PRACTICE

Supporting Twenty-First-Century Students with an Across-the-Curriculum Approach to Undergraduate Research

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Abstract

An across-the-curriculum (ATC) approach to undergraduate research (UR) is a productive addition to UR ecosystems at equity-oriented institutions. The ATC approach is differentiated from mentored UR experiences and laboratory course-based UR experiences by its ability to employ experiential, problem-based skills and practices for a broad variety of informal research activities at all levels of curriculum and without special facilities. In doing so, the ATC model encourages faculty to make the application of twenty-first-century student learning outcomes explicit for students who are new to research so that they see how inquiry, knowledge creation, and other aspects of problem-solving are used in practical ways that translate to professional and community contexts.

Keywords: *curriculum, equity, faculty development, inquiry-based practice, open pedagogy, student learning outcomes*

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The Needs of Twenty-First-Century Students

Twenty-first-century undergraduates benefit from access to a spectrum of undergraduate research (UR) opportunities provided in a robust and supportive ecosystem of practice. This expansive and pervasive across-the-curriculum (ATC) approach to UR, explained below, can broadly foster twenty-first-century skills (Dede 2010) and twenty-first-century literacies (National Council of Teachers of English 2019) by enabling participation at a variety of levels and within multiple contexts. Properly supported, an ATC approach to UR addresses the diversification of the twenty-first-century student body and the emerging professional contexts in which graduates will find themselves by embedding these skills and literacies in both general education and disciplinary curricula. At New York City College of Technology–CUNY (City Tech), an expanded ecosystem of UR using an ATC approach benefits from dedicated support through cross-disciplinary faculty development seminars in general education (the Living Lab) and from an open digital platform for teaching, learning, and collaboration (the OpenLab).

Traditionally, UR introduces undergraduates to the applied aspects of science by helping them build identities as novice researchers and assume professional skills in the laboratory (Linn et al. 2015). Students gain this exposure through a range of experiential activities that provide both the benefits of being iterative and interactive (Coker et al. 2017) and the development of social capital that engaging in research activity can provide (Garner et al. 2018). As a high-impact practice (HIP), UR provides a spectrum of other academic and intellectual benefits (Brew 2006; Kuh 2008). Characteristically, institutions offer UR through undergraduate research experiences (UREs). These are traditionally for high-achieving students who work on projects that contribute directly to the expansion of knowledge under the mentorship of primary investigators (Zimbardi and Myatt 2014, 239). To expand the spectrum of UR opportunities, institutions offer course-based undergraduate research experiences (CUREs), which are discretely packaged laboratory activities embedded in instructional curricula (Dolan 2016, 1). CUREs allow institutions to serve a greater number of undergraduates earlier in the academic program than traditional UREs, often at the

introductory level. CUREs benefit a wider range of students than UREs by providing a more accessible entry point to scientific research, regardless of the prior experiences of students or their plans to engage in further research apprenticeship (Bangera and Brownell 2014).

UREs and CUREs alone do not fulfill the diverse student needs found at institutions variously referred to as "third tier" and "fourth tier" (Labaree 2017, 11), "opportunity-granting" (Barlow and Corbett 2017, 60), or "ladder schools" (Halikias and Reeves 2017). These types of schools are also "anchor institutions" for their communities (Harris and Holley 2016, 8). Together, these terms are organized around institutional missions and cultures that focus on providing "social access" rather than "social advantage" to students (Labaree 2017, 8–13) and are "equity-oriented," indicating that they do not just position themselves as diverse by virtue of their student populations (Jayakumar and Museus 2012, 16). Instead, they strive to address systemic problems facing their students and communities as a core part of their mission.

These problems include the pervasive effects of structural inequality such as the lack of adequate academic preparation; food, housing, and income insecurity; or the need for orientation to the cultural dynamics and bureaucratic exigencies of the higher education environment. These issues are endemic at many equity-oriented institutions, and they affect retention and persistence in significant ways (Carter 2006). Students who face these problems move out of STEM programs, lag in progress toward their degrees, or fail to complete their degrees (Palmer, Maramba, and Dancy 2011). An ATC approach allows student populations who display the range of needs, interests, and capabilities found at equity-oriented institutions to experience the benefits of engaging in inquiry by opening up research activities to general education courses and other points across the curriculum (Hagedorn and Tierney 2002).

The importance of diversifying and expanding the avenues by which students can access UR is felt directly at equity-oriented institutions, due to both the desire to expand educational opportunity at the core of their missions and the sustained growth in diversity of their student populations. More students of all backgrounds are attending equity-oriented institutions (Espinosa et al. 2019). In fall 2017, 35 percent of all undergraduates attended two-year institutions (Ginder, Kelly-Reid, and Mann 2019, 4), and public two-year colleges enrolled more students than any other category of institution, including traditional universities (Espinosa et al. 2019, 37). Across all public institutions, 31 percent of first-year, full-time students attended two-year colleges, but this included 36 percent of black students and 43 percent of Hispanic students (Ma and Baum 2016, 5). Many equity-oriented institutions, like those designated as Hispanic-serving institutions (HSIs), are by regulatory definition underresourced and educate students who may not have attended college in a previous generation (Congressional Research Service 2008). The number of designated HSIs at which populations of Hispanic-identifying students exceeded 25 percent of the enrollment total grew from 137 to 435 between 1990 and 2014 (Boland et al. 2017, 4). In 2017, 523 institutions were designated as HSIs (Hispanic Association of Colleges and Universities 2019).

The ATC Approach to Undergraduate Research

Given the growth of enrollment at equity-oriented institutions and particularly two-year colleges, it is appropriate to consider their UR status. City Tech is a nonresidential, metropolitan, STEM-focused HSI and minority-serving institution (MSI) offering 26 baccalaureate and 27 associate's degree programs to 17,000 students per year, most of whom speak languages other than English at home. Over the last 20 years, most of the college's external STEM grants directly supported UR or the development of innovative undergraduate programs benefiting from UR in some way. The college offers hundreds of UREs and CUREs to its students each year and also provides these opportunities through bridge programs for middle and high school students. Since 2018, students have published or presented externally with faculty more than 160 times (New York City College of Technology–CUNY 2020). In many instances, however, these are the same high-achieving students working with the same faculty mentors over several years. To meet the wide-ranging need for inquiry-driven, experiential learning opportunities for all students, the college has deepened the continuum of UR activities and pedagogical scaffolds that support both UR and other HIPs intertwined with UR to establish a vibrant ecosystem for research.

Although hundreds of City Tech students participate in mentored UREs and formal CUREs each year, there is the potential with the ATC approach for every student to take part and benefit from developing the skills that inform the foundations of research and understanding how this translates to the ability to do meaningful work. Effective instruction is essential to achieve this goal. The college offers students the opportunity to engage in twenty-first-century problems relevant to their professional and sociocultural contexts (Nunez, Murakami, and Cuero 2010; Villatoro et al. 2019). During the Title V grant that funded the Living Lab from 2010 to 2015, unpublished data on experiential learning opportunities (ELOs) collected for the 2014-2015 school year indicated that more than 15 percent of students directly participated in formal UR activities, either in UREs (in the laboratory or in the field) or clinical practicums. At least 56 percent of students participated in ELOs across the curriculum, including all UREs, paid and unpaid internships, cooperative education, service learning, clinical practicums, field studies, civic engagement opportunities, campus leadership roles, and international applied learning.

TABLE 1. Select Examples of ATC Activities

Semester	Activity	Department(s)
Fall 2011	Two faculty members teaching the same first-level general education course brought together their two sections on one OpenLab site, and students partnered across sections to time their walk across the Brooklyn Bridge and used course concepts to calculate its length. They wrote about this in a public report.	Mathematics
Fall 2013	Students in a two-course learning community hosted a project on the OpenLab to share information—including study skills, navigation of the campus, and notable area attractions—as the culmination of their one-semester service-learning project. In subsequent semesters, students of other Living Lab faculty fellows built on this work with additional topics and materials.	English, Hospitality Management
Fall 2014	A group of upper-division students in a studio course prepared and delivered a master building plan for social service agency clients in the Industry City development zone.	Architectural Technology
Fall 2014	A group of design practicum students walked through a neighborhood in Brooklyn known as a creative hub and conducted a case study of local companies that would be willing to hire design interns. The results and other experiential coursework, such as field journals and usability reports, were part of students' OpenLab portfolios.	Communication Design
Fall 2014	A group of general education students conducted qualitative field research at locations such as SIMS Sunset Park Municipal Recycling Facility and blogged on the OpenLab about factors they discovered were related to Anthropocene climate change.	Social Science
Spring/Fall 2017	A faculty learning community developed through a SENCER Summer Institute led to a virtual student learning community on the OpenLab that focused on human impacts on the environment through evidence-based inquiry into the implications of deicing roads with salt (Mazumdar, Benakli, and Brown 2019, 5–7).	Chemistry, English, Mathematics

Although CUREs and classroom-based ATC activities were not officially surveyed categories, and no institution-wide data yet exists to assess the impact of these activities, an opportunity clearly exists to involve even more students and more often with research thinking and practice through an ATC approach. The ATC approach, with its melding of inquiry and analysis, place-based learning, and communication of progress, provides the direct learning support that often benefits students in equity-oriented institutions by allowing them to develop complex problem-solving skills in an environment with more frequent opportunities to practice them in meaningful contexts. Table 1 highlights examples of ATC activities by semester and academic department. What all of these examples demonstrate is relocation of knowledge acquisition from textbooks and lectures to knowledge creation through observation, analysis, creative thinking, and consensus building. These SLOs build students' ability to think about problems in the way research experience allows them to do. The health of the UR ecosystem on campus depends on continuous exposure of students to ATC activities in formal, countable ELOs (including UREs and CUREs) as well as in activities designed to treat them as "embodied learners" (Horn and Wilburn 2005, 750) by meeting them where they are in their learning process and making "the individuals in each group of students the heart of each semester" (Barlow and Corbett 2017, 76).

Implementation of ATC Undergraduate Research

An ATC approach to UR supports student development in ways that are attuned to their wide-ranging intellectual needs and professional goals while keeping in mind that learning is not a discrete or stepwise process (Seaman 2008). Students at equity-oriented institutions often come from low-income, first-generation, or non-traditional backgrounds. These institutions must have a strong focus on programming to address a continuum of needs for academic preparation, general education, and professional workforce development. The accessible and varied activities of the ATC model can complement this curricular environment by multiplying the points of entry into research available to students. ATC activities introduce the concepts and skills that scaffold research in as many locations as possible and as often as possible (Narum, Frederick, and Palladino 2017). Although they are not traditional UR, these research activities focus on the practices and principles associated with research design, do so with context-based opportunities relevant to students' academic courses of study, and are grounded in the processes of empirical inquiry.

The ATC approach draws inspiration and terminology from the Writing across the Curriculum (WAC) movement, which disperses the teaching of writing from English departments

into instructional curricula throughout the institution. WAC casts writing as a tool for inquiry, development, and reflection in courses of different levels, topics, and formats (McLeod 1987). Other fields have adopted ATC approaches to distribute inquiry, knowledge-making, and experiential learning activities into courses not usually designed to focus on disciplinary skills or practices like research. With an ATC approach, the research experience can be scaffolded, not only in one project or across projects in one course but throughout all coursework completed by a student toward an associate's or baccalaureate degree. An ATC method fosters the inclusion of research activities outside of traditional STEM fields and extends the important components of research-based thinking and practice into the wide array of courses students take, whether in general education or within a major, whether introductory or capstone, and whether the course meets in a traditional laboratory space or not. Ideally, this scaffolding provides students who have many different intellectual, social, cultural, and professional needs as well as various levels of preparation with multiple opportunities to move through progressively more complex and challenging research experiences and see how research practices inform their education more broadly.

Integrating research-oriented general education student learning outcomes (SLOs) into courses (in the arts and sciences and the professions alike) benefits students' abilities to apply and practice the knowledge, skills, and values they acquire in different contexts through applied problem-solving activities (New York City College of Technology–CUNY 2019). These contexts may include courses in students' majors, courses in elective areas, traditional UREs, student-led clubs, or (as many students at equity-oriented institutions are already in the workforce) their professional lives. Courses across the curriculum, both in general education requirements and in those in their major fields, may ask students the following:

- To derive meaning from experience and gather information from observation;
- [T]o use creativity to solve problems;
- [T]o gather, interpret, evaluate, and apply information from different sources to disseminate across cultural and linguistic barriers;
- [T]o work with diverse teams to build consensus in knowledge-making; or
- [T]o transform information into knowledge and knowledge into judgment and action. (New York City College of Technology–CUNY 2013)

By melding general education SLOs with experiential, inquiry-based projects that rely on collecting data, recursive thinking, testing assumptions, and broader twenty-first-century literacies and skills, equity-oriented institutions can provide students with opportunities to build their aptitude to engage in research-based thinking whether or not they further apply this aptitude in traditional UR contexts.

Equity-oriented institutions are particularly suited to benefit from an ATC approach. Although UREs provide excellent capstone experiences for prepared students, just as CUREs bring research into coursework at critical points in the intellectual and disciplinary development of undergraduates (Corwin et al. 2018), incorporating research-oriented general education SLOs will bring the benefits of UR to areas other than the traditional laboratory and to more students, many of whom may otherwise have little to no exposure to the kind of iterative, procedural, data-informed thinking introduced by UR. This expansive, inclusive, and wide-reaching approach exposes students to research experiences of various kinds throughout their undergraduate careers so that they may use what they learn about inquiry outside of disciplinary boundaries and in a variety of real-world contexts (Cantor et al. 2015). Faculty also can use ATC activities to recruit diverse students who might otherwise not consider UR to pursue increasingly more rigorous and formal research experiences (Shanahan 2018).

Integrating an ATC approach into the curriculum depends on an institution-wide commitment, not just to UREs and CUREs but to all the activities that involve and support research more generally. The ability of an institution's UR ecosystem to provide opportunities across the curriculum depends on provisioning resources that encourage instructors to integrate UR and other HIPs into their pedagogy and support these efforts over the long term. Institutional buy-in, especially in the form of tangible resources, is essential for the cultural shifts necessary to expand UR across the curriculum. In his own research, Mitchell Malachowski (2003) advocates for a shift in conducting research at primarily undergraduate institutions (PUIs) to foreground student learning and research opportunities. PUIs, he argues, must commit to prioritizing resources and recognition in hiring, tenure, promotion, and compensation for UR activities.

Others also have noted that realigning resources for faculty who engage in UR work, although necessary, is not common (Baker et al. 2018). In their efforts to increase inquiry-driven activities for students, Kimberly Eby and Laura Lukes (2017) call for institutional support for classroom transformation and faculty learning communities to make meaningful changes to pedagogy in these transformed spaces. These examples highlight the value of support for faculty and their involvement in reshaping learning experiences. At City Tech, institutional support for and from the entire faculty, not only research principal investigators, drives the development of the UR ecosystem and its ATC approach. For example, to better support

TABLE 2. Participation of Faculty in Living Lab Seminars

Seminar type	Faculty participants	Full-time status	Part-time status	Participating departments[a]
Grant-funded Living Lab seminar (2011–2015)	177	118	59	27 of 28
Institutionalized Living Lab seminar (2016–2020)	74	32	42	18 of 28
Total	251	150	101	27 of 28

[a]Twenty-eight academic departments were eligible to participate.

faculty and students, the UR committee collaborated with the Center for Teaching and Learning to develop and lead workshops about mentorship, which culminated in the committee-authored *A Handbook on Mentoring Students in Undergraduate Research: Proven Strategies for Success* (Brown et al. 2016; New York City College of Technology–CUNY 2016).

The ATC Community

Because of its mission as a STEM school, City Tech provides the benefit of what Emo et al. refer to as systematic and structured experiential learning to students (2015). As an equity-oriented institution facing deep, long-term fiscal austerity that will continue indefinitely, it has been challenging to update curricula to keep pace with the evolving needs of the urban technical workplace. The expansion of our curriculum and faculty over the last 15 years has seen global changes at the college that include making general education more meaningful and connected to students' fields of study. To facilitate this transformation, the college has invested deeply in professional development programming and community support to help faculty transform their courses. These investments expanded and formalized the ATC approach through the Living Lab's professional development program and continue to be supported on an ongoing basis by the OpenLab.

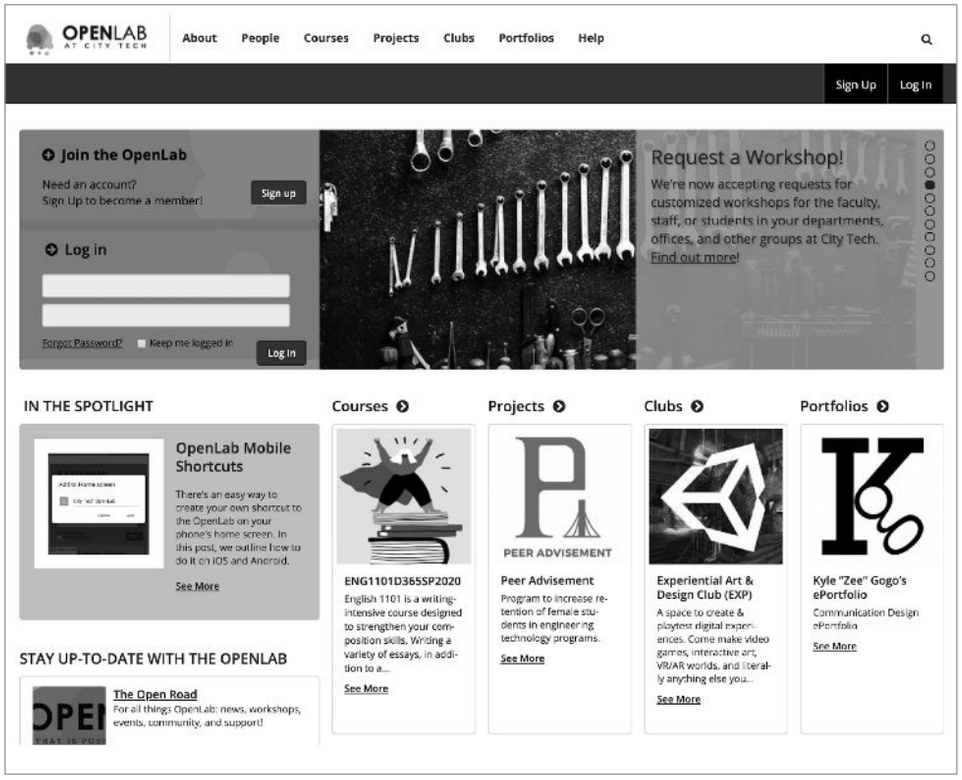
Innovation in Faculty Professional Development: The Living Lab

Funded by a US Department of Education Title V grant for HSIs, the Living Lab imagined that any classroom could become a kind of laboratory, much like the classroom-turned-laboratory recommended by Friend and Morris (2013) to create opportunities for experimentation, failure, discovery, and success. Further, the Living Lab reimagined the classroom experience to extend beyond the physical classroom into the communities and environments surrounding the college. The Living Lab used HIPs to construct an undergraduate experience from a meaningful general education combined with the applied disciplinary learning found in the college's technical programs. The grant integrated experiential learning, place-based learning, service learning, capstone experiences, and the OpenLab open digital platform to create an ATC approach and introduce students to the twenty-first-century literacies, skills, and tools needed to become educated and competitive professionals.

In the Living Lab, the mechanism for widespread cultural transformation was a cyclical faculty development seminar designed to institutionalize the integration of newly revised general education SLOs, the HIPs intended to accomplish them, and place-based learning across the curriculum, using the college's Brooklyn location as a laboratory (Leonard and Goodlad 2018). A major implementation of the Living Lab seminar was a cohort model: fellows received a course release to participate in one intensive semester and then three follow-up semesters in which they redesigned courses and collaborated with other members of their cohort. The college also recruited both full- and part-time faculty for a shorter seminar that compensated part-time faculty and offered recognition of service to all participants.

In both formats, fellows attended workshops, place-based experiences, and pedagogy seminars. They engaged with relevant research methods, collaborative discussion, mentorship, and the tools and practices available to them to turn their courses into laboratories for applied learning to engage their students. During the official grant period, 177 full- and part-time faculty (out of the college's 404 full-time faculty and more than 1,000 part-time faculty) participated in the professional development (Leonard and Goodlad 2018, 150–151), with members from all but one academic department (see Table 2). Since the end of the grant-funded seminar in 2015, the professional development has continued each year, involving approximately 15 full- and part-time faculty members per seminar, for a total of 74 to date, representing the range of departments and majors, providing compensation for part-time faculty members and recognition of service to all. It was essential for the success of the ATC approach that the seminars include part-time faculty, who teach most courses at the college.

FIGURE 1. The OpenLab Website, February 18, 2020



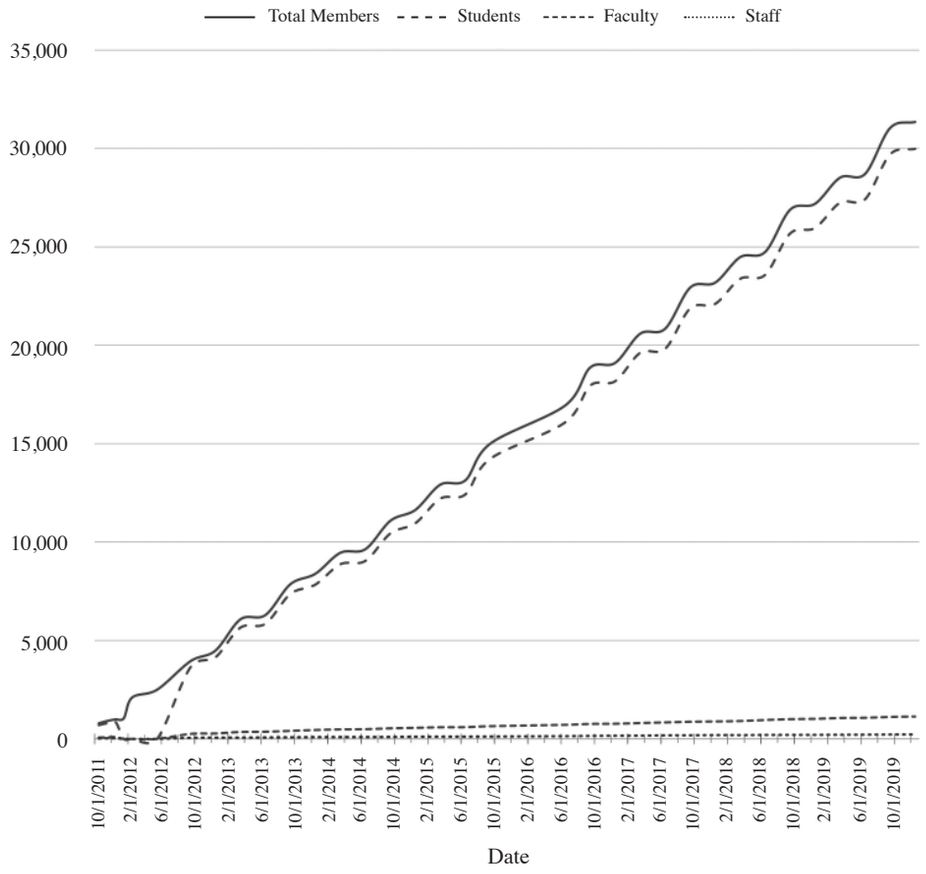
Innovation in Academic Community Support: The OpenLab

The OpenLab (OpenLab 2020; see Figure 1) is a bespoke, open-source, online platform developed to be an enduring part of the Living Lab. Its core function is to create connection and community across the college among students, faculty members, staff members, and alumni alike. Designed as an open network to inspire and create an online laboratory for experimentation and innovation, the OpenLab is itself proof of what a college can do when challenged to enhance the intellectual and social life of its community by networking and making visible the contributions of its members. It is a robust and heavily used digital platform for activities that fall within the ATC approach, with a steady increase in membership from its beta launch in 2011 to more than 33,000 current members (see Figure 2). Faculty and students from all 28 departments are active on OpenLab, as are staff members from a variety of offices and divisions. The vast majority (nearly 95 percent) of members are students. Accounts do not expire, so members of the OpenLab can continue to access their accounts as needed during, between, and beyond enrollment or employment at the college. In the 2018–2019 academic year, roughly 8,000 student members used the OpenLab. Open by default, the platform is available to nonmembers and non–logged-in members as well, both at the college and outside it.

The OpenLab creates a public space for "opportunities for collaboration, participation, and co-creation that are unthinkable with closed, proprietary software solutions," including coursework, UREs, CUREs, other ATC activities, and campus projects (Edwards et al. 2014). Membership provides a practical, hands-on opportunity to develop a relevant technological proficiency with a widely used software (WordPress.org 2018), to consider the possibilities of sharing work with larger audiences, and to implement best practices for online content.

The OpenLab provides a virtual space for the kind of immersive pedagogy that moves classrooms and their adjunct spaces toward a Freirian concept of education in which students and instructors are collaborators in knowledge production (Rosen and Smale 2015). The opportunity to share coursework openly means that the courses themselves become iterative, experimental spaces that allow students and faculty to collaborate, developing new possibilities for learning across courses and within particular disciplines. These acts of public blogging help students develop skills, including public writing and the technological savvy to publish their work, as they disrupt and transform the academic class structure "from knowledge consumption to knowledge production" (Owens 2012). Using open digital pedagogical spaces like the OpenLab does not merely offer an alternative medium but benefits students by offering meaningful opportunities to share

FIGURE 2. Member Growth in the OpenLab, Fall 2011 to Fall 2019



work with classmates and the world beyond the course, as opposed to submitting work solely to an instructor (Sample 2012). On the OpenLab, all members can chronicle their research, use blogs to update incremental work, and make visible multimodal data, sharing course learning and research projects that serve both the internal and external audiences with whom they engage and interact. Potential collaborators can avail themselves of content on the OpenLab, whether those collaborators are other students in the same field; students in related disciplines; individuals working on co-curricular or extracurricular projects or campus-wide initiatives; or students, faculty, employers, researchers, or industry professionals outside the college.

Conclusions

To position twenty-first-century students at the heart of UR ecosystem activity, there must be support for the twenty-first-century instructors who educate and mentor them, and frameworks such as the ATC model must be built to institutionalize their work. Instructors, as faculty fellows in the Living Lab general education seminar, have transformed the learning experiences in their courses and provided ATC opportunities, supported by participation in professional development to learn to use mapping technologies, to transform the neighboring environment into a living laboratory, and to use open digital pedagogical tools that bring students together and allow them to share their learning processes and accomplishments. These advances would not have been possible without an institution-wide focus, faculty peer leadership with support from the administration, and a platform like the OpenLab. The Living Lab and OpenLab were major achievements in institutionalization of an ATC model of UR and other congruent HIPs. Efforts continue to engage interested faculty across the disciplines, and even other institutions, in development of curricular activities, projects, and modules that accomplish SLOs through the ATC approach.

The legacy of the Living Lab resides in the students who have benefited from this meaningful general education experience, the faculty members whose pedagogy has been transformed, and the institutionalized resources. One resource is the ongoing general education faculty development seminar, which continues to engage faculty from diverse disciplines in multi-session seminars that explore HIPs. Critically, a significant portion of support

for developing ATC approaches has been institutionalized so that tools and resources are available for any faculty members interested in incorporating inquiry-based, experiential learning opportunities into their courses, regardless of program, discipline, course level, or tenure status. The Living Lab Learning Library (L4, OpenLab n.d.a.) houses a wide array of teaching materials; it is a public resource that anyone may draw from and contribute to. The Place-Based Learning Toolkit (Open Lab n.d.b.) provides resources and readings for incorporating place-based modules into courses or seminars. Beyond the institutionalization of the OpenLab is the recently launched Commons in a Box OpenLab (Graduate Center–CUNY n.d.), which allows other colleges, universities, institutions, and organizations to host and grow OpenLabs of their own to support open pedagogy and community engagement in all of its forms.

The Living Lab and OpenLab provided the tools to motivate a cultural shift at the college and expand the position of research in twenty-first-century undergraduate education; however, the long-term impact of the ATC model extends beyond the Living Lab, and even the OpenLab. Today, they are both part of a larger program of growth at a robust baccalaureate STEM institution that includes the 2018 addition of a 365,000-square-foot academic building for clinical health-care and laboratory science programs and newly approved majors in applied computational physics, biomedical informatics, and data science, all of which are supported by faculty who engage regularly in UR. In cooperation with Cold Spring Harbor Laboratory, a 19,000-square-foot DNA Learning Center will open on campus in 2021 and offer six laboratories delivering more than 500 DNA science–based CUREs to undergraduates, 550 secondary education summer camp slots, and 15,000 field trip experiences to NYC public school students per year (City University of New York 2017).

These recent additions to the college's research landscape will dramatically expand the UR ecosystem, but real and lasting changes in student opportunity will manifest through the interplay of institution, faculty development, pedagogy, and community over time. Not insignificantly, the dramatic institutional growth the college has effected over the last decade to meet the needs of twenty-first-century students also comes with unanticipated costs and challenges. One of the primary costs of a rapidly shifting institutional culture in an austerity environment is the lack of resources to coordinate institution-wide integrated collection of data (beyond IEPDS and accreditation-related requirements) that would provide an effective basis for assessing change and integrating its narrative more fully. As an equity-oriented institution, City Tech continues to seek effective ways to measure the impact of research efforts more generally in the short and long term, including participation in a 2020 ARIS (Advancing Research Impacts in Society) fellowship devoted to assessing impact pathways for research at MSIs, beginning with its own.

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