Authors
Lovell, Robin J
Egerer, Monika
Montgomery, Ryan
et al.

Publication Date
2022-09-04

https://escholarship.org/uc/item/7np735s7
pp. 429–436 in S. Seagroves, A. Barnes, A.J. Metevier, J. Porter, & L. Hunter (Eds.), *Leaders in effective and inclusive STEM: Twenty years of the Institute for Scientist & Engineer Educators*. UC Santa Cruz: Institute for Scientist & Engineer Educators. https://escholarship.org/uc/isee_pdp20yr

Pedagogical Training for Graduate Students: Applications in Academia and Beyond

Robin J. Lovell[*1], Monika Egerer[2], Ryan Montgomery[3], Elissa M. Olimpi[4]

[1] Sociology Department, Manhattan College, Bronx, NY, USA
[2] Department of Life Science Systems, TUM School of Life Sciences, Technical University of Munich, Hans Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany
[3] Lawrence Hall of Science, University of California Berkeley, Berkeley, CA, USA
[4] Department of Fish and Wildlife Conservation, Virginia Tech, Blacksburg, VA, USA
[*] Corresponding author, robin.lovell@manhattan.edu

Abstract

The ISEE PDP program offers vital support to graduate students that is often missing in the U.S. doctoral training tradition. This panel will explore some of the advantages and uses of the ISEE methodology in a variety of educational and also professional settings. First, we explore the relationships between learner identities and outcomes, including the benefits of "facilitation for equity" in the classroom, to facilitate research discussions, and beyond. Second, the paper delves into "backward design" as a method for establishing learning outcomes, curricular plans, and translating theory into practice. Finally, we discuss how ISEE concepts can help all learners of all ages and backgrounds to navigate their career goals and vision, including teaching educators and researchers how to use goal-oriented curricular development. While each vignette approaches the subject from different angles and professions, the structured planning and theory behind curricular design holds true across a variety of settings.

Keywords: backward design, equity & inclusion, STEM identity

1. Introduction

The ultimate goal for many who pursue a doctorate is to become a college professor; to inspire students while imparting one's enthusiasm for a subject through engaging lectures and meaningful course work. However, the role of higher education is not to prepare doctoral candidates to teach, but to conduct research. Further, the traditional Socratic method does not account for a variety of learning styles, student experiences, and backgrounds. This oversight, in the end, continues to privilege those who already succeed in higher education, leaving behind all those who might benefit from another learning pathway. In this article, four authors discuss how the Institute for Scientist & Engineer Educators (ISEE) Professional Development Program (PDP) influenced their professional pursuits.

The article proceeds in the following fashion. Dr. Robin Lovell describes their experience running a

Faculty Workshop for Digital Arts and Humanities (DAsH) curricular development, using backward design and scaffolding concepts to train faculty at Manhattan College. Dr. Ryan Montgomery describes how his experience with ISEE has been instrumental in developing a National K–8 Digital Science Curriculum, including a focus on learner identities and a formative assessment framework. Dr. Monika Egerer discusses how she uses inquiry approaches learned from ISEE PDP in her group's field research in urban ecology with student researchers and citizen scientists at the Technical University of Munich. Finally, Dr. Elissa Olimpi discusses how she has applied backward design principles to her outreach activities with diverse stakeholder groups.

The ISEE PDP skills each author employs have not only helped in their respective career development, but also in the quality of their work, including research and instructional design. Further, in each context it helps the PDP alumni create inclusive curricula that will ultimately advance diversity, equity, and inclusion in their fields.

2. Case studies in backward design

2.1 Creating a data-driven curriculum across disciplinary silos

The Digital Arts and Humanities (DAsH) program at Manhattan College is an interdisciplinary major and minor that welcomes students from across all schools at the college. The program draws on courses from many disciplines, evaluating each class to ensure it has at least 30 percent content, tools, and methodology that fits within the DAsH philosophy, explained in more detail below. The program director, Dr. Maeve Adams, and two fellow steering committee members, Dr. Adam Arenson and Dr. Robin Lovell, designed a faculty development seminar to help professors turn existing courses into DAsH-eligible offerings. This section outlines how Dr. Robin Lovell infused the DAsH approach with the pedagogical underpinnings they learned during the ISEE PDP training.

2.1.1 Data and digital tools as foci

The DAsH program brings the techniques of data analysis and digital representation to traditional questions in the humanities and social sciences. It also reaches "across the aisle" to include courses in business, engineering, and the natural sciences. To build out the course offerings necessary to support such a diverse program, Dr. Lovell, an Assistant Professor of Geography, Dr. Adams, a Professor of English, and Dr. Arenson, a Professor of History, set out to train fellow faculty members to build their courses with a standardized backward design approach for students. While the three professors had very different subject expertise, they settled on the DAsH approach collectively. The concept for the faculty seminar was to help guide curricular development, regardless of the discipline, to help students:

Find data ⟶ Clean data ⟶
Analyze data ⟶ Present an analysis

While this workflow may seem straightforward, the process of reflectively revising a syllabus to include proper learning objectives and structured assignments that follow this flow was quite challenging.

To ensure faculty properly equipped their students to clean, analyze, and present data, another important focus of the DAsH seminar was providing instruction to faculty to both obtain and teach digital tools as a skill set for their students. To give faculty members as many options as possible, the three facilitators gave basic descriptions and operating procedures for a range of tools: Voyant, Hypothes.is, n-Gram, ArcMap, Tableau, Audacity, Padlet, Omeka, StoryMap, Wordtrees, Excel, and others. These tools were taught in lightning sessions, providing a brief overview and enough content for faculty members to return to a particular tool if needed.

2.1.2 Backward design within a backward design

The facilitators use the faculty development seminar to create the experience a DAsH student should have, but for the faculty. In this way, the approach is very similar to what the ISEE PDP does with its graduate students. The deliverables each faculty member must produce include a revised syllabus, lesson plan, and assignment. To complete these items, each of the 12 faculty members completes a data search, data cleaning, data analysis, and a presentation of findings.

While each faculty member is experiencing the curriculum as a student, they are simultaneously applying this experience to their syllabus revisions. In this way, the learners are both experiencing and applying the principles of backward design. For example, when we kick off the seminar we define our objectives clearly, and ask that each faculty member do the same for their course as homework. We then provide ongoing assessment through daily surveys and individual feedback on assignments, providing multiple opportunities for peer and teacher intervention. Thus, the faculty members are seeing how a truly goal-oriented syllabus achieves learning objectives and then directly applying the concepts to their own syllabus.

2.1.3 Lessons learned from two DAsH faculty cohorts

The training program was run for two years, in 2019 and 2020, resulting in over ten newly designed, DAsH-ready courses. The feedback from faculty participants was overwhelmingly positive, and student feedback from the courses taught was similarly enthusiastic. The pedagogical approach inspired by the ISEE PDP program, including backward design, essential scaffolding, and continual assessment, created a template from which faculty could incorporate digital tools into human-focused courses. Further, it enabled a data-driven approach to assignments that seemed impossible to many of the faculty members at the beginning of the seminar.

2.2 Creating transdisciplinary research platforms in urban ecology using citizen science and ISEE principles

Urban ecology is a research field where the city is a laboratory and the hub of scientific investigations. It is where researchers may investigate the impact of city residents' habitat management on, for example, biodiversity and ecosystem functioning. Because cities are generally built and designed with people as the focus, research should involve stakeholders who make decisions in the process. Urban ecology thus requires transdisciplinary approaches to work with and engage the public in scientific research. Citizen science (CS) is an increasingly employed method that involves citizens in scientific research and knowledge production, and can work to address global problems including biodiversity decline. For example, insect pollinators are a widespread research topic for CS projects where volunteers may observe pollinators. Aside from a valuable source of data for researchers, CS is also an approach to increase interest in and appreciation of insect pollinators.

Our research group at the Technical University of Munich in collaboration with the Museum für Naturkunde Berlin harnessed CS in our ecological research on wild bees and pollination services in community gardens in Berlin and Munich. ISEE principles supported the design of a transdisciplinary CS platform where gardeners collected data on their plants alongside researchers, documenting bee diversity in the garden to collectively create conservation interventions together to later implement in gardens.

2.2.1 Prior knowledge, equity and inclusion to create multiple ways to productively participate

CS calls for pedagogical techniques that can effectively communicate the content of a research project as well as certain technical skills required for project participation and data collection. Furthermore, the methods should provide multiple ways for people to participate, regardless of educational background or prior experience. These CS guidelines echo ISEE principles around designing curricula with diversity (e.g., in ways of learning) in mind and working with prior knowledge of learners. One increasingly important topic in CS is to consider who is participating in the research process: are all stakeholders involved and equally represented? Who may be most likely to be "lost" along the pipeline of the research process? What is the background of CS participants that are important to consider in designing teaching and communication materials? Often, CS methods may be biased to certain community members that have time or the scientific background that create low barriers to entry due to prior knowledge. It is necessary to create equitable platforms that target those who may be most hesitant to be involved, but also to create communication strategies and teaching materials that communicate information in different ways.

The project "Forschen für Wildbienen" used ISEE principles around working with prior knowledge and equity and inclusion to target some of these challenges in CS. Just like in the college classroom, diversity in CS does not only include gender, age or ethnicity, but there are many other factors such as disability status, education level, and economic classes that should be included. Furthermore, gardeners already have a deep knowledge of their gardens and their plants. We created two projects where we worked with gardeners' prior knowledge of their plants to collect data on plant pollination and growth. Here, to be inclusive of those comfortable and also less comfortable with quantitative data measurements, we created tasks where one is more technical — gardeners count the flowers on their plants weekly — and one that engages more with art and creativity — gardeners photo document plant development weekly. We designed visual trainings, video clips, a phone app, and met with gardeners one-on-one to teach these methods.

2.2.2 Multiple ways to productively participate

At the end of the summer, gardeners submitted their data along with a survey questionnaire around their motivations to participate in CS. Surveys with gardeners afterwards found that regardless of attempts to explain different ways in the training, participants still had various forms of trouble. Surprisingly, although we had emphasized throughout the project that we see gardeners as experts in their plants, many doubted this expertise when it came to "scientific data" collection. Many felt doubt when measuring their plants, and communicated that they lacked expertise or were confused by various new observations. Here we hope to improve by creating more visual examples of different steps of pollination, but also more deeply working with backward design principles to show participants what success looks like.

The motivations of participants revealed that diverse age ranges and gardening backgrounds engaged in the work. People were highly motivated to participate in the CS project for education around pollinators and to contribute to something meaningful as nature conservation. Yet this is an important message for future more inclusive projects: those people that are environmentally aware are easy to attract in a project; but we also need to capture those who may have less interest in e.g. nature or pollinators. Furthermore, as discussed, providing multiple ways to learn, communicate and be productive enables teachers to engage more people in a process. In our project, we found that considering more than just the basic demographics was important — people's positive emotions towards insects like fascination or fear strongly predicted CS participation, and likely can play a key role in CS engagement and learning. One question is how to use this knowledge of nature connectedness and emotions to lower barriers to participation and increase equity and inclusion.

A diverse range of city residents in urban CS projects helps create livable cities designed for all people. Using the principles of inclusion, the knowledge created from CS can inform urban planning for both biodiversity and livability. New adapted research and teaching formats in CS must engage, inspire and empower the public for conservation in cities. Here, it is critical to overcome biases that gardeners can/cannot be scientists, and science can be performed also by citizens, regardless of whether they are wearing a laboratory coat. Furthermore, it is important for scientists to communicate that prior knowledge on, for example, a garden ecosystem is welcome and can be integrated into the research process. Using the PDP principles, overcoming these biases and communicating prior knowledge can be a structured and deliberate process.

2.3 Backward design for coherence

Initially, as a lecturer at the University of California Santa Cruz and Cabrillo College, Dr. Ryan Montgomery developed introductory astronomy courses and activities that would engage students and serve as effective educational experiences. Later, as an assessment developer on a large team developing national science-standards aligned with K–8 digital science curriculum (Amplify Science), he leveraged the principles learned through his experiences with the ISEE PDP to guide teams in developing coherent lesson plans.

2.3.1 Relationships between learner identities and outcomes

By coming to understand the importance of the relationship between learning identities and outcomes, Dr. Montgomery developed the ability to create activities and curriculum that allow multiple entry points for learners with differing prior experiences, including multiple ways of engaging with the content (simulations, reading, group work), and multiple ways for students to express understanding of that content (multiple choice, writing, argumentation, creating conceptual models, predicting outcomes).

2.3.2 "Backward design" as a method for establishing learning outcomes, curricular plans, and translating theory into practice

Backward design has been foundational in Dr. Montgomery's recent work co-developing a National K–8 Digital Science Curriculum (Amplify Science). In order to develop science units and assessments that stay focused on the learning goals, his role has been to help the unit development teams come into explicit agreement about the meaning and scope of the learning goals. This process of goal oriented "same-pagery" is essential to create coherent lesson plans, built by a team of developers. In order to develop this level of coherence through explicit agreement, it is essential to define concrete, observable student work products exemplifying student understanding of those learning goals. Creating and discussing these student work products allowed the development team to surface and reconcile otherwise invisible disagreements and misalignment in vision quickly, before significant development time was wasted. For instance, in a series of lessons intended to teach students the effect of distance on magnetic force, it was essential to spend time discussing the limits of what we expected students to know explicitly: do we want them to know the quadratic effect of distance on force? Or do we just want them to know that the force changes more at closer distances? These would result in different learning activities and different student work products, one learning goal requiring quantitative data analysis and resulting in students correctly stating the functional form of the relationship, and the other learning goal requiring qualitative comparisons between force changes and resulting in students correctly ordering the magnitudes of the force changes. This process allowed lesson development to proceed on a tight schedule, with a unified vision across the whole development team. Additionally, these created student work products served as an important check for developers as they explored and created activities for their lessons. As they developed their lessons they were able to check their coherence with the learning goals easily, due to the concreteness of the student work products, simply by asking themselves "is this activity/lesson I'm developing going to prepare students to be able to create this student work product?".

This reflexive approach is important because in educational lesson development it is often valuable to be able to switch into working in "forwards design" mode, allowing an engaging activity or compelling reading to serve as a foundation or guide for development. The difficulty with working in "forwards design" mode occurs when the resulting lesson/activity does not align well with the learning goals, and this misalignment goes undetected. These student work products were invaluable to our development process because they were concrete enough to allow everyone on the development team to be able to self-diagnose the alignment of their lessons with the agreed-upon learning goals. Finally, these student work products also served as the foundation for the development of assessments that allow students to express their understanding of the learning goals.

Previously, in developing college level courses aimed at engaging students in active learning, Dr. Montgomery was able to identify the opportunity to utilize the "section" portions of the classes (commonly used as TA office hours or homework assistance work sessions) as an opportunity to engage students in hands-on experimentation and learning sessions. Using backward design, he was able to define a set of learning objectives (including analyzing data, order of magnitude estimation, arguing from evidence, etc) and create weekly activities that fit within the "section" class-times that engaged students in practice with these learning objectives. In the model of formative assessment, students were given explicit feedback on their progress towards these learning objectives and could "make up" one of these activities during the last week of the course. Additionally, students' course grades were based on the cumulative learning and effort distributed widely across the course, scored and continually viewable online, so that students had the knowledge and ability to course-correct as needed.

2.3.3 Navigating career goals and vision

Finally, ISEE concepts helped Dr. Montgomery navigate his career goals and vision. The principle of formative assessment has served as a powerful model for making explicit his career goals, and measuring progress towards them with the appropriate timescale for success implicit in the formative frame. Throughout this process, being able to see progress, measured in effort, in the face of a complex career search was invaluable psychologically. It is hard to repeatedly apply for jobs, do your research, get your hopes up about a potentially great fit, and then to not get the position (or worse, to not hear back). But being able to take these experiences formatively, learning from them and seeing opportunities for improvement, helped both psychologically and through said improvement.

2.4 Designing effective outreach activities for an ecological research project

As a postdoctoral researcher at UC Davis, Dr. Olimpi coordinated a large, interdisciplinary project. This project was funded by the USDA and addressed how farms can be managed to support bird conservation, agricultural production, and human health goals. In the Central Coast of California, where this study was focused, there has been major concern that wildlife could carry foodborne diseases, such as *Salmonella* and pathogenic *E. coli*, which could be spread from wildlife to crops, and then from contaminated crops to consumers. These foodborne pathogens are responsible for outbreaks of foodborne illnesses, several of which have been linked to fresh produce grown in California. In an effort to exclude wildlife from farms, many farmers are pressured to remove natural habitat, but our research findings suggest that this strategy may be misguided. We found that conserving habitat around farms can support bird conservation, mitigate food safety risks, and decrease crop damage from birds.

An important part of this multi-faceted project was to develop outreach materials to share back research findings with grower participants and to communicate policy-relevant findings to the broader agricultural community. Outreach events included workshops on farms, speaking at agricultural conferences, and meeting with growers individually. Other outreach materials generated as part of this project included annual reports with farm-specific research results and a YouTube video. While these outreach activities did not include traditional classroom learning, they did provide many opportunities to apply principles and techniques Dr. Olimpi learned as a participant in the ISEE PDP.

2.4.1 Application of PDP principles: prior knowledge and backward design

To create effective educational materials and structure outreach efforts, Dr. Olimpi applied backward design principles and used prior knowledge and experience to inform her approach. Prior knowledge and experience were used to tailor messaging with the idea that starting from a place of shared values would produce the most effective outcomes. Information about prior knowledge and experience was gathered in two ways: 1) informal conversations in the field, and 2) a survey instrument designed to elicit feedback from growers on their values related to bird conservation, food safety risks, and farm management decisions. The survey instrument was developed to meet other project objectives but had the added benefit of eliciting growers' perspectives and prior knowledge. Backward design was used to identify the learning outcome goals for outreach events. Even though outreach events were often informal educational settings that did not involve formal assessment, Dr. Olimpi applied the rubric concept to identify assessment goals that learner participants should be able to complete by the end of the outreach event. Finally, outreach activities were designed to contribute to learner success of the assessment goals.

2.4.2 Outreach activity results and discussion

Through informal conversations and the survey instrument, Dr. Olimpi learned that many growers believed that birds provided benefits like pest control but could also damage crops and carry foodborne pathogens. Conversations with growers (and previous studies) also revealed that most growers were taking active measures to deter wildlife from farms by removing habitat and using other bird deterrent practices (e.g., sound cannons, sparkler streamers) to prevent crop damage and reduce food safety risks. By understanding these perspectives and experiences, Dr. Olimpi explored gaps in knowledge, contrasting management motivations with research findings. Although many growers had practiced habitat removal to improve food safety outcomes, our research findings suggest that habitat removal efforts are unlikely to achieve the desired outcome of mitigating food safety risks.

Dr. Olimpi used this knowledge gap on the effects of habitat removal on farms to then structure activities using backward design. The goal was for participants to understand how habitat conservation and removal impact food safety risks and crop damage associated with wild birds. As an informal assessment, learners should be able to draw connections between habitat management on farms, applying the concept that habitat removal could increase both food safety risks and crop damage. In each lesson, she presented a series of research findings that linked habitat conservation to bird benefits and costs to agriculture. In some cases, Dr. Olimpi used additional techniques to improve outcomes. For example, when meeting with growers one-on-one to share research results at their farms, she contextualized farm-specific results in the broader study. In these exercises, growers were able to compare pathogen prevalence and crop damage on their farms, relative to other nearby farms with different amounts of surrounding natural habitat. In this way, growers were gently prompted to translate theory into practice through a discussion of how habitat removal and restoration could impact outcomes on *their* farms.

3. Conclusion

While each case above outlines a completely different setting, the authors consistently apply a variety of the ISEE PDP principles. The concepts can be divided into three broad categories: goal setting, assessment, and content delivery. Goal setting tools include backward design, including setting course or research learning objectives. Assessment tools include continual and differentiated assessment throughout a learner's experience, student feedback on learning (meta feedback), the rubric concept, evaluating previous knowledge of the learners, and understanding learner backgrounds. Finally, for the most part content delivery in each case included purposeful scaffolding, including tailoring content to specific learners, institutions, or situations.

In the classroom and in field research alike, ISEE principles can be applied to teach inclusively and diversify scientific knowledge creation. With calls for more women and previously excluded communities in science, higher education needs a diverse range of effective teaching skills for all postdoctoral people to employ in their careers. The ISEE PDP helps develop those skills in a highly effective manner that even integrates into non-instructional settings. Not only does this show the vast applicability of pedagogical training for graduate students, but also the value for professional advancement for each individual. In essence, although not available at every institution, pedagogical support and instruction could help bolster a very challenging and competitive career, as Dr. Montgomery underlined. Further, as evidenced by Dr. Olimpi's and Dr. Egerer's examples, the concepts improve research design as well as instructional design.

This brings the paper to its final point: although absolutely critical to the development of effective teaching, the ISEE PDP also serves a dual purpose of improving *research* effectiveness. Because the reward system in academia (i.e. tenure and promotion) is so dependent on high quality research, it would behoove most high education institutions to develop a similar PDP. In this way, whether graduates branch into research, teaching, or a different profession entirely, they gain skills that are inclusive, effective, and support high quality scholarship.

Acknowledgements

This work was funded in part by the National Science Foundation (NSF), AST#1743117. The PDP was a national program led by the UC Santa Cruz Institute for Scientist & Engineer Educators. The PDP was originally developed by the Center for Adaptive Optics with funding from the NSF (PI: J. Nelson: AST#9876783), and was further developed with funding from the NSF (PI: L. Hunter: AST#0836053, DUE#0816754, DUE#1226140, AST#1347767, AST#1643390, AST#1743117) and University of California, Santa Cruz through funding to ISEE.