Tranforming Undergraduate STEM Education via Informal Learning

By David A. Ucko

With funding from the National Science Foundation, the National Academies of Sciences, Engineering, and Medicine convened a symposium in November 2020 on "Imagining the Future of Undergraduate STEM Education." In advance of the virtual meeting, an Idea Competition was conducted to solicit a range of responses to the question: What should undergraduate STEM education look like in 2040 and beyond to meet the needs of students, science, and society? Entries were judged on originality and future orientation, along with their potential to contribute to and advance discussion at the symposium.

Informal learning takes advantage of intrinsic motivation since it builds upon the "pull" of an individual's personal interests, rather than the "push" of a teacher. In composing an entry, I sought to apply that strength to enhance learner impact in the undergraduate context. My submission, which received an Honorable Mention, was couched in terms of a "memo" from a fictitious PULL (Personalized Undergraduate & Lifelong Learning) STEM Center written as if the year were 2040, reflecting back on the progress made since 2020. Not surprisingly, the other posted entries were all submitted from colleges and universities, with the exception of one from industry and one unaffiliated.

Conducted on Zoom, the multi-day symposium featured moderated panels with faculty, administra-tors, policy-makers, funders, and representatives of associations and industry. It also incorporated a series of online break-out sessions in which participants wrote future-oriented "stories." The agenda, background readings, submissions, and stories can be found at https://www.nationalacademies.org/event/10-21-2020/imagining-the-future-of-undergraduate-stem-education-symposium. The proceedings will be made available for download at https://www.nap.edu.

REFERENCES

Fox. E. J. (2004). The Personalized System of Instruction: A flexible and effective approach to mastery learning. In D. J. Moran & R. W. Malott (eds.), *Evidence-based Educational Methods* (pp. 201-221). San Diego: Elsevier Academic Press.

National Research Council. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits*. Washington, DC: The National Academies Press.

Ucko, D. A. (2011). SENCER synergies with informal learning. *Science Education & Civic Engage-ment: An International Journal:* 7(2) 16-19.

David A. Ucko is president of Museums+more. He can be reached at daveucko@gmail.com.

MEMORANDUM

TO: Director, PULL STEM Center

FROM: David Ucko

DATE: July 8, 2040

RE: Personalized Undergraduate & Lifelong Learning STEM Center

Here's a draft of the PULL STEM Center overview that you requested for our 2040 annual report.

Learners today take for granted the transformation of undergraduate STEM education initiated in 2020 by the coronavirus pandemic and Black Lives Matter movement. Spurred by financial exigencies and grassroots pressure, colleges and universities began to acknowledge shortcomings of the traditional instructor-directed classroom-based disciplinary-content model. It did not adequately prepare many students to become lifelong learners, and could not overcome the inequities in STEM learning. A variety of approaches had been tried to "fix" the system, but their systemic impact had been limited.

We know that along with their unique genetic makeup, learners embody unique sets of capabilities, interests, and educational and cultural backgrounds. The legacy educational model was created at a time when it was not feasible to individualize learning. By 2040 the "one size fits most" approach could no longer be justified. The key was taking advantage of the affordances of informal learning, expanding the campus to the community, and applying breakthroughs in artificial intelligence to facilitate truly individualized experiential learning.

The seminal Learning Science in Informal Environments synthesis (NRC 2009) and subsequent research validated the critical role of personal interest in generating and maintaining the intrinsic motivation for STEM learning. The powerful "pull" of relevance, in contrast to the "push" of teacher-directed instruction, makes learning both gratifying and ubiquitous. It is the primary driver of life-long learner, and why most people learn most of what they know outside a formal classroom.

After privacy concerns had been addressed, advances in AI and mobile technology made it possible to identify and continually update an online record of those topics, issues, and questions most pertinent to each individual. These developments enabled creation of personal learning pathways that evolve over time. Progress is recorded via blockchain technology in a virtual "wallet" that belongs to the learner and can be shared with faculty and potential employers.

STEM learning was also enhanced by "flipping" the entire university campus, opening new opportunities for contextual, experiential learning throughout the community. This expansion built upon relationships established within the then emerging STEM learning ecosystems and the partnerships between higher education and informal science institutions formed by SENCER (Science Education for New Civic Engagements and Responsibilities). Community organizations and businesses submit requests for projects or assistance, as well as offer internships, apprenticeships, and part-time employment.

AI-enhanced online and in-person faculty advising now make it possible to guide and support learners along their interdisciplinary pathways. They help learners select individual and team-based experiences that build on each other and increase in complexity over time. As an example, a learner interested in running marathons could choose from such projects as studying a sports training facility how nutrition affects performance; developing an activity at a science museum to explain the mechanics of running; designing an app at a tech firm for runners that calculates their CO2 production; or analyzing bone density of runners at a medical center. Her other interests would lead to further sets of relevant learning opportunities. These experiences would be complemented and assessed via learning modules generated by an AI-based intelligent tutor, along with individual and small group learner-faculty meetings conducted virtually and in-person. Upon satisfactory completion, learning units are awarded and added to the blockchain wallet.

Those growing up under less than ideal circumstances too often faced significant academic hurdles that could not be readily overcome. Individually-customized learning made it possible to address inequities resulting from the traditional system. In addition to choosing relevant framing, learners can start at different

points, proceed at their own pace, and select the actual means by which to learn and demonstrate competence. This adaptable personalization is especially important for engaging and retaining STEM learners from disadvantaged backgrounds, who may have lacked the resources, role models, and opportunities to consider pursuing STEM.

Studies also had identified gender-based barriers to pursuit of STEM in such fields as engineering and information technology. Among female students, for example, one barrier was a perceived lack of personal and societal relevance of academic course work. Our individualized, real-world focus addresses this perception head on.

The approach we use today bears a resemblance to the Personalized System of Instruction (PSI) introduced in the 1960s, which featured self-paced mastery learning, demonstrated by advancing through unit-based readiness tests. This so-called Keller Plan could be characterized as "different pace, same learning," compared to the traditional lecture-based "same pace, different learning." Other than the challenge of implementation prior to computers, the biggest weakness of PSI was student procrastination. Thanks to the ability of learners to customize based on their interests, that weakness has been largely eliminated; in addition, computerized AI makes it far easier to implement. Some characterize our new system as "different pace, different learning."

A critic may question the lack of required curricula to instill "scientific literacy," assuming that it is possible to agree on the components. Advocates note that while focusing on relevant, real-world, interdisciplinary content, learners must necessarily gain appropriate STEM-based subject-matter competence. Significantly, it occurs "just-in-time," preparing them to engage in "pulled" learning throughout their lifetimes. Furthermore, in an era of increasing automation and technological innovation, skills associated with lifelong learning will prove far more valuable than having had to learn (and perhaps forgotten) specific disciplinary content.

Our not-for-profit Personalized Undergraduate & Lifelong Learning (PULL) STEM Center was established by a consortium of universities to serve as the backbone organization to support an emerging network of participating institutions and its associated community of practice. Looking ahead, one of our most vital roles is now serving as a clearinghouse for research and evaluation studies that inform ongoing improvements in personalized STEM learning.