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A web-based tool for participatory science learning in the context of human psychology research

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Abstract: We describe MindHive (www.mindhive.science), an online citizen science platform for human brain and behavior research that uses a participatory science learning approach to engage learners in the full spectrum of scientific inquiry. Building on an open science philosophy, it features a collaborative study design environment comprising an experiment builder, a catalogue of validated tasks and surveys, and a public-facing study page; a peer review center where students can engage with and reflect on studies designed by peers from their own schools and schools around the globe; and GDPR-compliant data collection, data management, and data visualization and interpretation functionality. We describe research generated during the COVID-19 pandemic by students to illustrate how the platform supports student-teacher-scientist community partnerships for participatory learning in authentic inquiry.

Background and objective

Human brain and behavior science is increasingly recognized for its potential to address issues in e.g., public health (Van Bavel et al., 2020), climate change (Van Lange et al., 2018), poverty (Nobel et al., 2015), and crisis resilience (Masten & Motti-Stefanidi, 2020). A citizen science approach to human brain and behavior inquiry—which involves members of the public as partners in the full inquiry process—can thus empower the public to identify and address issues that are both personally and socially meaningful (Eitzel, 2017). Many citizen science initiatives, however, focus on physical and life sciences such as astrology and ecology, and merely exploit the public to collect or process data. Here, we explore the potential for citizen science to engage learners in brain and behavior research, and moreover, to involve them as partners alongside scientists in generating research questions and interpreting findings of relevance to themselves and their communities. To this end, we designed and implemented a citizen science platform that engages students, teachers, scientists, and community members in collaborative inquiry around human brain and behavior. A co-design effort by a team of learning scientists, brain and behavior scientists, high school science teachers, and technology designers and developers, the platform and curriculum support students in the design, peer review, and implementation of original research studies focused on personally and socially relevant questions, with the aim of broadening participation in science (Kapon et al., 2018). The learning activities and functionalities support a scientist-teacher-student (STS) partnership model (Rahm et al., 2003), and are aligned with a participatory science learning approach, which emphasizes learning through authentic problem solving and the social negotiation of understanding (Barab & Hay, 2001; Koomen et al., 2018; Lave & Wenger, 1991; National Research Council et al., 2012; NGSS Lead States, 2013).

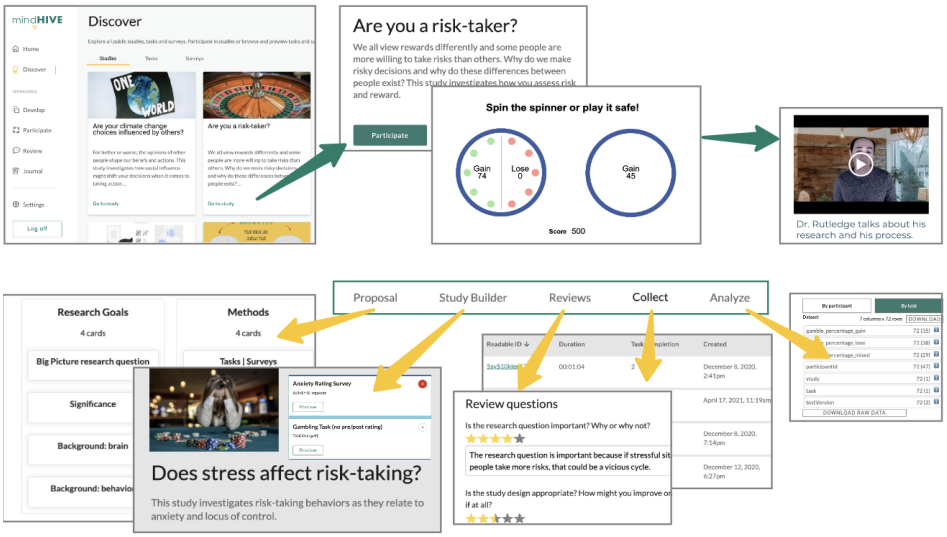
A collaborative inquiry environment

The platform consists of tools for learners and scientists to develop original research studies; give and receive peer reviews, collect, and analyze research data; and communicate with other users: scientists, participants, and teachers and students both within the classroom and across schools. Inthe **Discover** area (Figure 1, top) students can explore, preview, and participate in studies designed by students and scientists. While the **Develop** area (Figure 1, bottom) enables learners to build and implement their own, authentic brain and behavior studies, and to collaborate on these studies with scientists and other students. The **Proposal** tab comprises collaborative, text-based "cards," each containing prompts focused on a different section of the study proposal (e.g., research question, background, procedure, participants, etc.) that students can assign to themselves and each other. Students can also provide and receive comments on proposal cards from their teachers, peers, and scientists. The

collaborative capabilities and pre-organized sections are designed to provide the scaffolding necessary to navigate the complexities of study design in a stepwise fashion. In the **Study Builder**, learners can create a workspace to build a study procedure using tasks and surveys from a public database, reflect on feedback on their studies by other students in the **Review** tab, and manage study data via the **Collect** and **Analyze** tabs.

Figure 1

Screenshots from MindHive's Discover and Develop areas (top and bottom, respectively) Examples come from student engagement.



Data and analysis

To understand the learning opportunities and challenges associated with engaging students in authentic brain and behavior research, we collected artifacts of high school students who participated in the program in 2020 and 2021, which included their research questions, study designs, peer reviews, end-of-unit reflections. We further carried out interviews with 8 students across 2 schools, and with 4 teachers across 4 schools. Our analyses focused on describing the value of enabling students to contribute to the inquiry process with scientists, the insights they gleaned from participating in the peer review process, and the new research questions that arose from seeing the questions and results of other participants. For findings pertaining to students' learning from the study design and review process, see Matuk et al. (2021; in revision) and Dikker et al. (2021; 2022). Below, we describe student-initiated research generated during the COVID-19 pandemic to illustrate how our citizen science platform can support iterative, authentic inquiry in student-scientist research partnerships.

Student-led brain and behavior citizen science inquiry during a pandemic

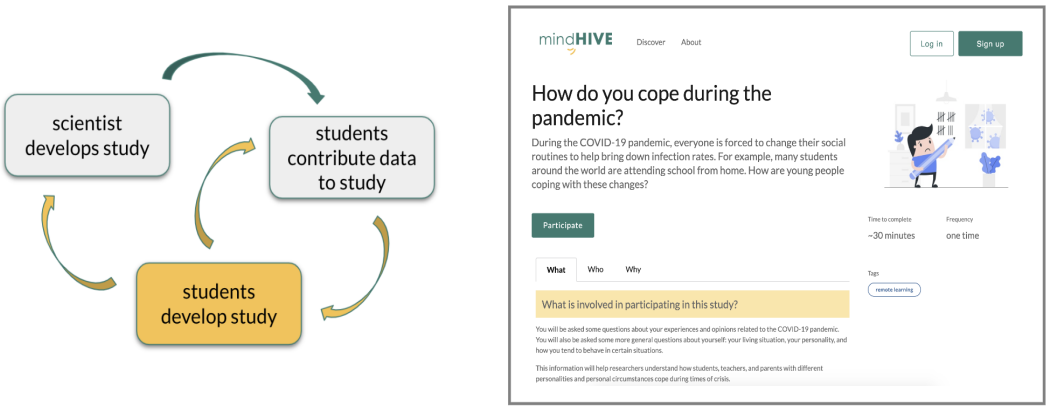
In Spring 2020, at the height of the pandemic, 18 juniors and seniors in an Environmental Science elective at a private New York City high school, participated in a 12-day unit taught by one of our teacher partners, in which they learned to use human brain and behavior research methods to understand youth's experiences during the pandemic. Students designed studies to explore the relationships between youth's pandemic experiences and mental health, remote learning, personality traits, and group dynamics. Professional scientists then translated students' research questions into a study titled "How do you cope during the pandemic?" (mindhive.science/studies/covid), obtained ethical approval from their institution's International Review Board, and collected responses over the course of the 2020-2021 school year.

Results from 206 undergraduate students who completed the study showed that students with more agreeable personalities (John & Srivastava, 1999) reported a greater ability to personally connect with their classmates in a remote format. Students who were more likely to seek emotional support as a coping strategy were also more likely to report connectedness with their peers and teacher in remote learning formats. Meanwhile, students more prone to personal distress (Kessler et al., 2002) reported greater connectedness to their teacher and peers in in-person rather than remote formats. These findings support teachers' subjective

accounts and resonate with published findings that remote learning increases the learning gap for vulnerable students (e.g., Dorn et al., 2020a). However, other findings from this study seem to counter the narratives told of remote learning (e.g., Dorn et al., 2020b). For example, some students reported faring better during remote learning than in in-person formats. Additionally, a great majority of students indicated that they would have preferred an asynchronous remote model although they were only offered synchronous remote classes. While these findings merit further investigation, they underscore the importance of including students as stakeholders in decisions about how they should learn, particularly under rapidly changing crisis situations that challenge commonly held beliefs about student needs.

Figure 2

The platform promotes a collaborative citizen science model where students and scientists co-create and iterate on each other's research studies (left), e.g., asking how high school students have coped with various aspects associated with the COVID-19 pandemic.



In Spring 2021, as part of their participation in the curriculum, 150 new high school students from 4 schools participated in the "How do you cope during the pandemic?" study and reflected on its questions and tasks (Figure 2). Many of these students also extended this initial research question through their own study designs (e.g., "How has the pandemic affected different age groups' mental health?", "Is it easier to focus online or in-person?"), which have been added to the platform for future students and scientists to implement and build upon. However, unlike Spring 2020, many studies designed by students in Spring 2021 centered on topics other than COVID-19, such as climate change and political beliefs. They branched out their research questions to include other socially personally relevant research questions, including *Has the Pandemic Changed the Environmental Impact of People's Eating Habits?* and *Let's Argue! Hearing Hot Topics: Does Political Affiliation Affect How We Interact with and View Others?*)

Figure 3

Examples of students' study designs during the Spring 2021 semester.

Significance

The human brain and behavior citizen science platform described here provides a sandbox for both students and scientists to pursue student-driven inquiry, and to contribute scientific understanding of socially relevant issues. It shows how such a platform can give students agency to inquire about issues that matter to them, and as such gain important STEM research skills.

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