



Raising undergraduate researchers' interdisciplinary consciousness through dialogue

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Accepted: 17 May 2024
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Abstract

The importance of interdisciplinary approaches for research and education in environmental studies and sciences is well known. Integration of the multiple disciplinary approaches taught in separate courses required within these undergraduate majors and minors, however, remains a challenge. Program faculty often come from different departments and do not have time or space to integrate their own approaches with each other, resulting in individual ways of understanding interdisciplinarity. Secondly, senior capstone, thesis, or other project-based degree requirements often come too late in an undergraduate education to design an integrative project. Students would benefit from prior training in identifying complementary or divergent approaches and insights among academic specializations—a skill built from raising interdisciplinary consciousness. We present a workshop designed to enhance undergraduates' interdisciplinary consciousness that can be easily deployed within courses or co-curricular programs, specifically summer research programs that are focused on dedicated practice within a field of study. The central question of this project is: How do we facilitate interdisciplinary consciousness and assess its impact on our students? We propose a promising, dialogue-based intervention that can be easily replicated. This dialogue would benefit academic programs like environmental studies and sciences that require the interaction and integration of discipline-based norms. We found that our dialogue intervention opens students' perspectives on the nature of research, who research is for, epistemological differences, and the importance of practicing the research process, a unique educational experience. These perspectives are crucial to becoming collaborative, twenty-first century professionals.

Keywords Interdisciplinary education · Undergraduate research · Research skills development · Dialogue-based workshop · Toolbox dialogue method · Assessment of student learning outcomes

Introduction

Twenty-first century college students face the difficult demand of becoming emergent experts in their chosen courses of study while also developing generalizable professional competencies. Students are expected to forge new connections between disparate disciplines, develop transferable skills, become civically engaged, collaborate with others, and produce original work to be uniquely qualified candidates for postbaccalaureate opportunities like graduate school, fellowships, or employment (Moll 2019; Corbett and Rosen 2020; Stamp et al. 2015). These demands come from the increasingly non-linear nature of career paths in our technologically and economically dynamic, interconnected world. Students need to be flexible, able to quickly adapt to new needs, and to apply multiple perspectives when addressing complex societal problems.

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Meeting the challenges of a twenty-first century education is not only the responsibility of students—it is our very charge as educators. It necessitates shifting the norms and practices of institutions of higher education and recognizing when disciplinary power asymmetries are in tension with the mission of interdisciplinary, collaborative problem solving (Imbruce and Prazak 2021). Many universities foreground interdisciplinarity as a valuable approach to education. A strong body of evidence shows that the integration of humanities, arts and STEM disciplines is associated with positive learning outcomes, creativity, and career preparedness for undergraduates (NASSEM 2018; Bourdeau and Wood 2021). Likewise, interdisciplinary research is becoming a mainstream approach for solving complex societal and environmental problems that lie at the intersections of traditional disciplines of study (Menken and Keenstra 2016; Repko and Szostak 2020).

Research and educational programs that focus on the theory and practice of team science and interdisciplinary research have burgeoned over the last few decades, highlighting the need for new career paths for “integrators”—professionals skilled in the process of combining a wide range of perspectives from different disciplines, as well as from the worlds of research, policy, and practice (Hoffmann et al. 2022; Reisman et al. 2022). Those who can merge, contrast, and identify complementary or divergent insights, and those who can collaborate, empathize, be self-reflexive, and seek to understand others’ perspectives, are the kinds of professionals in demand. And these skills, competencies and attitudes are, arguably, what interdisciplinarity cultivates (Boix Mansilla 2010; Rhoten et al. 2006; Ivanitskaya et al. 2002).

Environmental studies and sciences departments and academic programs have long faced the structural and theoretical challenges of designing and implementing interdisciplinary education (Clark et al. 2011a, b; Vincent and Dutton 2016). The main challenges that persist include centering humanities and social sciences in often natural science dominated departments; teaching professional skills through the practical or place-based applications of ideas to move beyond academic abstraction common to STEM education; finding interdisciplinary “through lines” between a potpourri of multidisciplinary courses for an environmental major; and incentivizing, evaluating, and rewarding interdisciplinary scholarship. Environmental studies and science programs can lead the charge on systematizing and valuing interdisciplinary education to meet twenty-first century workforce needs. They can do so by learning from and partnering with other programs with similar interests in interdisciplinary education.

Many institutions of higher education in the USA have summer programs and/or centralized offices that offer undergraduate research opportunities for experiential learning and

professional development (Murray 2017). These programs are ripe for integrating interdisciplinary training and can work for academic departments and/or students and faculty from all majors to cultivate interdisciplinarity. Every discipline has some form of inquiry—music or psychology, poetry, or engineering—undergraduate research experiences are unified in centering on an open-ended investigation. Yet, there are great differences between disciplinary forms of inquiry. In this paper, we report on an initiative within a summer undergraduate research program to pilot a novel and easily implementable intervention: a structured dialogue that centers on *interdisciplinary consciousness*. The intervention is designed to give students the opportunity to find similarities and differences among their understanding and experiences in research, which can be even more prominent when student groups participating in the dialogue are from a wide mix of disciplines. This intervention can be deployed at any type of institution and with any level of student in any field of study, meeting students where they are in their development.

We follow the determinants of interdisciplinary consciousness that Kjellberg et al. (2018) have identified as key to interdisciplinary deliberation and decision making: (1) self-awareness that comes with reflexive thinking about one’s own knowledge making, (2) sensitivity to similarities and differences in research processes across disciplines, (3) perspective seeking by considering problems from different intellectual perspectives, and (4) a “yes and” attitude to integrate new perspectives into one’s own views. Rather than supporting a particular kind of interdisciplinary thinking, such as the boundary crossing between natural and social sciences common to environmental studies and sciences, these four ways of thinking can be applied to any kind of interdisciplinary challenge; furthermore, they are suited to the broad array of undergraduate students in any research program. We argue that our dialogue intervention facilitates interdisciplinary consciousness to foster more holistic and integrative perspectives on the nature of research and a researcher’s role within the process. These perspectives are crucial to becoming collaborative, twenty-first century professionals.

The setting: Binghamton’s summer scholars and artists program

We implemented the dialogue intervention in Binghamton University’s Summer Scholars and Artists Program (SSAP) to enable undergraduates who are practicing being researchers in specialized areas to become aware of differences and similarities with their peers in other knowledge areas and to open their minds to new perspectives. Summer research programs have been hallmarks of high impact educational practices at many institutions for several decades (Kuh

2008). Binghamton University, a public research university, started SSAP in 2012 as a central program of its Undergraduate Research Center to foster original undergraduate student research and creative endeavors during the summer months. SSAP awards approximately 20 competitively selected participants a stipend to focus exclusively on their research for eight weeks, with guidance from a faculty mentor, and engage in professional development seminars. SSAP supports all disciplines and has provided awards for 190 participants from majors that range from English to history, biological sciences, theater, cinema, chemistry, engineering, and more. Projects are equally diverse, including experimental operas, documentary films, critical literary scholarship, scientific experiments, engineering prototypes, and beyond. Students convene approximately four times throughout the summer to introduce their projects, discuss their progress, practice research communication skills, and consider the broader impacts of their research. These meetings give students time to reflect on where they are in their research process and expose them to a wide range of discipline-based endeavors.

The multidisciplinary nature of SSAP makes it an ideal venue for (1) assessing interdisciplinary consciousness in undergraduate students across disciplines and (2) evaluating whether our dialogue-based intervention expands participant thinking of multiple perspectives and builds capacity for integrating these in constructing shared understandings of research—the essence of interdisciplinarity (Repko and Szostak 2020). Not only does the program allow students to engage in hands-on, in-depth research at the undergraduate level but it also brings together students whose majors and course schedules typically do not overlap, such as engineering students with English majors, artists with biochemistry majors, and many more combinations. Such diversity in interests exposes students to a wider range of discipline-based experiences and consequently, we believe, would produce an equally wide range of responses to discussion prompts that address the purposes for and definitions of “research.”

The central question of this project is: How do we facilitate interdisciplinary consciousness and assess its impact on our students? We designed a dialogue-based workshop to unearth students’ assumptions and perceptions about the nature of research, and their place within the research process, to develop a more nuanced and interdisciplinary understanding of research across the dialogue participants. We structured the dialogue around five themes we consider critical to interdisciplinary research and education: research objectives, the audiences who would benefit from knowing about the research, the research inputs, the process used to develop research outcomes, and how the identity of the researcher influences each of these themes.

Toolbox dialogue initiative overview and method

Authors at Binghamton University¹ partnered with the Toolbox Dialogue Initiative (TDI), a research and outreach effort that aims to understand and facilitate communication in collaborative, cross-disciplinary research through dialogue-based workshops. The Toolbox dialogue method employs a survey-like instrument, called the “Toolbox” (Eigenbrode et al. 2007), to structure the dialogue. A Toolbox is organized into thematic modules, with each module made up of a series of statements designed to promote reflection and enable collaborators to articulate and coordinate the often implicit and unacknowledged core beliefs and values they have as researchers (O’Rourke and Crowley 2020). Participants rate their agreement or disagreement with each statement and then discuss their reactions in dialogue (Rinkus et al. 2020). The Toolbox dialogue method has been carried out both virtually and in-person with a variety of groups, including research teams, undergraduate and graduate student cohorts, and community-based organizations (Hubbs et al. 2020).

Although TDI has primarily engaged academic researchers, the dialogue-based method has been adapted for use with students in NSF-sponsored Research Experiences for Undergraduates and in collaboration with the Whittier Scholars Program (WSP) at Whittier College. In 2013, TDI began working with WSP to develop a version of the Toolbox dialogue method that could help undergraduate students in an interdisciplinary program expand their appreciation for disciplinary ways of knowing. The scientific research Toolbox instrument, most often used with research teams in the past (Looney et al. 2016), was redesigned to focus on aspects of the research experience of students in WSP. The resulting instrument and data collected informed the Kjellberg et al. (2018) article and served as the foundation for the work presented here.

Data collection and analysis

A 3-h virtual workshop employing the Toolbox dialogue method was conducted with 20 students participating in SSAP in July 2021 (Table 1). The workshop began with a preamble introducing the students to the dialogue-based method and the concept of *interdisciplinarity*, followed by completion of the Toolbox instrument (pre) before being divided into two Zoom breakout rooms for the dialogue with 10 students in each group. The Toolbox instrument designed

¹ AUTHOR 1 and AUTHOR 2 were at Binghamton in summer 2021 when the workshop was completed.

Table 1 Student information ($n=17$): 20 students participated in the dialogue; however, 3 students (P3, P7, P13) did not provide permission for their information to be used for research purposes and therefore are not included in any part of this study. This sample size, while

small, is consistent with qualitative methods to illustrate how this intervention operates in student groups to foster interdisciplinary consciousness

Participant no	Gender	Academic year following the summer program	Disciplinary orientation	Major
P1	Female	Third-year undergraduate	Social and Behavioral Sciences; Arts and Humanities	Politics, Philosophy, and Law with minor in Environmental Studies
P2	Female	Fourth-year undergraduate	Medicine and Health Sciences; Life Sciences	Integrative Neuroscience
P4	Male	Third-year undergraduate	Life Sciences	Biochemistry
P5	Female	Second-year undergraduate	Life Sciences	Biochemistry
P6	Male	Fourth-year undergraduate	Arts and Humanities	Graphic Design
P8	Female	Third-year undergraduate	Social and Behavioral Sciences	Psychology, Linguistics
P9	Female	Fourth-year undergraduate	Life Sciences	Biology
P10	Male	Third-year undergraduate	Arts and Humanities; Social and Behavioral Sciences	Music, Psychology
P11	Male	Fourth-year undergraduate	Social and Behavioral Sciences	Financial Economics
P12	Male	Third-year undergraduate	Engineering	Mechanical Engineering, Minor: Sustainable Engineering
P14	Female	Fourth-year undergraduate	Arts and Humanities	Comparative Literature and Russian Studies
P15	Male	Third-year undergraduate	Social and Behavioral Sciences; Arts and Humanities	Political Science and English with a minor in Spanish
P16	Male	Fourth-year undergraduate	Arts and Humanities; Physical Sciences and Mathematics	Art History and Mathematical Sciences
P17	Female	Third-year undergraduate	Life Sciences; Arts and Humanities	Biology and English Literature
P18	Male	Fourth-year undergraduate	Arts and Humanities	Cinema
P19	Male	Third-year undergraduate	Physical Sciences and Mathematics	Biochemistry
P20	Male	Third-year undergraduate	Life Sciences	Biochemistry

Table 2 Learning outcome questions: These 4 questions were presented to students at the conclusion of the workshop

- Q1: Do you see value in learning about the intellectual perspectives of your fellow scholars? Please briefly explain your response
 Q2: Did you learn something about your own intellectual perspective? If so, what?
 Q3: Did you learn something about your fellow scholars' intellectual perspectives? If so, what?
 Q4: Did you learn anything that you could integrate into your research? Please briefly explain your response

for this workshop was adapted from Kjellberg et al. (2018), adding a module on researcher identity, resulting in five modules (Objective, Audience, Inputs and Outcomes, Process, and Identity), each with 5–6 prompts to which students indicate their disagreement or agreement along a 5-point scale (access the full instrument here: DOI redacted for blind review—see supplemental material for review). Once students completed the instrument, the facilitator of each group opened the dialogue by inviting students to suggest a prompt for discussion, leading to conversational interaction among participants. Each dialogue moved around the instrument based on the students' interests for approximately 70 min, with the facilitators intervening only as needed to encourage participation or ask for clarification. Following the dialogue, students completed the instrument for a second time

(post). At the conclusion of the workshop, students used the Qualtrics online survey platform to complete an open-ended survey comprising four questions, contained in Table 2, designed to assess the learning outcomes of the workshop. The dialogues were recorded with consent and transcribed.

We structured our data analysis to determine how the dialogue affected the interdisciplinary consciousness of the student participants. We first reviewed all responses to the learning outcome questions listed in Table 2 to look for the most common themes that students reported. Our review found three main themes within the dialogue that caused students to reflect, question, and open themselves to new perspectives: (1) research audience, (2) epistemological differences, and (3) the research process. In the next step, we looked at the instrument prompts that relate to these three

Table 3 Changes in perspectives post-dialogue: average absolute difference is calculated for students' responses to each instrument prompt on the 5-point scale (1=disagree and 5=agree) collected before and after the dialogue to look for magnitude of changes in agreement and disagreement. Standard error for the absolute differ-

ence is calculated to show how much variation exists in pre- and post-dialogue responses for each prompt. The means for pre- and post-dialogue scores are calculated to provide an idea of the average opinions on each prompt

Module/prompt no	Prompt	Pre-workshop mean	Post-workshop mean	Average Absolute difference	Standard error
Audience 3	Good research speaks to experts in the field	4.07	3.94	0.75	0.25
Audience 4	A good researcher shouldn't worry about what their audience thinks	3.13	3.29	1.06	0.26
Audience 5	Most undergraduate researchers at Binghamton feel the same way about their audience	2	1.8	1.12	0.28
Inputs and Outcomes 1	Good research is grounded in facts about the world	3.80	3.75	0.88	0.26
Inputs and Outcomes 2	Good research is grounded in the opinions of experts	2.63	2.59	1.18	0.21
Inputs and Outcomes 4	The goal of my project is to help me advance in my career	3.88	3.41	0.59	0.19
Objective 4	A good researcher should be primarily concerned with realizing their own vision for the project	2.73	2.65	0.91	0.28
Process 1	I use transferable skills (e.g., oral and written communication, critical thinking, logical reasoning) that I have learned in courses in my research process	4.63	4.53	0.65	0.31
Process 2	The primary reason for participating in research is to develop specialized skills	3.13	2.47	0.82	0.18
Process 3	A research project combines learned skills in original ways	3.88	4.06	1.00	0.28
Process 4	The research process is just as important as the result	4.44	4.41	0.59	0.27
Process 5	Undergraduate researchers with the same set of research materials, applying the same research process, should reach the same conclusion	2.87	2.29	0.94	0.23

themes and reviewed the student's responses. Since the goal of the dialogue is to facilitate reflexivity and encourage comparison of different ways of thinking (Rinkus and O'Rourke 2020), we were interested in the magnitude of change from pre- to post-dialogue, rather than change in a particular direction (e.g., towards agreement). To assess this, we calculated the average absolute difference between the pre- and post-dialogue instrument responses to yield a measure of change in thinking. We also calculated the pre- and post-dialogue mean scores for each prompt for an idea of the average perceptions before and after the dialogue. (see Table 3 for selected prompts with pre/post mean scores, absolute difference, and standard error.) After comparing the learning outcomes and the pre- and post-dialogue instrument scores, we analyzed the dialogue transcripts for themes of research audience, epistemological differences, and skills developed through the research process. The transcripts were divided into sections based on the selected prompts, identifying where student discussion of each prompt occurred during the dialogue and connecting these various points of discussion within and across each of the two dialogue groups. We then reviewed the transcripts to determine if the dialogue provided any insight into pre/post shifts in instrument scores and for evidence supporting the learning outcomes self-reported by students. Triangulation of the data

from the Toolbox instrument pre- and post-scores, dialogue transcripts, and learning outcomes survey, as described above, resulted in the findings discussed below.

Outcomes

Three main shifts in students' thinking about the research process and their place within it were identified as attributable to this workshop: (1) increased awareness of who constitutes an audience, (2) broadened consciousness of epistemological difference, and (3) valuing the skills developed through engaging in the research process. Through analysis of the dialogue transcripts, we can see how students reflect on themselves as researchers, compare themselves to others, and acknowledge new perspectives, thereby raising their interdisciplinary consciousness.

Audience

The dialogue complicated the notion of who an "audience" is when it comes to considering the people who consume, respond to, or interact with the research produced by experts in a field. Prior to the dialogue, student responses to the instrument tended towards the view that "good research"

Table 4 Student responses on audience: these responses are from learning outcome questions presented at the conclusion of the workshop

Student responses on audience post-workshop

- “I learned that audience is something that needs to be taken into consideration in various disciplines such as engineering, where the designs for products need to be needed by a certain group. I learned to think more about inclusion and how past research may have been doing the opposite, so anything that comes from that needs to be reflexive.”
- “I learned that even though there are many different topics and fields being covered, we share a rather consistent view on the inclusivity of research and that it should be used to the benefit of people and the planet...I learned that I believe research does not mean much if it cannot be understood and used. Thus, availability of research is critical to making the changes we want to see from research in general.”
- “My fellow scholars taught me that our separate fields have many walls set up between them to keep the general population, with limited knowledge of a given subject, to be fully immersed in what they are saying. We should strive to take down these often-arbitrary walls as much as we can, without sacrificing the intellectual integrity of the given projects and research.”

has a specialized audience and that information produced within certain disciplines is meant to be consumed only by those within the field (Prompts Audience 3 and 5). Students were of split opinion, however, about whether they should value audience opinions during the production of research or not (Audience 4). Should researchers strive towards impartiality about audience opinion and not let it influence their research? Or should they take audience desires into account to deliver effective research?

A closer look at the dialogue transcript further supports such suggestions and outlines how conversations resulted in earnest introspection. Many students approached the question, “A good researcher shouldn’t worry about what their audience thinks” (Audience 4) with difficulty, expressing how divided they felt about the ways they might approach an answer as they considered the various kinds of audiences there are for research products. A student majoring in psychology and music even voiced their discomfort, claiming, “On the one hand, musically there’s a literal audience, but also the audience whoever is reading your manuscript for the research. I’m not sure exactly what to think about should the researcher worry about what their audience thinks or not...I think maybe to some extent, but there has to be some kind of balance” [P10]—a comment that elicited a similar sentiment by a graphic design student who responded, “Yeah, I think I’m in an interesting impasse with this question myself... because I’m trying to conduct this scholarly research but also another section of my project is I’m making a booklet... I have to pick the typeface that transfers this information about the importance of script aesthetic” [P6]. Using their own discipline as the basis for experience while responding to this prompt, students discovered that their perspectives interestingly converged. Indeed, through their conversation, students tended to agree that while experts often write for each other, they nevertheless need to consider accessibility of knowledge when producing research because there is more than one kind of audience: “They’re also excluding a large portion of the audience that might be interested in that research outside of whatever specialization in their field that they’re working on” [P5]. This response was followed

by: “But I think after listening to what people have been saying, what I think is a researcher collects the information and makes it accessible which might involve balancing how much jargon you’re using or defining things...” [P8]. This conversation led the graphic design student past the conflict he initially felt about the importance of communicating with an expert audience versus a general audience. He found clarity in what he heard from the group, “And I think what we’ve been talking about is the importance of that presentation [of research outcomes], making that presentation accessible, making it digestible for, I guess, the widest audience possible. Because I think that’s something that we value. Or I would. [P6]”.

We see two important findings from the dialogue: First, the immediate recognition that “through listening” and comparing viewpoints, students developed a new understanding of what a researcher is in relation to their audience, and second, the students moved towards recognizing the importance of making their research more widely available when considering their audience, a conclusion that integrated the varied viewpoints. This enhanced awareness of their audience after engaging in dialogue with each other complicates how students understand the objectives of research. These conversations allowed students to consider that the audience *should* be more varied or broader than they previously thought and that the goal of research is not just to realize a personal or purely disciplinary vision, but to have broader societal benefit. Such observations support the shift in responses that we saw when students answered the post-dialogue instrument. Table 3 shows that after the dialogue, students began to wonder about their audience, with more students seeing that there are a range of different feelings on the matter and moving towards the realization that good research has something to say to everyone, not just experts in the field.

The responses to the learning outcome questions presented in Table 4 illustrate how students’ reflexivity, awareness of others, and integration of perspectives led them to new conclusions about who research is for. These findings illustrate that when students reflect on who their audiences

are, they also begin to evaluate how they feel about their audiences—an observation supported by the student recognition that making research available and understandable to more than just experts matter. Through the interdisciplinary consciousness raised in the Toolbox dialogue, students increased their awareness of who should be considered part of a research audience, contributing to their understanding of what research is, and has in common, across disciplines. Collectively, this contributes evidence that the dialogue process can help undergraduates enhance their framework for why interdisciplinary communication is a vital skill, imperative to developing into an effective contemporary scholar.

Epistemological difference

Such changes in audience awareness further influenced shifts in perception towards the nature of knowledge generation, altering how students understood the purpose of research as a means of uncovering truths. Prior to the dialogue, the instrument scores showed that most students, regardless of discipline, strongly agreed that good research is grounded in facts about the world (Inputs and Outcomes 1), with only three students disagreeing [P6, P16 and P19]. All but one student from STEM majors agreed that “all undergraduate researchers with the same set of research materials, applying the same research process, should reach the same conclusion” (Process 5), while students from social science, arts and humanities disagreed.

Through the Toolbox dialogue, we saw students tackle how interpretation and perspective inform the processes of research and data collection and how subjective research can be, no matter the discipline. Despite initial agreement about research being “grounded in facts about the world” (Inputs and Outcomes 1), participants from STEM fields voiced their struggle with the ambiguity they saw in the question, claiming that their research starts with facts from previous studies rather than opinions generally held about the world. But as students continued to share their experiences and perspectives, they expressed how the approach and methodology they use start as opinions derived through their study and life experiences. Through conversation about the role of facts in research, students explored the differential and subjective parts of the research process, with the linguistics student taking a structural view of the research process: “It’s not really a question of the facts as an objective thing, because nothing is objective, everything is filtered via human perception, and subjectivity and power relations. The act of collecting data is still influenced by the researcher and the equipment, and even things like language. They all impact what we end up with” [P8].

One student majoring in political science and English grappled with objectivity and subjectivity by reflecting from their humanities perspective on the prompt, “all

undergraduate researchers with the same set of research materials, applying the same research process, should reach the same conclusion” (Process 5). They remarked, “I feel like the empirical stuff is important, but the synthesis after is where the next step is,” before seeking their science peers’ opinions, asking, “Maybe in science that’s not true, because you can’t really interpret numbers differently than the person next to you....” [P15]? Interestingly, rather than reinforcing the objectivity of statistical data analysis, a biology student responded, “it’s not the numbers that change from person to person. It’s the conclusions you draw from the numbers that will change” [P17]. The engineering student drew a parallel with this response, reflecting that they need to learn what technology exists and then “take your own perspective and try to find something new from the same existing parts” [P12].

The assumed binary between facts derived from research and opinions that come from interpreting said facts unraveled during the dialogue, demonstrating that reflection, perspective seeking, and integration of perspectives can help students appreciate that the process and purpose of research are more complex and nuanced than they previously realized. Students commented that they “paused for a second” when considering issues of fact versus opinion (Inputs and Outcomes 1), “because technically we can never prove anything in science, so technically everything is an opinion” [P9]. Other students viewed the use of facts or opinions as dependent on the objectivity versus subjectivity of methodological approaches associated with disciplines. For STEM students in particular, their personal research projects developed from finding a balance or “compromise between the difference in opinions that the experts within the field have” [P5]. As the conversations about epistemological differences evolved, so too did the binary thinking of fact versus opinion that many students originally brought to the dialogue.

Important here to note, also, is that these conversations were not limited to STEM student experiences but spanned disciplines. In response to the prompt “Good research is grounded in opinions of experts” (Inputs and Outcomes 2), a student of cinema voiced the difference—as they understood it—between creating their documentary film and the process of engineering a product that another student was working on:

...I’m choosing what I cut out. I’m choosing what I put in. I’m choosing the order in which [it goes] as well, so film [is a] very different from, I think, P12, who had the engineering project. Engineering, it’s very difficult to make it something that’s framed in a certain way. It just is, and it’s [a] piece of technology. That could be my own limited understanding of it, but film is very subjective, and it can also be objective at the same time...[P18].

Table 5 Student responses on epistemological difference: these responses are from learning outcome questions presented at the conclusion of the workshop

Student responses on epistemological difference post-workshop

- “It is significant to engage in dialogue and collaborate with other students with disparate perspectives on a topic of interest in order to avoid having a myopic point of view or limited understanding of a concept and issue that requires an interdisciplinary approach to fully comprehend.”
- “...I learned [that] my own people-with-humanities perspectives can learn something from the stereotyped nature and objectivity of scientific research, and STEM researchers can learn from the more individualized approaches taken by humanities scholars.”
- “I learned that my perspective differs even from those of other STEM researchers—just because we work in similar disciplines does not mean we have the same ideas.”

The engineering student, however, quickly voiced how similar their processes were:

“Building off what you were saying, one thing you mentioned is that, when you’re asking these questions, you really have to take a step back and try not to confirm your own bias or lead them in any direction. I was participating in this program called [NSF I-Corps] earlier in the summer, and it’s all about customer discovery and talking to the people who legitimately have a problem that you’re trying to solve. It’s the same exact approach. I would ask people questions about, what do you do every day; how do you get electricity; how do you get clean water; as opposed to saying, do you think this would help you; do you like this technology; is this applicable in your situation. I think there is a lot more overlap in a lot of these disciplines than people realize [P12].”

Here, we see how such conversations allowed students to better understand their own personal research processes and, more importantly, how these processes compare to those outside of their own disciplines. Many students anticipated that STEM fields revolve around issues of objective fact, and that humanities, arts, and social science questions develop from subjective opinions. However, their open dialogue fostered a greater understanding that they all approach research projects with consideration for both objectivity and subjectivity. Such thoughts were also reflected in their post-workshop reflections, as Table 5 demonstrates.

Students acknowledged the importance of discussing such topics with people *outside* of their disciplines, especially. By engaging across disciplines, students saw how their research connected, diverged, and intersected with others, or as one student commented: “To take a step back! Allow others to view my work with a fresh set of eyes to gain further perspective and to decalcify some of my own perspectives that hardened over time with seeing the same thing over and over again” [P18]. This dialogue enabled students to broaden their own understanding of how they approach knowledge generation, and thus how they value knowledge, in relation to others. This is a means of generating appreciation and understanding of other research processes, a step towards

reducing hierarchies and power dynamics between disciplines in higher education.

Building skills through the research process

We originally approached this project with the assumption that students viewed skills acquisition as a potential decision-maker for participation in the program. We designed dialogue prompts that would make salient the importance of both specialized and transferable skills that a research experience imparts for future career success. Not surprisingly, almost all students agreed in their pre- and post-dialogue instrument responses that they use transferable skills in the research process (Process 1). More surprising was that their pre-dialogue responses indicated a split in agreement about whether the primary reason for participating in research is to develop specialized skills (Process 2), and that the dialogue complicated this idea further. After the dialogue, all but three students were either more ambivalent or in disagreement with specialized skill acquisition being the *primary* reason to do research. This shift away from the importance of specialized skills was connected to what students believe they gained from research that would help them advance their careers, *practicing* skills through the research process (Process 4). Through this dialogue we learned that students value engagement with the research *process*, moving beyond the dichotomy of transferable and specialized skills to the navigation of the research process itself as skill building, a process that is applicable to future careers. In one student’s words:

So what I want to do basically as a career, hopefully, is to be a designer....in the publication space. So essentially what people who would want to hire me would want to see is that I can synthesize a lot of linguistic material into visual language. And I think that’s a huge portion of this project for me, is not only taking and synthesizing my research into the actual written piece of research but also synthesizing that written piece of research into this visual kind of aspect. So I think in that sense, yes, it’s going to help me practice those skills and showcase those skills, so that’s where I think

Table 6 Student responses on research process: these responses are from learning outcomes questions presented at the conclusion of the workshop

Student responses on research process post-workshop

“I particularly liked the idea of separating the research into the process and result, and moreover into the research and the presentation. I think looking at those things as fundamentally related but treating them separately has great utility.”

“I learned strategies that can be used to explain how my knowledge of ethics can be applied to my research broadly speaking. I think talking with others gave me the ideas and the web [mind map exercise] then helped me bring these ideas back into context with what I am doing.”

“I was enlightened that my perspective on the process of research in S.T.E.M was analogous to other students. We share common goals of cultivating skills and helping others gain research experience.”

it’ll help me. Where the specific research, again, might not advance me in any specific way [P6].

Students view their summer experience not as “learning” skills but more importantly as “practicing”—a distinction that acknowledges how students value the opportunity to cultivate skills through the processes of developing, planning, and conducting research. These processes were viewed as transferable skills since they could be applied to many possible situations that they might encounter in their future. And through these processes, the ability to be creative and take chances can bloom unlike in other educational experiences. Their experience with SSAP allowed them to develop their own ideas and engage with research that they developed rather than the research of their professors or PIs. They voiced that they had more curiosity to explore and see if their projects had merit:

Even though I’m in the engineering field, creative freedom has always been something that’s really important to me. Having that freedom to play around with something and mess up and try it again, and build on what you learned from that, is huge. I think that’s something that’s extremely valuable. [P12]

Throughout all of high school and just normal chemistry class and normal biology class in college, the labs you’re in, the classes, are very structured. That’s no longer the case with independent research. The ability to mess up and the ability to learn from that, and the fact that that’s OK, it’s been weird. [P20]

Much of this change in anticipated outcome derives from the fact that while many students did not view their specific projects as part of their long-term career goals, they did view the generalizable aspects of the research process as key to their career success. As one biology student put it: “[It’s] maybe not what I’m going to be doing for the rest of my life. But it’s [the research project] giving me...skills that can be applied to other biology fields...skills that can be applied to basically any profession” [P9]. By viewing their experience as a means of learning through practicing, versus preparing for their career, students appeared more willing to take risks in their projects and engage more openly with

the process. This is what we call failing with a safety net. Through SSAP, students took advantage of an experience to play and be messy with their ideas, which we suggest originates from the kind of experience the program creates. Without the pressure of grades and an obvious through-line to their career goals that major courses symbolize, students demonstrated a greater willingness to engage with possibility rather than tangibility, viewing the process of research as a product in and of itself: the experience of engaging in independent research is now a skill that can be replicated or built on for other kinds of projects. Table 6 further outlines post-workshop reflections from students that emphasize how they came to new conclusions about the research process by comparing their experiences of it, their perspectives on it, and their goals for it.

Initial successes

This project investigated how to implement and assess an intervention designed to facilitate interdisciplinary consciousness in the context of a summer research program. We found that our dialogue intervention facilitates self-reflection, sensitivity to differences and similarities of other’s perspectives, and integration of perspectives within undergraduate researchers. These skills are markers of interdisciplinary consciousness that we believe are crucial to becoming collaborative, twenty-first century professionals, particularly in environmental studies and sciences where multiple kinds of stakeholders with different types of expertise need to work together towards shared solutions.

To assess outcomes, we considered student pre- and post-dialogue instrument responses, dialogue transcripts, and learning outcome reflections. We found that students expanded their view of a research audience to include non-specialists as well as specialists, noting that this was crucial if research is to be for the common good. We also found that students could see past the binary of objectivity and subjectivity in research and recognize how they operate in parallel at different stages of the research process across project types. And finally, we found that students value engaging in the research process—to give themselves space to practice how to do research independently, make mistakes,

learn what to do for the next time—a process they believe is crucial to becoming successful professionals. These findings suggest that articulating interdisciplinary consciousness as a capacity rooted in three ways of thinking—self-reflection, sensitivity to difference and similarity in others' perspectives, and integration of perspectives—and facilitated in a dialogue-based process that can be practiced in its own right, as a key part of the research process, could further students' professional development.

The Toolbox dialogue workshop provided students the unique opportunity to reflect on their experiences with those whose disciplinary positionality and perspective was outside of their norm. This allowed students to sit back and experience moments of realization and connection between disciplines. By facilitating a dialogue that brought students together from majors that ranged from Russian studies to finance to biochemistry, we observed students ask for other's perspectives, demonstrate *aha* moments, and grapple with the difficulty of a question as simple as: who is research for? Not only did students begin to process their own experiences, but they also processed the experiences of their peers, both in majors adjacent to but also vastly different from their own.

In doing such work, we ascertained two important things. First, we helped to shape the interdisciplinary consciousness of participants, fostering reflexivity about their own disciplinary perspective and their ability to integrate the perspectives of other disciplines (Kjellberg et al. 2018). Following the workshop, most students articulated how valuable the experience was and how much they had learned both about their own project as well as the projects of others. Second, we assessed how impactful an undergraduate research program is when moments of interdisciplinary reflexivity and perspective seeking are added. In summers prior to the implementation of the workshop, SSAP students interacted with each other through professionalism workshops and a post-program symposium where participants shared their work from the summer. While these opportunities allowed students to see the project outcomes of their peers, practice their oral communication skills, and acknowledge the breadth of research covered by the program, they did not necessitate moments of reflection, and so students may or may not have gained a better understanding of what the research process is and in how many forms it may appear. The addition of the workshop, however, instigated such reflective moments and fostered peer-to-peer interaction that resulted in personal growth and recognition that interdisciplinary consciousness is important.

In the academic and applied fields of environmental studies and sciences, differences in perspective and miscommunications between the parties that hold them can lead to paralysis or politicization of issues that greatly affect the common good. Undergraduates are demanding application and relevance of their environmental academic work; environmental majors are bursting with students, having been on

the rise over the last decade, and students are driven to make a difference in the world. Explicitly fostering interdisciplinary consciousness as part of the undergraduate experience can enable students to transition to professional life better prepared to understand differences and find points of integration to move forward productively.

Challenges

The successes of this project—as with any—come with caveats and limitations. Not every student participated in the discussion of every prompt. Depending on the topic or the Toolbox prompt discussed, certain students had more to say than others. Participation in topics also varied based on the group, while some students were actively engaged in conversations about audience in one Zoom session, participants in the other Zoom session were less engaged around this topic. We attribute uneven participation to our hands-off facilitation style.

In our data analysis, we mitigated the uneven participation in the dialogue by first assessing the learning outcome reflections that all students filled out to ascertain which dialogue prompts were most impactful across students regardless of the extent of their verbal participation in discussion. The pre- and post-dialogue survey instrument responses gave us another data set to find where shifts in thinking occurred. These three data sets, analyzed together, helped us overcome the limitations of uneven participation in the dialogue and gave us confidence in our findings. In the end, we found that the workshop was easily implementable, and we repeated it in July 2022 in-person, using the same methods and survey instrument included in this article. In our next stage of data analysis, we intend to look more closely at the identities module, to enhance our understanding of how students view bias, privilege, social position, and their responsibilities as researchers in relation to their peers.

Looking forward

We encourage other institutions to consider how they might similarly implement their own version of the dialogue-based workshop. For many in higher education, it can be difficult to create completely interdisciplinary majors, courses, and experiences because of limited funds and institutional incentives. We chose to implement this workshop in a cohort based undergraduate summer research program—something we recognize is resource intensive and not possible at every institution nor for every student that can have competing demands on their time and may have limited international applicability. However, the dialogue-based intervention developed by TDI can be mapped onto other kinds of existing programming (i.e., courses, departmental seminars,

co-curricular workshops), for an easier and more convenient way to foster interdisciplinary consciousness in students. As our findings indicate, such dialogues demonstrate important gains for students navigating an increasingly competitive and demanding professional world. To realize how the practice of research is valuable not only across disciplines but as a professional skill is powerful. And having undergraduates become attuned to hierarchies of disciplinary power within higher education could bring us one step closer to embracing pluralities of knowing. Even one small dialogue, during one short summer program, could catalyze lasting change in participants who likely have not had the opportunity to engage in such reflexive work with a diverse group of budding experts and may not have such an opportunity again.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s13412-024-00942-0>.

Acknowledgements We would like to thank Cassandra Wentzel for contributing to the redesign of the Toolbox Dialogue Instrument for Binghamton University undergraduate researchers. The workshop was made possible by Author 2's NSF CAREER award #2042970, "Evolutionary Disease Ecology: Can evolutionary responses to environmental change modify the biodiversity-disease relationship?" Author 3's work on this article was supported by the USDA National Institute of Food and Agriculture, Hatch Project M1CL02573.

Author contribution Marisa Rinkus, Michael O'Rourke, Valerie Imbruce and Jessica Hua contributed to the study and workshop conception and design, as well as data collection. Vanessa Jaeger contributed to the literature review for the manuscript. All authors contributed to data analysis. Valerie Imbruce wrote the abstract and introduction and lead the draft preparation, submission, and revisions; Marisa Rinkus wrote the methods, data collection and analysis sections; Vanessa Jaeger wrote the outcomes and conclusion. All authors read and commented on drafts and approved the final manuscript.

Data availability All data and software applications that support our published claims adhere to social science standards. The Toolbox instrument used to promote and assess dialogue in the workshop underlying this study is openly available in Humanities Commons at: DOI redacted for blind review—instrument provided for review as supplementary material.

Declarations

Ethical approval This research was reviewed by Michigan State University, Human Research Protection Programs, Social Science Behavioral/Education Institutional Review Board, and deemed exempt: IRB# × 17-980e Category: Exempt 2.

Competing interests The authors declare no competing interests.

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