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A How-To Guide on Bringing Undergraduate Research to Community and Technical Colleges

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Increasing the interest and participation of students in STEM is a priority for colleges, universities, and the nation as a whole. As new generations of students embark in training and in learning novel technologies to deal with the challenges of emerging infectious diseases, crop and food production, and the development of new and better sustainable alternatives in the face of a changing environment on our planet, we must also evolve our approach to teaching and learning. One strategy that may be found helpful as students face the challenges ahead is to instill inquiry and problem-solving skills as part of their education as early as possible, whether they pursue a technical career or a graduate college degree. Although many existing technical and community colleges were built with the purpose of teaching a specific skill to supply the demand of a workforce in developing industries, the disappearance of some industries and evolution of others call for a different approach to teaching and learning at this level of education. Here, we present two alternatives to teaching and learning, by implementing scientific research that can result in the development of more holistic students, who are ready to tackle the challenges encountered as they graduate and enter the workforce.

INTRODUCTION

Many community and technical colleges do not have the infrastructure and resources to support scientific research activities on campus. Research shows, however, that early exposure to undergraduate research experiences increases persistence and success, as well as closing achievement gaps in the sciences (1–6). With calls to increase the number of STEM graduates by millions, increasing accessibility and exposure of students to undergraduate research opportunities is a must.

Students choose community and technical colleges over research universities for a myriad of reasons: including cost, proximity to resources, and perceived ability to succeed (7–10). This gives community and technical colleges a unique opportunity to serve a population that may not have all of the resources needed to succeed at a research university. While there are many universities that have the resources to

serve STEM majors, at the community college and technical college level, there are fewer resources available (11). For this reason, the focus of this article will be on community and technical colleges.

The mission of many two-year colleges differs from that of universities, as the focus is on employment rather than the quest for knowledge (12). Many community and technical colleges have programs that are in high employment demand for two-year degrees, such as allied health programs (nursing, dental hygiene, and respiratory therapy), but lack formal science programming. Proposed possible reasons for this include the perceived lack of employment opportunities at the associate's degree level in the sciences and the level of rigor in two-year programs being perceived as inadequate to ladder into a four-year science major (13, 14).

Northeast Wisconsin Technical College (NWTC) is a small technical college in Green Bay, Wisconsin, serving about 20,000 students each year. Like many other technical colleges, NWTC lacked a formal science program and had no capacity for scientific research, though faculty members who taught science classes to allied health program students thought a formal science program would be beneficial to both the student population and the larger community. Through much hard work, the faculty members at NWTC not only built a science program but also built the capacity for students to participate in undergraduate research. The following outlines how this was done and offers some practical advice on how interested faculty members can do the same at their institutions.

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Do your homework

At community and technical colleges, there will most likely be two audiences that faculty will need to persuade that bringing science programming and research onto campus is a worthwhile endeavor. These include institutional leadership, who may not have a background in science, and colleagues to assist in the endeavor. For many at the institutional leadership level, finding the best way to recruit, retain, and graduate students is a priority (15). There are many high-quality studies on the positive effects of undergraduate research experiences on student outcomes (16–21). However, colleagues are likely to have other concerns, including whether the students are ready for the rigors of scientific research or the faculty have enough time, with traditionally higher teaching loads. To assist with faculty buy-in (22), while still relatively new, there are examples of successful implementation of research-based programs elsewhere, as compiled by the Community College Undergraduate Research Initiative (CCURI) (23), ASM Conference for Undergraduate Educators (ASMCUE) (23, 24), the Small World Initiative (now TinyEarth) (23–25), and the Science Education Alliance-Phage Hunters Advancing Genomics and Evolutionary Science (SEA-PHAGES) programs (26).

Build a science program backwards

At a community or technical college, the students may be seeking either to further their education or to find employment after graduation. To meet the needs of the students, it is first important to find out the needs of potential employers and universities. For faculty at NWTC, this meant reaching out to employers in the area about the skill set needed for entry level positions. This started out as a simple e-mail asking for feedback about their preferred skills for new employees. Many employers across the sciences listed several skill sets needed to be successful at their company, and surprisingly, the skill sets were consistent: pipetting, accurate measuring, following standard operating procedures (SOPs), and accurately recording data. The employers were enthusiastic about the formation of this program, as many stated that they have to do much of the training onsite, using up valuable resources.

After faculty met with employers, they met with local university partners across the state. The goal of these meetings was to discover what skills and knowledge students would need to acquire in order to successfully transfer into a four-year degree at the university. Faculty from NWTC listened to the concerns and suggestions from faculty at the universities, and surprisingly, here too, the concerns and suggestions were consistent across the universities. This allowed for the development of program outcomes, which included the following: synthesize theoretical knowledge and empirical results to build understanding of complex scientific processes; apply the steps of the scientific method to solve problems; design sound laboratory protocols and

experiments; execute common laboratory procedures and measurements with precision, repeatability, and validity; collect, document, and analyze data from laboratory procedures and report results and conclusions; and model safe, hygienic laboratory practices. Many of the university partners were excited about the formation of this program, as this represented not only a new pipeline for student transfers, but also access to trained students to assist with research projects, where grant dollars are precious and any mistake is costly.

After these meetings, a curriculum was designed and developed to fulfill the needs of the university partners and employers using a competency-based approach. The curriculum was then presented back to the universities and employers, who overwhelmingly approved it. Many employers and university partners also agreed to be on the advisory committee for the program. This entire process took roughly a year to achieve.

Building a lab

With many new courses being proposed and research experiences being built into the curriculum, a new laboratory was required. To this end, an old underutilized physics classroom was selected to renovate into a laboratory in which both classes and research could be conducted. The state of Wisconsin offers block grants to help build capacity for new programs, and since this was a new program that was projected to bring in new students, the block grant was awarded. It is of utmost importance to be involved in every step of a lab renovation. Working with contractors and room designers, the person responsible must map out every detail, from Americans with Disabilities (ADA) compliance to placement of potential equipment, as well as voltage needs and light placement. During the process of planning the space, it is also important to work with equipment vendors. Many companies offer new lab programs that include deep discounts on equipment or inclusion of consumables. It is important to get many quotes from multiple companies and let the companies compete. Measurements of all equipment must be included in these quotes and provided to room design contractors. Though money and space may be limited, it is important to plan ahead and get the greatest capacity for storage equipment, such as freezers and refrigerators, first. The next priority is equipment used for routine manipulation, such as pipettes, centrifuges, and incubators. Finally, specialized equipment, such as PCR machines or biophotometers, should be considered.

When designing a lab on a budget, maximizing the amount of equipment should be a priority, even if some may not be immediately needed. Patience is also required, as construction and shipping delays are common.

With consumable reagents, many companies will offer similar new lab discount programs. Some companies also offer free reagents for educational use. It is important to maximize the use of discount programs and storage

capacity. When needed, it is also important to consider making and storing your own reagents, such as competent cells and glycerol stocks of bacteria.

Funding mechanisms

With the laboratory in place and small quantities of reagents to use, the next step is to find ways to fund research on campus. There are grants that are available to help develop research programs, such as the National Science Foundation's Advanced Technology Education (ATE) and Research Experiences for Undergraduates (REU) programs, and the Major Research Instrumentation (MRI) Program (27). Starting a brand new research program presents a unique situation, as many grants require preliminary data to receive funding. To address these issues, one can take advantage of several offers that vendors have. As previously mentioned, vendors will offer deep discounts to new labs, and some offer free trial reagents or free reagents to teaching laboratories. Further, many vendors have academic labs "field test" their reagents to see how they perform. Local area employers may also be able to share resources on projects that they can give to students on campus because of changing priorities at the company. Partnering four-year universities may be willing to collaborate and share grant opportunities with two-year schools as well. Former primary investigators also may share resources created during post-doctoral or graduate fellowships or may share preliminary data to help with grant opportunities.

Academic departments may open some money for research, finding savings due to faculty retirements or by running student labs more efficiently. Deans and department chairs may be open to course release time when research time involves students.

Another unique challenge at the two-year college level is the traditionally high teaching load of faculty (28). Many institutions, however, do not require a high workload in the summer months. At NWTC, the department agreed to fund 100 hours during the summer as instructional time for an on-campus research internship. This also came with a small budget for consumables per student. Instead of receiving pay for the summer, the students received a credit for their research. While this time with students is limited, it has allowed for the collection of preliminary data on faculty projects. Through negotiations with department deans about the value of on-campus research and the possibility of grant funding in the future, the department agreed to some credit-hour workload release if a grant is acquired by a faculty member.

Be prepared for multiple rejections

Due to limited resources, changes in demand, economic pressures, and political reality, faculty need to be patient when trying to build a research program (29). Rejection should not be taken personally or as an indication that an

idea does not have merit but rather as an opportunity to listen to concerns and to remove those concerns in future proposals. The process of building a science program at NWTC took five years, the continuous effort of many faculty, and commitments from leadership at the college and state level.

Building research into a new curriculum

Part of what ensured the curriculum married the needs of the university partners and the employers was the inclusion of three experiential courses: Laboratory Internship, Experimental Design, and Capstone. Most of our industrial and academic partners felt the best time for the internship would be during the summer months. Even though the internship would only require a minimum 80-hour experience, these external partners indicated that they would prefer that the students work a minimum of 30 hours per week for 8 to 12 weeks of the summer. While most industry partners agreed to pay students for such a commitment, many students at NWTC are considered non-traditional or as belonging to an underrepresented group, and having to give up existing higher-paid full-time employment to fulfill an internship requirement would represent a great hardship to some students. In response to this, the biology faculty developed an internship experience that allows for greater flexibility. In this model, through an internally developed competitive application process, a student would participate in a collaborative project of the faculty member's design; the 80-hour requirement would still exist but would be spread over 10 weeks during the summer semester.

During the third semester of the program, the students participate in an experimental design course. Here, they learn how to research a question, formulate a testable hypothesis, propose a project, design experiments, defend their rationale, and execute experiments. Students who wish to pursue a project in the biology track work under the guidance of a biology faculty member to assist with the question, scope, and cost of the project. Biology faculty members present the students with synopses of their projects, and students can design projects within the bounds of the capacity of the lab, faculty expertise, and the aim(s) of the faculty project(s) being done at the time.

During the capstone course, students work in teams (under faculty guidance) to execute the experiments proposed during the previous experimental design course, record and analyze data, troubleshoot, and repeat when necessary. At the end of the project, a symposium is held where students present their project (either orally or in poster form). Some projects may also be publishable, and the Council for Undergraduate Research (CUR) maintains a list of journals that regularly publish undergraduate research. Another example of building research into the curriculum is through preexisting course structure. There are many advantages in taking this approach, great examples of which come from the City University of New York.

Developing and integrating research into preexisting curricula

As mentioned earlier, community and technical colleges do not possess the infrastructure and resources to support scientific research initiatives on their campus for faculty and students (7, 29). A practical solution institutions may implement to resolve this problem and transition to a research-based way of educating is encouraging a collaborative space for working on practical projects intended to provide solutions to problems that affect the lives of all people. Such approaches have been proposed and implemented worldwide in an effort to encourage curricular development, pedagogy, and extra-curricular activities that enable students to develop the values, skills, and knowledge to contribute to addressing these problems (30).

Here we describe how integration of research into General Microbiology classes is being done at LaGuardia Community College, one among seven junior colleges of the City University of New York (CUNY). LaGuardia's core values are to educate and graduate one of the most diverse student populations in the country to become critical thinkers and socially responsible citizens who will help shape a rapidly evolving society.

Although most of the students who are required to take General Microbiology at LaGuardia are Allied Health majors who may not be involved in doing scientific research again throughout their careers, they can benefit from taking this research-based class, in that their life-long analytical and problem-solving skills will likely increase (3). The course stimulates scientific research interest, creating connections between students and microbes in their lives. Every student who takes the course has the opportunity to have an authentic research experience as part of their education. The literature suggests that students experience a positive outcome in collaborating with peers and reviewing one another's work, which is a crucial aspect of scientific advancement (31, 32). Research in General Microbiology at LaGuardia was first implemented in the fall of 2014. Using a scaffolding model, students gradually build their skills and experience how scientists work, starting with developing a hypothesis, collecting and isolating microbial samples, and developing a plan about what experiments to run for data collection. During the subsequent identification of their microbial specimen, they spend copious amounts of time analyzing results and making sense of the experiment's outcomes. Furthermore, students have the opportunity to learn and use molecular techniques and identification protocols that other microbiology classes do not use. Finally, they are required to submit their project for assessment in manuscript format. Due to the amount of time and attention students need from the instructor for guidance and feedback, the course is limited to 16 to 18 students per class.

Although we do not have enough data yet at LaGuardia to suggest that teaching a research-based course is a more effective way of teaching science, positive feedback has been

received from students who have taken the class. Some students even changed their minds about staying in the Allied Health Field and switched into the Biology, Environmental Science, or Liberal Arts and Science Programs to further pursue research and/or a science career at a senior institution or university. The approach to teaching and learning science through research in the curriculum is a model used in various institutions, including LaGuardia for upper-level science students (e.g., capstone courses) (31, 32, 33). Evidence suggests that this pedagogical approach (course-based research experiences) increases students' mastery of content, their interest and enthusiasm in the laboratory exercises, and their critical thinking skills (34). The CUR maintains a consortium of many schools that have course-based undergraduate research experiences (CUREs) that have now become an established part of STEM education.

Final thoughts

Community and technical colleges face many challenges that often discourage faculty and administrators from implementing extracurricular and research-in-the-curriculum programs. Yet the examples provided in this article demonstrate that by pooling both human creativity and economic resources, research programs can be developed and implemented at junior institutions. Our goal is to educate community college and technical school students with new technological and pedagogical tools. Only by exposing students to the many possibilities that exist can we unpack their academic and intellectual potential. Historically, research was limited to Ivy League schools or primarily research institutions; however, scientific research can now be made available to students of low economic status in traditional teaching institutions by utilizing the methods mentioned here. Whether by creating new programs to meet university and employer needs or building research into the curriculum, new faculty are not only bringing ideas to these institutions, but making research initiatives a reality. Development and implementation of research programs are pivotal to educating the new generation leaders.

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