

Reinventing Higher Education

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Problems and Needs

Results from research in STEM education over the past forty years have shown that most students finish their science, math, and engineering courses without developing meaningful understanding of core concepts and ideas. The knowledge that most students acquire is incomplete, fragmented, and plagued with misconceptions. Students' ability to transfer their understandings and skills to real situations is quite limited. These findings also show that adopting research-based teaching strategies significantly improves student performance in STEM courses. Nevertheless, traditional educational structures and practices do not enable and support the wide adoption of alternative teaching models. Additionally, while research and practice in STEM have become largely interdisciplinary and multidisciplinary, the curricula and educational models that guide college STEM education remain anchored in the distant past. The rich, complex, collaborative, and creative ways in which faculty approach their research and design work are often left outside the classroom doors.

Current investments in STEM educational reform at the college level are not paying off because the underlying educational models and structures remain untouched. Most STEM courses focus on the acquisition of vast amounts of knowledge rather than on the development of productive ways of knowing, thinking, and acting in the world. Educational changes tend to take place at the course level rather than at the program level failing to ensure alignment, coordination, integration, and continuity in educational experiences throughout the curriculum. Deep and structural educational reforms need to be promoted and supported if we want to meaningfully and productively educate a diverse STEM work force that can successfully address the grand challenges facing modern societies and earth systems. This will require major philosophical, structural, and functional changes that demand long-term support and strong accountability measures that promote significant change in institutions of higher education.

Innovation, Exploration, and Evaluation

Faculty in higher education are rather creative and innovative in their research efforts but tend to avoid exploration and risk-taking when it comes to education. This traditional culture needs to be disrupted to allow for the continuous and dynamic design, implementation, and evaluation of educational models and pathways that break traditional disciplinary boundaries and conventional conceptions of what it means to learn in STEM. In particular, we need:

- A major paradigm shift in the ways we conceptualize learning, from the current educational framework whose central goal is the acquisition of disciplinary knowledge to a framework that focuses on the participatory development of integrated competencies for critical collaborative decision-making and problem-solving in relevant contexts
- The reinvention of foundational STEM courses by breaking disciplinary boundaries and shifting the attention from knowing a selected set of concepts to developing and applying core STEM practices and ways of thinking to the analysis of complex systems and processes in our world

- The development of more flexible and integrated career paths that rely less on the completion of formal courses based on artificial lecture-lab splits and more on the active participation in diverse, meaningful, and authentic experiences in the students' fields of interest
- The re-evaluation of overarching learning objectives to bring to the forefront the need for professionals that are socio-cultural-environmental literate, can think systemically, and demonstrate socio-cultural-environmental responsibility in their decision-making and actions

The successful development and implementation of these educational reforms will require considerable investment in educational research and evaluation directed at answering questions such as: What crosscutting ways of knowing, thinking, and acting should be developed to prepare individuals who can confront questions and problems of relevance in our world? In which different ways can those competences be more effectively developed? What learning progressions are most beneficial for diverse sets of students? Which core experiences should be enabled to achieve targeted educational goals? How do these different experiences contribute to the professional development of diverse individuals? What institutional constraints should be removed and what new structures should be in place to support the development and implementation of living curricular reform efforts that transcend conventional academic units and divisions? How can those models be best adopted and adapted by different types of institutions?

Successful reform should lead to diverse research-based educational pathways for STEM majors that: a) generate professionals who demonstrate knowledge integration, problem-solving and decision-making skills, understanding of and concern about major societal and environmental issues, and adaptability, flexibility, and resilience to work in diverse environments; b) can be adopted and adapted by different types of institutions serving diverse student populations; and c) are flexible to respond to diverse student interest and needs, and can be easily modified to respond to the changing needs of modern societies.

Success would also be measurable in terms of concrete changes in the structure, functions, and interactions of academic units in institutions of higher education to best support the success of all types of students through the implemented educational pathways. For example, research and undergraduate teaching missions and activities would be integrated in synergistic manners. Mechanisms to support the work of teaching teams involving faculty across different departments and colleges would be institutionalized. Curricular design, implementation, and evaluation would be approached collaboratively across multiple units.

Nowadays, major investments are being made to broaden participation in post-secondary STEM education. New technologies (e.g., digital tools, intelligent systems) are being introduced with the promise of revolutionizing approaches to education. New spaces (real and virtual) are being built to enable collaborative learning environments. However, most resources are being used to expand and reproduce an educational model that has proven to be ineffective in developing meaningful and transferable understandings for large and diverse populations of students. There is little doubt that technological tools will increase access to and reshape how students participate in education. The crucial questions are what students will be asked to think about, what types of experiences they will have the opportunity to engage in, and for what purposes. We must reconceptualize the answers to these questions now if we want to prepare a STEM workforce ready to address the grand challenges facing the world.