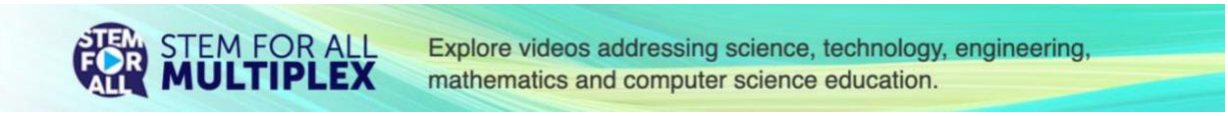

Developing K-12 STEM Career Pathways for the Future of Work
STEM for All Multiplex Theme of the Month Synthesis: November 2021

Introduction

There is a natural affinity between STEM education and the workplace, in part because STEM fields have long been essential drivers of innovations that may start as technical improvements to, say, medical procedures, transportation, or communication, but as they are incorporated into social practice, they have transformational effects on social, economic, and political ideas and practice. Thus, STEM literacy is seen to make an intrinsic link between the individual and the evolving future. The phenomenon- and inquiry-based approach of the STEM fields, and the social/collaborative discourse by which they proceed, seem especially valuable for the learner, (Dewey 1916), when they are not completely shaped by workplace requirements (job training) but serve to build children's capacities to shape their lives as well as their work. It is no wonder then, that links to the workplace have been an important thread in science education over the years (Bopardikar et al. 2020).

This month's Theme, *Developing K-12 STEM Career Pathways for the Future of Work*, explored strategies *that explicitly relate* STEM learning with workplace opportunities and skills. In her introductory blog post, Dr. Joyce Malyn-Smith of Education Development Center (EDC) and STELAR briefly set out the key ideas in the strategy:

> *The majority of career pathways are formed around specific skill standards that define what successful workers need to know and be able to do [which guide] ...strategies that can be used to build students' skills and dispositions in key areas including interdisciplinary teamwork, design and systems thinking, lifelong learning, and real-world problem solving. The career pathway system provides us with a framework to develop K–12 pathways for these emerging fields, and doing so is key to ensuring that all youth have equitable access to pursuing careers in these fields*.

"Fundamentally, a Career Pathways System is about the coordination of people and resources. Within education, this includes aligning our country's K–12 and postsecondary education systems" (Malyn-Smith et al. 2017). Dr. Malyn-Smith pointed out that the strategy supports innovations that may aim at encouraging STEM career awareness, or exploration of career possibilities, or indeed preparation for specific careers. These different lenses will vary in importance for students over the course of their education, and the designers of career pathways bear in mind that over a student's educational career, there are well-known transitional points, so that:

> *Part of the career pathway also means a system wide commitment to helping students make those transitions. So from middle school to high school for example, both providing information and student support in transitions. And from middle to high school, students are making preliminary decisions by picking the high school they're going to, whether it's going to be a career in technical high school, or it might be a magnet or a career pathway or a straight classical education.*

As Joyce Malyn-Smith pointed out in her blog for the November 2021 Multiplex Theme, linking STEM learning to STEM career pathways is an important strategy for broadening participation in STEM fields. In addition, it enables natural connections between the school and the community. Consequently, it can

make an important contribution to the development of a "STEM learning ecosystem" approach in which community resources of many kinds engage students in authentic learning that is culturally situated. (See the October Theme, *It Takes a Village: Using the Concept Of "Learning Ecosystems" to Improve Stem Engagement* and the September Theme, *Partnering Culturally Responsive Teaching and Place-Based Science Education*.)

The Expert Panel

This month's expert panel explored the importance of career pathways, and the elements used by ITEST projects to create robust, effective pathways into the future STEM workforce. Dr. Joyce Malyn-Smith was joined by Dr. Jon Boxerman of WestEd, Dr. Jaymee Nanasi Davis, University of Hawaii Maui College, Dr. Jacqueline DeLisi of EDC, and Dr. Helen Zhang of Boston College. These members of the ITEST community of practice will share their experiences in developing STEM pathways in formal and informal K–12 learning. Several key themes emerged during the panel, which were supported and amplified by the resources assembled by the panelists, and by the discussion after the webinar.

1. Project-based, Problem-based. The STEM career pathways approach can be a good fit with the principles advocated in the Standards — student-centered, phenomenon-based, and focused on sense-making. As Jacqueline DeLisi noted, one important aspect of many implementations of STEM career pathways is that "students' work is often project-based. And in some way, it reflects the nature of the work and the profession, and both in the process of engaging in a project, but also producing the product that are both important aspects of the student's work."

Practical or open work in STEM education can of course vary along several dimensions, according to the freedom of the student to ask the question for investigation, develop the methods, and make sense of the outcomes (Weir and Barclay 1994, Simon and Jones 1992). Jaymee Nanasi Davis contrasted "project-based" curriculum with "problem-based" approaches:

> *They're really similar, because they're both founded on the same educational theories of social constructionism....the main difference between problem-based and project-based is that project-based is a little bit more structured. It'll have an outline and a set of action steps that students have to take as part of the project completion.*
>
> *In problem-based, it's less structured and students have to figure out on their own what the steps are....what to do and how to do it. And of course, problem-based is centered on a problem, and students are working towards a solution. For our projects STEMulate, we operationalize five tenants of problem-based learning; real-world, student centered, collaborative, group work and open-ended outcome... Creating a student-centered environment is key.*

In either approach, the source of the work can effectively move outside the classroom, as challenges are sought that are valuable or important to the students' community. "So it's not something made up, and it's not like a case study. It's something that's real." The students' learning is contextualized within a partnership between the school and local industry, cultural institutions, or other community stakeholders.

Mentorship and the authenticity of the problems or projects also are important ingredients in the broadening participation impact of STEM career pathways, and the influence between students and

community is mutual. In a community that historically is under-represented or distanced from STEM and STEM careers, Jon Boxerman noted,

> *My first point is that pathways expose students to STEM, but that can look quite different and mean different things depending on the context and the community. So this leads me to my second point; efforts to boost participation and interest in STEM must attend to the local context. At a time when participation by indigenous students and other students who have historically been excluded from STEM is already disproportionately low, the absence of students from higher level STEM courses seems to limit the range of cultural perspectives that will be available to shape and expand the STEM community of the future.*

The pathways approach, if it truly attends to context, will take care to engage with the funds of knowledge in the community — both community members with "mainstream" expertise, and those whose STEM involvement is more culturally rooted. In a project with NASA, Jon Boxman told us,

> *The subject matter experts…are often NASA scientists, but they can be other STEM professionals working in the industry, local elders and knowledge keepers, teachers, et cetera... [They] help make tangible the process to pursue STEM as a career and to see how STEM relates to their everyday lives.*

2. Interdisciplinarity. Since so many authentic problems that students may engage with in the workplace or community cross disciplinary boundaries, the STEM career pathways approach is a good fit with the current practice in STEM fields, which more and more relies both on deep disciplinary knowledge, and on collaboration across disciplines. As Jacqueline DeLisi said, "Throughout all of these project-based experiences, students develop their skills as collaborators and communicators, and they work in teams and they coordinate their work with others."

3. Partnerships. The Career Pathways approach necessarily entails partnerships with community stakeholders, including industry. Building such partnerships is an art and skill in itself. It takes time for the partners to understand the strategy that they are implementing and to create a reality together. Initial connections can grow over time into multidimensional relationships that can benefit the students, the teachers, and the community stakeholders. Workplace visits, mentorships, and other active collaborations can provide learning opportunities for all partners.

4. Equity. Equity in STEM careers, as in STEM education, begins in awareness. one of the core aims of the career pathways strategy. Very often, students and their communities have no real knowledge of the variety of career paths they might follow, building on their interests in STEM topics. They also may not understand how important it is for the future success of the STEM enterprise at all levels that as many diverse voices participate and contribute to the various fields of research and development.

People implementing the strategy, if they truly take account of the local context, will recognize that the demands of the workplace can be in tension with other imperatives. As Jon Boxerman noted,

> *These kinds of careers are not necessarily encouraged or valued in part because of a narrow our community definition of STEM. Why would one go to school to be a marine scientist when a career as a fisherman puts food on the table? Knowing about how oceans operate is scientific knowledge and knowledge fishermen use to catch fish, but it is second nature. Folks don't tie marine careers to careers outside the community beyond their subsistence lifestyle.... pursuing a career in STEM is an equity issue, because too often STEM career pathways may not be accessible or visible. Equity in STEM education is achieved through implementation of diverse*

policies, practices and programs that can remove systemic barriers and provide localized support for broadening participation in STEM within and across diverse communities.

5. Artificial Intelligence. One special area of emerging research and employment that was highlighted is artificial intelligence (AI). Helen Zhang brought her experience with two NSF/ITEST projects that are aimed at "developing AI literacy and everyday AI for use... aiming to help middle school students develop a fundamental understanding of AI and also its impact on future jobs." The complex of technologies, applications, and issues related to AI is becoming pervasive in the workplace and in many aspects of everyday life. For this reason, career pathways relating to AI are an important venue for raising basic understanding of the nature of AI, its current and potential uses, the various kinds of employment that the emerging AI industries can offer — and the ethical and social questions that AI raises.

AI is a socio-technical system that has societal and political impact. In other words, it's not just a single technical tool. While the use of AI has brought tons of convenience to our life and the industry, AI can be potentially biased and can also cause societal problems. Therefore, it is critical for us to prepare our students, all the future workforce to recognize these ethical issues and how these issues will in return impact their future work.... our career development, particularly for this AI future should focus on building students' adaptability skills, such skills can help them thrive in the future. And wouldn't limit them within certain career fields.

The expert panel, plus the resources, the playlist, and the active discussion during and after the webinar, provided an introduction to some of the many forms that the STEM Career Pathways strategy can take. Within the diversity of the presentations, certain cross-cutting themes emerged from the panel and discussions: The career pathways strategy can complement and reinforce the active, student-centered, phenomenon-based philosophy of the Standards; the career focus can bring the students and the community together in exploring career opportunities in students' local context; the strategy provides natural opportunities for students in under-represented groups to encounter mentors who can relate to their experiences, and put a human face on STEM careers.

Recommendations for Researchers

This month's Theme suggests at least four important areas of research:

Short-term indicators of long-term trajectories. Dr. DeLisi spoke directly to the question of assessment of the impact of STEM career pathways projects. Proximal effects may include measures such as "students' interest in science, their understanding of the relevance of science to whatever career pathway or career interest they have with the recognition that their career pathways is going to be dynamic and change."

There is much to be examined, however, about the relationship between short-term outcomes such as these, and longer-term impacts on these measures, as well as other measures relating to student identity with respect to STEM and to careers.

Learning outcomes for participation in such pathways. If the career pathway strategy is not focused solely on workforce development, training, etc., then there is a need for research on STEM learning outcomes with regard, for example, to the three strands of the NGSS — disciplinary content, cross-cutting concepts, practices.

Processes and indicators of successful partnerships. The career pathways strategy depends on the development and maintenance of effective partnerships between schools and other stakeholders in the community. The broad success of this strategy could be enhanced by case-study and cross-case research on these partnerships, with attention paid to the needs, expectations, and benefits/challenges for each component in the partnership.

Boundary-crossing issues. Such partnerships inevitably raise "cultural" issues, and it would be valuable to have studies of these partnerships framed in terms of boundaries and boundary-crossing — a research framework originally developed to understand collaborations among partners with different aims and areas of expertise.

Recommendations for Policymakers and Administrators

Since the implementation of STEM career pathway efforts require the development and maintenance of partnerships, policymakers and administrators should become familiar with cases of successful implementations from diverse communities. Policymakers will do the field a great service by facilitating the collection and dissemination of good case studies of such partnerships and using such cases to inform the design of career pathways projects in their regions or communities.

Both administrators and policy makers need to put in place reasonable and effective formative research, so that they can learn about and improve their efforts - the "design-based research" framework may be useful in this connection — as will the formation of partnerships with researchers from universities or independent research organizations.

Recommendations for Teacher Leaders.

Teacher-leaders can play a key role in at least three phases of the design and implementation of a STEM career pathway effort: a) in helping to identify partners, potential project themes, and areas of particular interest and value for their students and their community; b) by participating as pioneer teachers in the implementation of the program, taking the stance of "reflective practitioners" so that they track the challenges, strategies, and lessons learned from their experience, and c) by building on their own and others' experience to develop professional development for their colleagues to facilitate broader teacher participation, and continued sustainability of the program as an educational as well as a vocational enterprise.

Additional References

R. L. Batchelor, H. Ali, K. G. Gardner-Vandy, A. U. Gold, J. A. MacKinnon, and P. M. Asher (2021) Reimagining STEM Workforce Development as a Braided River. *Eos, 102*. https://doi.org/10.1029/2021EO157277.

Bopardikar, A., D. Bernstein, S. McKenney, and B. Drayton (2020) Work-based curriculum to broaden learners' participation in science: Insights for designers. *Research in Science Education.* 50:1251-1279. https://doi.org/10.1007/s11165-018-9731-x.

Dewey, J. (1916). *Democracy and Education*. New York, NY: Free Press.

Malyn-Smith, J., Blustein, D., Pillai, S., Parker, C. E., Gutowski, E., & Diamonti, A. J. (2017). Building the foundational skills needed for success in work at the human-technology frontier. Waltham, MA: EDC.

Simon, S.A., & Jones, A.T. (1992). *Open work in science: A review of existing practice.* OPENS Project, Centre of Educational Studies, King's College, University of London.

Weir, S. and T. Barclay (1994). Reflecting on practice: A tool for teacher change, *Hands On*!, TERC.

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