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# Harmonized Mutual Development through Exploring and Creating Sound

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**Abstract:** The science of sound presents a holistic learning opportunity to engage embodied intelligence and lived experience in mutually shared soundscapes where material objects become sites for the pursuit of curiosity and aesthetic beauty. When young people are presented with this view of the realm of science learning and practice, the possibility for alignment and harmony between personal knowing, social relations, and a living environment can emerge. And even more compelling, the possibility for what we describe as harmonized mutual development in a community of learners moves within reach. This paper explores the potential of a curricular and pedagogical design to produce a kind of collective ethic in learning that is often elusive in formal learning environments.

## Introduction

The pervasiveness of sound, its ease of measurement, and its cultural relevance reveal the sonic world as a "natural laboratory" through which young people may become intuitively familiar with waves and their properties. From speech, to music, to street noise, sound is an integral part of our everyday lives. People are intuitively familiar with many aspects of sound waves and their perceptual signatures such as pitch, timbre, loudness, direction, and echo. People are also familiar with many objects that generate sound (vocal cords, flutes, drums, strings). Listening to Waves (LTW) is an educational program that guides students to learn the hidden and ubiquitous world of waves through the exploration of sound and vibrations. In LTW, students make and analyze sound, create waves and vibrations in physical objects, build musical instruments, use digital technology to analyze waveforms and acoustic properties and to create sound and music, and explore how sound is propagated through the environment and represented in the brain. The program was designed by Dr. Minces, a neuroscientist specializing in the science of music, and Dr. Alexander Khalil, an ethnomusicologist. The design draws from their experiences as scientists and their experimentation with sound.

Being together in a soundscape provides the basis for the design of a set of science workshops. We make a series of moves to grow roots in a disposition toward scientific thinking and practice that prioritizes everyday access to beauty and wonder. First, the design aims to re-prioritize the soundscape as an active context for learning. Second, the design honors social environments that cohere learning environments as fundamental to what makes science practice meaningful. Third, the design re-privileges embodied ways of knowing, situating learning trajectories within young people's sensed and shared experiences (Marin, 2020). Fourth, the design aims to forge a meaningful connection between personal learning and collective, mutual learning that animates shared life. This includes aesthetic, material, contextual, and social relations.

Our program design is informed by a theoretical understanding of learning and development as situated. Young people who participate arrive with their own ideas and experiences with sound and science. This program supports them to expand and integrate those experiences with new ways of exploring, representing, and understanding sound. We consider students' socio-historical sense of both sound and science, their processes of identity development, and their practices for taking on new roles (Bell et al., 2012). LTW uses a project-based design that supports students to connect their everyday knowledge and practices with disciplinary science practices (Barron & Bell, 2016) while inviting them to become increasingly full participants in a community of scientific practice (Lave & Wenger, 1991). The program design integrates middle school students, their teachers, and scientists into joint activity to support development and sustained participation. In this way, the design establishes conditions for making visible and analyzing when and how these project-based activities can support the development of particular identities and sustained engagement (Vygotsky, 1978; Chaiklin, 2003). The designers' relational challenge is of particular importance here.

### Becoming and development: A relational design tension

How do designers navigate existing classroom practices that constrain learning environments toward performances of individual intellectual competence and classroom behavioral management while working to establish parallel—and at times, disruptive—forms of meaningful collective learning? Designs for collective learning in classrooms as formal learning environments encounter some practical impediments born of a set of

developmentally-framed obligations: (a) for students to demonstrate competence independently, (b) to maintain dominant patterns of knowledge production, (c) to accept separation as necessary—as a severing of the social conditions of human learning, and (d) for educators to effectively assess individuals, allowing for students' independent and hierarchically organized advancement or delay. Even the most collectively designed academic task must eventually be filtered into individual grades, advancement, and future placements. When and how can designers effectively honor the social, cultural, historical, political, and ethical conditions of learning?

Our research design endeavored to work in concert with these challenges. We asked, what does a collective learning design allow for in terms of relationality and future practice? In what ways can individual sensory awareness yield mutual and shared learning conditions, and in turn, a learning environment where social engagements directly yield creative inquiry that makes scientific practice and science identities accessible to and sustainable for the full collective of participants? When can individual styles, approaches, interests, and knowledge be activated in service of mutual advancement in practice that moves the whole beyond what could be accomplished individually? In essence, we wondered, what would be the symphonic version of this design, and in turn, the learning opportunities that move beyond the efficiency of collective delivery (and yield more than a system aiming to avoid holding back the individual)? For learning designers, we see this as a threefold challenge intertwined with frames of development, assessment, and organizational differentiation that sort students into groups of more and less capable. Assessment practices and organizational differentiation are pre-existing conditions of classrooms and schools. Developmental frameworks may be the most pliable of the three, and therefore, the most accessible to different approaches in design.

Given our interest in identity, practice, and transformed participation, we have increasingly focused on questions in the realm of human development and processes of becoming. In our observations and in survey results reported elsewhere (Minces et al., 2021), we recognized processes of becoming in young people's engagement with the program. Likewise, we noticed our tendency to look for signals of development-in-progress in our qualitative data, yet were drawn up short by the ways in which developmental frames are frequently used to render students—like those who participated in our study—as behind a developmental norm due to contending with under-resourced circumstances and underrepresentation in science-based fields more broadly. Increasingly, the developmental frame seemed to be in tension with aspects of our situated approach to design and the processes of becoming that most intrigued us during field observation and analysis. Our design emphasized processes for engaging as a learning community in a learning environment that prioritized relationships with self, social environment, and soundscape that could reposition young people's relationship with science and prioritize equity (DiGiacomo & Gutiérrez, 2014).

Matusov's studies of democratized learning environments align with the ethos of the learning environment designed through LTW: "The participation inquiry involves issues of what facilitates and hinders such transformations, what are their directions (and how they are desired by community members), what are means for the transformations …" (Matusov, 1997, p. 340). By designing the learning environment first as a space of relation, we aimed to theorize means by which design can contribute to a prioritized collective ethic in learning while contending with the persistent perceived conflict between individual assessment and practice as communal.

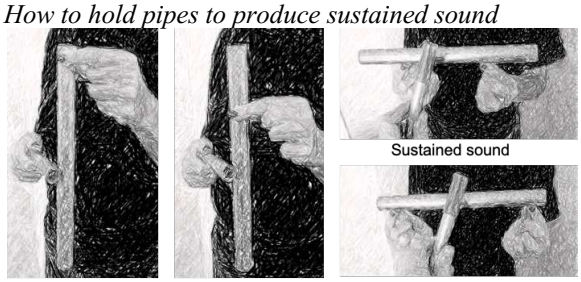
As learning scientists have continued to advance theoretical approaches to understanding development in relation with learning, the notion of becoming has been conceptualized to address equity and ethical relations in learning environments. This approach to relational aspects of becoming gives us analytical purchase on the processes of transformed relationship with science that are at the heart of the pedagogical design: "Pedagogies aimed at social transformation therefore involve examining and rearticulating the meanings that degrade our perceptions of, and relationships with, others as well as ourselves (Philip, 2011). Political-ethical becoming, as we theorize it, is thus not simply reorganizing our thoughts, but reshaping our relations" (Vossoughi et al., 2021, p. 204). Students participating in LTW workshops arrive having already been "embedded in relational ecologies" (Vossoughi et al., 2021 p. 217) that have organized their existing relationships with science at school, soundscapes, sound and music-producing materials, and formal learning environments. The design seeks to ally with students in reconfiguring relationships with the environment that emerge from re-prioritized social and peer relations of the classroom cohort. Prioritizing shared moments of surprise and access to beauty through sound and waves traveling through material requires shifting power relations in learning in that personal and peer sensory experiences are privileged in processes of producing knowledge. Given the theoretical problems we have described, the following questions arise: What mediates engagement in an environment that can be repurposed as a means for young people to forge their own pathways toward science and its potential and presence in their lives? And in what conditions can the design of the learning environment support transformed relationships between the intellectual progression of individual students and a collective intellectual practice where students contribute to the community of practice in ways that matter to the collective, in turn, expanding social practices in the classroom beyond behavioral means and toward political-ethical becoming?

## Program Design

LTW program contains several modules that are integrated into eighth-grade science classes, and have been implemented primarily with underrepresented and low-income students. Participating in the program has been shown to improve the students' attitudes towards science, including the perception of themselves as capable of doing science and their intention to pursue a science career (Minces et al., 2021). This paper focuses on one of LTW's modules, the *sound vibrations lab*. A fuller description of the program can be seen in (Minces et al., 2021). The *sound vibrations lab* was facilitated by Dr. Minces. In it, students explore how pipes vibrate, which allows them to understand how musical instruments are built. For the reader to understand this module, they need to know that, for an object to vibrate freely, it needs to be held at points called vibrational nodes, referenced colloquially as sweet spots. When a pipe is held at a sweet spot, it produces a long musical tone; when it is held at other points, it produces a short "thunk!" sound (see Figure 1). A video of the pipes making these different sounds can be seen at www.listeningtowaves.com/ISLS. Building on this surprising phenomenon, this module alternates between children exploring how pipes vibrate and discussing their observations collectively.

**Figure 1**

*How to hold pipes to produce sustained sound*




## Methods

We paid close attention to students' self-conception as science learners and doers as well as their sense of their potential to become members of (or their existing sense of membership in) a scientific community. The results of survey data addressing this question are outside the scope of this analysis (see Minces et al., 2021). Here we focus on students' thinking practices during project-based work (e.g., how students notice, investigate, and describe sound) and students' recognition of and/or attention to connections across school and daily life contexts. We gathered artifacts of student work, field notes from observations, and multi-camera video recordings of workshops. Our video analysis attended to student strategies, question types, negotiations among group members, responses to challenges, use of tools, proposed solutions, and descriptive practices. Our unit of analysis was the learning environment established through the project-based learning design. Our analytical goal was to understand whether and how the environment supported individual and ensemble engagements with science practice and identities and the degree to which personal interest in sound could become a bridge to personal interest in science.

LTW was implemented at a large urban middle school near the United States-Mexico border (87% Latinx, 8% African American, 47.5% English Learners, 91.5% low SES), involving 350 8th grade students. The program's duration was one month and was incorporated into the 8th-grade science curriculum, in which students learn about waves. We worked with each cohort of students for three two-hour sessions. We used grounded theory to categorize and code qualitative data (Glaser & Strauss, 1967; Charmaz, 1983). Our analysis identified four contexts across which embodied collective inquiry emerged: shared sensory environments, repurposed everyday materials, personal curiosity and awareness, and distributed social relations for learning. We then categorized three types of practices where students generated and sustained these relational contexts: a) manipulating the soundscape to notice new conceptual opportunities, b) expressing interest in sound, everyday objects, and peers' strategies, and c) embodied expressions of knowing to guide interpretation and meaning. Data revealed a distributed interest in contributing to one another's learning and accomplishing together.

## Analysis

Data for this analysis comes from a series of Object Vibration Lab workshops given with six middle school science classes taught by three teachers. Each session was held in the school's library where the students were spatially positioned around six long tables arranged in a u-shape configuration, in such a way that they could easily alternate between attending to the facilitator and working together in small groups. In the vignettes described here, 26 students were seated as follows: 10 on the left, 10 on the right, and 6 at the base of the u-shaped configuration.

Video data highlighted two girls at the bottom of the frame in Camera 1 and four boys at the top of the same frame as well as four boys at the top of the frame in Camera 3, which was across the room from Camera 1 at a diagonal. All students in between were engaged in various similar modes of social engagement, making each other laugh, exploring, and listening. In the vignettes that follow, the activities described are exemplars of participants' observed experiences during the Object Vibrations Lab. These vignettes occurred roughly fifteen minutes into the workshop and were simultaneous, as is represented in Table 1. In general, the Object Vibrations Lab alternated between small group and personal exploration punctuated by moments of facilitated demonstration and brief instruction (e.g., defining terms, explaining observed phenomena, and guiding practice).

## Public demonstrations: Exploring the movement of vibrations through objects

The opening experience of this workshop led students in this class to pause in surprise and good humor. The facilitator quietly picked up a pipe and a mallet (another pipe with duct tape wrapped around the end), and he began playing it. The tone rang out a few times and all of the students quickly turned their attention toward him, beginning to listen. A few students shushed each other. After playing a few times, he walked over to a group of boys visible in Camera 1 and handed the pair of pipes to Hugo (1), one of the boys who shushed his friends. Hugo tried and produced the unexpected "thunk" to quiet smiles (see Figure 1). He tried again and got a small ring out of the pipe, not quite as resonant as the facilitator's turn. The facilitator said, "pretty good," as he took the pipes and turned to offer them to another student, which led to the following exchange about five minutes into the session:

| | |
|---|---|
| Student 1: | Me, me! [waving hands as facilitator silently held up a pair of pipes, offering another turn. Then, upon receiving them, he produced several muted "thunk" sounds causing giggles and looks of surprise around the room.] |
| Facilitator: | [He handed the pipes to a second student. Again, this student's effort resulted in several "thunks." A third student repeated this process to murmurs of, "Ooohhh."] |
| Student 4: | My turn, my turn, my turn…[reaching out for the pipes] |
| Facilitator: | Let me show you again. [He played the pipe several times with a wringing tone.] |
| Multiple: | Oh, Oh, Oh, Oh! [as if something just became clear to him]; You gotta…(inaudible); I got you. I got you! Four students then stretched out their arms, waving for the pipes; the facilitator gave them to Bianca, also visible in Camera 1.] |
| Bianca: | [She grasped the pipe lightly between her thumb and pinky a quarter of the way down, struck it lightly with the mallet a few times, and produced a sustained ring.] |
| Facilitator: | Oh, nice! [smiling and nodding] |

Students around the u-shaped table were then watching intently as she made the resonant sound. The facilitator then continued to offer turns as students waved for a turn. More "thunks" were produced as surrounding students then began to offer them suggestions, as they sensed they had discovered the secret. It is important to note that the production of the soundscape as a learning environment emerged through a series of unmet expectations. Initially, the facilitator's first ringing tones garnered attention as if someone had rung a bell. However, when he handed the pipes to Students 1 and 2, and the tones were thunks, the successive inability to produce the same tone drew everyone's attention to a place of shared wonder. When the facilitator provided a second demonstration, the students began attending to three aspects at once: his body position as some noticed how he held the pipe this time (embodied practice), the quality of the tone that confirmed a sustained tone could be produced at will (the soundscape), and the pipes themselves as reliably resonant objects (repurposed material). A distributed desire to test their new ideas ran through the room, evident in the change in how they offered suggestions to peers.

## Negotiating the soundscape as a learning environment

The next step in the workshop was to give every student a pair of pipes, with one fashioned as a mallet with duct tape wrapped around one end. Having experienced a collective mystery, the facilitator explained to the group that they would be exploring how things vibrate in advance of a future workshop where they would begin making musical instruments. He let them know he would eventually explain how to get the pipes vibrating in the most effective way, but first, students were encouraged to explore and discover different sounds they could make.

Students spent the next several minutes trying different ways to make sound with the pipes. Their attention was sustained, and they had to be interrupted for the next period of instruction. The sound in the room was a blend of the tinkling of metal, a series of thunks, and some sustained sounds. In many ways, it was like the sounds of windchimes on a windy day. The students worked together in small groups and independently when

taken with an idea. They effectively turned their shared environment, through the soundscape, into a space of relationship which came with mystery, aesthetic value, and the opportunity to test ideas and to theorize about the materials and how vibration moved through them. In so doing, the subtle possibility of becoming began to emerge. In Table 1, below, roughly one minute of simultaneous activity is presented in the table. The first row presents the facilitator's discussion. The second row highlights Diego, who was sitting to Hugo's left, was visible in Camera 1, and was called up to the front of the room to volunteer to demonstrate how to find the "sweet spots" that would allow sustained vibration. The third row represents Bianca, who played the first successfully sustained tone in the early demonstration, and her classmate, Maya. Simultaneously, students were engaged in personal exploration while negotiating their activity with peers as the facilitator offered instruction.

First, we note the negotiation that took place between Bianca and Maya. As the facilitator brought attention back to the front of the room to reveal the "nodes" that allow the most vibration to pass, also called sweet spots, Bianca continued to quietly play her pipes. While it was nearly inaudible on the recording, Maya clearly sought quiet to listen. To be clear, Bianca also signaled her interest in listening, keeping her eyes on the facilitator and trying out things the facilitator suggested. Likewise, the room was far from quiet during this bit of instruction. Sounds of quieted attempts to play the pipes continued. Maya, quietly and repeatedly muted Bianca's pipe with her hands. Eventually, as Bianca ignored Maya's efforts, Maya took all four pipes, and they laughed before returning attention to the front of the room.

Meanwhile, Diego and Hugo were engaged in a similar negotiation. They settled it by sharing the pipes and playing on each other's before turning their attention back to the facilitator. In each case, personal exploration was negotiated in tandem with peers, all the while, making sure not to miss the instruction about how to find the "sweet spots". As the facilitator sought a volunteer (Diego) to come demonstrate at the front of the room, negotiations were winding down. At the same time, the facilitator began comparing their pipes with instruments like the marimba and the xylophone, noting that the *keys* on those instruments are held at the nodes. The students signaled their readiness for more, quieting as a whole and observing the demonstration.

During the Object Vibration Lab, the learning environment, which can be influenced and changed, is the soundscape. It acts as a pull on students' practice and attention. The *shared* experience of delight or discovery worked to amplify the effects of experience. As the soundscape and the material (pipes) were reprioritized for more than pattern maintenance or extracting information, sound became available as a shared context for the pursuit of understanding, and in turn, began to extend meaning to acts of exploration that were distributed through the collective rather than grasped by individuals alone. In asynchronous or independent circumstances, persevering in the exploration of vibration through material and sound would take more effort to sustain. In socially supported circumstances, negotiating practices and processes of exploration granted momentum to the group. In other words, as practices emerged to respond to the change in the role of the soundscape, so, too, did the possibility of becoming part of a new way of knowing through practice. Their practices mattered personally and also socially. They were acting as curious explorers in search of patterns, surprises, and beauty, in addition to agreed-upon understanding. In that sense, the possibility of being part of science practice opened the subtle possibility of becoming a member of a science-oriented community, in an embodied and sensory-based way.

**Table 1**

*Finding "Sweet Spots" together – material + soundscape*

| *Time →* | *15:07* | *15:13* | *15:17* | *15:23* |
|---|---|---|---|---|
| *Facilitator* | "So, the pipes have two sweet spots. Now, when you see a marimba or a xylophone, you'll see that the keys are held at these two specific sweet spots." | | Facilitator looked to Diego, gesturing toward him and asked, "What's your name?"<br><br>He responded, "Me?"<br><br>"Yeah."<br><br>"Diego." | "So…so…[pause to await Diego's arrival at the front and give the group time to quiet down]…So, Diego will be holding the keys at the sweet spots. Okay?" Facilitator gestured with both hands as if a pipe was resting on the thumb and index fingers of each hand. |
| *Cam 1 Boys including Hugo &* | Diego played two pipes, holding one upright in left hand a little above the "sweet spot" while tapping | As Hugo quietly tapped his other pipe, holding it near the node and smiling, Diego | "Can you come help me out, Diego?" Facilitator invited Diego to the front of the room. | Diego stood by, facing his classmates from the front of the room and smiling. |

| | | | | |
|---|---|---|---|---|
| *Diego (volunteer)* | with the other. Hugo, who only held one pipe, also upright in the left hand, reached for one of Diego's. At first, Diego pulled it back and laughed, then gave it over. | reached over with his own pipe and tapped Hugo's once. He then turned to the front of the room. A moment later, the facilitator looked over. | Diego rose from his chair saying, "Yes, en inglés." | |
| *Cam 1 Girls including Bianca & Maya* | Bianca held one pipe vertically near the node with her left hand while tapping it lightly with the mallet, keeping her eyes on the facilitator. | Maya watched the facilitator. Without looking at Bianca, she took hold of Bianca's pipe and laid it on the table. | Bianca immediately picked it up again. Maya repeated the action, taking the pipe and setting on the table, this time sparing a brief glance directly toward her friend. | Bianca picked up the pipe again, and, again, Maya took the pipe saying, "stop." She then took all four pipes, and they chuckled. Both then turned their attention to the front of the room. |

## Aligning "felt" aesthetic experience with emergent science-rooted & personal identities

At this point, the facilitator began explaining what nodes are and how they function in a vibrating material, such as the pipes in students' hands. The explanation was both modeled and embodied. Having received the first signals of possibility when students struggled to produce sustained tones, and having explored on their own and in small groups, the students could hear and experience for themselves that finding the "sweet spots" signaled a subtle relationship between vibration and material. With Diego volunteering, the students were about to learn that each pipe had two nodes. They explored this idea, mimicking holding their own pipes at the nodes while watching Diego and the facilitator model the practice at the front of the room. At the same time, they began to negotiate the aesthetic value of the various sounds they produced. They began a pursuit of beauty, first encouraged by the facilitator in describing the workshop and attempting to make connections with their own aesthetic judgements.

Facilitator: First, um, can you put your fingers like this? [holding palms upright 6 inches apart, pinching thumb and forefinger together.] [Diego's hands were in his pockets and eyes were on his feet. Then he matched the facilitator's gesture while his friends smiled and chuckled.]

Facilitator: Perfect. Okay. Hold steady, okay? [He then placed the pipe on Diego's fingers as Diego laughed and glanced toward this friends.] First I will put the pipe on [pause]…Diego is holding it at points that are not sweet spots. [Diego slightly bent his knees and then stood upright in acknowledgment of not being on the nodes.]

Facilitator Now check this out. [He repeatedly tapped the center of the pipe causing "thunks."]

Diego: Muy feo. [Diego stated this playfully as he shook his head. The facilitator nodded in appreciation.]

Facilitator: Yeah, you couldn't really hear it, right?

Student 5: "I like that!" [stated definitively in swift counter-response to Diego's assessment.]

Facilitator: So now, I'll move you to the sweet spots. [As he repositioning Diego's hands until he held the pipe at the nodes, another student leaned forward for a better view.]

Student 6: Oh, yeah!

Facilitator: "Let's see what happens." [The room quieted briefly. The facilitator struck the pipe one time, and it rang in a sustained way.]

Diego: Hermoso. [He nodded and smiled at the facilitator with a knowing look who thanked Diego and let him return to his seat.]

Then everyone began, again, to explore in earnest. It is notable that their connection with the learning environment and available materials continued with gathering momentum. Rather than experiencing a loss of interest once the initial mystery was explained, the students continued to study patterns of sound and vibration personally, among peers, and through observations of other's approaches. When Diego returned to his seat, the boys in his group smiled at him in acknowledgement. Having explained that the nodes, or sweet spots, could be found one quarter length from either end of the pipe—which they had begun referring to as *keys*—the facilitator

encouraged everyone to play for a few minutes and suggested playing in pairs using both nodes. Hugo held his pipe at the node, and began to play rhythmically as a kind of performance for himself and the room. He danced along as he played, and the boys nearby began to pretend to play along (acting as if they were drumming their pipes together but not quite striking them…like playing air guitar). While others had been striking their pipes in the cacophony, this stood out as intentionally musical. This sound carried, and others across the room joined in, un-choreographed and seemingly unintentionally. For instance, a group of boys on the other side of the room, visible on Camera 3, were finding the nodes when one of them suddenly pretended to play the pipe in rhythm like a drum. This occurred as rhythmic sounds echoed from Hugo's pipes across the room.

These subtle processes of generating alignments between embodied sensory experiences, personal aesthetic preferences, and the discovery of new conceptions of relationships between sound, material, and environment positioned students in an emergent relationship with their own ways of knowing and validation of their practices in ways that related to the ways professional scientists experience, discover and explore the world. The satisfaction of new discoveries for the students was evident in their consistent drive to share findings, and their continued openness to receiving instruction that enhanced what they were already inclined to do in their explorations of material. For many of the students who participated in LTW workshops, recognized science identities seemed inaccessible, as described in pre- survey data. LTW opened student-driven opportunities for just-in-time feedback from their own practice, peers, and a pedagogical design that aligned their practices, strategies, and interests with what scientists do and what science aims to achieve. It was subtle yet meaningful.

## Discussion

The design of Listening to Waves consistently brought students to awareness of a shared soundscape that was part of each of their daily lives, and therefore accessible and familiar. As with the start of typical classes, students quieted and oriented toward the facilitator, an act of respect that grants a limited use of the soundscape for the collective. The designed practice—to model the use of two small metal pipes to produce a sustained resonant tone and then to invite student after student to do the same—produced a shared response of wonder and curiosity. When everyone witnesses the same action and result and then, each in turn, fails to produce the same effect, the everyday nature of sound and material produces access to a new conceptual context, and in turn, a site of inquiry (see Table 2). In Table 2, we note the ways that observed practices began to overlap across four relational contexts students generated over time. It was collective experience that amplified curiosity that could power active engagement.

**Table 2**

*Becoming an embodied collective in inquiry*

| *Shared sensory environment* | *Everyday materials repurposed* | *Personal curiosity validated* | *Social relations validated for learning* |
|---|---|---|---|
| Noticing a new conceptual opportunity | | | |
| | Everyday objects organize & coordinate attention | | |
| | | "Felt" ways of knowing guide interpretation & meaning | |

As a connection was established between familiar experience and conceptual opportunity, students were subtly made aware that everyday objects presented renewed sites for learning about interactions between sound and materials as vibrations and then as waves. The subsequent modeled repurposing of everyday objects both as unexpected conduits for novel sounds and as an introduction to the world of waves that had previously been invisible, organized students' attention in two ways. First, it returned attention to their embodied experience of learning. They were free to touch, tap, blow, roll, slide, pluck, and generally manipulate everyday materials for aesthetic interest, guided by their own curiosity. Second, it validated their social engagements as part of their inquiry practices. They readily observed and adopted each other's strategies in their inquiry process. They invited both peers and teachers to join in their discoveries. They sought mutual recognition of the beauty and wonder they were discovering as well as validation of their practices for investigating the possibility and producing sound. As they shifted their conceptual awareness of the shared soundscape, and in turn, experienced repurposing everyday materials to explore vibrations and waves through varied materials, their personal curiosity, or lack thereof, and their social worlds became increasingly valid resources for pursuing their learning. Exploring together in person, in shared space, with this pedagogical design strategy functioned like an accelerant to making science-related experiences of the shared environment and, in turn, science-related identities accessible. We, in turn, conceptualized the notion of *harmonized mutual development* defined as a process in which individual explorations of a shared environment yield an increasingly integrated intellectual practice allowing individuals to

develop and mutually align their inquiries toward a collective practice of becoming, much like what is experienced by individual musicians who form musical ensembles.

Harmonized mutual development was a possibility we sensed as we observed during LTW. As we analyzed the data with a developmental frame, important aspects of students' participation were obscured. Rather than individual processes of internalization, we recognized mutual instances of becoming. When we can understand and clearly signal what harmonized becoming can look like, the competitiveness and stage-based performance demands can be lessened, and the whole group can move at an accelerated pace toward both content knowledge and access to alignment as a full participant in science worlds—not only to pursue careers, though that path is more available through removal of self or system imposed exclusion. Students can begin to move beyond identities like, "I'm just not a science person." Instead, young people can move into mutual engagements that amplify and accelerate sites of becoming. Here, we are concerned with the ways young people come into contact with science learning as a process of engaging their experiences in the world with sustained wonder, curiosity and an awareness of the presence of potential beauty. We argue that embodied collective inquiry generates conditions for harmonized mutual development.

## Endnotes

(1) All names are pseudonyms.

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