Physics teachers' perspectives on factors that affect urban physics participation and accessibility

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The accessibility of secondary physics in U.S. urban school districts is a complex issue. Many schools do not offer a physics option, and for those that do, access is often restricted by various school policies and priorities that do not promote physics participation for all. To analyze this problem in greater depth, I adopted a qualitative phenomenological methodology to explore urban physics teachers' views on school- and district-based conditions that may marginalize traditionally underrepresented students. Teachers from three large urban districts shared concerns and suggestions regarding administrative commitment, student preparedness for physics, reform initiatives and testing mandates, promoting physics enrollments, and implementing high quality instruction. Data from interviews and focus groups provided contextual insights into ways in which physics study may be improved and encouraged for urban youth. Teachers believed expanding access could be facilitated with differentiated levels of physics, incorporating mathematical applications with multiple representations, educating students and counselors on the ramifications of choosing or not choosing elective sciences, well-designed grant-funded initiatives, and flexibility with prerequisites and science course sequencing. Teachers experienced frustration with standardized testing, lack of curricular autonomy, shifting administrative directives, and top-down reforms that did not incorporate their feedback in the decision-making processes. Data from this study revealed that physics teacher networks, often housed at local universities, have been a key resource for establishing supportive professional communities to share best practices that may influence school-based reforms that promote physics participation in urban schools.

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I. INTRODUCTION

This study is based on research that has suggested physics is a necessary component of students' academic preparation for postsecondary science, technology, engineering, and mathematics (STEM) study [1,2]. If access to STEM gateway courses is limited and/or discouraged, it will negatively impact the future of the U.S. scientific enterprise [3,4]. Furthermore, access to physics education has been inequitable. Research has shown that urban high schools have an urgent need to provide consistent opportunities for physics study [5]; a recent study of New York city found that physics was offered in just 45% of the high schools [6,7]. Restricted STEM access is problematic in an increasingly globalized economy, particularly as underrepresented minorities in the U.S. remain an untapped resource in fulfilling the ranks of future scientists and engineers [8,9]. In order to propose feasible solutions for the problem, related factors were identified and explored during conversations with urban physics teachers. Since they were in the field and serving on the front lines, their vantage points provided valuable insights for widening and diversifying the pipeline in physics education. This rationale and the supporting literature guided the discussion points that were addressed in the focus groups and interviews.

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II. MOTIVATION AND PRIOR RESEARCH

A. Participation and interest in secondary physics

Recently, the National Academies reported the concern that "the scientific and technological building blocks critical to our global economic leadership are eroding at a time when many other nations are gathering strength" [3]. This report and its follow-up have increased attention on improving K-12 mathematics and science education and addressing the relatively low number of underrepresented minorities in STEM fields [3,4]. To explore how physics course taking may have contributed to this low number, several reports have found ethnic disparities in physics participation. The National Center for Education Statistics examined trends in a three-course sequence of biology, chemistry, and physics, and reported that 29% of White and 43% of Asian students completed the sequence, while 21% of African-American and 19% of Hispanic students did [10]. The American Institute of Physics (AIP) reported that during the 2008–2009 academic year, 52% of Asian students and 41% of White students enrolled in high school physics, compared to 25% of Black and Hispanic students [5].

Research has suggested several potential variables related to disproportionate participation in physics. Socioeconomic status has been identified as a correlating factor [11]. In wealthier school districts, 47% of high school seniors enrolled in physics in 2008–2009, while in economically disadvantaged schools, 24% enrolled [5]. Socioeconomic differences and cultural capital may have had a significant impact on advanced course taking, since educated parents have been more likely to confront school personnel about academic progress and access to higher level courses [12]. More research is needed to examine additional explanations for low secondary physics participation in predominantly minority urban schools. In a nation where 45% of all school-aged children are racial minorities [13], this issue requires immediate and targeted solutions to expand their career choices and promote their social mobility [14,15].

Though the statistics revealing disparities have been clear, students' reasons for choosing physics, should they have the opportunity, have been linked to several variables. Academic achievement in STEM course work has been shown to be a predictor of underrepresented students' interest [16], particularly their prior success in mathematics [17,18]. Students have also been influenced by their academic experiences in elementary and middle school science [19], which has often been characterized by teacher-centered pedagogical practices [20] and lack of curricular time [21]. High teacher quality has been found to promote STEM interest, and for women and underrepresented minorities, a mentor, teacher, or counselor has frequently been cited as an important influence in their STEM persistence [22,23]. Other research has revealed that students may not have taken physics because they considered the subject too abstract, intellectually rigorous, and lacking in exciting inquiry-based laboratory experiences; a poorly regarded physics teacher was also cited as a negative factor [24]. Many students have needed to recognize how science and engineering are relevant to their future before committing to a degree in a STEM field [25,26]. Family background has been a contributing variable, since students often have made curricular choices that aligned with their family and/or community values, rather than their own inclination [27].

Even if a student expressed interest, he or she may have had within-school barriers that prevented them from choosing physics. The existence of prerequisites has affected access; this could have been in the form of required courses such as chemistry or algebra II, which may have prohibited certain tracks of students from having the opportunity to take physics [28,29]. Eisenkraft has stated that Michael Faraday, one of the greatest experimentalists of the 19th century, might not have succeeded in today's physics classes because his mathematical abilities were considered deficient—which is why he created the field concept to understand magnetism [30]. Another factor related to physics participation has been school counselors' judgments about students' likely career paths, which may have determined what courses they could take [31,32]. Consequently, a student's access to physics can be limited by past opportunities in mathematics and science and their perceived potential for success.

Many stakeholders in physics education have rejected this notion and supported the idea of "physics for all," suggesting that physics should be open to broader participation among secondary students [33,34]. Physics education researchers have reported strategies for implementing research-based curricula so all students could be challenged and experience success in physics classrooms [30,35–39]. Such practical strategies have included the use of multiple representations of physical phenomena [35], modeling materials that sort multiple representations into generalizable models for broader contexts [36], and the use of technological tools such as probeware with handheld sensors [37] and iPod Touch applications [38]. Other strategies have been targeted specifically for urban youth and have focused on themes of agency and empowerment. Basu [39] developed an inquiry-based conceptual physics course for ninth grade students that encouraged active participation as a means for developing intellectual and social identities. Students designed and enacted their own physics lessons to express voice, become more engaged with science, and made progress towards future aspirations. Elmesky and Tobin [40] conducted similar research to access the cultural capital that students brought to the science classroom. Students designed their own science videos and conducted qualitative research with other students and teachers as a means to challenge power differentials. Their findings concurred with Basu in emphasizing the need to give voice and autonomy to urban students so they may develop stronger science identities. In doing so, science became more accessible to traditionally underserved students.

Prior research has explored inequitable participation in secondary physics, students' reasons for choosing elective physics courses, and ways in which the physics curriculum can be made more meaningful. However, research has not explored the views of high school physics teachers on physics accessibility. Their perspectives, which have been shaped by daily interactions with urban students and years of physics teaching experience, revealed key factors that affect physics availability and quality. These insights may inform school- and district-level policy reforms that encourage physics course taking in high needs schools.

B. Research questions

This study addressed teachers' perceptions of the factors influencing physics participation, and their ideas for how accessibility might be improved for urban students. The questions posed were designed to challenge teachers to critique policies and procedures that, in their view, may have influenced physics participation in their districts. The following research questions were examined.

(1) What factors do urban physics teachers believe influence the decision making of high school administrators regarding the extent of their support for physics course work?
(2) How have physics teachers interpreted the influence of specific state- and district-level mandates on participation and the availability of physics and how it is taught in urban schools?
(3) How might physics teachers support participation and improve the quality of physics education in urban schools and/or districts?

III. METHODOLOGY

A. Context and participants

The locations for this study included three urban school districts in the southeast, midwest, and northeast regions of the U.S. Each district had a student population of at least 350 000 and a high school population of at least 100 000. The demographic distribution of the student populations in the respective districts is represented in Table I. The demographics closely aligned with those of the ten largest school districts in the U.S., which educate 37% of all high school students [41]. The National Center for Education Statistics (NCES) has defined a *large city* in an *urbanized area* as a city having a population greater than 250 000 [42]; this is not to say that the cities in this study are representative of all urban areas, rather these cities provide insights into teachers' views of the challenges facing urban districts with significant student populations. The approximate percentage of high schools offerings physics is noted; these data were obtained from informal discussions with school administrators who estimated based on their knowledge of the schools. The disparity in the percentage of high schools offering physics is likely due to different school configurations. Two of the districts had a large number of small schools, while the third had mostly large schools. Research has shown that school size is a significant predictor of physics availability [5,43].

Focus groups were convened in each city with 4–6 high school teachers of physics for a total of 16 subjects in these groups (see the appendix for semistructured interview protocol). An additional three teachers were interviewed individually. The focus groups and interviews were conducted over a period of approximately three years (2009–2012). The range of professional teaching experience for the teachers ranged from 2 to 22 years, and each teacher had a primary certification in physics. For the majority, this meant they had completed an undergraduate degree in physics; a few had engineering backgrounds but had completed the equivalent of a physics major—typically 30 credits of course work. The teachers all taught physics as their primary subject, while a few had one section of mathematics or chemistry as part of their daily schedule.

Participants were recruited through professional networks affiliated with local universities or through teacher education programs. The focus groups and interviews were usually held in the evening at the colleges and universities where the networks were based, though two individual interviews were held in schools. The physics teachers in the focus groups mostly knew each other from participation in the networks, which allowed for candid, fluid discussions about the issues they faced. Although the teachers shared some perspectives on physics education, they came from a variety of backgrounds and frequently differed on how they believed urban physics education might best be improved. Common themes were identified to present their views of contributing factors to physics participation and access.

One group of teachers worked in a city where grant funding supported nearly all of the physics instruction, so all of the research subjects in this city worked in grant-funded schools. The high schools that participated in the program (40 out of 120 total schools in the district) could choose among three science curricula with varying thematic elements: (1) learning science content through inquiry, (2) learning inquiry through science content, and (3) science in everyday life. Each of the three curricula included at least one semester of physics, and the grant also provided the necessary resources and laboratory equipment. The teachers initially received coaching to implement the curricula, but this funding ran out midway through the three-year grant period. Two subjects from a second group of teachers worked in a district with grant-supported instructional support for students who had failed

TABLE I. Demographic characteristics of urban school districts.

Characteristic	District 1 (Northeast)	District 2 (Midwest)	District 3 (Southeast)
Ethnicity of student population	13% Asian	4% Asian	6% Asian
	34% Black	45% Black	11% Black
	38% Hispanic	41% Hispanic	73% Hispanic
	15% White	9% White	9% White
Poverty rate of 5–17 year olds	27%	27%	23%
Graduation rate	57%	64%	59%
Approximate percentage of schools offering physics	45%	33%	97%

high-stakes science exams the first time they were taken. These teachers also received science coaching for a limited period of time, which ended as funding was exhausted. Since only two of the research participants from this city worked in grant-funded schools, their experiences were not representative of all participants from their district.

B. Design

The framework for this study was designed to elicit physics teachers' views of various factors that influenced physics participation in urban secondary schools. Data analysis was conducted using a phenomenological approach. Phenomenology describes the meaning of common lived experiences for multiple individuals [44], in this case, their experiences as physics teachers in urban schools. This process has its roots in grounded theory, where key statements from interviews are identified through open coding in an effort to explain as well as describe social phenomena [45]. Axial coding is utilized to identify thematic elements by synthesizing significant ideas that have been stated repeatedly throughout the interview process [46]. This method results in the identification of common themes, or "units of meaning," in qualitative research data [47]. The transcriptions from the interviews and focus groups were analyzed to compile "textural" and "structural" descriptions [44]. The textural descriptions describe *what was experienced*, including examples of the teachers' interactions with students and administrators that, in their view, shaped their views of physics accessibility. The structural descriptions described *how things were experienced* and incorporated the settings and logistical policies of the urban districts; these reflections provided a richer context for understanding the physics teachers' interpretations. A composite description combined the textural and structural to relate what the subjects experienced and how the setting may have influenced their perceptions. The iterative interpretation of participants' statements from these semistructured sessions led to emerging theoretical understandings regarding the issue of physics access.

An important consideration in phenomenological research is the need for the researcher to strive for objectivity when collecting and interpreting data. Personal experiences must be "bracketed," or held in check, so the focus of the study remains on the participants [48]. Bracketing is a dynamic interpretive process. It involves repeated self-reflection on the part of the researcher, identifying and questioning one's assumptions and reexamining them when interpreting qualitative data [49]. For example, after teaching physics in public high schools for seven years and conducting research on physics access in urban schools, I have strong opinions on expanding physics participation among high needs students. Consequently, after reading the transcriptions of the interviews and focus groups, it was essential to analyze contextual details with caution when formulating subjective interpretations. Although some teachers expressed what might be considered a deficit view of students' abilities to take physics, after further reflection it was apparent that these teachers were making relevant claims about the role of remediation in schools with large numbers of traditionally underserved students.

C. Limitations

This study has several limitations. First, most of the participants were part of professional networks affiliated with universities. Consequently, they were more likely to be self-motivated and collegial, seeking professional development on a regular basis. Secondly, they may not have been representative of physics teachers in urban schools, many of whom had their primary certification in other areas of science [43]. NCES has reported that 42% of physics teachers in the U.S. did not major in physics and 57% of physics teachers teach subjects other than physics [50]; another study reported that only 47% of physics teachers have majored or minored in the subject [51]. These numbers are likely exacerbated in urban schools where physics availability is often limited. The subjects in this study had majors or the equivalent in the field and therefore may have had different constraints than teachers with lower levels of preparation. Finally, the viewpoints presented in this paper are those of physics teachers alone; this was done to highlight shared experiences from subjects with similar school roles. Although the perspectives of administrators and guidance counselors were not included, their views would likely present broader explanations for school-based policies related to physics accessibility.

IV. RESULTS

A. Research question 1

What factors do urban physics teachers believe influence the decision making of high school administrators regarding the extent of their support for physics coursework?

The teachers shared their beliefs regarding how physics course work was made available in their schools, and who should be encouraged to take it. Two themes emerged from the data. First, they felt that administrative commitment to physics was a key factor in promoting a vibrant and inclusive physics culture within the school. It was difficult for teachers to build this culture on their own. Secondly, there was much discussion regarding student preparedness; this involved their own views on what skills students needed to be successful in physics, and whether students were being appropriately evaluated for their physics readiness. Since physics is typically an elective science course, students must choose to take it, and even if they do so, there may be institutional barriers to discourage their participation.

1. Administrative commitment

Many teachers commented on the importance of the principal in deciding whether there would be an institutional commitment to physics. As the instructional leader of the school, principals ultimately made decisions on how curricular offerings were structured and prioritized. The background of the principal (i.e., whether the person had a degree in science or worked in STEM-related fields) was frequently cited as a favorable characteristic for physics support. One teacher commented that his principal, a former engineer, set the tone among his staff by stating that he felt physics enrollments should be expanded:

> *I think a lot depends on the principal. We happen to have a principal [who] was a civil engineer before he became a math teacher then principal, and he is very much in favor of physics, so he's pushing it. That really, really helps because for one thing he had a talk with guidance and finally got it through to them that they need to encourage it and they're finally doing that.*

This teacher also mentioned the importance of the guidance counselor in encouraging students to enroll in physics, a common concern. Since students typically met with counselors to plan their schedules and discuss appropriate elective choices, the counselor played an influential role in directing students towards a particular course of study. Another teacher shared this view and was more critical of counselors' tendencies to discourage those whom they believed would not be successful:

> *Some counselors are poisoning kids' minds as far as not taking physics. They have to get these kids graduated, so they don't want any sort of obstacle that's going to bring their GPA down or cause them not to graduate, so that's why they would deter the students from taking any of the hard sciences. They're more likely to take chemistry than physics.*

This teacher felt that too many counselors were fixated on the low-level goal of graduation, without considering how physics might benefit the student. He felt that the "hard sciences" (chemistry and physics) were discouraged because they were tougher courses and the students might get lower GPAs (grade point averages). Counselors frequently assumed important roles in the college application process, so their interest in helping students maintain their averages may have superseded the benefits gained through participation in the physical sciences. Since many underrepresented students claimed that a counselor or mentor influenced their persistence in science and mathematics [23], it is logical that their discouragement could have the opposite effect. Interestingly, the fear of students' failure was a pervasive element throughout many issues related to physics participation.

The final element of administrative commitment involved the costs associated with high quality physics instruction. In one respect, purchasing necessary equipment could solve this issue. One teacher stated, "Well, as far as administration goes, I would say the greatest challenge is getting them to fund the effort to really outfit the physics program the way it needs to be outfitted." This teacher believed physics participation in his school was suffering because he did not have the resources to perform exciting demonstrations and design interesting labs. Research has shown this is an important consideration in attracting students to physics [24]. Another teacher credited her development as a physics teacher to the coaching that was paid for by the administration:

> *Last year I had an instructional coach that they hired at my school. She actually taught physics for multiple years. It was amazing, she gave amazing help. She'd come to my class, look over my lesson plans. I grew last year more in one year than I had at any other point in my life. She was awesome.*

For this teacher, the money allocated towards coaching was essential for her pedagogical growth. This was particularly important for her since she was the only physics teacher in the school. School-level administrators' commitment to physics, whether through their personal advocacy or through the devotion of financial resources, was perceived as critically important in promoting physics participation and improving its quality.

2. Student preparedness

The preparedness of students to be successful in physics was of particular concern to all of the participants in this study. Physics was typically taught in grade 11 or 12 in their schools. It was usually required that potential students have a certain level of mathematical proficiency, such as algebra II, before they could take physics. For the most part, the teachers viewed the math prerequisites as inflexible and unnecessary. One had recommended for years that algebra II be designated a corequisite rather than a prerequisite, though she said the administration disagreed with her suggestion. Another explained that he incorporated small amounts of innovative math instruction when it was a useful tool for understanding the concepts:

> *I just gave my students a microcosm of trigonometry so that they could work with some vectors and that's why I'm where I'm at this year ... vectors were something that was extremely foreign to them and many of them were very intimidated by the idea of a trig function, and I just stopped and I went to the math modeling materials. Once they were comfortable with that, then the train left the station again for vectors and now finally we are into two-dimensional motion.*

He used "modeling materials," which were designed to facilitate the development of quantitative and qualitative models that are consistent with experimental observations [36]. They needed multiple representations of vectors (e.g., graphic, trigonometric) to make sense of this concept [35]. By using this strategy, he demonstrated that mathematics was not a roadblock to physics understanding, and its application and usefulness can be taught more effectively within the everyday context of a physical concept. Other teachers concurred that completing algebra II and trigonometry before physics was not needed to be successful, consistent with recent statements from the physics education community [30,33].

Some teachers questioned the wisdom of placing physics last in the high school science sequence, a common practice in U.S. schools [34]. One commented that physics should really be the first science taught, but she met resistance because of the perception that higher math skills are necessary: "So when I say the pyramid's upside down, physics should be done first, then chemistry, then biology, then Earth/space science, and then everyone says, 'Oh, it's the math. It's the math. They can't do it.'" The lack of confidence in students' mathematical skills was reported to be pervasive among administrators. Though this was a legitimate point for some physics courses, it did not seem as though there was much conversation with administrators about solutions for increased access for those who were not considered mathematically proficient.

The teachers revealed some concerns about student preparation with regard to basic skills and scientific habits of mind. These deficiencies could impact whether their students could reach targeted proficiencies in physics. For example, one teacher described how her students did not have the basic skills to engage in inquiry-based learning:

> *They don't have the reasoning skills and abilities to do science the way I want them to do science, with inquiry, to collect data, to design their own experiments, to make a graph, to analyze the data. They struggle with that.*

She found that it took considerable time to address these issues, which took away from time spent on physics concepts. However, the questions regarding student preparation were not limited to mathematics and science skills. Another shared that some students needed remediation on a more basic level:

> *Some of them, you know, write very badly. Their arithmetic skills are lacking. It's like, at this point those things should have been addressed already. You know, there's only so much I can do, once they're in high school and I'm trying to teach them physics, I can't also teach them their multiplication tables and rules for working with fractions. It's like there's only so much I really can do.*

Although issues related to student preparedness may seem as though they can be managed within the classroom, the lack of basic skills can permeate other classes. Consequently, teachers reported that administrators and counselors may have decided to focus on remediation, or they may have decided that physics was too difficult a class for these students to do well. Some administrators required success in chemistry for students to qualify for physics, not because chemistry is necessary to understand physics, but because students must have strong analytical skills and mathematical proficiency in chemistry. Students who demonstrated these skills were more likely to be successful in physics. Some teachers believed that administrators' commitment to physics may also have been diminished when there was a need to develop skills that would be directly tested with high stakes, as seen when examining the following research question.

B. Research question 2

How have physics teachers interpreted the influence of specific state- and district-level mandates on participation and availability of physics and how it is taught in urban schools?

Repeatedly, the teachers brought up issues related to testing and policy mandates when discussing physics education in their schools. Accountability constraints weighed heavily on their instructional practices. These constraints also influenced the extent to which administrators prioritized physics access. However, for one group of teachers working within a district-wide grant-funded curriculum, there was satisfaction with the available resources. External grant funding guaranteed physics access for all (at least temporarily) and the materials to teach it well. The sustainability of these programs was another issue with which the teachers had to contend.

1. State testing and district mandates

For many teachers, state standardized tests were driving curricular decisions in ways they felt were unwarranted. They lamented the need to cover too many topics without appropriate depth, limited autonomy in selecting topics, and the unintended consequences of accountability measures. One teacher was initially pleased with his school's physics options, where he taught both college-prep physics (mathematically based) and conceptual physics. In his district, there was a standardized test for every science (chemistry, physics, biology, Earth science) and students had to pass one of these exams to graduate. The principal felt that not enough students were passing the physics test, so she decided to phase out physics and place the students in Earth science instead. The physics teacher expressed his frustration with this decision:

> *So, I had a big mix that first semester of my second year because once it became clear that students were*

not going to be passing the physics [standardized test] or that most students were not going to be passing it, so instead I wanted them to take conceptual physics. The principal decided that those students would mostly be better off taking Earth science and trying to pass that [standardized test] than taking a conceptual physics class. So, that was the writing on the wall that there wasn't a place in that testing atmosphere for conceptual physics—for taking physics just for the sake of learning the science and appreciating what it has to offer.

He was quite disappointed that his students would miss out on the wonders of physics, which he believed was an important part of their scientific literacy. His principal so feared student failure that she sacrificed physics for what she perceived to be an easier science class. In the city where he worked, more students were enrolled in Earth science than chemistry and physics combined, suggesting that many administrators were choosing to deemphasize the more difficult physical sciences to improve their standardized test scores in science. This practice disproportionately affected underrepresented students [7]. The teacher left his school after his second year to work in a school with a commitment to physics evidenced by multiple sections and two other full-time physics teachers:

There will be two teachers there currently teaching physics and one has been there for 4 years, and there is a physics teacher who has been there for 15 years. But you know, there is much stronger physics tradition and there, it seems like the best of both worlds because there are these other teachers who can offer support and offer resources. And, you know, introduce me to all the materials that they have but in terms of planning and everything, I can do as much as I want independently.

Other teachers were frustrated with the pacing guides that were mandated by district administrators. These guides outlined the required physics topics and suggested timelines for completion. Some felt that there were too many topics to cover during the academic year, which left students with little conceptual understanding. Some teachers (those who did not have physics standardized tests) disregarded the guides to teach physics in more appropriate ways. One teacher commented:

They kind of presented the physics curriculum at the start of the year and said, "You should follow that." And I looked at it and I'm like, "No, no, I'm not going to spend my day teaching this that really should take a lot longer." I believe more in depth rather than the surface, so I kind of just threw it away. And no one's checked in on me about it.

Some teachers who were tenured and confident in their pedagogical ability were willing to ignore such directives and do what they felt best served their students academically. They believed students would have a richer physics exposure if they deeply understood key principles. This issue was a symptom of the distrust that many teachers felt towards district administrators. There was a general feeling that those in charge did not understand the harmful ramifications of accountability measures, particularly for traditionally underserved students. The teachers believed that their voices should have been part of the discussion when the decisions were made. Accountability was generally viewed in a negative light. It was seen more as a reason to punish schools and teachers rather than a mechanism to improve instruction.

2. Grant-funded resources and curricula

Some of the physics teachers saw positive outcomes from different large-scale grant-funded resources that were at their disposal. The consensus was that most of these programs added value to their teaching and made physics appealing for potential students. Forty high schools in one city received textbooks and equipment to complement an inquiry-based physics and chemistry curriculum (one semester of each). One teacher felt these lab materials made a considerable difference in her students' interest:

So at least now with all this equipment, all these things I have, I can try to make it interesting for them. I can say, "Okay, let's do this lab, let's do this," and it gets them engaged, and they're actually starting, this is the first, maybe second year that they're saying, "This is pretty cool." And so I can kind of see a little bit of a turnaround thanks to Bill Gates and his money and all this [grant-funded] equipment, that I'm hopefully making a little bit of an impact on these kids and the apathy they have.

By making physics inquiry based and exciting, her students' motivation had improved. Physics as a discipline will be more attractive to students if they know they can participate in experiments rather than passively sit in the classroom [37,39]. Another teacher in the same city commented on the new physics curriculum, which provided physics instruction for every sophomore in the 40 participating schools: "I actually have a full program of sophomores, and they take physics for one semester. That's the only program I know of that does that. It's got some real advantages because it aligns with the [standardized test]." In this sense, the grant-funded program increased physics participation and quality for a significant number of children. The teachers liked the program because it required physics, provided the resources to teach it well, and aligned with the standardized test required of the students.

The one reported downside of the grant-funded initiative had to do with professional development. At first, coaches were brought into the district to train the teachers with the new curriculum. However, the funds for this training ran out during the second year of implementation. This was true with grant-funded programs in two of the three districts. Consequently, the teachers were left in an uncertain situation. To complicate matters, the initiative was likely to be abandoned because of a change in district leadership and unimpressive test results. One teacher commented: ''[The grant-funded program] is kind of winding down now, because they got rid of all the coaches. They ran out of money. The chips were down and they had to make cuts. I don't think they've gathered the data that would support a conclusion that it's helping kids.'' Teachers saw this as a disappointment in many respects. The program provided physics for all in the participating schools, yet because scores did not rise fast enough, it would be cut and replaced. They were grateful to have the materials and coaching, but they felt exasperated by the decision to abandon the model based on inconclusive test results. It was difficult to prioritize physics when limited assessments were used to determine its value to the big picture, and a large improvement in test scores was expected within one or two years. Expanding physics accessibility was frequently restricted by political considerations beyond teachers' control.

C. Research question 3

How might physics teachers support participation and improve the quality of physics education in urban schools and/or districts?

Teachers in the study expressed their ideas about promoting physics among their school populations. One common theme was the urgency to bring physics alive through hands-on instruction that emphasized its relevance.

Stressing the relevance and excitement of physics

All teachers felt that the importance of physics must be made explicit to foster interest and increase enrollments. If students know physics is relevant to their lives and career goals, they have been more likely to become engaged [39,40,52]. One teacher described his recruitment strategy: ''I showed them the graduation rate of people who took physics and people who did not take physics, as a pitch towards trying to encourage the students to take physics.'' Another teacher was compelled to reach the same goal by communicating a more altruistic message: ''We owe it to the population to understand that everything around us is physics.'' Both felt it was part of their jobs to communicate how physics could help their students become more

TABLE II. Summary of research findings on urban physics accessibility.

Thematic element	Related issues and proposed solutions	
Will physics be offered? Why or why not?	**Administrative commitment**	**Student preparedness**
	Support from principals to offer physics and expand enrollment	Flexibility with science curricular sequence
	Guidance counselors encouraging physics	Multiple representations and modeling to complement mathematical understanding
	Money for resources and coaching	Flexibility with mathematics prerequisites
	Collaborative effort to promote physics culture	Reconciling need to remediate basic skills with access to physics
	Mentors for underrepresented students to persist in STEM	
How do mandates and reform initiatives influence physics availability?	**Testing and state mandates**	**Grant-funded initiatives**
	Fewer topics, more depth	More curricular resources and professional coaching
	Less reliance on testing dictating whether physics can be an option	Physics for all through curricular uniformity
	More physics teacher agency in decision making	Focus on sustainability efforts for new initiatives
	Improve alignment between physics and standardized tests	Allow more time for initiatives to show results through appropriate measures
How can physics quality and student participation in physics be improved?	**Encouraging physics enrollment**	
	Emphasize relevance, inquiry, hands-on instruction	
	Educate students on the need for physics in certain careers and college entrance	
	Leverage peer influences and teacher quality to promote physics	
	Offer multiple levels of physics for different learners	

informed citizens. A third teacher emphasized the role that peers played in a student's choice of whether to take physics: ''I think historically the number one reason that students choose the courses they do is their friends. [It's the] combination of the personality of the teachers and their friends.'' This fits with the idea of promoting a ''physics culture'' by creating a buzz about the subject; it also helps if the physics teacher has a reputation as interesting and engaging [24].

One way to achieve this interest was to incorporate more hands-on instruction within different levels of physics. One teacher felt all students should take physics, both to prepare them for college and to produce a more educated, scientifically literate citizenry. Another teacher related how his school, which had a strong commitment to physics, had various levels of physics with different instructional approaches. In this sense there was a place in physics for students with different learning styles. He still wanted to propose an engineering-based physics class with a strong inquiry-based focus, as he described:

> *I love laboratories, so I build my class around labs. I kind of sacrifice a little bit of the problem solving to do the actual lab, and they've responded so well, so my recommendation has always been like, okay, you have a regular, you have an honors, you have an AP. Why don't you have an inquiry-type physics class where you just do laboratories with them. Just get your hands on, like kids growing up in the neighborhood, changing gears on their bicycle, tearing things apart, dad's radio, the television .... I hear, I forget. I see, I remember. I do, I understand.*

This teacher maintained his enthusiasm for teaching because of the physics culture in his school and the administrative dedication to physics participation. The support he received in the form of professional autonomy, agency in decision making, and abundant lab resources was essential to his success in recruiting students and providing effective instruction. His predominantly Hispanic school had a remarkably high number of students taking physics, far above the average for underrepresented minorities nationwide.

D. Summary of findings

Table II summarizes the thematic elements of the physics teachers' issues and their proposed solutions for improving physics access and enrollment in urban schools. They shared common challenges in their efforts to strengthen their own instruction and the physics programs in their respective schools. They discussed concerns with school-level administrative commitment to physics, student preparedness in terms of mathematical prerequisites and basic skills, the unintended consequences of reform initiatives and testing mandates, impediments to physics quality, and suggestions for developing their pedagogical skills. Each theme is outlined with teachers' insights for advancing physics participation.

V. DISCUSSION AND IMPLICATIONS FOR POLICY AND PRACTICE

This study examined issues related to physics access and participation for children in urban schools, as seen through the eyes of their teachers and administrators. A variety of issues were unpacked as they reflected upon how they could reach more students. Limited gateway opportunities have impacted diverse participation in the sciences [6]. Since physics is necessary for many majors in postsecondary STEM fields, it is necessary to analyze potential inequities for underrepresented students. Several implications were evident from the data.

First, the ability grouping of students, whether intentional or not, appeared to be a latent variable that contributed to disparate access. Administrators may have felt as though they were doing the right thing in deciding whether or not certain students could handle physics. However, this decision became an equity issue when physics access, a gateway opportunity, was limited. Traditionally underserved students need to be in schools where there is a pervasive belief in their capacity to succeed. Questioning their preparation may have avoided assumed failure; however, school leaders must overcome this hesitation and recognize the value of opportunities for participation in advanced science courses like physics. Expanding access will require creative solutions, such as offering differentiated levels of physics [30], training physics teachers to incorporate mathematical applications with multiple representations [35], educating parents and counselors on the ramifications of choosing or not choosing elective sciences [12], and being flexible with prerequisites and science sequence [34]. These solutions are grounded in research and require committed school-based leadership for successful implementation.

Second, another important outcome from this study is evidence that teachers must be more involved in decision making that affects physics availability, participation, and quality. An approach that engages multiple stakeholders in formulating school-based physics policies would be most effective, yet too often, science teachers have had limited influence in shaping curriculum and policy decisions that affect their students [53]. However, they are typically in the best position to understand the unintended consequences of top-down reforms.

Many participants in this study felt powerless in their efforts to promote physics access for their mostly underrepresented minority students. Those who felt most effective had an active voice in getting the support to provide engaging, rigorous physics instruction, an important dimension of teacher agency. Research has shown that in order for teachers' participation in decision making to be effective, it must be authentic and have a tangible impact on outcomes [54]. Perhaps if teachers were active agents in the decision-making process, they would achieve a compromise that would maintain physics rigor and availability while accurately reporting student progress. The physics teachers in this study demonstrated that they had the skills, competence, and vision to propose viable pathways for physics access. It is essential that school and district leaders value their input when formulating policies that affect participation.

Third, the impact of standardized testing on physics access must be examined more closely. One aspect of the No Child Left Behind Act (NCLB) was the requirement that public schools measure the proficiency of all children in science three times during the span of grades 3–12 [55]. Physics has often been marginalized because it is not typically tested; some general science exams might have a few physics-related questions, though not enough to warrant a full physics course. Other tests may be misaligned with relevant physics content. Too often, such tests drive the curriculum. In states where there is a high-stakes physics exam, fear of student failure may discourage schools from even offering physics. Promoting alternative evaluation measures would be a potential mechanism for measuring the value added from physics study. Although NCLB required the reporting of student achievement data, there was no such requirement for opportunity to learn in particular subject areas such as physics [56]. Perhaps data on course availability should be required when future legislation is drafted, so policy makers have evidence that will inform new initiatives that potentially impact physics access. Also, grant-funded programs, which these teachers believe have tremendous promise, might target urban districts where data have shown that physics education needs improvement. One teacher argued that curricula could be aligned with assessments in productive ways if grant funding supports effective pedagogical practices. These programs need time to strengthen physics teacher quality and to increase student achievement in science.

Finally, the impact of the standardized testing culture was evident in teachers expressing a general lack of curricular autonomy. They were under pressure to guide their students towards higher achievement with constraints such as prescribed pacing guides, limited budgets, and shifting administrative directives. Operating within these constraints was challenging, though not impossible. Physics teachers, largely due to their participation in supportive networks, borrowed ideas from each other to make instruction more meaningful and exciting. They shared strategies for negotiating with administrators over physics-related policies and resources, meeting the objectives of standardized testing while maintaining physics rigor, and developing curricula that addressed the needs of students with varying preparation and postsecondary aspirations. Data from this study suggest that physics teacher networks are a key resource for professional development and school-based reform.

With low rates of physics participation in urban schools and an undesirable accountability culture, it is necessary to look towards teachers for their views on improving physics access. Evidence from this study has shown that their insights are invaluable in promoting a physics culture within their schools. By embracing their belief that all children can learn physics and exploring the feasibility of their suggestions for improvement, physics can be made more accessible for traditionally underserved populations.

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APPENDIX: INTERVIEW PROTOCOL

(1) Please share how your school makes decisions regarding the offering of advanced science courses, particularly physics.
(2) How are students evaluated regarding their suitability for enrollment in these courses? Do you allow all interested students to enroll? Or do you have strict selection criteria?
(3) If selection criteria are in place, who evaluates the students' suitability for success in these courses? Is there an appeal process?
(4) Are mathematics performance and prerequisites viewed as essential for success in advanced science? If so, on what evidence do you base this assumption?
(5) What is the minimum enrollment for these courses? What is the maximum enrollment?
(6) What levels of physics and chemistry does your district typically offer (conceptual, college prep, Advanced Placement, IB)?
(7) How do financial considerations impact course offerings?
(8) How are teachers selected to teach these courses? Is certification in the discipline absolutely required, or is there an exemption for a percentage of instructional time in another discipline?
(9) Please share what types of resources your school has to teach these science courses (textbooks, lab materials, lab space, instructional technology).
(10) What factors do you think most influence whether students choose to enroll in chemistry and physics?
(11) What are your greatest sources of support in your lesson planning?

(12) What physics-specific professional development opportunities have you had over the past two years? Do you seek these on your own? Did your school administration facilitate?
(13) Describe the feedback you have received from administrators after you have been formally or informally observed. Was this feedback helpful to you? What types of feedback do you wish you had available?
(14) What is it like being the only physics teacher in the school (if applicable)? Do you feel elevated status? Neglected?
(15) Do you feel as though you are an effective physics teacher? Why or why not?
(16) Are you satisfied with the work ethic of your students? Their motivation? Attitude? Academic performance? Attendance? Punctuality?
(17) Have you seen gains in your students' appreciation of physics?
(18) Are there ways in which more support from your administration or university program would improve your sense of self-efficacy?
(19) What are the greatest rewards of your job?
(20) What are the greatest challenges of your position?

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