Chapter 16
The UNPAK Project: Much More Than a CURE

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16.1 Introduction

Back in 2010, a team of faculty researchers at primarily undergraduate institutions (PUI) initiated a program of research in plant science, led by faculty and conducted by undergraduate students, and emphasizing CUREs (course-based undergraduate research experiences).[1] Shortly after garnering a first grant from the National Science Foundation in 2011, the team held a multi-campus acronym contest and adopted our endearing and enduring name: UNPAK, for Undergraduates Phenotyping *Arabidopsis* Knockouts. Here, the "UN" refers to undergraduates engaging in hands-on and authentic research, and the project's development of protocols for amassing the data that students generate across many campuses into a centralized database. The "A" in UNPAK refers to our focal plant species, *Arabidopsis thaliana.*

Outside the lab, *Arabidopsis* is a small, short-lived weed found throughout temperate biomes, related to cabbage and turnips. It is also a human commensal,

[1] Auchincloss et al. (2014), Rodenbusch et al. (2016) and Dolan & Weaver (2021).

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growing as a weed alongside roads, stream banks, fields, and other cultivated landscapes.[2] In the 1980s and 1990s it emerged as a model system to unite plant researchers in genetics, physiology, ecology and evolution. The *Arabidopsis* genome project and later spin-offs parallel the human genome project in many ways, including sustained focus, massive government grant support, and international scope. These projects enabled many applications of basic science and ancillary technologies.[3]

Knockouts, the "K" in our acronym, are now a key and routine technology for UNPAK and the entire plant genetics community, thanks to pioneering projects in the 2000s that created them by introducing large DNA "tags" into the genomes of plants. These tags simultaneously mutate the DNA-based information in the gene and molecularly tag the gene's physical location. Comprehensive collections of these induced mutations, known as knockout libraries, were created. Our project focuses on one created at the Salk Institute, with coverage of the vast majority of the 25,000+ genes comprising the *Arabidopsis* genome.[4] Similar comprehensive knockout libraries exist and are widely used by researchers, not only in *Arabidopsis* but also in yeast and many other microbes, and in fruit flies, mice and other animals.[5]

The potential of such libraries relates to the "P" in our acronym—the phenotypes associated with an individual instance of knockout mutation. Every tagged mutant in any knockout library must be confirmed: has the tagged mutation altered the organismal characteristic(s) as predicted or expected based on the gene disrupted, and with existing genetic knowledge? Here, UNPAK innovates by focusing on less investigated and more complex phenotype traits, those relevant to ecology and agronomy. How likely is a mutant seed to germinate? How fast? How slow or how fast do knockout mutants produce flowers? How often do full-size fruits or seeds fail to ripen? UNPAK also focuses not just on specific mutants or types of mutants, but on a large and randomly representative portion of the overall genome (10+%).

UNPAK was gratified when the National Science Foundation's announced in 2016 its "Ten Big Ideas" and included the statement that a "universally recognized biggest gap in biological knowledge is our inability to predict an organism's observable characteristics—its phenotype—from what we know about its genetics".[6] This affirmed UNPAK's hard-won phenotyping pipeline: growing plants in standardized conditions, measuring traits reliably and reproducibly, and checking data quality as it compiles into a database shared across UNPAK campuses and beyond UNPAK.[7] With the concept of a gene now in its second century, we UNPAKers want young biologists to learn and research genetics and genomics while keeping sight of phenotypes via "eyes on" and "hands on" work, both connected to the "minds on" activities of asking answerable questions, designing experiments, analyzing and interpreting results, and extracting data appropriately from databases to conduct meta-analyses.

[2] Lee et al. (2017).

[3] AGI (2000), Koorneef and Meinke (2010) and Buell and Last (2010).

[4] O'Malley and Eckert (2010).

[5] Hillenmeyer et al. (2008) and Rancati et al. (2018).

[6] Gropp (2016).

[7] Full details are in Rutter et al. (2019).

UNPAK's earlier publications have discussed its aims and progress in mentoring and researching plant genomics and evolutionary ecology, and some of the CUREs implemented by the UNPAK team.[8] Members of UNPAK who are social scientists have assessed its impact on students' development of social, cultural, and human capital in the context of networked research, the role of faculty recognition and mentorship in student development, and the impact on faculty career development.[9]

Here, we reflect on UNPAK's emphasis on authenticity and how that intersects with students gaining not just access to STEM learning, but also a sense of inclusion and belonging. The investigators participating in this conversation have a mix of backgrounds. Some work in ecology or environmental biology and others are more focused on molecular biology, or on education and the social sciences. This is also a circle of colleagues who helped UNPAK in its earliest years and at critical turning points in its decade-long existence. We agreed to respond in writing to a series of questions addressing how faculty have balanced their teaching and their research, and how their teaching and research connects to plant and environmental science, and applications of these sciences. We discuss our views of how UNPAK, directly and indirectly, helps diverse students to persist into future education and careers, whether outside of STEM or in STEM, and whether or not they pursue careers directly relevant to "the environment" or "sustainability". We hope it offers some illumination on how STEM faculty and staff in higher education support society-wide efforts to conceive and build a future that is more environmentally sustainable, and also more inclusive and just.

16.2 UNPAK and Its People

Question To introduce UNPAK and our group please share your current position and institutional affiliations, when you joined UNPAK, and any comments about how your job and expertise are interdisciplinary, including any relevance to environmental science, sustainability or conservation.

Matthew T. Rutter I am now a Professor in the Department of Biology at College of Charleston in South Carolina, and also Academic Director of Stono Preserve. I am a regular faculty member in Biology, but also act as director of College activities at our Stono Preserve property, a 1000-acre natural and historic site 17 miles from the main campus. The College of Charleston is a public, primarily undergraduate urban college, with about 10,000 students. My job as a faculty member is primarily STEM, although my role at Stono Preserve has involved working across almost every discipline at the college, and is more project management. I am interested in

[8] Rutter et al. (2019, 2020) and Murren et al. (2019).

[9] Thompson et al. (2016), Thompson and Jensen-Ryan (2018) and Jensen-Ryan et al. (2020).

both conservation and education, conducting research in both areas, so I suppose I am interdisciplinary.

I was one of the founding members of UNPAK, so I got in right at the beginning! I was an early Assistant Professor, going through my 3rd year review. I was Principal Investigator for the College of Charleston's original UNPAK awards, and have continued that role as UNPAK transitioned to its current form, where we have a summer undergraduate research experience and CUREs as our main activities.

Courtney J. Murren I am also Professor in the Department of Biology at the College of Charleston. In addition to Biology, I do work in environmental studies and in education. I joined UNPAK before UNPAK was a thing. I helped with analyzing and designing experiments that were the pilot data for the first grant submissions. At that point, I was an Assistant Professor. My involvement moved from being in the greenhouse collecting data, to writing proposals and working with new faculty who have since joined UNPAK, especially after April Bisner joined the team in 2015 as project manager. Now, being tenured and a full professor frees me to add to my research portfolio work on education research, which is not a topic that "counts" towards research productivity at our institution. I do it because it is super valuable work, grant funding agencies value this expansion, and I care about getting opportunities in the hands of students!

Hilary S. Callahan I am a Professor of Biology and department chair at Barnard College. Ours is a distinctive liberal arts college serving about 2700 students in 2021. Barnard does not admit men nor grant graduate degrees, but it has formal links to—and is geographically right across the street from—Columbia University. Since my undergraduate days, I have tried to combine my STEM expertise with my activism on a variety of issues. The urge to "change things" in positive ways is something I admire in Barnard's students.

Courtney Murren welcomed me to join her and collaborators at the College of Charleston in the earliest stages of creating UNPAK. At the time, I was tenured and well versed in working with program directors within the funding agencies. UNPAK became one of the more ambitious, intense and thoughtful projects I have done, and it also helped me to pioneer various remote technologies in the early 2010s. In our early years, team meetings were frequent, and always via conference call. Later, we started to use the original Google Hangout platform and now, like so many others, we rely on Zoom. In a decade, I have traveled just a few times to work in-person with other UNPAK team members, flying twice to the College of Charleston and once taking Amtrak to Hampden-Sydney in Virginia.

Michael Wolyniak I am the McGavacks Associate Professor of Biology and the Director of the Office of Undergraduate Research at Hampden-Sydney College, a small liberal arts college for men located in central Virginia. My training is in genetics and molecular biology. That said, I have had several experiences with working as an interdisciplinary scholar and teacher. I regularly teach bioethics courses that require students to consider issues related to science and society. I am a part of our institution's Core Cultures program that looks at widely read texts about the history of Western civilization to identify how society has evolved. With respect to my scholarly work, I focus on course-based undergraduate research experiences (CUREs) and how they may be best integrated into scientific coursework. This has given me a lot of experience working with education experts. While I have not directly taught environmental science, conservation or sustainability, the issues come up regularly in classes, typically because of the impact that humans and their choices have on their environment. None of this would be possible without an interdisciplinary approach.

I was blessed to be a founding member of UNPAK, joining in 2010 as a new professor. I originally joined UNPAK to gain opportunities that I could use in my classes to expose students to exciting research opportunities. Over time, my involvement with UNPAK has focused on CUREs and finding ways to integrate CUREs into all of my classes.

Jennifer Jo Thompson I am a Director of the Sustainable Food Systems Initiative and an Associate Research Scientist in the Department of Crop & Soil Sciences at University of Georgia. I am an interdisciplinary scholar. My primary discipline is anthropology, but I work primarily on collaborative, inter- and transdisciplinary research focused on sustainable agriculture and food systems. One thrust of this research focuses on the way various publics engage with science, including how to support students to develop various forms of capital in science.[10] I continue to have components of my research, teaching, and service that focus on expanding participation in science.

I joined UNPAK early, in 2012, when I took a postdoctoral position with Erin Dolan. Our early work on the project specifically focused on social capital: whether undergraduates participating in a networked research project would have unique access to additional social resources due to their potential for access to additional faculty and students across institutions. Ultimately, we found that despite valiant efforts to encourage communication and connections across groups (e.g., early efforts with Google Hangout, etc.) undergraduates built social ties primarily within their labs (with their faculty mentors and fellow students). There were exceptions

[10] Thompson et al. (2016) and Thompson and Jensen-Ryan (2018).

among those students who had unique opportunities to visit and spend time in other labs, and build connections with other students or faculty. Our data suggests that this is because undergraduates are focused on building skills, identity, and relationships *within* their lab. In 2013, I became a co-PI (with the second UNPAK grant), and our work shifted somewhat to understanding how to expand undergraduate participation among students from underrepresented groups. This work focused on understanding, in greater detail, how undergraduates developed their identities as scientists and how faculty were able to support this identity development by recognizing and affirming their potential.[11]

April Bisner My job and expertise combine STEM and project management. The UNPAK project's research goals are relevant to environmental conservation and sustainability in that we study gene-environment interactions, and this is a model issue relevant to climate change such as increased drought, or flooding. I was hired as the UNPAK project manager in 2014. At the time I had nine years of experience working on a variety of research projects with increasing management and training responsibilities. I have been with UNPAK for nearly seven years. In our early years, prior to 2018, we had more full-time student interns. Today, we do more work with a virtual or in-person summer REEU (Research and Extension Experiences for Undergraduates), which is a program funded by USDA through AFRI-EWR (Agriculture and Food Research Initiative, Education and Workforce Development). With CUREs, our network of partner institutions also continues to grow.

Question If you are willing to share, can you describe your experiences growing up, your family or your early and later schooling? Does that background affect your current work in STEM research, mentoring and teaching?

Courtney J. Murren I was raised in the woods in a family of modest means with a family business. My parents and grandparents had a nature-loving ethic and any down-time we had as a family was at the nearby shore or mountains. Nature was my teacher. I pulled apart tulip poplar inflorescences, replanted shore grasses in little rows, excavated acorns and climbed trees. I read, and read, and read growing up. Today, I encourage my students to look, observe, be curious and read. Having been from modest means, I had to work all the time and had no "backup" resources. I had not thought of graduate school during college until mentors told me that tuition was waived and that there are stipends for working while studying, to help with living expenses and health insurance. Academics sounded more stable than the family business and I loved the explore/research components so I thought I would give it a try. I traveled as an undergraduate to the tropics with a group of other undergraduates on an NSF REU (Research Experiences for Undergraduates). That trip opened my world.

[11] Thompson and Jensen-Ryan (2018).

As a faculty member, I'm committed to paying stipends to all students, hiring students through programs such as Federal Work-Study, and as much as possible providing opportunities for students to travel for their work in their early career. I also take time to talk to students about the paths into graduate school as it is quite different from many of their peers who are seeking schooling for health careers.

Hilary S. Callahan I did not have parents or grandparents who were scientists or in STEM professionals. My dad attended a business college, and worked as an auditor for the USDA for his whole career, often with side hustles, as we call them today. My mother pursued her college degree, a teaching career and an M.Ed., all while doing most of the work at home with three daughters. Over time, I have noticed a divide between professors and scientists with backgrounds like mine, and those who have parents or other relatives who are also professors, scientists, or professionals in remunerative fields. I always try to bear in mind that some work much harder than others to develop the know-how and resources for navigating toward opportunity and eventual success in STEM careers or other careers.

Michael Wolyniak I was raised to always pursue excellence, which I think was essential to me getting to where I am in my career arc. I was blessed with a K-12 education that gave me the opportunity to engage in the STEM disciplines and to develop my interests. I often felt a degree of pressure to always succeed, and this pressure influences how I now mentor my students. I do not want my students to feel that they have anybody to please but themselves when it comes to their professional development and considering their career opportunities. I feel as if I have a stronger sense of empathy for my students and a better ability to consider their backgrounds when mentoring them as a result of my upbringing and education.

Matthew T. Rutter I grew up within walking distance from a state park—there is no question that made a tremendous impression on me and gave me a broad interest in biology, ecology, and environmental conservation. One of my parents worked on the non-academic side of a university, and the other was a high school math teacher. They both completely supported me in the idea that I could follow my intellectual interests, and were supportive of an academic career, particularly one that incorporated teaching. I was fortunate to have that kind of support, and try to relay it to my students.

April Bisner Science was a second career for me because I did not have the attention span or grades when I was in high school and was more drawn to the arts. Attending community college as an adult learner was a valuable experience. It allowed me to attend small classes with enthusiastic professors and gain hands-on experience in the lab and field. This prepared me for transferring into a four-year institution to complete my studies.

Jennifer Jo Thompson I do not come from a family of scientists—and I definitely experienced a kind of science aversion in high school that pushed me toward the social sciences and humanities. As a PhD student, I started developing an interest in science as an important domain of culture—a domain that is powerful, but which also receives a great deal of skepticism from the public, especially when science is emergent and uncertain. At this point the issue of when and how people engage with and (dis)trust science across their daily lives drives a good deal of my research.

16.3 UNPAK as Plant, Agricultural and Sustainability Science

Question Have you or your students gained, via UNPAK, a more nuanced understanding of complex issues in plant science, and more broadly in fields relevant to agriculture or sustainability? How strongly motivated are you and your students to engage in UNPAK because it is *environmental* research and learning? Is this interest primary, secondary, ancillary, non-existent? Do your interests, or students' interests, include environmental activism?

Michael Wolyniak We are addressing the sophistication and nuance of the relationship between genotype and phenotype. I have gained a more nuanced understanding of the effects of mutations on plant biology. UNPAK does help engage students mostly by increasing plant awareness which is something many students lack—even biology students! I would say environmental research and activism are valued moderately by my department and slightly by my institution. Generally, words seem to be prioritized over actions.

Also, my interests in UNPAK revolve around students at Hampden Sydney gaining the scientific experience, which is necessary to develop a spark that encourages them to develop scientific careers. I am not directly attempting to promote environmental research and learning. That said, the work that I have done with UNPAK students has, in several cases, led to students seeking and obtaining additional environmental related research experiences. Thus, UNPAK has served as the springboard for these students to gain environmental research experiences for themselves.

Matthew T. Rutter I would say the environmental research component may be secondary to more general and fundamental questions about biology.

Hilary S. Callahan At Barnard, UNPAK appeals to students interested in spending time in our greenhouse, and working with plants. All biology majors take genetics, so many enjoy an opportunity to connect course material to research. And our

greenhouse is wonderful because it is filled with plants from all across the globe.[12] Probing a little more deeply into the science of UNPAK, I often discuss with students how places like the lab or the greenhouse are "real"—meaning empirical and material rather than theoretical—but not "real world" in the same way as a farm or a forest reserve. The UNPAK project has appealed to me because it allows me to authentically pursue my long-term interest in how different environments have different levels of predictability, specifically from the point of view of plants. I'm also interested in how much or how little environments are disturbed, subsidized or controlled by human activities, both inadvertent impacts and deliberate activities like human labor or other inputs.

I also think that students working in the UNPAK network learn that "fast silver bullets" for improving crop phenotypes do not exist. We cannot magically use biotechnologies or other technologies given how drastically the environment impacts phenotypes and the side-effects of these technologies on other organisms, soils, or the atmosphere. Thus, training in UNPAK helps students to be better at understanding and communicating to other scientists and to lay-people the benefits and risks of biotechnologies in agriculture, or in human health for that matter. I think experience in UNPAK can, potentially, help students move past naive or oversimplified narratives about biotechnology, such as the misconceptions that it is easy and magic and profitable, or that it is inherently dangerous or evil. To me, the key is to encourage thinking holistically, whether one is thinking more narrowly about plant-gene interactions or more broadly about any issue in environmental and sustainability science.

Question Are UNPAK students gaining specific insight into the consequences of scientific knowledge about agriculture and crop genetics? Do they gain insight into multiple sectors of society or the economy: basic research vs. applied research, biotechnology vs. agriculture, conservation vs. policy?

Courtney J. Murren We have particular sub-projects centered around crops and agriculture. We have partners who contribute with this lens.

Michael Wolyniak The issues in this question are covered more in my bioethics courses as opposed to my UNPAK courses. It would make sense to try to combine the science and the societal questions in greater detail in my UNPAK coursework; however, time constraints often prevent that from happening.

Matthew T. Rutter The students are definitely learning about the consequences of knowledge. It is probably focused on agriculture, biotechnology, basic research, and conservation rather than on policy. Much of it is treated broadly, but when students focus on the effects of individual genes or environmental treatments it can become quite narrow. I have seen it affect the personal components of students'

[12] See Gershberg (this volume).

lives. This is particularly true in CUREs where many students really haven't touched or interacted with plants very much. For lab and summer students, there certainly are professional elements of their lives that are influenced.

Hilary S. Callahan Most of my UNPAK students have had lots of high school biology, such as AP or IB Biology (Advanced Placement, International Baccalaureate). Barnard also requires an intense series of courses during their first two years. They have listened to lectures and memorized diagrams of molecular biology processes like the use of CRISPR-Cas9 to "edit" gene sequences.[13] I am clear to them about how UNPAK is not about doing that first-hand, but instead focusing on another step in the genomics pipeline, the task of phenotyping plants, important in constructing knowledge and databases in plant organismal biology, and also in the context of human health and disease. From time to time, there have been students whom I have mentored in UNPAK who have become enthralled with thinking about the jobs of farmers, including large-scale farmers in the agri-business that dominates the U.S. today. That was fostered by my UNPAK lab being right next-door to the lab of my colleague, Jon Snow,[14] who focuses on honey bees. The relevance of UNPAK's work to agriculture is also evidenced by its recent development of a Summer REEU, supported by the USDA.

16.4 UNPAK Prioritizes the Undergraduate Experience

Question How much do you prioritize and value mentoring and teaching undergraduates who are preparing for their own careers and lives? Is this a job duty or expectation? A personal avocation? A bit of both?

Courtney J. Murren It is a high priority! It is a job duty, expectation, and avocation. At the College of Charleston, this job duty can vary from regularly to infrequently. For me, I cannot remember a semester or summer where I did not work with undergraduate students in 'independent study'. I am passionate about being part of the solution in expanding opportunities, and helping students on their personal journeys in biology or environmental studies and their related interdisciplinary professional lives.

Hilary S. Callahan As a new professor, I received vivid advice from a colleague about developing "a reputation for doing excellent research that is, additionally, really meaningfully involving undergraduates." Over the years, I internalized this advice, and I have it in common with colleagues who helped create UNPAK. Moreover,

[13] https://www.nobelprize.org/uploads/2020/10/advanced-chemistryprize2020.pdf

[14] See Snow (this volume).

work with students has always helped me dispel the cynicism and gloom that periodically creep into my career and my life.

Michael Wolyniak I consider [research] mentoring a central part of my career. I feel it is a personal calling that allows me to gain immense satisfaction from helping my students to attain their professional and personal goals. In graduate school, I considered the work I was doing to be largely a means to an end so that I could obtain a position such as the one I now have that focuses on teaching and mentorship. I am certainly expected to be a mentor and a teacher as part of my job description; however, for me it is the favorite part of my job.

Jennifer Jo Thompson My teaching/mentoring is heavily focused on graduate students, with no professional expectation to teach or mentoring undergraduates. I do teach one mixed-level course, and often have at least one undergraduate participating in research in my lab. An exciting twist is that I am part of a team initiating a collaboration between The University of Georgia's Graduate Certificate in Sustainable Food Systems and Spelman College's undergraduate Food Studies program. This collaboration should expand my personal mentorship of undergrads, but also expand culturally appropriate mentorship and build a pathway for more diverse recruitment into our grad programs. From my perspective, all this begins with working with faculty to support *and reward* effective and inclusive mentorship.

Matthew T. Rutter I value mentoring and teaching undergraduates extremely highly, and it is one of my very top priorities. I participate as a personal avocation, although it is valued at my institution so it does fulfill expectations.

April Bisner One of the great pleasures of my job is helping to train and mentor a diverse group of students. Our intern component of the UNPAK project allows me to work closely with students over the course of a few years and watch them grow as scientists and people. I have also kept in contact with some of our alumni and it is always nice to hear where their lives have headed and what influence our project had on them.

Question Is student work within UNPAK different from the types of jobs or projects and the styles of learning that you experienced during your own undergraduate years? Is your work distinctive relative to most of your professional colleagues, either in your institution or in your sub-discipline?

Hilary S. Callahan UNPAK is so completely different from my undergraduate experiences. The vast majority of my learning about biology and genetics was in the classroom, or involved solitary reading and problem sets. One exception was field trips, which were so important to inspiring me to study ecology. I still value hands-

on, place-based, and in-person experiences with faculty and students interacting out on islands or boats or in forests. With UNPAK, we are not in the field, but we are getting data from plants grown in chambers or greenhouses. Students seem to self-select into this type of work, and at the same time many do yearn to work in more natural environments.

Also, UNPAK students certainly have "ownership" of their work, while also seeing that *sole* ownership of a project is rare. In joining UNPAK, students are constantly reminded that they have joined something larger than themselves. My students at Barnard always think it is cool to see students on other campuses also doing summer internships, research projects in their classes, and so on. At its best, UNPAK unites several senses of belonging into one over-arching experience. Students who do UNPAK are also quite intentionally choosing to learn about plants, which is already distinctive as compared to so many other students who do cellular or molecular work, or who work with animal models.[15]

Courtney J. Murren UNPAK is distinctive in my research portfolio by not having a field component! Also, we have over-arching long-term goals, and we ensure that students understand this long-term focus. This matches with others in our biology discipline who have long-term goals.

Michael Wolyniak The work I do in UNPAK has become less distinct because CUREs have become more mainstream. For me, the work remains distinct in the plant-based focus that I take with UNPAK materials.

Jennifer Jo Thompson I did not have any experiences like UNPAK as an undergraduate. Working with UNPAK has given me the skill and confidence to continue to collaborate in large-scale, multi-institutional, interdisciplinary research and teaching endeavors. Although more and more anthropologists work in teams, it is still somewhat unusual to work on 'big data' projects like this.

Michael Wolyniak I think the UNPAK project makes our work, in courses and in the lab, integrate thoroughly to draw undergraduates more deeply into authentic research experiences. This is important both at our institution and in my own sub-discipline of genetics. I never worked on a project as an undergraduate that involved discovery contributing to a larger project. I do think it is quite distinctive. While I certainly had an outstanding scientific education as an undergraduate, there was much more separation between teaching and research. UNPAK has shown me how to meld those two things together in the class to give my students the best educational and potential professional development opportunities that they can get.

April Bisner Work with UNPAK is different from the projects that I worked on in my undergraduate years. Students are given the opportunity to design their own research

[15] Also see Snow (this volume), Maenza-Gmelch (this volume) and Rhodes et al. (this volume).

project with the help of mentors. They also have an influence on additional traits that we study in group projects. UNPAK succeeds in being hands-on by having all of the phenotyping measured by students. The data is checked by students and then quality-checked by professors and myself before uploading it to the database. In many cases, students plant and maintain experiments from beginning to end. Students are involved in the statistical analyses of results and under certain circumstances the writing of manuscripts based on those results.

Question What are your views on how actively students in UNPAK are analyzing, dialoguing or arguing from data and evidence? Do they do this? Is it important to the students? How? Why?

Courtney J. Murren The final presentations at the last three summer REEUs (2019, 2020, 2021) are evidence that students are substantiating their claims with data and evidence, and also built from the theory of those who came before us. UNPAK students think and work as scientist-learners, as individuals and in teams.

Michael Wolyniak UNPAK students are certainly actively analyzing and arguing the strengths of their predictions and conclusions based on evidence. These are very important skills to develop for a successful career in science. With respect to dialoguing, UNPAK has been hit-or-miss in terms of encouraging students to collaborate in their research. This is something that I have tried to encourage in my own classes, to a limited degree of success. Since collaboration is so important to the way modern science is conducted, it is a skill that I continue to try to promote among my students.

Hilary S. Callahan I think that general critical thinking and learning scientific methods are front and center in UNPAK, but I also see UNPAK as part of the new trend of "big data research" in which it is also important to recognize that new hypotheses and new explanations sometimes emerge from more descriptive data-exploration and data-mining.[16] I personally see big-data biology as a direct descendant of classical botany and natural history, sometimes referred to as digital natural history. I like that our focus on phenotyping keeps a bit of old-fashioned observational natural history in UNPAK. Students spend weeks focusing on a plant that is almost uselessly cute. UNPAK requires students to look at plants daily for many days in a row, with dedication and Thoreau-like patience. They gain an appreciation for more subtle phenotypes of plants, the timing of life-cycle transitions or the difficult life of a seed. A balance of strong observational skills with critical thinking is something I have valued from the very start of UNPAK, and even from my initial plunge into academic biology.

[16] Leonelli (2019).

Matthew T. Rutter My students are actively participating in all of those activities. It is more important to some students than others—some students are still adjusting to learning to think instead of just learning facts. I do think this involves the development of critical thinking, even in a very broad sense of using evidence to build a picture of reality, and predicting future realities.

16.5 UNPAK Supports Access and Persistence in STEM Training

Question Do you think UNPAK is a good pathway for supporting students to persevere in completing their degrees, pursuing advanced degrees, or staying within STEM fields, especially environmental sciences or sustainability?

Hilary S. Callahan I situate my thinking and commenting on this issue by reminding myself that Barnard is an expensive private college and it is really hard for students to gain admission and financial aid to attend. That being said, we have extremely high graduation rates. Having UNPAK in my department ensures that there is somewhere for students to go if they want to take a step away from the high-pressure pathway of preparing for a career in human health.[17] In the middle of a huge city, it is nice to be able to have a place where topics like agricultural yields or weed management are part of our classroom and laboratory and casual discussions, and to learn about research opportunities relevant to such questions.

Courtney J. Murren The social-professional network of the lab environment was really essential! It is not the sole path for students with specific STEM goals, but it makes a big contribution.

Michael Wolyniak There is no better way to encourage students to sustain themselves in STEM fields than to give them the chance to engage in science at it is actually done by and with "real scientists". UNPAK does an outstanding job in providing that initial spark necessary to develop a passion for scientific research. It is a critical springboard for helping students obtain the confidence and skills necessary to pursue an advanced degree in any STEM discipline, but especially in the environmental sciences or sustainability.

Question In what ways do you think UNPAK is helpful in broadening students' understanding of the potential breadth and diversity of STEM training options and STEM career options, especially in environmental sciences or sustainability-related fields?

[17] See also Snow (this volume) and Rhodes et al. (this volume).

Hilary S. Callahan I think a lot of students find it refreshing to think about the ecology of plants, and crop ecology, mainly because our college has a strong emphasis on pre-medical preparation. Being a bit "off beat" may help students to pause to think about careers other than being an MD. I have watched some of my UNPAK students at Barnard go into STEM teaching, nursing, epidemiology, even law.

Courtney J. Murren In paper discussions, seminars and workshops with faculty from diverse STEM sectors, we are encouraging of students' personal journeys as individual ones. Given my own interests, I often engage in discussing careers in environmental or sustainability fields.

Michael Wolyniak By participating in an UNPAK project, a student is learning how science is done. In turn, the student learns how scientists are trained, and what is required of them in graduate school. In this way, UNPAK is helping students to better understand that there are more options available for life scientists than simply medical school.

Jennifer Jo Thompson Since a lot of students enter biology thinking about careers in medicine, opportunities to learn about careers in research and ecology are important. UNPAK does this.

Matthew T. Rutter Many students haven't thought of the relevance of plants and plant biology to STEM careers or to environmental sciences. Many who are interested in environmental sciences haven't necessarily thought about the role of genetics and genetic variation in natural populations. UNPAK does help to make those links.

Question Have your initial motivations for joining UNPAK been matched by your experiences? Did UNPAK under-deliver or over-deliver? Does this make work with UNPAK distinctive in some way?

Michael Wolyniak My motivations for joining UNPAK were both altruistic and selfish. Altruistic in the sense of providing my students with outstanding research opportunities for their own development, and selfish in the sense that it would look good for my tenure and promotion opportunities. UNPAK has over-delivered in every sense as I have been able to accomplish both of these goals as a result of my participation.

My UNPAK work started out as distinct because of my lack of training as a plant biologist. Over time my UNPAK work has become less distinct, but this is a positive reflection on the influence it has had on the way that I treat all of my science courses and how they are taught. UNPAK has also profoundly changed my teaching philosophy and showed me the value of authentic research experience as a central part of an effective scientific course. Because of UNPAK, I now teach my classes in a

more unstructured and research-focused fashion. In short, my other classes came to resemble UNPAK rather than the other way around.

Hilary S. Callahan I thought that UNPAK was an excellent fit for Barnard, historically and today a college for women, and a college that counters minoritizing women in STEM and in many other aspects of the academy and society more broadly. For me, as a tenured professor, accomplishing work that was "just mine" became less of a priority. Additionally, from an NSF ADVANCE grant at my institution, I learned that collaboration is an effective pathway toward productivity and long-term impact.[18] I think UNPAK has done that, and I am optimistic that it will continue to do that through the final decade of my career.

Matthew T. Rutter As one of the UNPAK founders, I was extremely interested in its science: the connection between genotype, environment, and phenotype in plants. I really had no idea how far UNPAK would go, so I have to say it has exceeded my expectations. Although we can always do more, it amazes me to think how many students we have taught through the program, and how we have amassed hundreds of thousands of data points!

Courtney J. Murren I agree that UNPAK did over-deliver, but differently than I initially imagined! UNPAK involves huge amounts of team work. Other projects have smaller groups of scholars. I've often in my career been part of bigger projects and had other projects with fewer collaborators at the same time.

Jennifer Jo Thompson I was motivated based on my interest in understanding how people engage with science and with scientific knowledge, and my interest in expanding access to participation in science. Although my own work has moved away from working directly with UNPAK, it has been exciting to watch it develop and greatly expand opportunities for faculty and students to participate in research over the years. Its reach has expanded far beyond my initial expectations!

In other ways, my work with UNPAK has deeply impacted the inter- and transdisciplinary work I continue to do. It was my first experience working on a collaborative, cross-disciplinary project, and as a social scientist among a team primarily focused on natural science. The other PIs' respect for, and commitment to supporting the social science was deeply affirming for me as a postdoc and it ultimately inspired me to continue to work on inter- and transdisciplinary projects.

[18] Lee and Bozeman (2005).

16.6 UNPAK as a Philosophy and a "Way of Being"

Question Is UNPAK more "liberal arts" or more "vocational"? What do you think about this divide? Is it valid or bogus?

Hilary S. Callahan I dislike the idea of putting a college education into cause-and-effect or return-on-investment relationships, especially if that rigidly shapes students' eventual career satisfaction and learning. That being said, employability and career satisfaction are important, especially for students coming from less advantaged backgrounds. I have worked hard to clarify for myself as a supervisor and for my diverse and ambitious students, in UNPAK and elsewhere, that this is a resolvable issue. A paid job in research part-time during college or full-time during the summer is a way to simultaneously support students tangibly, enhance their learning, and furnish a credential. What's more, that research job adds directly to the collective knowledge of science. Keeping that complex messaging in mind is important, and I know that is part of Barnard's campus culture, and I hope elsewhere.

Michael Wolyniak I see UNPAK as more of a liberal arts project. Training students to develop the critical thinking skills necessary to adapt to any vocation as opposed to providing the training tools for one particular vocation. This does not mean that the liberal arts and the vocational training need to be completely separate. I like to think of myself as a "practical liberal artist" in the sense that I encourage a traditional liberal arts approach to scientific research but with an eye towards potential career opportunities that can develop from the work. UNPAK is certainly effective in allowing students to gain this vital critical thinking ability while also considering what direct employment opportunities may be available as a result of the experiences that they gain from the work.

Matthew T. Rutter I would say more "liberal arts". But I am not sure about the validity of this divide. I think life, even centered around a vocation or skill, should hopefully draw from many areas and be lived like one from the "liberal arts"!

Question To what extent is UNPAK democratic and creative? Does it offer opportunities for all participants to be included in decision-making, pursuing funding, or expanding the network?

Hilary S. Callahan Every year, students come onto Barnard's campus in an evermore urgent hurry to change the world and solve its problems, but they also are there for four years of learning. Whenever I am designing a course or a research project like UNPAK, I am trying to thread the needle between those two extremes. As faculty, I need to provide some top-down and efficient guidance. I also want to avoid extinguishing students' passion and idealism.

Also, after four years at Barnard, they have fifty to sixty or even more years for a career and the rest of their lives. Recognizing that, I try to have my teaching and mentoring be reasonably well-aligned with political principals like participating in democratic decision-making, and learning that it is important to understand both how and when to lead and how and when to select leadership to follow, or leadership to rebel against. I do not think that is explicitly a goal of UNPAK, but it is something that percolates through Barnard, and probably through other liberal arts campuses in the UNPAK network. Many students that I work with in UNPAK and in other projects are working hard on that balance.

Michael Wolyniak UNPAK has been an awesome force for me in democratizing the research process among my students. I recall in my undergraduate years that student research was largely reserved for people who had the classroom achievement or the persistence necessary to attract the attention of an advisor. UNPAK, by taking place in the classroom, allows all students to participate in the research regardless of their previous background and experience. This is a powerful tool that allows me to potentially inspire many more students than I could have before, and to attract people who may have slipped through the cracks under the apprenticeship model of undergraduate research in developing the sparks necessary to gain a passion for STEM research. The democratization of the process can even allow students to participate in formulating the research questions that we will ultimately pursue in a given class

Jennifer Jo Thompson My thoughts are perhaps somewhat dated, but some of our earlier data suggests that there is an ebb and flow in this over the course of the overall UNPAK project and over the course of students' engagement with the project. When UNPAK was first beginning, students were helping develop structured protocols and thus had agency, ownership, and input into the project development. Once those protocols were (necessarily) codified, students coming into UNPAK no longer had that as a major locus for creative input. My impression is that students continue to have creative input around the specific questions they explore, within a defined set of parameters. This seems like a reasonable balance given the competing demands of the project. At the same time, we found that students who remained with the project for several years often developed independent projects, which gave them greater ownership and agency. Is this the same thing as 'creativity' and 'democracy'? I am not quite sure.

Matthew T. Rutter It is semi-democratic. Students, particularly lab and summer students, have a chance to shape questions. Students in a single CURE are typically learning how to measure plants and work with data and as yet have not had as much creative opportunity in my classes—although the approach that we are launching in our most recent NSF-IUSE-funded work aims to change this. The democratic element is important to me primarily for the more experienced students.

April Bisner UNPAK is democratic and creative in that students are encouraged to think about other phenotypes they may want to measure outside of the core phenotypes and decide with their classmates or research group which of those phenotypes the class or group will measure. I learn from our student interns and incorporate suggestions on how to improve protocols and workflow. I think it is very important for students to think outside of the box and make decisions as a group.

Question Are there other ways that UNPAK has fostered an improved network of colleagues or even friendships with colleagues? Examples please!

Hilary S. Callahan Long before 2020 and 2021, our UNPAK members were "hanging out" using Google tools, and that type of experience is now so ingrained in everyone, so it is no longer as special. It is gratifying to see Zoom enabling other scholars and educators to do this work, and to communicate better.[19]

After so many years, when we meet in person at conferences or other events, it is similar to picking up with life-long friends from middle school or high school. We have many shared experiences. We have celebrated each other's promotions; some of us have seen each other's children grow up and so forth. This is a huge benefit of extending research for more than the usual three-year cycle of funding, and students pick up on that. In a meeting this semester with a recent UNPAK student, she described UNPAK's investigators at College of Charleston as "angels" because of their patience and genuine concern for all. I do, very much, feel privileged to be involved in a project with that much authentic commitment to teaching and mentoring, and to collaborating.

We had a few informal commemorations of UNPAK's tenth anniversary this year, and I do remember Matt Rutter referring to UNPAK as a philosophy and even "a way of being" and that really resonated with me, and with this book's spotlights on authenticity in STEM research.

Michael Wolyniak I cherish the professional and personal relationships that have developed as a result of my affiliation with UNPAK. I still associate with the majority of my colleagues from the beginning of UNPAK to this very day I am still able to send my students to exciting summer research opportunities that are affiliated with UNPAK. Taken together, UNPAK has been one of the most important parts of my professional development. Thank you to the UNPAK PIs for always welcoming me into your labs and groups. I treasure my professional and personal relationships with each of you and they have really shaped my expectations for collaboration. Thank you!

[19] Also see Patterson et al. (this volume).

Matthew T. Rutter Perhaps it is from being in UNPAK since the beginning, but I have literally dozens of new professional colleagues and absolutely count many of them as my friends. Frankly, at the start I knew my local colleagues well and our other collaborators ranged from new acquaintances (Mike Wolyniak, Jenn Thompson) to a collaborator I knew but would get to know much more through UNPAK (Hilary Callahan). Now any of them would be instant buddies that I would insist come out for a good drink and a meal if I were so lucky as to encounter them at a meeting or a visit. As UNPAK has expanded, I can sincerely say that each person I have met has been so impressive and fantastic in their line of work—all are the epitome of teacher-scholars. Some we manage to get to Charleston periodically, some I am just starting to get to know, some I feel like I know very well despite never having been in the same room. I enjoy every minute of it.

16.7 Coda

Hilary S. Callahan Among myriad ways to wrap this wide-ranging conversation, one is to pause to reflect on the shifting context within which UNPAK has continued into a second decade. In hurricane-prone Charleston as well as throughout the U.S., storms and floods impacted many UNPAK campuses, even as UNPAK campuses in California and Seattle experienced wildfires as common climate-related events. On and near several UNPAK campuses, shocking violence and loss of life have drawn media coverage, grief, and rage. Campuses are spotlighted as homes for both ongoing protest of and healing from violence and loss of life, even as they persevere as places for learning and thinking with data and scientific evidence, including the tools for tracing the connections of the sustainability crisis to structural racism, to oppression and injustice.

All of this makes it notable to reflect on turns in this conversation that probed activism or politics.[20] All of us acknowledge, and some even emphasize, that UNPAK is inherently intertwined with broader cultural and political currents. Indeed, the grant that initiated the project in April 2011 was delayed for four months because of a debt ceiling crisis and the failure of a polarized Congress to approve a Federal budget. Fast-forwarding past additional shutdowns and impasses during the Obama administration, we arrive in January and April 2017. UNPAK scientists and students watched or participated in prominent public marches to highlight the role of women and science in society more broadly. Then, in January of 2021, we watched Washington D.C. struggle through massive chaos to resume the hard work of democracy.

The many months of the Covid-19 pandemic forced UNPAK and many others to rely heavily on virtual tools to conduct research, teach and learn together. Amidst

[20] See Pfirman and Winckler (this volume, Chap. 19).

frustration and fatigue, some have drawn inspiration from the potential benefits of these tools. For UNPAK, this led to a proposal and new award based at the College of Charleston from the National Science Foundation. The next phase of UNPAK—D-CURE, for Digital-CURE—is premised on virtual work as not just productive, but potentially accessible to more students and campuses, and to more diverse students. Optimistic about this next project, UNPAK is proud of its long journey and prospects for continuing along its ever-adaptable and widening path, learning and training in STEM in solidarity.

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