“Construction workers for the bridge”: relationalities encountered by a physics teacher in an RET program

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RET (Research Experience for Teachers) summer programs have gained popularity as spaces to support teachers in bringing cutting edge topics in science classrooms. Previous research has utilized teacher identity as a construct to understand teachers’ experiences in RET programs as they learn new scientific ideas in research-based settings and experiment with strategies to translate this learning into classroom curricula. In this work, we adopt relationality, a precursor of identity, as a construct to examine the journey of one teacher participant through a quantum science summer RET program. Using a qualitative case study approach, we analyze this participant’s pre and post interviews at the beginning and end of the summer program and identify emergent relationalities of importance. We demonstrate how this teacher’s relationalities with both human actors as well as non-human entities evolved and influenced the realization of the goals of the program towards teachers’ learning and curriculum development.

2024 PERC Proceedings edited by Ryan, Pawl, and Zwolak; Peer-reviewed, doi.org/10.1119/perc.2024.pr.Bano

I. INTRODUCTION

Research Experience for Teachers (RET) programs aim to engage science teachers in research-based learning of cutting-edge scientific topics and provide support to turn this learning into classroom implementation of new curricula. Some scholars have utilized teacher identity as a construct to understand the changes that science teachers experience as they participate in RET programs [1,2]. While teacher identity is a powerful construct to describe trajectories of teacher learning [3], we take a step back and utilize the construct of relationality, through which identity develops, to examine the trajectory of a teacher participant in a Quantum Science (QS) summer RET program. As Vossoughi and Bang point out, analyses of relational activity are often not attended to in education research [4]. Thus, we attend to this call in the literature to tease out the very materials that influence the trajectory of identity formation. In this specific case, we illustrate how these relationalities and their evolution over time guided the teacher participant's decision making and positioning as he learnt QS and developed QS curriculum.

II. THEORETICAL FRAMEWORK

In this section, we first review some extant literature on exploring teachers' experiences in RET programs. In particular, we lay out how the teacher identity construct has been used in previous research on RET programs. Then we describe the analytical construct of relationality used in this work to elucidate the journey of a physics teacher in a summer RET program in Quantum Science (QS).

A. Teachers' experiences in RET programs

RETs have become a widely adopted model for in-service science teachers' professional learning. Thus, much research has focused on evaluating the impact of these programs. As these programs place teachers in an investigative research setting, attention has been paid to how these programs affect teachers' views regarding inquiry-based science instruction [5,6]. Additionally, other scholars have utilized the construct of "teacher identity" [7] to examine teachers' experiences in RET programs. For instance, Varelas and colleagues [1] utilized teacher identity to understand how teachers make sense of their practices as scientists as well as science teachers and how they navigate the emergent tensions between their identities. In more recent work, Davidson and Hughes [2] investigated teachers' sense of belonging in the "community of science practice" and found that both program design factors such as research group structure as well as personal factors such as teachers' sense of expertise in doing the research work are of importance.

Scholars studying teacher identity define an essential feature of identity to be "an ongoing process of interpretation and reinterpretation of experiences" [7]. We situate our research in this space of interpretation and reinterpretation of experiences that teachers navigated during their time in an RET summer program. In order to make sense of teachers' accounts of their experiences, we utilize the construct of "relationality", which is closely related to but different from identity.

B. Teachers' experiences and relationality

Drawing on previous work by Vossoughi et al. [8], we define relationality as the ever-evolving product of the act of positioning human actors and non-human entities within a sociopolitical context. We posit that the positioning of human actors and non-human entities results in the making of relations, which are subject to change from moment to moment. We use the concept of relationality to capture the results of this dynamic process of making and remaking relations. We use the term relationality (over the term relationship) to consider in our analysis transient and changing relations with the same weight as longer term, more stabilized relations.

We were interested in analyzing the relationalities teachers were developing with human actors, or "subjects" (in our case, other teacher participants, university scientists) as well as non-human entities or "objects" (in our case, abstract entities such as Quantum Science curriculum, tangible entities such as lab equipment) in the course of the RET program. We view relationality as a precursor to identity construction, following Nasir and Hand's statement that how people learn to be in relation results in shifts in identity [9]. A set of relationalities coalescing in a particular moment may allow individuals to try out a transient identity, while relationalities experienced over time may lead to more stable identity construction. Thus, focusing on relationalities allows us to capture and understand how the materials that lead to identity construction come together. This can then help us examine how components of RET programs afford or constrain various types of identity constructions for teacher participants.

Bang and Vossoughi recommend that "we attend more deeply to the ways designs for learning and processes of partnering organize for particular kinds of interactions and relationships." [4] In particular, they challenge the privileging of subject-object relations (such as those between students and academic outcomes) over subject-subject relations (such as student-student or student-teacher relations) in educational settings. They argue that greater attention to subject-subject relations can help center student agency and epistemic heterogeneity in learning. In this context, we understand agency as the capacity of an individual to act upon their world within, and sometimes against, the context of larger structures and norms. [10] Inspired by this call to action, as a first step, we sought to excavate emergent relationalities experienced by one teacher

participant in an RET program with both subjects and objects in the program. This program aimed to partner with teachers to support their learning of QS and implementation of QS curricula in their classrooms. Our aim was to identify relationalities of importance to teachers in such a program and the affordances they offered in realizing their goals and the goals of the program.

III. METHODS

A. RET Program Context

Our study examines the journey of a high school physics teacher participant, Mr. Isidoro, in a paid six-week summer RET program henceforth referred to as the "Quantum Science Summer Program (QSSP)". This program was primarily based in an interdisciplinary science research center of a private research university. Participating teachers taught different areas of high school science, were from the district public school system and applied for the summer program in the preceding spring. Each participant was referred to as a teacher researcher, hosted by a research lab led by a faculty member and matched with a research lab member (graduate student, postdoctoral researcher or staff scientist) who acted as their research facilitator. During the first week of the program, teacher researchers spent most of their time getting oriented, establishing relationships and planning projects with their research facilitators. In addition, they participated in a bootcamp where quantum science concepts were reviewed by a participating faculty member in a lecture format. Starting in the second week of the program, teacher researchers spent most of their time in research labs with one morning dedicated to a curriculum development session, another morning dedicated to curriculum group work and one afternoon at a content instruction session delivered by a faculty member approximately each week.

B. Participants and data collection

In this work, we sought an in-depth understanding of Mr. Isidoro's journey through the QSSP by employing a case study methodology. We chose to elucidate Mr. Isidoro's journey as a revelatory case as he pioneered the implementation of a month-long QS curriculum module in his physics classroom and displayed the participation we aspired to cultivate through the QSSP. The main data source for this study was semi structured interviews conducted with Mr. Isidoro at the beginning and end of the six-week QSSP. Both interviews lasted approximately one hour and consisted of questions about thoughts and feelings on navigating research work and curriculum development in the QSSP, and interactions with other teacher researchers and research facilitators.

C. Data analysis

Interviews were transcribed verbatim and the interview transcript data was analyzed to make meaning of Mr. Isidoro's approach to the QSSP. The unit of analysis was his reflection on a specific event or activity in the QSSP, for example, learning new QS concepts or interacting with the research facilitator. The first author first identified all relevant segments of data for each interview and sorted them into categories based on potential emergent relationalities, for example, with curriculum development or another teacher researcher. Then, the first author composed analytic memos by comparing interviews at the beginning and end of the QSSP to investigate how these relationalities evolved through the course of the QSSP. Finally, findings written in this paper were shared with the research participant, Mr. Isidoro, to validate our data analysis.

IV. RESULTS

A. Mr. Isidoro's background

Mr. Isidoro was candid about his motivation and goals at the beginning of the QSSP. His childhood experiences of studying in an under-resourced school in a working-class majority Latino community motivated him to become a physics teacher and use science education to positively impact his students' lives. In the context of QSSP, Mr. Isidoro shared an aspiration:

> *Us as educators, we are the construction workers for the bridge to allow students to walk over to this whole entire brand new field of STEM.*

From the beginning, Mr. Isidoro positioned himself as an agent to support his students' engagement with quantum science (QS). He visualized this relationality as that of a worker who builds a "bridge" to "allow" students cross the chasm that separates them from having QS knowledge. In the framework of subject-subject relations, he positioned himself as an agent with a purpose, but did not explicitly consider his students' agencies or their goals with regard to STEM. In the following sections, we analyze Mr. Isidoro's statements from pre- and post- interviews to understand the relationalities he experienced, and how these evolved over the course of 6 weeks.

B. Relationalities at the beginning of the QSSP

Mr. Isidoro's main goal for the end of the summer was to have a "finished, completed curriculum" in QS that he could implement in his physics classroom. This goal was aligned with a stated goal for teacher-researchers in the QSSP program.

Thus, one important subject-object relationality to consider was how Mr. Isidoro felt about QS content itself. Mr. Isidoro had taken courses in QS and other related fields as an undergraduate student. He shared how he intended to deepen his knowledge of QS in the program:

And I can't really develop curriculum until I conduct the actual hands-on research and then ask all the questions and then start creating […] *That's how my brain works. Over the years I learned more when I'm working by hand and visually next to somebody learning it and watching them do it and observe it compared to just reading through a textbook.*

Though he had learnt QS through textbooks and coursework previously, he wanted to deepen his understanding through engaging in research and having discussions with quantum scientists. Therefore, another emergent subject-subject relationality, was that with other quantum scientists Mr. Isidoro interacted with, including his research facilitator David. He approached his relationality with David with a specific intention:

I have to really see how his [David's] *brain works,* […] *and do my best to translate that into curriculum. And how can students better learn what he is trying to figure out?*

Mr. Isidoro was interested in understanding how a scientist like David thought about QS concepts. He wanted to use that understanding to create curriculum, as he wanted to convey to his students to understand a scientist's way of thinking about QS. Thus, the subject-subject relationality between the teacher researcher and research facilitator was an important factor in realizing the curriculum development goal Mr. Isidoro had.

How Mr. Isidoro positioned and related to David beyond the intellectual is also crucial to note.

So it's very rare to see any, for me personally, walk into this building [physics building in a prestigious university]*, it's very rare to see any Latinos.* […] *And when I spoke with David, the first thing, I already knew he was Latin American, and I spoke Spanish to him. And you see that happiness, right? Like, "Oh, this is another Spanish speaker." And that's what I mean by connection and barriers. David is from Chile. He has a family over there still. I have my family too in Mexico as well. But then when we're together and we talk in this same channel, we feel like we're back at home.*

Mr. Isidoro identified as Latino and was acutely aware of the marginalization of Latine and Spanish-speaking people in physics and STEM. In addition to the above quote, he repeatedly and emphatically shared how much he felt at home in his interactions with a Latin American physicist who he could speak to in Spanish. To Mr. Isidoro, this signaled the potential of being understood in his experience as a marginalized person in physics. This sense of similarity may have created connection and comfort in the context of this subject-subject relationality and served as the bedrock of a fruitful collaboration between Mr. Isidoro and David. This is evidenced by some vignettes Mr. Isidoro provided of his relationship with David at the beginning of the program:

So we talk a lot. We laugh a lot. We like joking a lot, goofing off a lot. […] *And when we get to business, we get to business. And I'm learning from him, we understand each other as we have our different barriers, and I feel like that's just a Latin American thing, and it's easy for us just to get along.*

C. Evolution of relationalities by the end of the QSSP

At the end of the summer, Mr. Isidoro reflected on his work in QSSP and called QS concepts "Goliath scientific ideas" that he only began to understand fully four weeks into the six week program. He felt positive about working hard and gaining this understanding, but also shared a tension he had encountered:

every day you're learning something brand new and it makes you rethink of your previous mindset on how the curriculum should be developed and that was the biggest struggle I had.

Mr. Isidoro's efforts to develop a deep understanding of QS had affected his relationality with curriculum development. As he discussed quantum science ideas with scientists, he realized that curriculum design was not going to be as simple or static as he had expected. He shared:

So I feel accomplished in myself to really think about this […] *or this curriculum document to not just get a fully completed model, but start developing this platform of a curriculum that allows other voices to join in the conversation. what's important, what's not important to include in a high school classroom?*

At the end of the summer, Mr. Isidoro viewed the QS curriculum he created as a dynamic "platform" rather than as a static product. Such a framing of the curriculum stood in contrast to the "finished" product he had hoped for at the beginning of the program. Key to this new framing was to have the curriculum open to change based on ongoing conversations about diverse strategies to teach QS in high school physics classes.

Mr. Isidoro's own changed relationality with the QS curriculum may have allowed him to imagine and articulate how his teacher peers could approach QS teaching. This in turn had potential to translate to teacher-student relationalities beyond the QSSP into teachers' classroom:

how this is life-changing curriculum, not just for the students, but also for the teachers, to make them re-feel the love of learning, to make them refill... re-feel or- […] make them to feel again how much fun it is to learn, to make them feel again how much fun it is to teach brand new concepts and not teaching something repetitive, to make them feel again like an actual science teacher. And for many teachers who are experienced, they're teaching the same thing over and over again. It would be nice for them to teach something brand new and also for students to feel in the same boat.

Mr. Isidoro realized that QS was a brand new and challenging topic for many teachers to introduce to their classrooms while they were learning it at the same time. But he framed this practice as "fun", contrasted it to the repetitive nature of teaching and characterized this ongoing learning as core to "feeling like an actual science teacher". By doing so,

he provided an alternative to the usual teacher-student relationality in the classroom where the teacher is positioned as authoritative and all-knowing. He framed it as a positive quality for students to be learning QS with the teachers ("in the same boat"), rather than only learning from them , saying, "that's what creates a strong motivation and influence for students in the classroom". Thus, by imagining such a relationality for teachers of QS, he also brought to the surface the notion of co-construction of classroom learning with students. By imagining the possibility of such a teacher-student dynamic, he also reimagined the teacher-student subject-subject relation as one that centers students' participation and students' thinking in the learning process.

Another influential factor in Mr. Isidoro's journey was his (subject-subject) relationalities with quantum scientists he interacted with, including his research facilitator David. He shared:

> *For me as a researcher, it's my priority to not just shadow the researcher, but to really understand their background in education, growing up, their origins, their roots, what helped them out a lot more learning chemistry, what helped them out more learning quantum science and so I really dig deep into that.* […] *Because at the same time, I'm trying to figure out ways to replicate their success story for my students and sharing our individual origin stories with each other really opens up minds.* […] *showing awareness for students and what's really out there for them and showing them that there's more.*

Over the course of the program, Mr. Isidoro certainly cultivated tight-knit intellectual relationships with his research facilitator and other quantum scientists in the program (data not shown). However, a critical aspect to these relationships was understanding various individuals' unique journeys to becoming Quantum scientists ("background in education, growing up, their origins, their roots") with the intention of sharing these stories with his students. At the beginning of the program, Mr. Isidoro saw his subject-subject relationality with students as that of a construction worker building a bridge for his students into QS – a one size fits all model of equity previously described as "increasing opportunity and access to high quality science learning" [11]. However, towards the end of the program, Mr. Isidoro's perspective, while still focused on paths of success for students, had shifted closer to considering his students as agents who could have different journeys and entry points into QS, perhaps like the Quantum scientists he encountered in the program. Perhaps, developing a close relationship with David and understanding the human aspects of his path into QS may have moved Mr. Isidoro towards this framing. Thus, he shifted more towards to a model of equity described previously as "emphasizing increased achievement, representation and identification with science". [11]

IV. CONCLUSIONS

Our analysis demonstrated the utility of the relationality construct to elucidate important aspects of Mr. Isidoro's journey in the QSSP. First, it allowed us to highlight Mr. Isidoro's approach to curriculum development, of seeing it as a dynamic platform rather than a static product. This is an important insight as curriculum development on a new, cutting-edge topic is challenging for many teachers. Perhaps, a flexible relationality with curriculum development is beneficial for teachers in teaching new and complex physics ideas in their classes. In future work, RET programs can be designed to foster such a flexible relationality. Second, the relationality construct allowed us to start mapping out how a changed relationality to one program component, even a subject-object relationality (such as to QS curriculum) may have effects across contexts, and even on subject-object relationalities (for example, from the QSSP setting to teacher-student relationalities in the classroom). With regard to educational equity, we found hints of how deepening of subject-subject relationalities with agentive actors in the QSSP setting (such as to Quantum scientists) could then shift affect teacher-student relationalities and the teachers' approach to towards equitable outcomes for students in the classroom.

ACKNOWLEDGMENTS

We thank Mr. Isidoro for his participation in this research study. This research study was supported by the National Science Foundation (NSF) through grant no. 2121044.

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