bringing these groups together to work toward a shared goal: strengthening America's competitiveness.