A Pandemic-Resilient CURE Shifts Community College Students From Knowledge Consumers to Authentic Knowledge Producers

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Academic food security aims to provide students with sufficient access to knowledge (one key academic nutrient) in order to limit intellectual hunger. In this analogy, the student is seen as a consumer of knowledge. Academic food sovereignty, on the other hand, aims to shift the focus from student knowledge consumership to student knowledge producership. Our efforts to democratize authentic undergraduate research experiences and our computational biology approach to the discovery and analysis of sea star ovarian gene expression aim to shift the paradigm to sustainably realize "academic food sovereignty." Essential for this paradigm shift is the realization that faculty of community colleges and primarily undergraduate institutions can be valued in equal partnership with research-intensive institutions. In this article, we report how a genuine, sustainable inter-institutional partnership formed; developed into a community-college centric, authentic course-based undergraduate research experience (aCURE); and evolved into a pandemic-resilient small tri-institutional networked aCURE. Qualitative and quantitative data on the impacts of our efforts are presented, and the broader impacts of this academic bridging and learner-autonomy-respecting bidirectional partnership are discussed. Sustainability is essential for "academic food sovereignty," and we emphasize the many legs of the proverbial stool for stability in the future.

Der Mensch ist was er isst" ("Man is what he eats"), coined by Ludwig Andreas von Feuerbach in his review of the chemist Jakob Moleschott's book *Lehre der Nahrungsmittel für das Volk*, has multiple interpretations (e.g., literal, philosophical, political), regardless of the original intent of the author (Cherno, 1963). This phrase becomes powerful when we look beyond the literal nutritional interpretation to gain a deeper understanding of food security and food sovereignty in academia, especially with respect to science, technology, engineering, and mathematics (STEM) education. Food security focuses on access to sufficient and nutritious food (i.e., no hunger), whereas food sovereignty goes beyond and adds a focus on food producers (Patel, 2009; U.S. Food Sovereignty Alliance, n.d.). But how do food security and food sovereignty relate to academia and STEM education?

Academic food security concerns the goal to provide students with sufficient access to knowledge (one key academic nutrient) in order to limit *intellectual hunger*. In this analogy, the student is seen as a consumer of knowledge, which limits curiosity. Traditional laboratory exercises work in this manner, as they feed—with minimal curiosity-derived motivation (Oudeyer et al., 2016; Singh & Manjaly, 2022)—the student a diet of protocols and examples from the buffet of the STEM field. Just as in physical food security, academic food security de-emphasizes where the knowledge comes from, how this knowledge is produced (and who produces it), and the value of knowledge providers, which may unintentionally lead to intellectual malnutrition and a lack of curiosity-derived motivation.

Academic food sovereignty, on the other hand, aims to shift the focus from student knowledge consumership to student knowledge producership (i.e., knowledge construction). This shift augments active learning within the construction-of-understanding ecosystem framework (Lombardi & Shipley, 2021) and provides sovereignty (i.e., autonomy), which enhances curiosity-derived motivation (Oudeyer et al., 2016; Singh & Manjaly, 2022). The disciplines of biology and science education had the "vision and change" to focus on knowledge production and active learning (American Association for the Advancement of Science, 2011), and the Council on Undergraduate Research (2021) supports and promotes "high-quality mentored undergraduate research, scholarship, and creative inquiry." Nevertheless, with the multiple efforts to achieve academic food sovereignty, we have yet to shift the paradigm to sustainably realize this goal. The question now becomes, How can we shift the paradigm and make sustainable impacts on science

and STEM education, even during uncertain pandemic times?

In this article, we report how a genuine, sustainable inter-institutional partnership formed and evolved into a community college–centric, authentic course-based undergraduate research experience (aCURE) with inherent pandemic resiliency. We discuss the broader impacts of this academic bridging and learner-autonomy-respecting bidirectional partnership and emphasize the sustainability essential for academic food sovereignty.

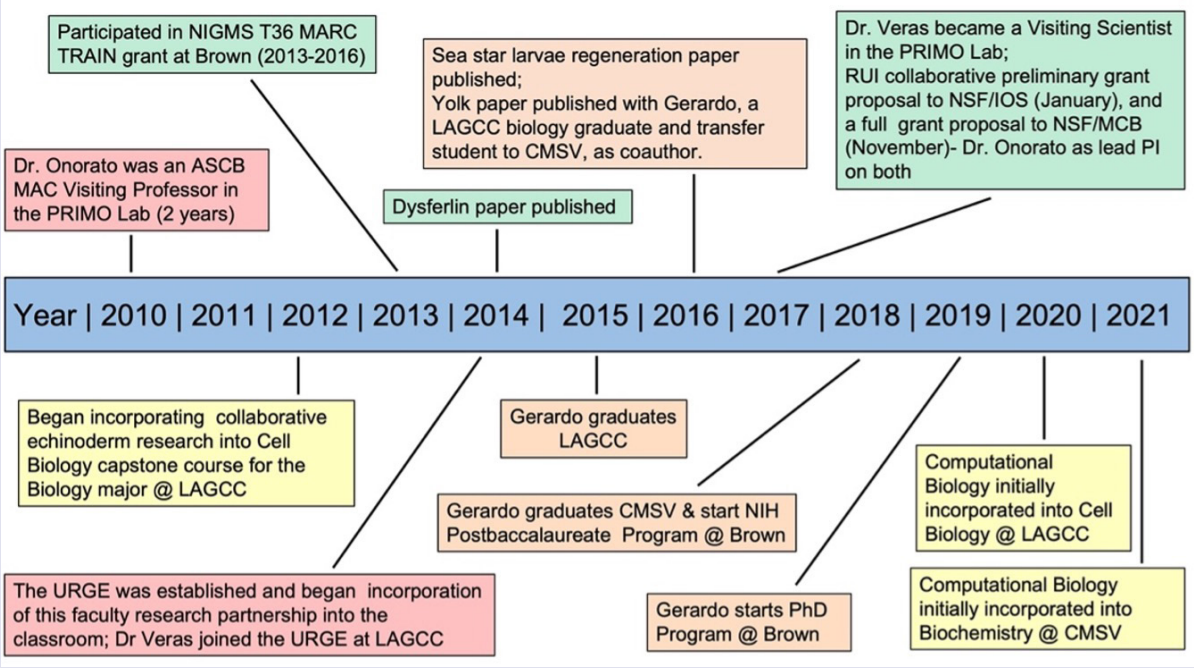
Building the PRIMO (Providence Institute of Molecular Oogenesis) and Undergraduate Research Group on Echinoderms (PRIMO-URGE) partnership

Dr. Thomas M. Onorato (one of the coauthors of this article) has been a longtime advocate for the sovereignty of community colleges, both in science education and in life science research that brings authentic undergraduate research experiences (AUREs) rooted in faculty scholarship to community college students. For instance, in 2008, he said to the then-head of the City University of New York (CUNY), "I came to LaGuardia Community College [LAGCC] to inspire the future Nobel Laureate. A lot of community college students have the potential, but to really spark an interest in research, CUNY must invest in research at the community college level" (LaGuardia Live Wire Staff, 2008, p. 2).

Onorato utilized professional development resources provided by the American Society for Cell Biology Minorities Affairs Committee (ASCB MAC) Linkage Fellow (LF) and Visiting Professorship (VP) programs to establish a research sovereignty at LAGCC. This allowed him to leverage the unique celebrated diversity of the college and broaden participation of underrepresented minorities (URMs) by providing more AUREs to the diverse and nontraditional student body (Campbell et al., 2013; Segarra et al., 2017, 2020). After using the ASCB MAC LF program to establish a more research-cognizant environment through such initiatives as the "Cell Talks" colloquium, Onorato approached Dr. Gary M. Wessel, from Brown University, in 2010 to serve as his ASCB MAC VP host scientist (Campbell et al., 2013; Segarra et al., 2017, 2020). They successfully participated in the program for the maximum time frame (two consecutive 1-year terms), resulting in three joint research publications. After ASCB MAC VP support ended, the research collaboration was sustained through mutual participation in the TRAINing for Success in Biomedical Research Careers Program at Brown University from 2013 to 2016 (grant #1T36GM101995-01; Allen-Ramdial & Campbell, 2014). These experiences led to a sustainable research collaboration that contributed significantly to the scientific research community while initiating a paradigm shift in science education at community colleges to democratize AUREs (Figure 1).

FIGURE 1

Timeline representing milestones in the ongoing research collaboration between LaGuardia Community College (LAGCC) and Brown University.

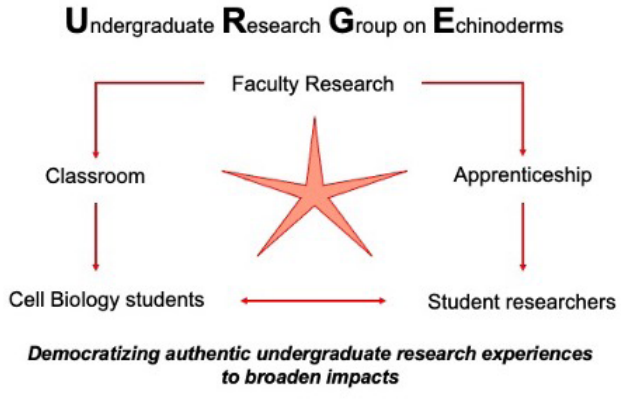


To maximize the impact of our research partnership, we discussed how to incorporate aspects of our research in echinoderm reproductive biology into the cell biology capstone course for the associate of science (AS) degree in biology. In 2012, students began performing primary cell cultures of sea star ovarian cells to try to establish an echinoderm cell line, which to this day has never been achieved by scientists (Conkling et al., 2019; Rinkevich, 2011). Students started determining the optimal conditions for sustaining long- and short-term cell cultures. In 2014, Onorato formally established the Undergraduate Research Group on Echinoderms (URGE) at LAGCC (Figure 2). As collaborative research interests evolved, the AUREs were incorporated into the wet labs. In 2016, students began to investigate sea star larval regeneration and culture of dissociated embryonic cells. In 2019, Onorato was perfecting lab techniques to study coelomocytes (the immune cells of the sea star) right before the COVID-19 pandemic forced classes online. These efforts to democratize AUREs strengthened community college sovereignty through the bidirectionality of this partnership.

Fundamental to the success of this partnership and our efforts is the mutual respect between community college and research-intensive institution faculty. Onorato and his students were an equal counterpart with significant contributions to make, and vice versa. Onorato had project ownership and sovereignty to explore his own research interests based on the collaborative research. For example, he began investigating the sea star microbiome and culturing of protists associated with the sea star *Patiria miniata*. Although these were not direct interests of priority to the PRIMO lab, Wessel showed interest, welcomed discussions, and provided input, as would two scientists discussing their research at a symposium. The educational product that indirectly and unknowingly developed from the genuine passion and core values of this research partnership between a community college and a research-intensive institution was an early stage aCURE. Our research collaboration that birthed aCURE was never meant to be a guided CURE (Doctor et al., 2021) but was driven by the aspiration to shift the paradigm of community college students from consumers to producers of authentic scientific knowledge.

FIGURE 2

The Undergraduate Research Group on Echinoderms (URGE) model.



A pandemic-resilient networked aCURE

The key element of the aCURE based on the PRIMO-URGE partnership is the incorporation of our original novel research into the cell biology capstone course. The research experience can vary each semester based on our current research projects and the feasibility of conducting experiments with students. The most challenging part is the experiment's circumstances (e.g., what can go wrong will go wrong, negative results, cell culture contamination, animals dying, and limited resources at the community college). Therefore, Onorato made the decision to teach by his own experiences and used his recent experience of writing and submitting a preliminary grant proposal to the National Science Foundation Integrative Organismal Systems (NSF IOS) division of the Biology Directorate as lead project investigator in collaboration with the PRIMO Lab and Dr. Janet E. Rollins from the College of Mount Saint Vincent (CMSV) to shape the revised laboratory assignment. Students write a group mock NSF grant proposal based on the interests of the PRIMO-URGE and can use any data generated from their wet lab experiences as preliminary data in the proposal (Online Appendix 1). Thus, students could generate a strong written assignment even if there were failed experiments. Moreover, the assignment challenged students and shifted their role from knowledge consumer to knowledge producer because they had to propose original hypotheses and experimental procedures to test while providing a broader impact of their proposed work.

The spring semester began in March 2020 at LAGCC. Students were going to culture sea star coelomocytes to (i) identify the types of immune cells present in *P. miniata* using various colorimetric staining techniques in addition to fluorescent

microscopy; (ii) purify phagocyte cells using centrifugation techniques; and (iii) determine the differential expression of the Dysferlin protein in both freshly isolated and long-term cultured coelomocytes. However, COVID-19 spun us into chaos, and in-person classes were canceled. Onorato made use of free and temporarily provided paid resources such as Virtual Urchin labs, online simulations, Labster, and JoVE to provide some type of "lab experience." Students did literature review presentations virtually and the mock NSF proposal, but these were based on current literature and past data from previous classes. These activities hardly came close to resembling the aCURE past students received. COVID-19 diluted authenticity.

Knowing the fall 2020 semester would be fully online, Onorato needed to reconstitute the authentic nature of the CURE in cell biology to a pandemic-resilient aCURE. Therefore, we evolved our collaborative efforts to continue providing an aCURE in the COVID-19–induced environment by integrating an online computational biology component into the course. PRIMO Lab faculty and graduate students attended online lab sessions, which were recorded and shared with all sections of the course to ensure students in all lab sections were included. LAGCC students in each section interacted with PRIMO Lab members, presented their preliminary findings, and received constructive feedback on their research. Our aCURE began evolution to a novel, embryonic-stage tri-institutional networked aCURE, with potential to metamorphose into a sustainable multi-institutional networked aCURE (Connors et al., 2021). The pandemic-induced shift to online learning environments, the "Zoom deluge," and the core values of our sustainable ongoing research collaboration were driving selective pressures of this evolution.

The laboratory activity involving computational biology (fall 2020 and spring 2021)

Single-cell RNA sequencing (scRNA-seq) data sets obtained from ovaries of the sea star, *P. miniata*, were provided by the PRIMO Lab during the fall 2020 semester. Students were trained to join this research using bioinformatics analyses with free online tools (e.g., Echinobase, BLAST, Pfam, and ScanProsite) to annotate the transcripts present in cells from 12 different clusters of cells with distinct transcript profiles. The students annotated these transcripts, determined putative cell type and functions of cells in each cluster, and wrote a research report by collaborating in small groups. This research provided training in tissue structure, cellular function, and reproduction, integrated with computational gene expression and molecular composition. The spring 2021 students extended these results by learning to use the RStudio program to computationally analyze and display these data. These students wrote a mock NSF proposal using their data to test their cell type analyses. The ultimate goal was to incorporate early-stage students into a world of research using an online remote-learning environment. Computational biology was initially incorporated into the cell biology capstone course for the AS in biology at LAGCC during the fall 2020 semester (one section, $n = 18$) and continued in the spring 2021 semester (three sections, $n = 46$).

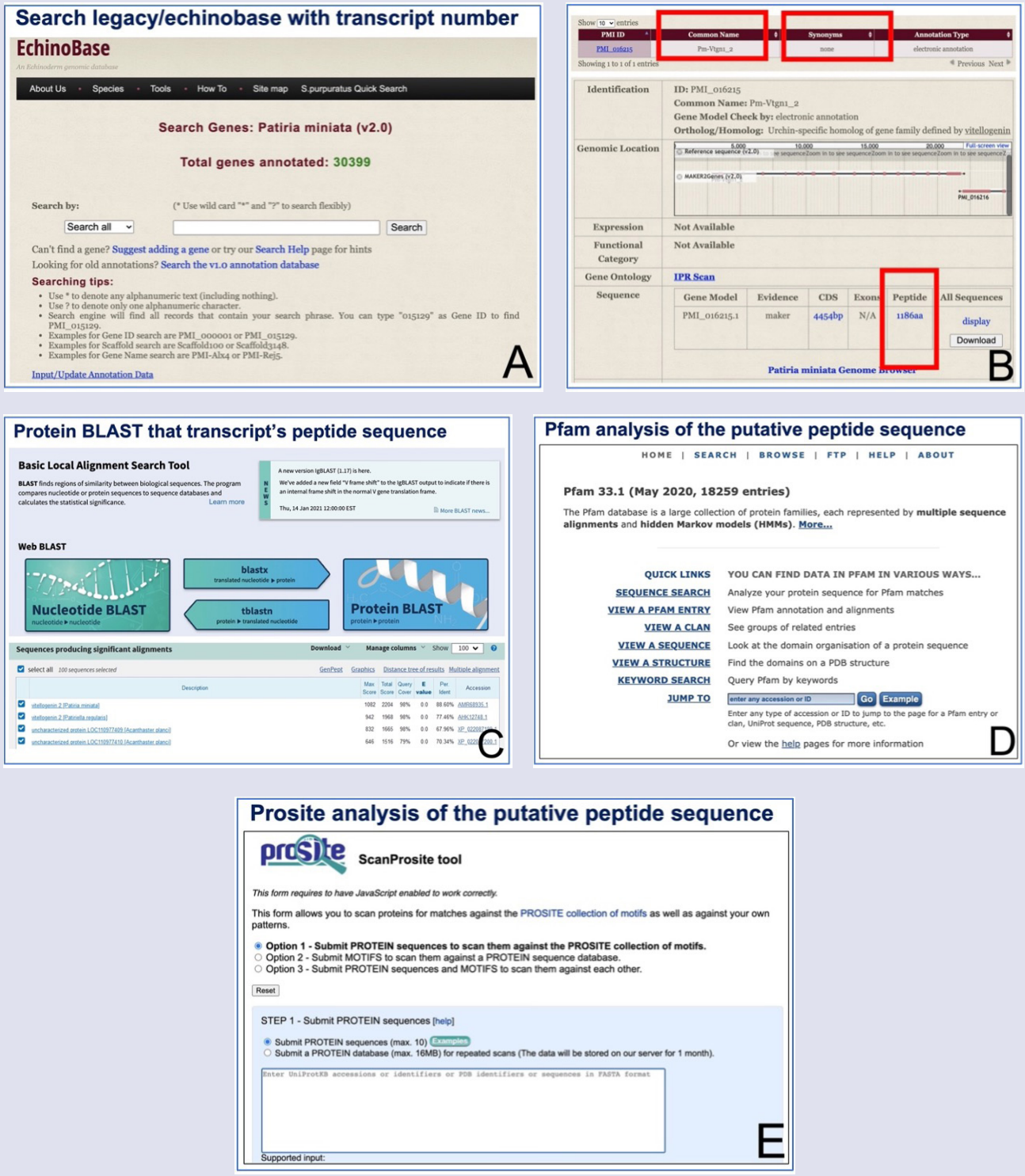
For the fall 2020 and spring 2021 semesters, students followed a general procedure to analyze the scRNA-seq (Figure 3). Groups of four or five students were assigned transcripts from the 12 clusters of cells generated by the initial analysis of the raw data. First, students performed a *P. miniata* gene search on http://legacy.echinobase.org/Echinobase (Figure 3a) to generate key information for their annotations (Figure 3b). Next, students performed a protein-protein BLAST alignment on the putative peptide sequence obtained from the Echinobase search (Figure 3c). Finally, students performed Pfam analysis to search for putative conserved domains in the peptide sequence (Figure 3d) and ScanProsite analysis to any other conserved motifs, such as post-translational modification sites (Figure 3e). Onorato and his students learned together as partner scientists. In the fall 2020 semester, students analyzed the data set with two rounds of gene annotation (Figure 4a and 4b). Students used these data to complete their lab assignment: a research manuscript instead of the mock NSF research proposal, due to the ongoing COVID-19 pandemic. The richness of the student-generated conclusions was inspiring. For example, one group concluded that Cluster 10 potentially represents oocytes (Figure 4c).

After seeing the rich analysis and student work produced in fall 2020, we built on this experience for the three lab sections of cell biology offered during the spring 2021 semester. In spring 2021, students initially did similar annotation analyses on scRNA-seq cluster data sorted differently than in fall 2020. We expanded the bioinformatics analyses to include the use of RStudio software to visualize these data. Students generated feature plots and violin plots for transcripts in their assigned clusters (Figure 5a). They also learned how to use RStudio script to compare the expression of two different transcripts within the same cluster and across clusters (Figure 5b).

This computational biology project was also incorporated into a biochemistry laboratory at CMSV in spring 2021. Rollins decided early in the semester to introduce a bioinformatics component into her in-person biochemistry lab ($n = 7$ students). We positively utilized the "Zoom deluge" as Onorato introduced the project to the biochemistry class via

FIGURE 3

General bioinformatics procedures students followed to analyze single-cell RNA sequencing data from the sea star *Patiria miniata* ovary.



Note. (a) Students searched genes from the legacy Echinobase v2.0. (b) Students entered into a spreadsheet the hyperlinked PMI transcript number, common gene name, and synonyms and obtained the peptide sequence; red boxes highlight the key areas students focused on from the generated Echinobase results. (c) Students obtained a protein BLAST of the obtained peptide sequence for the transcript, with example result indicated on bottom of figure. (d) Students used Pfam for further annotation analysis. (e) Students used the ScanProsite tool to find conserved domains and motifs.

FIGURE 4

Examples of work generated by LAGCC students during the fall 2020 semester.

Fall 2020 students First annotation analysis students performed

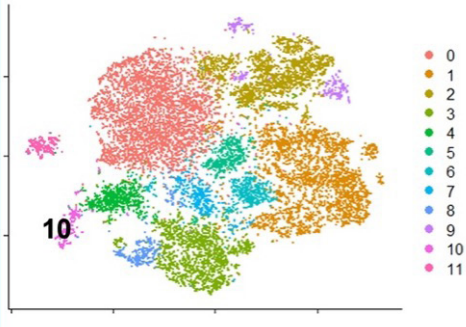
	Transcript #	Enchinobase Pm gene search	Synonym	NCBI Acession #	Pro-pro BLAST top hit name	Enchinobase link
1	PMI-001705	Pm-TectaL_2	alpha tectorin-like-2	AMR68934	vitellogenin 1 [Patiria miniata].	http://legacy.echinobas
				AFH56436	vitellogenin [Parvulastra exigua].	
2	PMI-011310	Pm-Ecm/Tspn/Vwc/Vwd_4	none	XP_022108407	uncharacterized protein LOC110988832 [Acanthaster planci]. (63.06%)	http://legacy.echinobas
				QAA95953	asterias large peptidase inhibitor [Asterias rubens]. (54.41%)	
3	PMI-016215	Pm-Vtgn1_2	none	AMR68935	vitellogenin 2 [Patiria miniata].	http://legacy.echinobas
				AHK12748	vitellogenin 2 [Patiriella regularis].	
4	PMI-007024	Pm-Vtgn1	none	AMR68935	vitellogenin 2 [Patiria miniata]	http://legacy.echinobas
				AHK12748	vitellogenin 2 [Patiriella regularis].	
	MI-024583	none	none	AMR68934	vitellogenin 1 [Patiria miniata].	http://legacy.echinobas
				AFH56436	vitellogenin [Parvulastra exigua].	

A

Fall 2020 students Second annotation analysis students performed

Annotation	Transcript #	Pfam results	Prosite	Possible function:
alpha tectorin-like-2	PMI-001705	Vitellogenin_N	*Vitellogenin domain profile, VWFD domain profile,*	
		DUF1943	*Bipartite nuclear localization signal profile,N-myri*	
		VWD	Protein kinase C phosphorylation site,Casein kinase I	
			cAMP- and cGMP-dependent protein kinase phospho	
None	PMI-011310	Thyroglobulin_1	Thyroglobulin type-1 domain profile, Pancreatic tryp	
		VWC	Cysteine-rich region profile,Pancreatic trypsin inhibi	
			Protein kinase C phosphorylation site,Casein kinase I	
none	PMI-016215	VWD	VWFD domain profile,Casein kinase II phosphorylati	
			Tyrosine kinase phosphorylation site 1,Tyrosine kina	
			cAMP- and cGMP-dependent protein kinase phospho	
none	PMI-007024	Vitellogenin_N	Vitellogenin domain profile,VWFD domain profile,N	
		DUF1943	N-glycosylation site, Protein kinase C phosphorylatic	
			Tyrosine kinase phosphorylation site 1,Tyrosine kina	
			cAMP- and cGMP-dependent protein kinase phospho	
none	PMI-024583	Vitellogenin_N	N-glycosylation site, Protein kinase C phosphorylatic	
			phosphorylation site, Tyrosine kinase phosphorylati	

B



Cluster 10 Results

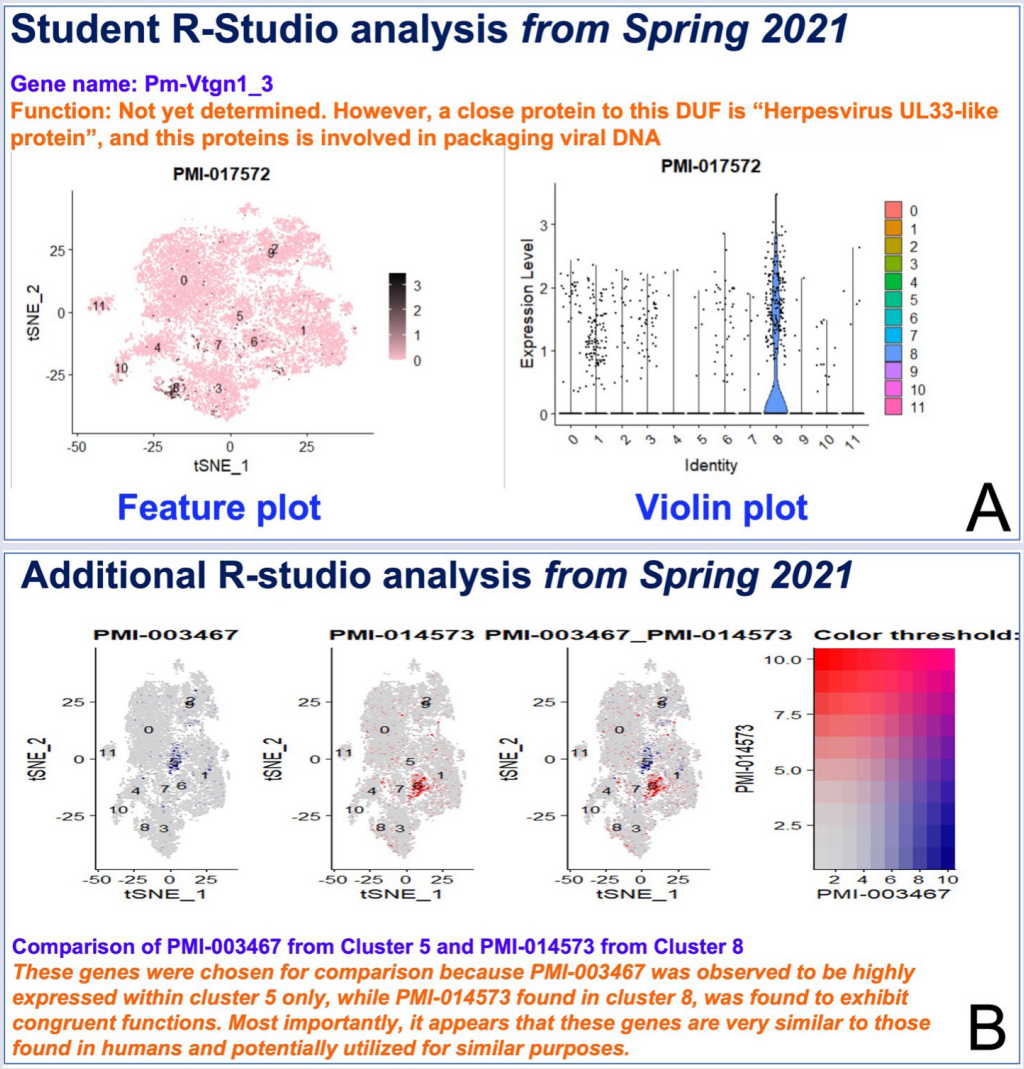
In cluster 10, the first annotation is serine/threonine-protein phosphatase 6 regulatory ankyrin repeat subunit C-like. The pfam description or results concludes this annotated gene is an ankyrin repeat; this repeat is a transcriptional initiator, cell cycle regulator, cytoskeletal function, ion transporter and signal transducer. Of the eighteen annotated genes in cluster 10, **six yield histone H2 or H3 results**. Histones are the chief protein components of chromatin, they act as spools which DNA winds around and play a role in gene regulation (13). Additionally, transcript **PMI-028605 yields the pfam results of enhancer of rudimentary homolog; a protein that is essential in the synthesis of DNA, RNA, and sugar nucleotides**. Many of our annotations play a function in cell function, whether through mitotic factors such as histone H3 [Orchesella cincta] or aid progression through the cell cycle such as E3 ubiquitin-protein ligase UHRF1-like isoform X1. Based on our results, cluster 10 could have possible functions in the ovaries as **oocytes**, which are cells in the ovary which may undergo meiotic division to form mature female reproductive cells called the ovum.

C

Note. (a) first round of annotations done by students; (b) second round of annotations done by students; (c) conclusion students made regarding potential cell type represented by Cluster 10.

FIGURE 5

Examples of the RStudio analysis LAGCC students performed during the spring 2021 semester.



Note. (a) student-generated feature plot and violin plot for transcript PMI-017572; (b) RStudio analysis comparing two transcripts, PMI-003467 and PMI-014573, and their justification for choosing to compare these two transcripts.

a synchronous tutorial presentation. Students were assigned a partner and given four clusters each. They annotated the clusters, highlighted two proteins of biochemical importance, researched the classical biochemical role, and speculated about the role of these proteins in oogenesis. Additionally, students were also assigned to investigate a way of testing their hypothesis. For example, CMSV students identified heparanase, an enzyme that functions to proteolytically cleave heparan sulfate, which is an abundant component of the extracellular matrix that binds to proteins and signal molecules, ultimately altering their activities.

Computational biology was incorporated into a community college cell biology capstone course and a junior- or senior-level biochemistry course for biochemistry and chemistry majors at a 4-year small Catholic liberal arts college. This shows how this pandemic-resilient aCURE can be incorporated into multiple subjects within STEM. Furthermore, linking cell biology and biochemistry through computational biology approaches fosters integrative learning and a more liberal arts–educated student.

Assessment methods

The SCB 255 fall 2020 and spring 2021 surveys (Online Appendix 2 for the spring 2021 survey, which was the same for fall 2020) and CMSV Chemistry 434 Biochemistry II Lab Survey (Online Appendix 3) were given online through a hosting service (https://www.LimeSurvey.org) that encrypts the data. All participation was voluntary and anonymous and in no way affected students'

grades. All results were analyzed as aggregate data, and all the question results were significantly different compared with an equal distribution, indicating that students were not randomly choosing answers. All of the responses were biased toward the positive end of the scale. To determine the mean of student responses, we assigned numerical values to the response choices as follows: 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree. The sample sizes for the survey results represented in Online Appendix 6 are n = 53 for LAGCC and n = 7 for CMSV. These n values represent students who voluntarily answered the survey, not the number of students who completed the classes.

Because Connors and colleagues (2021, p. 939) report that one of the benefits of participating in networked CUREs is "a hands-on, inclusive, scientific research experience that promotes project ownership," we also wanted to determine the student impact of our aCURE. The Classroom Undergraduate Research Experiences survey, Undergraduate Research Student Self-Assessment, and the Survey of Undergraduate Research Experiences are mainly used to assess and document CURE research outcomes. However, they fall short in their ability to measure elements of CUREs, such as project ownership (Hanauer & Dolan, 2014). Hanauer and Dolan developed and established the validity of a new instrument to assess project ownership, the Project Ownership Survey (POS). We wanted to gain insight on how incorporation of computational biology into the cell biology capstone at LAGCC affected students' project ownership and enriched research experiences during an unexpected shift to a fully online environment. Our adapted POS (Online Appendix 4) was administered using Google Forms, and the survey link was emailed to students in June 2021, after grades were submitted. A total of 38 responses were collected, which included seven responses from the fall 2020 class. A Google data summary was then generated (Online Appendix 5).

Efficacy of the PRIMO-URGE aCURE

A core value of the PRIMO-URGE research collaboration is to democratize AUREs and have students visualize themselves primarily as knowledge producers. One way to do this is to create aCUREs that genuinely incorporate faculty research; however, to truly democratize such experiences, increased participation of URMs is essential. Our established research partnership can increase URM participation in aCUREs and initiate momentum toward true democratization of AUREs. Here, we illustrate the inclusiveness of this pandemic-resilient aCURE and efficacy in democratizing research experiences

FIGURE 6

Responses from students who self-identified as Hispanic for selected questions in the discovery and relevance section of the Project Ownership Survey.

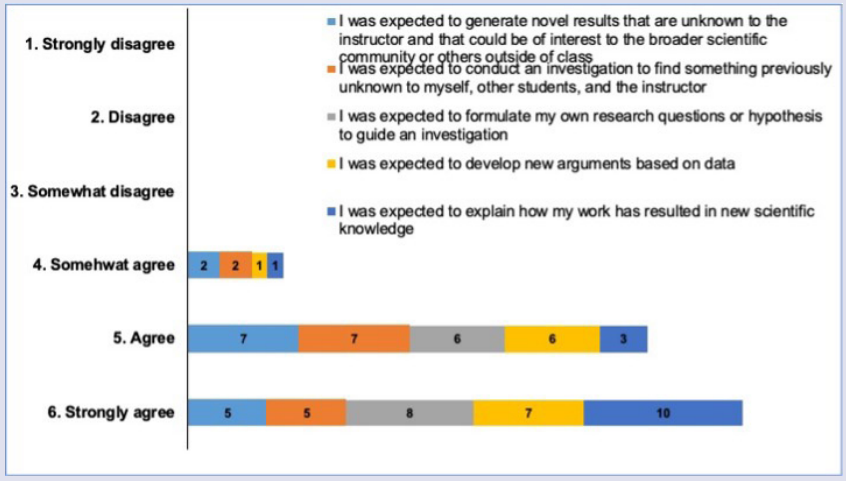
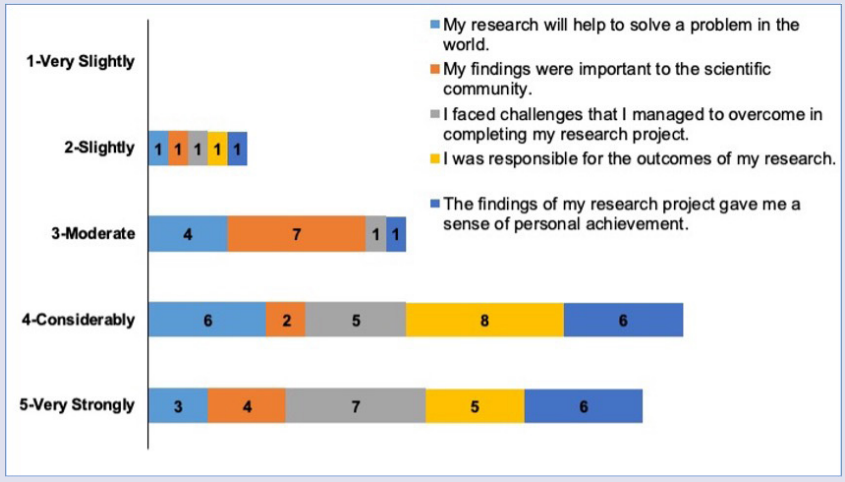


FIGURE 7

Responses from students who self-identified as Hispanic for the first five questions in the project ownership (Part 1) section of the Project Ownership Survey.



(Table 1). For example, URM student participation was 44.7% (7.9% Black, 36.8% Hispanic). Moreover, 86.8% of all participating students in our aCURE had never previously conducted research. This finding is extremely significant because our aCURE provides students with an overall sense of project ownership (Appendix 7), while impacting more students than the traditional research apprenticeship model. Additionally, we looked at the responses of Hispanic students to POS questions that related to discovery and relevance (Figure 6) and project ownership (Figure 7). Our pandemic-resilient aCURE gave Hispanic students a sense of personal achievement (Figure 7). However, we can improve how the aCURE impacts how Hispanic students feel regarding the importance of their research findings on the scientific community (Figure 7).

We also wanted to compare LAGCC and CMSV student responses with the aCURE provided by the online computational biology lab assignment during the COVID-19 pandemic. There were no significant differences between the mean responses for the nine common questions of the survey for LAGCC and CMSV (Table 2). In this article, we report the distribution of student responses for several survey questions (Online Appendix 6). These data suggest that if they are given the opportunity, community college students will respond similarly to 4-year small liberal arts college students. This computational biology assignment had a similar impact on the perception of understanding and integration of the material for community college students and 4-year college students.

These data and the pandemic-resilient aCURE developed from a sustainable research collaboration that respected community college academic food sovereignty support the need for a genuine paradigm shift in which knowledge producership is more deeply valued than knowledge consumership. Academic food sovereignty can also imply "new social relations free of oppression and inequality between men and women, peoples, racial groups, social classes and generations" (Change for Children, n.d.). The student feedback provided in this study in context of the PRIMO-URGE collaboration provides evidence to how such an aCURE can lead to academic food sovereignty, especially when we look beyond student knowledge consumership and acknowledge the paradigm-shifting nature of knowledge produc-

TABLE 1

Cell biology student demographics from the Project Ownership Survey.

Gender	Number of students (n = 38)	Percent
Female	27	71.1%
Male	11	28.9%
Race/Ethnic identification		
Black	3	7.9%
Hispanic	14	36.8%
Asian	9	23.7%
Native American	0	0.0%
Pacific Islander	0	0.0%
White	3	7.9%
Other	2	5.3%
Prefer not to respond	7	18.4%
Enrollment status		
Full time	32	84.2%
Part time	5	13.2%
Nonmatriculated or on ePermit	1	2.6%
Previously conducted research outside of class		
No, I have not previously or am not currently conducting research outside this class	33	86.8%
Yes, in the CUNY Research Program	4	10.5%
Yes, in the NIH Bridges Program	0	0.0%
Yes, in a summer research internship outside of CUNY	0	0.0%
Yes, in another setting then mentioned above	1	2.6%
If this course goes back to in-person, would you keep the lecture?		
Online only	5	13.2%
Hybrid (online and in-person)	33	86.8%
If this course goes back to in-person, would you keep the lab?		
In-person only	15	39.5%
In-person with a bioinformatics online component	20	52.6%
Online only with no in-person lab experience	3	7.9%
What semester did you take cell biology?		
Fall 2020	7	18.4%
Spring 2021	31	81.6%

TABLE 2

Mean responses for the nine common questions of the survey for LAGCC cell biology and CMSV biochemistry students.

Instructions	LAGCC mean (n = 53)	CMSV mean (n = 7)
The instructions for this lab assignment were clear and straightforward.	3.981	3.857
Confidence		
After working on this lab assignment, I feel more confident about my ability to succeed in class and my major.	4.020	4.000
Understanding		
The lab assignment enhanced my understanding of course concepts.	4.038	3.286
The lab assignment helped me understand how science is connected to my daily life.	4.154	3.286
The lab assignment helped me understand how science is connected to society in general.	4.180	3.714
Integration		
The lab assignment helped me to improve my ability to draw connections and integrate information from different fields of study.	4.058	4.000
The lab assignment increased my awareness of connections between biology and chemistry.	4.078	3.857
The lab assignment increased my awareness of connections to other courses or some of my co-curricular experiences.	4.020	3.714
Interest		
My interest in science has increased since working on this lab assignment.	3.941	3.571

ership (i.e., knowledge construction). Such academic food sovereignty augments active learning within the construction-of-understanding ecosystem framework (Lombardi & Shipley, 2021) and enhances curiosity-derived motivation (Oudeyer et al., 2016; Singh & Manjaly, 2022).

It is more commonplace in assessing the efficacy of collaborations between primarily undergraduate institutions (PUIs) and research-intensive institutions to provide qualitative evidence through one-directional evaluations of students and PUI faculty involved in the collaboration. However, the impact on the faculty and students at the research-intensive institutions is infrequently documented and can lead to a dangerous inference that they are not impacted by or do not benefit from such collaborations. We provide qualitative evidence of how the PRIMO-URGE pandemic-resilient aCURE impacted Brown University's faculty and graduate students (Online Appendix 8). This study illustrates the power of a genuine bidirectional valued partnership, which is critical in creating sustainable and more meaningful aCUREs in the future. These novel testimonies, when integrated with the aforementioned student impacts, provide the initial steps toward achieving academic food sovereignty and more sustainable, socially just, and diverse STEM knowledge producers at all academic levels and institution types.

Sustainability of aCURE

In this article, we have shown that given the opportunity to be valued as knowledge producers through the PRIMO-URGE aCURE, community college STEM students feel as confident in their ability to succeed academically as their 4-year college counterparts (Table 2, Confidence) and that they have ownership of their research experience (Online Appendix 7). This aligns with the culture of the college and university in keeping URM and nontraditional students in STEM motivated, enthusiastic, and encouraged (Cole & Espinoza, 2008; Johnson, 2007). However, multiple factors can influence a student's decision to change majors, as suggested by a study conducted by Seymour and Hewitt (1997) to understand why students leave STEM to pursue non-STEM degrees. These factors include loss of interest, poor teaching by STEM faculty, being inundated with information, pace, and gaining more interest in a non-STEM major after taking a general education course, which can result in students changing majors. For URM students, other extenuating factors such as being a first-generation college student and "fitting in" influence how they acclimate to the rigors of the STEM major (Cole & Espinoza, 2008; Seymour & Hewitt, 1997). PRIMO-URGE-inspired aCUREs can better prepare students who graduate with an associate's degree to enter a 4-year college or university to major in STEM. In addition to doing summer research, the transferable skills obtained in such aCUREs will make students competitive with

their 4-year college and university peers. Thus, aCUREs like ours can serve as a critical component to produce inclusive, diverse, and confident leaders and STEM workforce developers.

We would like to see continued growth in our STEM programs. To this end, the aCURE documented in this article has the potential to be extended to high school students. CUNY's College Now (CN) program provides a likely pool of students interested in beginning their STEM careers. This dual-enrollment program established on 17 campuses (11 senior colleges and six community colleges) allows high school students to earn college credit by taking college-level courses. Moreover, LAGCC recently became the second community college to provide a STEM Research Academy, where only high school sophomores are the target population. The program introduces motivated high school students to STEM via participation in hands-on research with faculty. We began extending our computational biology approach to the discovery and analysis of sea star ovarian gene expression reported in this article to our mentorship of STEM Research Academy students during summer 2021. Collectively, the PRIMO-URGE aCURE incorporated into a community college cell biology capstone course and a biochemistry course at a small liberal arts Catholic PUI, along with expansion into the CN program and STEM Research Academy for high school students will further democratize AUREs that sustainably realize academic food sovereignty.

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