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Physics Teachers as Physics Experts: Research Participation as Professional Development

Abstract

This article reports on the results of an exploratory phenomenological study of six Nebraska high school physics teachers and their perceived impact of participating in a collaborative scientific research program that provided training in experimental procedures and advanced, extra-curricular physics topics, all building on fundamental high school physics concepts. In the context of this paper, subject matter expertise will refer to teachers' understanding and confidence in the subject as well as their view of self as a teacher, scientist, and physicist.

A conclusion is drawn that through collaborative scientific research activities, secondary teachers who are teaching physics outside their primary field of training can build confidence in this particularly challenging subject area and achieve a progressive view of self not just as physics teachers but physics experts. This document suggests subject-specific on-going teacher professional development opportunities may be crucial to helping physics teachers become physics experts.

Introduction

It is widely recognized that teaching, like many professions, benefits from continuous learning. Teachers receive extensive formal training, including four years of college classroom work, in many cases one year of practicum, and typically earn post baccalaureate credits to maintain certification. However, because students need more than a planned curriculum and substantial classroom time to succeed, training should be both ongoing and subject matter specific (Van Driel et.al, 2012).

The correlation of science career choices with students' "physics identity" (Gee, 2000; Lock et.al, 2013; Goodwin et.al, 2016) suggests that the development of such identity (as much an individual's perception of how others view their expertise and contributions as their own confidence in mastering course objectives) is of significant importance to teachers and their own students. Our belief is that professional development for physics teachers should not be limited to lectures covering content, demonstrations of enrichment activities or the modeling of expert teaching, but should include participatory work in experimental activities closely aligned to physics classroom content. The physics-based out-of-school program Cosmic Ray Observatory Project (CROP), helps physics teachers become physics experts through their training and engagement in astrophysics experiments set in a secondary science context that continue throughout the academic year. CROP workshops, offering both formal and informal teacher professional development opportunities, aim to advance participating physics teachers broad physics content knowledge through a focus on high energy cosmic ray particles. The equipment and training provides each teacher opportunities to work with select student teams or engage entire classrooms in the program's active research activities. Through CROP, high school physics teachers and students, undergraduate and graduate university students, and professors are offered a rich research experience that extends far beyond the classroom and empowers teachers with knowledge of experimental practices and physics content beyond the high school curriculum.

Keywords: Professional Development, Physics, Out-of-school programs, CROP, Phenomenology, Qualitative

The problem

Over the past 20 years, the U.S. teacher education and teaching preparation systems have expanded. New teachers entering the workforce go through more training paths than ever before (National Academy of Engineering [NAE], 2009). But even as U.S. K-12 students have shown improved performance in mathematics, the National Science Board's Science and Engineering Indicators (National Science Foundation [NSF], 2008) suggest they have not made the same improvements in science. In many cases, college and university programs may not provide the extensive range of physics content learning and physics teaching and research experiences necessary for graduates to become effective high school physics educators. (National Research Council [NRC], 2012). Once college students graduate, meet their state's certification requirements, and are employed, they primarily learn through on the job experience. As in all professions, teachers often take years to gain the skills they need to be effective in their roles.

Exacerbating this problem are the many science teachers (physics in particular) who teach outside their field, often without full certification. According to the Physics Education Coalition nationally "only 47% of physics classes are taught by a teacher with a degree in the subject" and 58 percent of high school students are taught physical science or physics by a teacher lacking even a related minor (Ingersoll, 2004). Belying the simple aggregate statistics is the observation that out-of-field physics teaching is even more prevalent in rural communities (U.S. Department of Education [DOE], 2005; Legleiter & Adams, 2004), particularly critical in the state of

Nebraska. The Council of Chief State School Officers (CCSSO) places Nebraska in the nation's bottom 12th percentile for high school physics teachers certified in the field, and advises that over 77 percent of Nebraska's science teachers have been trained in a single natural science field (most often biology) and need additional preparation in the physical sciences area. This shortage of science teachers, severely acute in physics, suggests that particular attention needs to be paid to making subject content specific training available. In addition, the expectations that every student meet their state learning standards can place teachers under tremendous pressure. Teachers' workloads pose particular challenges in addressing this need. These facts underline the great need for specialized physics teacher training opportunities for educators to become more experienced in their field and to grow more confident in their ability to teach it (Osborne et. al, 2003). Creating collaborative research experiences that connect practice to interactions with teaching colleagues may have additional benefits (Goddard et. al., 2007) and in the end increase teachers content expertise and their confidence to teach physics.

Certainly many high schools physics teachers have excellent training as educators, yet they do not necessarily have substantial training in the requisite physics topics. Insufficient knowledge in a subject matter can negatively affect teachers' performance in the classroom. Therefore, ongoing physics teachers' professional development opportunities are critical. Though school districts routinely provide professional development opportunities, studies have found that physics teachers see little value in those not focused on physics content or pedagogy. Programs like CROP can be an alternative solution to providing teachers with enrichment and first-hand research opportunities.

We propose that one way we can facilitate a physics teacher's development toward physics expertise is through active participation in a physics-specific research experience that introduces "advanced physics content" to high school physics teachers and connecting this to the more basic physics and mathematics concepts. Studies indicate teachers that participate in scientific research activities are more likely to incorporate the skills and knowledge acquired into their classroom, increasing student interest in science (Glynn & Koballa, 2007; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010; Moen & Allgood, 2009). The goal of the study is to explore the experiences of six high school physics teachers in Nebraska to understand their perceptions of the impact of participating in CROP as a means of enriching their knowledge in fundamental and advanced physics topics and their confidence in teaching it.

Cosmic Ray Observatory Project

While we believe any similar research experience tied to reinforcing fundamental physics content in the context of exploring more advanced topics will produce a similar outcome, this study was conducted on a group of teachers participating in the Cosmic Ray Observatory Project (CROP). Conducted by a large midwestern university situated in a rural state, CROP was funded by the National Science Foundation (NSF) in two separate cycles from 2000-2007 by the Elementary, Secondary, and Informal Education Division (ESIS) to work with metropolitan area schools, and from 2013-2016 by an ITEST award to pilot expansion into rural schools. CROP educates high school physics teachers and teams of their students in the construction, maintenance, operation, and data analysis of simple particle detectors, and through coordinated extracurricular activities to perform experimental research studying cosmic ray showers. CROP also facilitates physics teachers' knowledge of college–level modern physics, specifically elementary particle physics, situated within a foundation of high school physics. Over the years CROP has encouraged high school physics teachers' active participation in hands-on scientific research both in class and through out-of-school activities (Shell et. al, 2011).

Why focus on cosmic rays? The nature and origins of these particles are of keen interest to physicists and astronomers and, we have found, fascinating to high school students. Though invisible to the naked eye, cosmic rays surround us all the time. Thousands of them pass through our bodies every second, and they subtly influence our world in various ways. Learning about cosmic rays may give us information about the dynamics of the Milky Way galaxy and unusual particles such as muons, pions, and other phenomena. Furthermore, there is a broad range of related topics in the areas of general physics (conservation of momentum and energy, classical mechanics, thermodynamics, motion, sound, optics, quantum mechanics, and relativity) participants learn about.

During CROP workshops, interactive sessions explore new content, while other sessions are devoted to working in the laboratory with cosmic ray detectors to facilitate the development of firsthand research skills. Through CROP workshops and activities, physics teachers have the opportunity to revisit and enrich physics lessons related to the Next Generation Science Standards (NGSS) as shown in Table 1.

Methods

Creswell (2013) explains that qualitative research starts with ideas, points of view, or perceptions and the study of a research problem inquiring into the meaning individuals assign to a social problem or phenomenon. To study this phenomenon, qualitative research uses emerging qualitative approaches to inquiry, the collection of data in a natural setting, and data analysis that establishes patterns or themes. For this study, phenomenology research methodology was selected because of its emphasis on the phenomenon of a study. In this case, the phenomenon relates to each teacher's perceptions toward participating in science-based out-of-school programs. The final study report includes the voices of participants, the feedback of the researcher, the description and interpretation of the problem, and a call for action (Creswell, 2013).

An initial graphic explanation of the main ideas and variables to be explored

Table 1. Next Generation Science Standards explored in CROP.

Topics	Next Generation Science Standards (NGSS)	National Science Education Standards (NSES)
Structure of atoms	HS-ESS1-2	Teaching Standard A, E Professional Development Standard A Content Standard B
Structure and properties of matter	HS-PS1-4	Teaching Standard A, E Professional Development Standard A Content Standard B
Chemical reactions	HS-PS3-3	Teaching Standard A, E Professional Development Standard A Content Standard B
Motions and forces	HS-PS2-5	Teaching Standard A, E Professional Development Standard A Content Standard B
Conservation of energy and increase in disorder	HS-PS3-3, HS-PS3-4	Teaching Standard A, E Professional Development Standard A Content Standard B
Interactions of energy and matter	HS-PS1-4, HS-ESS1-3, HS-PS3-3	Teaching Standard A, E Professional Development Standard A Content Standard B
Waves and their Applications in Technologies for Information Transfer	HS-PS4-5, HS-PS4-3,	Teaching Standard A, E Professional Development Standard A Content Standard A
Engineering Design	HS-ETS1-1	Teaching Standard A, E Professional Development Standard A Content Standard A

(the key factors) and their presumed relationships or conceptual framework of the phenomenon was built (see Figure 1), which represented the system of concepts, assumptions, expectations, beliefs, and theories that support and inform the research study. (Huberman & Miles, 1994).

The exploratory component of this phenomenology study, which follows a social constructive approach, is related to the exploration of teachers' described lived experiences. As stated before, to gather information about what the participants experienced and how they experienced it (Moustakas, 1994), in-depth, open-ended, formulated, and individual interviews were used.

Researcher Positionality

Given the interpretive nature of qualitative research, it is important to acknowledge the philosophical assumptions that underlie one's research method and design. Researcher positionality, or bracketing, refers to the biases and subjective experiences of the researcher, including: how researchers perceive reality (ontology), the role of values throughout the research process (axiology), the relationship between the researcher and what is being researched (epistemology), and the language used to present information (rhetoric) (Creswell, 2013). We believe there are multiple realities and that each person gives unique meaning to their experiences. By exploring teachers' perceptions of their participation in CROP, we strived to discover the essence and true nature of their experiences without bias. The rhetoric in the study reflected our goal of giving voice to the CROP teachers by examining their perceptions. The purpose was to convey in-depth understanding that help us become more aware of the impact participation has on teachers (in CROP), and their perceptions of this experience in connection to their self-concept and professional growth (See Figure 2).

Different stages (see Figure 3 and Figure 4) were involved in the discovery of the meanings embedded within the study participant's narratives. The first stage necessary before beginning data analysis was Epoche, or suspension of judgment. Personal bias and prejudgments were "bracketed" and set aside, which allowed descriptions of the true nature or essence of a phenomenon as viewed by the participants.

Data were gathered through the collection of semi-structured one-on-one interviews aimed at understanding the individuals' experiences and views, which contributed to the shaping of their perspectives (Van Manen, 1990). This technique allowed interviewees enough room to provide detailed responses. Participants were asked to recount individual experiences related to their participation in CROP in order to obtain a diverse array of perspectives among participants experiencing the same phenomenon (multiple realities).

Interview sessions were audio taped with the participant's consent and then transcribed verbatim. Once the interviews were transcribed, the phenomenon was classified by analyzing the raw data through carefully reading the interview transcripts in search of key words or phrases, looking for patterns within the data, forming into larger themes through coding.

Analysis of data focused on significant statements, emergent themes, and general description of the phenomenon in question, which provided insights of the scope of high school physics teachers' perceptions in connection to their participation in CROP. Qualitative research relies on various methods and approaches for organizing and analyzing qualitative data. During this study, Huberman & Miles (1994) and Wolcott (1994) approaches to data analysis were followed when analyzing data (Table 2). In addition, MAXQDA software was used only to organize the data.

Six (6) Nebraska high school physics teachers participated. All interviewed teachers were certified experienced high school teachers from public and private schools in Nebraska who taught at least thirteen years and who participated in CROP for at least one and a half years. This group of teachers was considered to be part of a purposeful sampling for the study (Creswell, 2013); each participating teacher in the CROP study was from

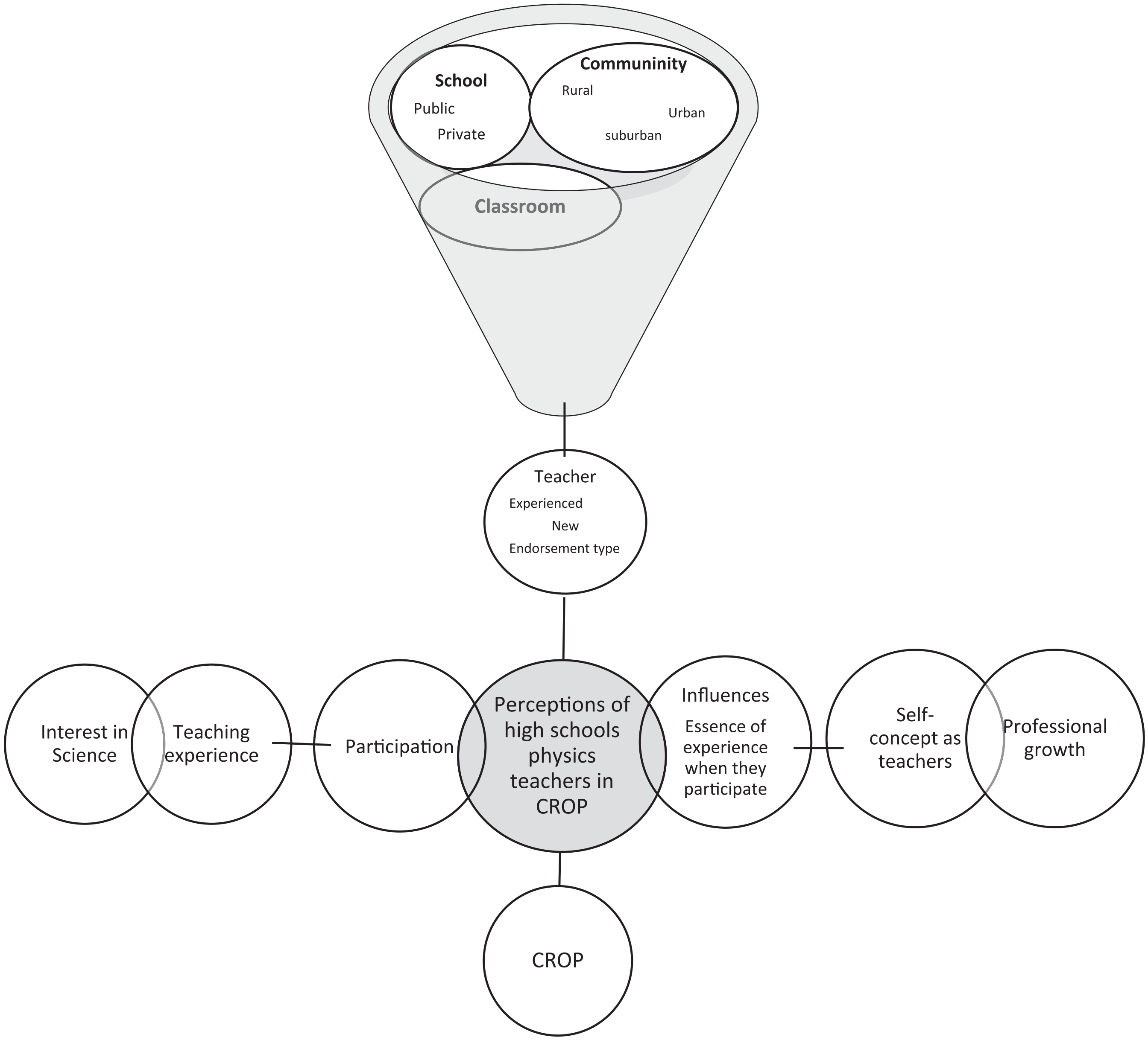

Figure 1. Conceptual Framework of the Phenomenon.

a different school and at a different stage in their career. One participant teaches in a suburban high school district, two participants in urban high schools, and three in separate rural high schools in Nebraska. All of the participating teachers were full-time physics teachers. All teachers carried multiple endorsements (Table 3). Their teaching experiences ranged from 13-38 years, with an average of 23.5 years of work experience teaching a variety of general STEM classes that includes biology, chemistry, computer science, mathematics and physics. Two out of the six participating teachers took the minimun required chemistry credit hours in college as part of their teaching training programs in science education. Two teachers took biology credits hours as part of their teaching training programs (one with a secondary level emphasis' and one with emphasis in middle school level). One teacher took the minimun required credit hours of Mathematics and one teacher took Physics credits hours as part of their teaching training. Two out of the six participating teachers indicated that their initial Bachelors degrees and professional goals were other than teaching (one in food engineering and one in

Figure 2. Conceptual Framework of Researcher Positionality. Based on Creswell's interpretive Framework (Creswell, 2013).

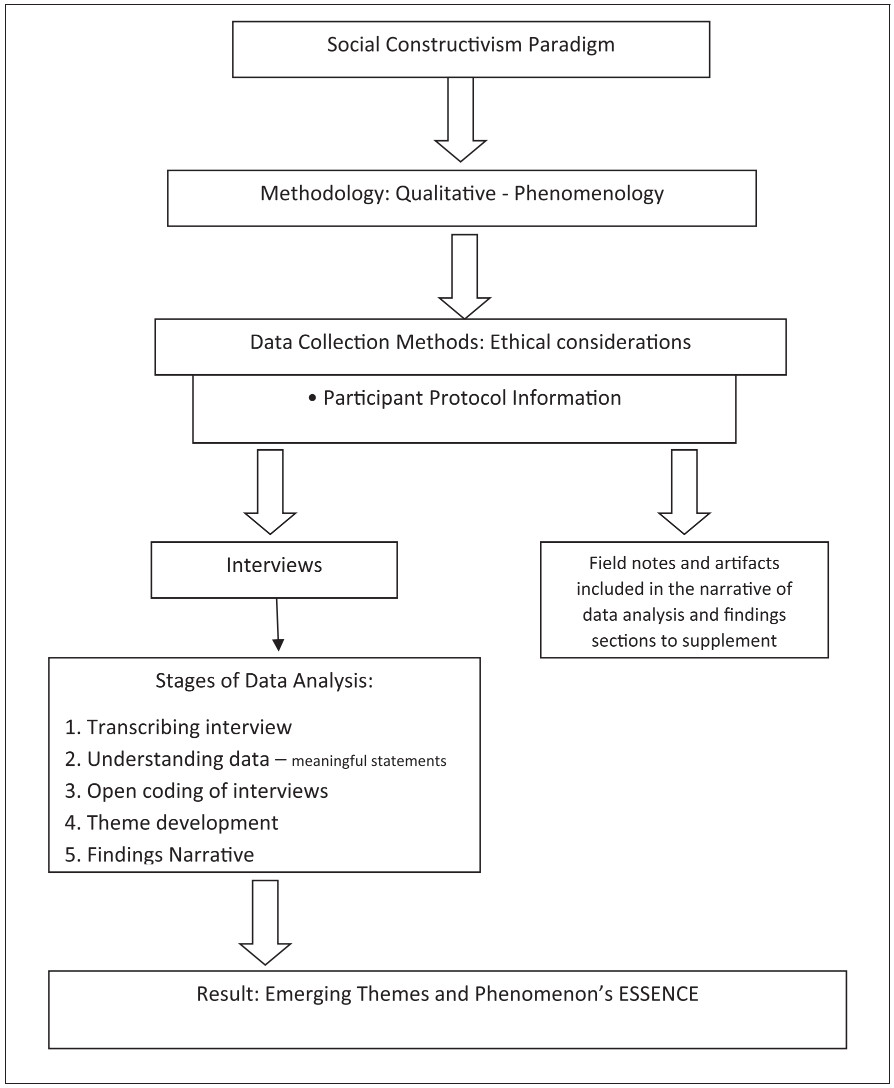

Figure 3. Logic Model: Research Plan Based on Qualitative Research shows the qualitative research plan model to which this study referred (Creswell, 2013).

microbiololgy), later on these teachers earned endorsements to teach physcis classes at the secondary level. Five out the six (6) participants (83%) are male, and one is female (17%). Pseudonyms were created to ensure teachers' confidentiality (Table 3). Participating teachers were invited to take part in the study not only for their roles as physics teachers but also for their willingness to openly share their views. This level of enthusiasm supported the development of trust and rapport recommended by Creswell (2007) for conducting in-depth interviewing.

Results

Ericsson (2016), suggests that research on education with students is well established in the science, technology, engineering, and mathematics (STEM) field; however research related to physics high-school teachers and content may be limited as the investment into research and the number or researchers into this field is limited (Pavesi et. al, 2008). The source for this study and subsequently this article is rooted in this need to give participating teachers an opportunity to voice their views on the impact of their participation in a science-based out-school-program in connection with their self-concept and professional growth.

A total of 36 emergent codes were derived from the data analysis. From these original codes, four themes later emerged which addressed the research study questions (See Table 4 and 5): I am science inquisitive; Sharing knowledge is what I do; More learning, more power; and Becoming bilingual in Physics (See Table 6).

Theme 1: I am science inquisitive

Emergent codes that contributed to the discovery of this theme are: *I always liked science, science curiosity, how things are made, my favorite subject, and childhood memories related to science.*

Based on the participants' feedback, their shared image of the "ideal physics teacher" is someone born with a distinctive personality, who, is inquisitive, loves science (physics), and sees teaching as a calling. Conversations revealed a common narrative in which each teacher's inclination toward science began at an early age. This internal pull toward science where curiosity was a key ingredient seems to be something all embraced. This factor—curiosity— helped them realize they love learning new science understanding how the natural world works and the inspirations behind it.

> "I always have loved science! Even in high school, it was my way to understand how the world around worked. Even when I watched TV shows, I was fascinated with space shuttles like the Enterprise. I remember all that stuff.

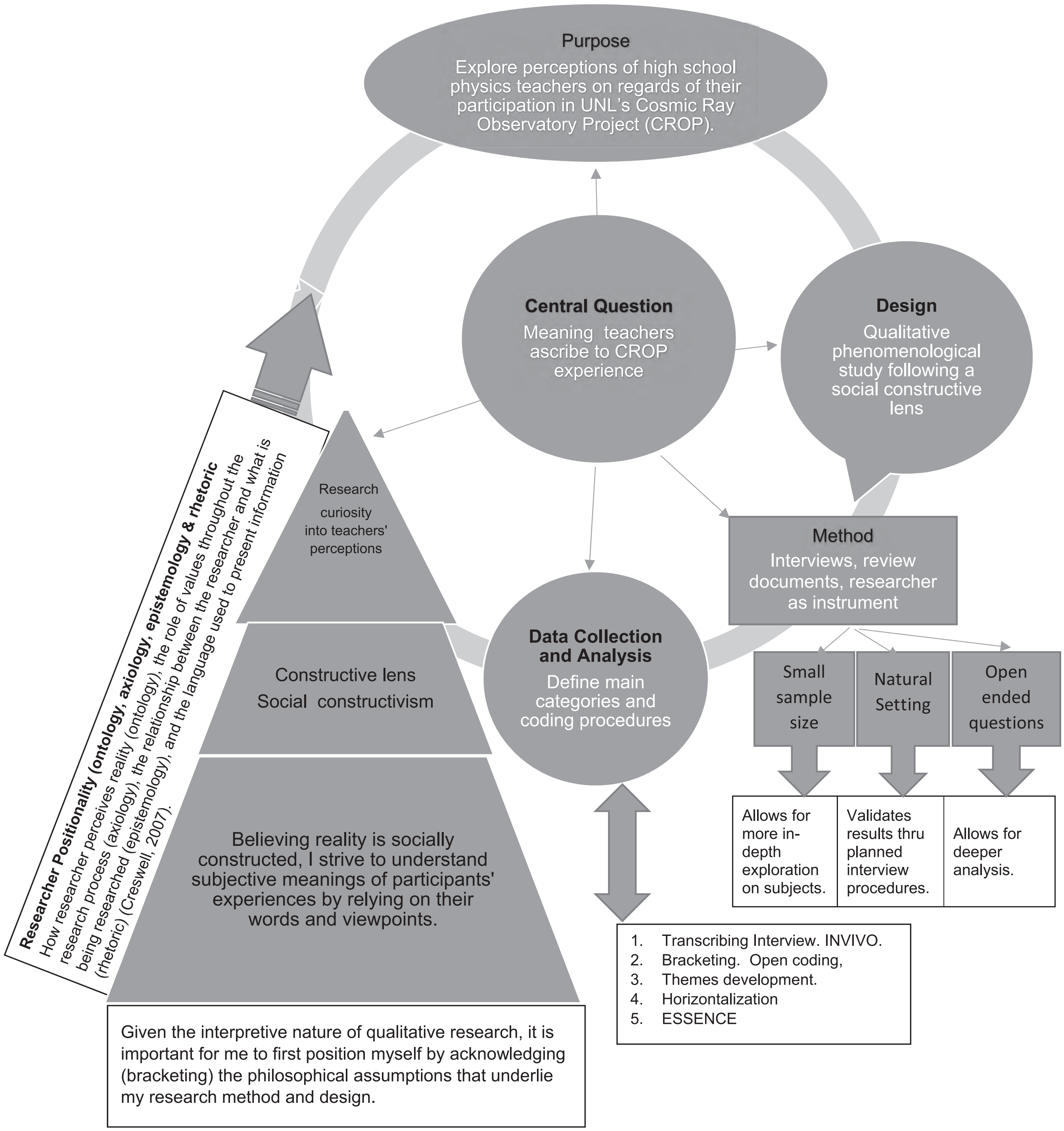

Figure 4. Conceptual Framework of the Study.

I just always had an inkling. I just love science. There are interesting things that happen in the universe, and it is fascinating to see how things evolve but science does not change." Simon

"Science was one of my favorite subjects in high school. It answered all my questions. It motivated me to double major in food science and technology, and then natural sciences education." Pato

All teachers described an active desire to learn and a natural curiosity for science. As they described their experiences, it begged the question: How can we create such curiosity in new teachers, or build and enhance curiosity? For all of these

Table 2. Qualitative Data Analysis Approaches

Analysis Strategy	Huberman & Miles (1994)	Wolcott (1994)
Outlining ideas	Write margin notes	Highlight certain information in description
Taking notes	Write reflective passages in notes	
Summarize field notes	Draft a summary sheet on field notes	
Using words	Make metaphors	
Identify codes	Write codes, memos	
Reduce codes into themes	Patterns and themes	Identify patterned regularities
Count frequency of codes	Count frequency of codes	
Relating categories	Noting relations among variables, building a logical chain of evidence	
Framework of literature		Contextualize in framework from literature
Display the data	Make contrasts and comparisons	Display findings in tables, diagrams, and figures; compare cases & with a standard

Based on Huberman, A., & Mile, M. (1994). Qualitative data analysis; Wolcott, H. (1994). Transforming qualitative data: Description, analysis, and interpretation.

teachers, helping students learn means being able to give concepts a place for exploration and application (Zacharia & Barton, 2004). In doing this, teachers hope students develop an inquisitive attitude. For physics teachers to achieve this, however, shouldn't they have an inquisitive attitude themselves? Perhaps, further research on this topic may provide insights into the factors that trigger or strengthen physics teachers' natural curiosity.

Theme 2: Sharing knowledge is what I do

The main emergent codes yielding to this theme are: *be a source, real life application, adapting information. I love teaching; my job as a teacher, helping my students is the goal, sharing knowledge, CROP.*

Teachers also described their role as educators as a calling, a vocation, and mission. It became apparent that they all view themselves as educators called into teaching with a mission to help their students achieve. This view explains teachers' motivation to participate in as many teacher development opportunities as they can for the benefit of their students.

> "I have been teaching physics since 1977-1978, and I have always enjoyed it. If you really want to be a good teacher and you are excited about the field that you are in, as I am about physics, you would always want to jump at these kinds of opportunities because they are so enriching for both yourself and the students." Miles

> "I have been teaching physics for almost 20 years now. I like teaching physics. Over the years, I have taught other science classes, but if I could have chosen, it would have always been physics classes. I like it because there are so many things you can do. It is cool for my kids to see that the basic concept applies to anything. I want my students to see that physics is a universal topic. So, yes I enjoy teaching' physics, and I have been at it for about 20 years now. I am with CROP because of the exposure that the kids get to that level of physics. I have been with you guys for ten plus years now, and every time it has been a top notch experience for myself." Pato

> "I have been a teacher for 37 good years. It went pretty quick. I feel pretty comfortable teaching physics by now. It has been a good experience. Over the years I realized that giving my students and me the opportunity for enhancing knowledge is worthwhile." Matt

> "I think as a physics teacher you want to find ways to get your students interested in physics. So, you go to summer classes, summer workshops, and training to try to learn more and grow as a teacher. You just try to get kids more interested in science. Moreover, do a better job of teaching." Luis

Table 3. Participant Teachers Interviewed Demographics

Participant n=6	Gender	Ethnicity	Type of Endorsement	STEM Subjects Taught other than Physics	Years teaching	Year Joined CROP	School types by location	School type
Miles	M	White	Multiple	Mathematics Computer Chemistry	38	2001	Suburban	Private
Matt	M	White	Multiple	Life sciences Chemistry	37	2005	Urban	Public
Tim	M	White	Multiple	Biology (Middle School) Life Sciences	13	2011	Rural	Public
Simon	M	White	Multiple	Chemistry Physical General Science	13	2014	Urban	Public
Luis	M	White	Multiple	Biology	20	2004	Rural	Public
Pato	F	White	Multiple	Chemistry Earth science	20	2006	Rural	Private

Table 4. Emergent Codes: Derived from significant statements relevant to the topic.

Confidence	I always like science	Sharing knowledge	Enhancing knowledge	Collaborations	CROP
PD = Job security	Science curiosity	I love teaching	Sometimes hard but needed	Pacing chart = limits	A different language
More experience = job security	Childhood memories related to science	Helping my students is the goal	Be a source	Not enough time for extras	Cutting edge
Creative: what else can I do?	How are things made	Enhancing knowledge = greater self-esteem	Getting students interested in science careers	Overwhelming schedules	Changing the way you look the natural world
Not afraid of new learning	Inspired by space	Knowing the answers = really cool	Broadens my horizons	Incentives needed	Great college relationships
Nontraditional	My favorite subject	My job as a teacher	Real life applications	adapting information	A new culture

Theme 3: More learning more power

Some of the emergent codes that led to the discovery of this theme are: *confidence, not afraid of new learning, enhancing knowledge, greater self-esteem, be a source, job security, cutting edge, collaborations, CROP*.

This theme refers to teachers feeling scientifically confident in teaching physics. It also speaks to teachers' views about who are they as physics teachers, and their professional value and motivations for the discovery of new knowledge. Equally important is the impression that teachers considered the ideal physics teacher to be a content expert very enthusiastic about the subject, who implements practical teaching activities, and consistently reflects about lessons, outcomes and future steps to take in the classroom. Thus, all participants felt it is important to know the content they teach beyond the curriculum and know how to explain and apply it.

A common characteristic among interviewed teachers was their goal for students' long-term educational experiences, which speaks to their teacher identity. An appreciation gathered from the interviews is that effective teachers do not just teach; they also re-learn themselves and apply this knowledge in their teaching. For instance, one of the teachers from a small, rural school indicated he enjoys having access to the CROP equipment as it allows for more inquiry opportunities with his class. Teachers also stated that involvement in CROP "energized" them and gives them "a leg up" by strengthening and deepening their understanding of science and the scientific process.

> "CROP is a wonderful opportunity to learn and to do work at a very fundamental level of physics by understanding the way cosmic rays are both detected and created. It opens up the door for interest in other related physics areas." Miles

> "I have been doing CROP for many years, and I still learn something every time I come. Being a teacher, I have a tendency to watch [my peers] teaching styles as much as the content taught. This opportunity helps me prepare my classes better. I would say CROP is a form of professional development as far as me as an educator. It has made me a better teacher. It impacted me in such way that I have gotten a lot better at applying the activities to the content. I may be even a little bit better than I would have, had I not participated in". Pato

A key finding gathered from the interviews was the teachers' views of CROP as a professional development experience that advanced their learning, even if not one required by their school. Another was the common statements by teachers of newfound feelings of being scientifically knowledgeable in teaching physics. Teachers stated that enhancing their knowledge was "empowering." Regarding professional development, teachers also agreed that participation in a science-based afterschool program such as CROP helped them achieve much-needed physics knowledge.

> "CROP is a fantastic opportunity to learn and to do work at a very fundamental level of physics by understanding the way cosmic rays are both detected and created. It opens up the door for interest in other related physics areas." Miles

> "CROP is kind of like a professional development opportunity in a particular area. You gain knowledge but, even better, you get to know other teachers and work together." Matt

> "It is not official PD, but the fact that we are learning and applying makes it the best PD there is because it is not just ideas. It is actual nuts and bolts putting it to use and helping us understand what we are learning so that as we teach it, we are better able to teach the students. That is the purpose of PD." Tim

> "I do think CROP is a professional development option. When you do professional development, you are supposed to be working on improving your craft and trade. Participating in CROP, you are working with the latest discoveries in particle physics." Simon

Table 5. Research Study Questions.

1. How does teachers' participation in CROP affect their professional development in terms of professional growth?
2. How does teachers' participation in CROP affect their self-efficacy in terms of self-concept?
3. How do teachers' life experiences influence their participation in science-based out-of-school programs?

Table 6. Guiding Themes and Associated Research Study Questions: Questions vs Themes.

Study questions \ Themes	I am science inquisitive	Sharing knowledge is what I do	More learning, more power	Becoming bilingual in Physics
1. How does teachers' participation in CROP affect their professional development in terms of professional growth?		✔	✔	✔
2. How does teachers' participation in CROP affect their self-efficacy in terms of self-concept?		✔	✔	
3. How do teachers' life experiences influence their participation in science-based out-of-school programs?	✔			

The notion that enriching teachers' physics knowledge boosts their feelings of empowerment is significant. The more physics they feel they understand, even beyond the class curriculum that they teach, the better informed they are of fundamental concepts in physics. Teachers agreed that participation in a physics-based program (such as CROP) has helped them achieve advanced physics knowledge and increase their confidence in the classroom. One teacher admitted,

> "Physics is not my strong suit. Just giving me more background means when topics come up, I can answer a lot more questions than I could have before." Tim

> "I have a much better understanding of subatomic and quantum mechanics and physics than I did before, and I am not afraid to bring that into my classes where appropriate. Last fall I had an astronomy/cosmology course that I taught for a semester. I had students go to the Zooniverse,[1] and classify galaxies. We looked at images from Sloan and Hubble and wherever else they gather these images from and classify the galaxy as spirals, irregulars, non-spiral, globular, or elliptic. These helped them focus on research and collaborative work, which we learned from CROP." Tim

> "It broadens my horizons on the topic of high energy particles. It has given me awareness. The more you understand a subject, the better you can explain it. It helps your students. We learn some new things, or even just relearn things you already knew or different ways of teaching old things and take a new approach. I think I am a better teacher, and it affects my students." Luis

> "The best thing about CROP is the exposure I get to an advanced level of Physics. It's probably given me the confidence to take on some areas of science that I would not have before, that I would have thought are out of my realm. I am just a high school science teacher. However, I realized that the core concepts apply to any level of physics or science in general and that you can start there and build on that. I am more confident to tackle things. When an experiment does not work, I am not afraid that it failed. Because one of the things I have learned through CROP is that you learn from things that don't work, too." Pato

Beyond the content enrichment they experienced, teachers valued the relationships developed with university professors and CROP staff. They cited the possibility for collaborative research together with their students, and the potential for broadening their horizons with university professors and other teachers.

> "Collaborating with the professors and exposure to other schools has been great. The collaborative aspect has been beneficial to me as a teacher. I am not afraid to ask questions or share what I learned. Moreover, then just the camaraderie, the collaboration with other teachers has been a positive thing." Pato

> "Getting to work with a world-class university and its faculty helps me better see what impact I am making. For someone from a small town of 200 people, it is a big deal to go to Lincoln and to hang out with these folks from other schools. Sharing information and helping each other accomplish objectives is ultimately what make us better for the future." Tim

Every interviewed teacher openly discussed their perceptions toward their school districts' teacher professional development experiences. All agreed that educational training sessions or curriculum days are necessary, especially since professional development courses are required to maintain their teaching certification. However, the majority (70%) expressed a desire for more emphasis on high school physics in all aspects of the curriculum, including content knowledge and real scientific research experience.

> "I think that is the one thing I really wish for professional development, and speaking of curriculum development. I really wish they would not spend so much time on curriculum that is not our curriculum. I really wish that there would be a spotlight

[1] The Zooniverse is the world's largest platform for people-powered research. The aim is to study authentic objects of interest gathered by researchers, like images of faraway galaxies, historical records, diaries and videos. https://www.zooniverse.org/.

where if you are teaching physics you have to go and do something physics related. I really wish that more physics teachers would be doing CROP or doing something more in this field and so active research." Simon

"When we meet on conferences I expect to get the knowledge in my field and learn how to implement it. For physics teachers, this is seldom and limited to only a couple hours. It is not engaging. To me, district meetings, workshops, are more like a one day of a recipe kind of thing. The problem I have with this is that I have been in a lot of workshops by the district… some curriculum days I see teachers bring papers to grade. That is not really what should happen. There is a clear lack of engagement; it is obvious that some teachers are not paying attention." Tim

Reflecting on teachers' perceptions of their districts' professional development days, it was evident that they have strong feelings about the idea that these curriculum days should be more often based, exclusively, on their needs as physics teachers and their physics curriculum. They felt they should concentrate on specific topics of physics content every time. They also noted a lack of collaboration among physics teachers during these curriculum days. In the end, what they would like is to be able to make the most of these opportunities and the time they dedicate. They want their students' learning needs met, and to be able to address any difficulties students may have with the subject matter or feel confident responding to their questions that are beyond the scope of their textbook. These feelings speak to the fact that teachers see themselves as guides and mentors responsible for enhancing their students' knowledge. The bottm line, based on the information gathered, teachers want to be ready to help their students, connect with their fellow teachers, serve as a resource to their school, and establish educational partnerships to further their own experiences as well as their students.

Theme 4: Becoming bilingual in Physics

Emergent codes contributing to this theme are: *a different language, a new culture, broaden horizons, changing the way you view the natural world, CROP.*

This theme emerged from the teachers' views on their participation in CROP as entering a new culture to be learned: a physics culture with a sophisticated scientific language, in a new collaborative scientific environment where meaningful learning occurred only when coherent understanding of concepts being learned was achieved. Learning to be bilingual in Physics is also a theme that emerged supporting sub-question one (1) related to professional development in terms of professional growth. This theme addresses how teachers' physics learning experiences, in connection with their participation in CROP, is analogous to learning a new language. For instance, teachers feel that since this is an opportunity to do work at a very fundamental level of physics—trying to understand the way cosmic rays are detected, how they're created, and what kind of impact they have on the world around us opens up the door for understanding areas related to cosmic rays of a complex and advanced nature that is somewhat new for most. For example,

Simon explains that when he first joined CROP workshops he felt he was learning a new language. Not being able to understand much of the lecture, he thought…

"The funny thing is I do remember how I felt when I first got the pre-test. I thought: what does all this mean? It was all foreign to me and I felt inefficient, but then—the neat thing: when I got the post-test I felt like I really improved! My knowledge on the cosmic rays subject improved and I understood the language and concepts way better". Simon

"The professors had trouble realizing some of us came from really tiny communities. I am a small town teacher. They're so used to being part of large collaborative thing with so many bright minds together . . . that I didn't always understand the words they were using. And so, they brought it back in a new, simpler way. This happened to me few times in the beginning. Now I've been accused of that myself, so I have to really consciously think, is what I'm saying too far above for my students to understand? Maybe I back it down and then take it back up again. In the end, I think this has helped me teach better where I am". Tim

"What I enjoy the most is learning about the history of the cosmic ray, and how science and technology have progressed. Dr. Claes and Snow are experts at translating this information at all levels". Matt

In the same context, Pato expressed that she now has a stronger level of self confidence. She reflected that at the beginning of her participation in CROP, however, she had trouble understanding most concepts and felt uncertain. She also thought she was entering a new culture. She explained,

"Coming from a rural community, I was not used to this kind of academic exposure. This was a bit new to me. I thought because professors are so used to being in so many scientific conferences among scientific minds they had to be reminded we don't always understand the words they were using. I used to ask a lot of questions. The professors brought it back in a new way—a simpler way, so I could understand what they were saying. It felt I was discovering a new culture". Pato

As a result of discovering this new CROP culture, Pato indicated she learned that even if scientific experiments don't go as planned.

"…You can build on a mistake as much as you can build on something that went right. This is the kind of new approach I have learned from CROP and I applied in my physics classes at school". Pato

Research shows content specific out-of-school experiences have an overall positive and statistically significant effect for self-perceptions, positive social behaviors, and knowledge gain (Kremer et al. 2015). Through the data gathered in this study, it is apparent that participating teachers use CROP to supplement their physics knowledge and curriculum in a variety of ways: to enrich their physics research knowledge, to supplement instruction of physics to their students, and to add a research style to their class experiments. Teachers felt that CROP has not only increased their content knowledge in physics, but also broadened their approach to teaching inquiry skills by boosting their self-concept.

Lastly and upon analysis, the essence of the phenomenon in this study is rooted in the words empowering, opportunity, and choice. Participants see their participation in CROP as an opportunity for enrichment, collaboration, and helping their students; they have remained as CROP participants by choice and appreciate the opportunity because it is empowering and offers expertise. Intertwined into all the presented narratives is an essence of struggle, perhaps inherently tied to the nature of balancing school and teaching responsibilities with CROP participants' responsibilities.

Conclusion and Implication

Physics teaching is a complex and challenging career that requires ongoing learning, in large part due to the difficulty of its content. We have learned how important a teacher's comfort level with subject-matter content is to their confidence in teaching. With minimal preparation of so many school physics teachers, we advocate for professional development that will deepen content knowledge. The hope is to lead teachers from self-identifying as teachers who happen to teach physics to experienced "physicist" educators. Such professional development should have as its ultimate goal cultivating expertise in the nature of science, the process of scientific research, and an understanding of how the physical world works in everyday life. Such professional development should include a focus on content, a reflection on teaching practices, and some real experimental experience, which offers an application of the content and the opportunity to be engaged.

Physics is not easy to teach without adequate subject matter knowledge and being good at physics does not necessarily make one good at teaching it to others. Based on the data gathered, learning physics can be a lot like mastering a second language. We can assume that good physics teachers are not just the most knowledgeable physicists or those with the highest teacher qualifications, but those who find effective ways to engage their students in developing an understanding of the complex and abstract concepts they need to learn. Teaching Physics requires ample understanding of the subject, and knowledge on how to gather, interpret, and communicate scientific data and its applications. It is a balancing act like no other.

Based on our data, the CROP experience helped physics teachers gain both a stronger understanding of the subject matter and an enhanced feeling of confidence through an engaging research experience that offered opportunities for collaboration with other high school physics teachers. The teachers participants left CROP exceptionally motivated, having developed an intrinsic curiosity for science research and application and in most cases, they stated they felt "revitalized" as they recharged their sense of enthusiasm, flexibility and sense of purpose.

It is evident that teachers have far more responsibilities than just teaching. They wear many "hats": instructor, counselor, nurse, mentor, facilitator, and coordinator to name just a few. Most teachers regardless of where they teach will come across diversity: non-English-speaking students, students within the foster care system, first generation, high mobility rates, children at high risk and even latch key students. Many students have learning disabilities, behavior problems, and other diverse learning needs. Teacher preparation and professional development, as essential as it is, can be a challenge for many teachers since they may have additional leadership responsibilities with their schools districts, which limits their schedules.

This study represents just a small sample of the many teachers preparing every year to teach high school physics in classrooms across our nation. Our teacher participants all expressed their common belief that feeling more confident with their subject area helps them achieve a progressive view of self. If the goal is to improve the way physics is learned and taught at the secondary level, we must pay attention to what teachers have to say about their science learning experiences and professional development needs, and develop a comprehensive understanding of their views in order to better provide them with opportunities for active learning, content knowledge, and overall professional advancement.

Finally, further research focusing on the relationship between high school physics teacher advancement and out-of-school science-based programs is needed to narrow the gap between what exists for secondary science education and what should be readily available to empower physics education professionals, including new emerging teachers.

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