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ORIGINAL ARTICLE

Beyond the Classroom: What do Teachers Know about Teaching Physical Science in the Science Center?

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ABSTRACT

This study pursues a twofold objective: first, to assess Physical Science teachers' knowledge in teaching at science centers, and second, to investigate their perceptions of their roles in facilitating teaching within these centers. Employing a qualitative case study method with interviews and observations, eight teachers voluntarily participated. Content analysis was applied to the collected data. Findings reveal a preference for hands-on approaches and demonstrations, however, highlight some teachers' insufficient understanding of the science center concept. Views on curriculum alignment vary among teachers. In addition, teachers perceive their roles at science centers as non-facilitators, behavior managers, and observers. Implications emphasize the need for targeted professional development to address conceptual gaps and enhance effective integration of science center experiences into the curriculum.

KEYWORDS: Informal learning; Science centers; Physical Sciences; Qualitative case study

INTRODUCTION

Informal learning settings are particularly expected to be employed as a constructive learning environment for teaching science, not as a substitute for traditional classrooms but rather as an extension of school walls with more grounded objectives. The terms "programs and experiences developed outside the classroom by institutions and organizations" (p.17) are often used to describe informal science education, according to the National Science Teacher Association (NSTA) (1998). The informal learning environments that are most well-known are science centers, zoos, and museums (Carvalho, 2021; Eren-Şişman et al., 2020). In these informal settings, visitors can experience through touching and doing (Photo, 2022), learn while having fun (Adams, 2020; Weitze, 2003), comprehend science by connecting it to daily life (Persson, 2000), and understand the relationship between science and technology (Goff et al., 2018; van Dijck, 2003). The informal learning environment focused on in the study was the science center.

Science centers attract diverse visitors, including children, students, adults, families, and teachers, with a prominent emphasis on school groups (Tang and Zhang, 2020). According to the National Research Council report (1996), visits to the science center foster active engagement in science, enhance understanding of the natural world, and encourage the application of scientific principles by visitors. A thorough body of literature extensively explored the comprehensive impact of science centers on various dimensions, particularly the contributions of science centers to enhance scientific literacy and public awareness (Falk and Needham, 2011; Staus et al., 2021); promote comprehensive learning and understanding of science concepts, as emphasized by Falk and Needham (2011) and Aaron Prince and Chiu (2018); and cultivate positive attitudes toward science and encouraging self-efficacy, as evidenced by ECSITE (2008), Falk and Needham (2011), and Ozturk and Başbay (2017), among others. The literature further highlights the role of science centers in enhancing motivation for learning science and fostering engagement in science and technology, supported by studies such as Neresini et al. (2009) and Powell and Colin (2008). In addition, science centers contribute to instilling interest and enjoyment in science (Gumede and Photo, 2024; Oliveira et al., 2021), fostering psychomotor skills, science process skills, and scientific thinking skills (Ozturk and Başbay, 2017; Sassos, 2014), and even influencing career choices in the domain of science (NRC, 2009; Salmi, 2003; Sorge et al., 2019). When teachers have the knowledge and the skill to teach and guide students in these environments, partnerships between science centers and schools have the potential to increase the benefits that have been suggested for these environments. However, there is limited research addressing the integration of science teaching practices within science centers. Therefore, this study sought to address the gap by investigating the knowledge teachers possess regarding the teaching of science in science centers. In addition, it explored the extent to which teachers perceive their roles in facilitating teaching within the science center setting. Through these inquiries, the study aimed to provide a deeper understanding of the dynamics involved in science education within the unique context of science centers.

Conceptual Background

Numerous researchers have directed their attention toward the dynamics of teaching and learning within informal learning environments, particularly in museums (Nygen et al., 2023; Yoon et al., 2013). Furthermore, there exists extensive research on the impact of teaching and learning in museums on science education (Aaron Price and Chiu, 2018; Carvalho, 2021; Cil et al., 2016; Morentin and Guisasola, 2015; Rennie and Johnston, 2018). However, the authors of this study have discovered that research on teachers' views of teaching Physical Sciences in an informal learning environment such as the science center is limited. In addition, few studies focus on teachers' knowledge of teaching Physical Sciences in the science center and how teachers perceive their role in facilitating teaching within the science center.

Informal learning

Informal learning can be characterized as any effort aimed at gaining an understanding, knowledge, or skill, unfolding beyond the structured curricula of educational institutions (Boekaerts and Minnaert, 1999; Lave, 2021; Photo, 2023). In other words, this category encompasses all forms of learning that occur outside the planned instructional frameworks of both formal and non-formal educational institutions and programs (Bereiter and Scardamalia, 2018; National Research Council, 2009). Understanding the distinction between formal and non-formal education is crucial to understand the concept of "informal learning." The term "formal education" refers to the planned, disciplined learning that takes place in an educational setting, usually in accordance with a set curriculum (Meterlerkamp et al., 2020; Rogoff et al., 2016). On the other hand, scheduled educational activities outside of traditional formal settings are referred to as non-formal education (Gerber et al., 2001; Sahrakhiz et al., 2018). Tang and Zhang (2020) described that these activities are often developed to achieve certain learning objectives but lack the formality of an ongoing curriculum. On the contrary, informal learning thrives in the unstructured settings of daily experience. It entails the unplanned pursuit of information, abilities, and comprehension that arises naturally outside of the boundaries of formal and informal educational institutions and is motivated by individual curiosity (So et al., 2018). In this research, emphasis was placed on the science center as a prominent example of informal learning environments where informal learning takes place.

Informal learning environments

The idea that inquiry teaching fosters scientific reasoning skills is extensively documented in educational literature (Kennedy and Odell, 2014; Knezek et al., 2013; Vieira et al., 2011). Kennedy and Odell's influential work in 2014 particularly showed the potential of accelerating cognitive development, specifically reasoning abilities, in high school students through long-term, inquiry-based interventions. Beyond formal inquiry-based learning settings, the establishment of learners' practical knowledge base is possible in improved informal learning environments (Photo, 2024). What is frequently overlooked is that science learning commences long before children enter formal educational settings. The effectiveness of formal science education is significantly influenced by the cognitive framework shaped through prior informal experiences (Rennie and Johnston, 2018). According to this research, when visiting informal learning contexts, teachers who understand what it means to teach in these types of settings should interact with their students as facilitators of knowledge delivery. The findings from Photo (2022) research suggested that teachers ought to provide lessons in informal learning settings and connect them to classroom instruction. In this current study, the informal learning environment setting was the science center.

Teaching in informal learning environments

While various studies have explored the use of teaching science within formal learning settings such as a classroom, little attention has been given to understanding teachers' awareness of teaching science in informal spaces, such as science centers (Darling-Hammond et al., 2020; Eshach, 2007; Gilbertson et al., 2022; Heba et al., 2017; Ramey-Gassert, 1997). Studies in formal teacher education have emphasized the critical significance of teachers' awareness of the ability in shaping their self-perceptions and professional practices within science classrooms (Ennes et al., 2020). Therefore, teachers' knowledge of teaching science, especially in informal settings, significantly impacts decision-making, persistence, and the level of effort invested in each activity.

Significance and Objective of the Study

Science centers are understood to enhance and broaden scientific education in schools, foster scientific literacy, and increase public interest in science (Morentin and Guisasola, 2015). Furthermore, a science center offers teachers an environment for learning where resources of scientific inquiry which are typically unavailable in schools allow for the direct investigation of natural phenomena (Aaron Price and Chiu, 2018; Eren-Şişman et al., 2020). Instead of simply conveying factual knowledge in science centers, teachers who receive training in exploration, discovery, and science process skills may be better equipped to organize field trips that will advance both their owns and their students' comprehension of scientific inquiry (Ceyhan and Köseoğlu, 2019). Research about the professional development of teachers in non-formal contexts reveals that most of them are unaware of the advantages of science centers (Ceyhan and Köseoğlu, 2019; Cox-Petersen et al., 2003). In that perspective, we believe that a heightened focus on research is necessary for physical science teachers to assess their proficiency in navigating informal learning environments. Specifically, the study sought to investigate the questions below:

1. What is the teachers' knowledge of teaching science in the science center?
2. To what extent do teachers perceive their roles in facilitating teaching within the science center?

METHODS

The study employed qualitative case study research to investigate teachers' knowledge of teaching Physical Sciences in an informal learning environment such as a science center.

A case study is a research approach that allows the investigation of a phenomenon within its context using diverse data sources (Maree, 2016). The selection of a case study in this research was appropriate, as it enabled the authors to gain a comprehensive understanding of each teacher's unique situation (Creswell, 2013). In this study, the case was physical science teachers who intended to visit the science center. Since the teachers visiting the science center were being evaluated within the real-life context of the science center itself, the utilization of a case study was considered suitable and, hence, employed in this research study.

Participants

The study used a purposive sampling strategy to identify and recruit eight willing participants who had expressed their intention to visit a science center. Purposeful sampling is a strategic approach for selecting individuals with profound knowledge in a specific subject (Creswell, 2013). This sampling is commonly used in qualitative research to identify and choose cases that produce rich information (Maree, 2016). In the context of this study, teachers specializing in physical sciences were selected as they could offer valuable insights into teachers' knowledge of teaching science in the science center as recommended by Creswell (2013). The selection process was focused on teachers from eight distinct secondary schools located within the KwaMbonambi educational circuit in South Africa. The different regions of South Africa were considered in this study; however, this specific region was selected because it has a science center and participants were easily accessible to the researchers. In addition, in 2022, KwaMbonambi circuit received a pass rate of 81.7% for Grade 12 students. However, in the domain of physical sciences within the circuit, the pass rate was 71.7%, ranking it as the 11th out of 12 districts. This suggests that there is substantial room for improvement within the KwaZulu Natal province in enhancing performance in physical sciences. According to a diagnostic subject report released by the Department of Basic Education, the examination results for paper 1 in Physical Sciences revealed poor performance, particularly in areas related to the Photo-electric Effect and Static and Current Electricity. Similarly, weaknesses were observed in the responses to questions on chemical equilibrium in paper 2. Research conducted by Eren-Şişman et al. (2020) and Eshach (2007) suggests that a more effective understanding of these topics can be achieved through dedicated educational environments such as science centers visits. Therefore, our research targeted teachers responsible for teaching physical sciences in the Further Education and Training (FET) phase, covering Grades 10–12. All the participants involved in this study possessed a similar educational background, holding a Bachelor of Education degree with a major in physical sciences. Furthermore, each participant had an extensive teaching experience of over 8 years in their respective roles. The scope of this study was communicated to the physical science teachers who intended to visit the science center. They were consequently invited to partake in this research. The researchers conducted interviews before the teachers visited the science center. Interviews with the physical science teachers persisted until a point of data saturation was achieved, as articulated by Maree (2016), signifying that the collected data became consistent, and no new information emerged from the participants (Creswell, 2013). Table 1 below provides an overview of the demographic information of the participants relevant to their teaching subjects.

Instrument and Procedures

In this study, the interviews and observations were conducted for data collection. The interview questions were semi-structured and open-ended. The interviews were audio-taped using a smartphone. During the data collection process, interviews were divided into two phases: An initial individual interview with the teachers before they visited the science center and a follow-up interview after their visits. At the beginning of each interview, participants were encouraged to seek clarification on any aspect of the study. The questions were organized around three key themes: (1) Educational background and teaching experience, (2) teachers' knowledge about teaching science in a science center, and (3) teachers' role. Table 2 illustrates sample questions that were included in the study.

In our research study, all the teachers who took part were subject to observation during their visits to the science center, following their initial pre-interviews. This comprehensive observation lasted for three hours, comprising five distinct sessions: Career guidance, science demonstrations, exploration of exhibits, a lesson on safety at sea, and an experiment. These observations were aimed at monitoring teachers' roles when they are at the science center drawing inspiration from Creswell (2013). We

Table 1: Participants' demographic information

Participants	School	Teaching subject	Grade teaching	Years of teaching the subject
Mrs Rose	School A	Physical sciences and technical sciences	10 and 12	9 years
Mr Eliot	School B	Physical sciences and technical sciences	10 and 11	8 years
Mr Sean	School C	Physical sciences	10 and 12	8 years
Mr Oliphant	School D	Physical sciences	12	10 years
Mr Xolani	School E	Natural sciences, physical sciences, and mathematics	8, 10 and 11	9 years
Miss Noni	School F	Natural sciences and physical sciences	8 and 10	8 years
Mrs Lily	School G	Physical sciences	12	9 years
Mr Mzo	School H	Maths literacy and physical sciences	10 and 11	9 years

Table 2: Examples of semi-structured interview questions

Key themes	Semi-structured interview questions
Educational background and teaching experience	• Please tell us about your educational background, where did you study and for how many years. • Which subjects are you currently teaching?
Teachers' knowledge about teaching science in a science center	• Are you presenting any lessons at the science center? • What are your thoughts on teaching at the science center?
Teacher's perceptions of their role in the science center	• How would you describe your role as a facilitator in the science center? • What specific responsibilities do you associate with your role in facilitating teaching science within the science center? • In what ways do you believe your role in the science center differs from your role in a traditional classroom?

employed an observation template that focused on five key aspects: Behavior, interaction with the environment, social interaction, recording, and conclusion. Under the behavior category, researchers assessed the teacher's actions, focusing on whether the teacher provided guidance to the students, engaged students' attention by linking the content to the classroom, and motivated students through active involvement and praise. In the interaction with the environment aspect, we examined whether the teacher facilitated understanding by drawing on students' prior knowledge to connect what they had learned in school with their current experiences at the science center. In addition, we assessed whether the teacher summarized the information/knowledge gathered at the science center. Within the social interaction aspect, we closely observed whether the teacher actively participated in discussions with groups of students or facilitators. We analyzed the teacher's actions and attitudes toward the science center facilitators, including their willingness to engage with them, as well as their ability to seek clarification or elaboration on demonstrations and exhibits. The recording aspect focused on whether the teacher made notes during the visit and whether they captured photographs of students or the demonstrations. Finally, the conclusion aspect centered on how the teacher wrapped up their visit to the science center.

Data Analysis

In the pursuit of our research objectives, a comprehensive content analysis was employed to examine the study's findings. Verbal and visual data sourced from teacher interviews and observations, following Maree (2016) methodology, were systematically collected. Following Eshach's (2007) approach, data analysis involved the careful examination of information derived from participants, emphasizing the breakdown of data into manageable components. All the interviews were audio-recorded and transcribed verbatim, capturing each spoken word with precision. In addition, structured observations within the science center were conducted and thoroughly analyzed, providing invaluable insights crucial for validating the data analysis process. To investigate teachers' knowledge and their views of teaching science within the science center, we employed inductive reasoning, incorporating coding and category creation. The coding process was derived from the literature review and research questions, and subsequently merged into categories grounded in the study's objectives, following Creswell's (2013) principles. Furthermore, we systematically sought relationships among these categories, applying a methodological framework parallel to prior research. This involved semi-structured interviews and observations to qualitatively understand what teachers know about teaching physical science in the science center, and to know how teachers perceive their roles in facilitating teaching within the science center.

Findings

The collected data in this study were examined concerning two distinct research questions. Therefore, this section presents the findings drawn from the thorough examination of the data.

Findings of the First Research Question Analysis

For the first research question, teachers' knowledge of teaching science in the science center was examined. In line with the analysis of the obtained data, teachers' knowledge of teaching science in the science center were examined under categories of teaching methods, science center concept, curriculum alignment, and science center grade level inclusivity. These categories and the corresponding number of teachers' responses are shown in Table 3 below.

Teaching Methods

The majority of the teachers (n = 7) shared a belief in the existence of distinct teaching methods personalized specifically for implementation within the science center. More specifically, two physical science teachers emphasize the importance of the demonstration method when teachers visit science centers. Meanwhile, the viewpoint of five teachers is consistent with a preference for the hands-on approach, illustrating it as the principal teaching strategy used by teachers in the science center setting. To provide further context, some of these teachers' responses are summarized below.

> *Mr. Sean: "…teaching in the science center is done through the use of graphs, demonstrations, and experiments."*
> *Mr. Oliphant: "As teachers we use experimental or hands-on teaching methods to engage learners more than what you see in classes because of the visual things they see in the science center."*
> *Mr. Eliot: "Most teaching taking place in the science center is lecturing or direct instruction, where the learners are being taught by the science center facilitators."*

Science Center Concept

The collected data further showed that even though teachers could state the types of methods one should use when teaching in the science center, their understanding of the concept "science center" appeared to be inadequate in some teachers (n = 1) and adequate in others (n = 7). For example, there were

Table 3: Teachers' knowledge of teaching science in the science center

Category	Sub-category	Number of participants
Teaching methods	Demonstrations	2/8
	Hands on	5/8
Science center concept	Adequate knowledge	7/8
	Inadequate knowledge	1/8
Curriculum alignment	Align with school curriculum	6/8
	Does not align with school curriculum	2/8
Science center grade level inclusivity	All grades	2/8
	Grade 12s	6/8

teachers (n = 7) who understood science center as a facility that equip teachers and learners with science knowledge and has resources to cover practical component of science. Furthermore, these teachers considered the science center as a place for arousing science interest in students. For example, Miss Noni stated that, "…*the science center is a place where there are science-related exhibits, and they teach maths and sciences to students and teachers. After students visit a science center, they become more interested in learning science."* In addition, Both Mr Oliphant and Mr Xolani emphasized in their descriptions how effective the science center functions as a learning environment for teaching physical science topics. They highlighted key areas of focus within this setting, specifying that it provides an ideal platform for the instruction of topics such as mechanics, electromagnetism, and chemical reactions. Their observations emphasize the significance of the science center in facilitating a comprehensive and specialized learning experience for students in these specific branches of physical science. Contrary, Mrs. Lily displayed a limited understanding of how physical science could be effectively taught in a science center. Furthermore, despite her familiarity with the science center environment, Mrs. Lily faced challenges in articulating a thorough understanding of the science center concept. Mrs. Lily's explanation of the science center was characterized as follows.

> *"I can say the science center is the center that provides learners and teachers with the skills to um… or skills to conduct experiments, practicals and also, they help educators and learners to improve the learners' results and curriculum understanding."*

Curriculum Alignment

In addition, the data further revealed that most teachers (n = 6) expressed a belief that teaching in the science center is closely linked to science classroom teaching. They emphasized the interrelated nature of lessons, suggesting that what is covered in the classroom can be visibly demonstrated and experienced by students in the science center. Moreover, these teachers shared a sentiment that the science center serves as a valuable enhancement to classroom teaching. According to them, concepts previously taught in the classroom are improved and solidified through practical applications in the science center, prompting a positive response from students who recognize and appreciate the real-world relevance of their classroom learning. Furthermore, there was an agreement among some teachers (n = 3) that science center teaching actively supports and complements lessons in the classroom. They illustrated this integration by describing instances where theoretical concepts, such as chemical reactions, taught in the classroom are reinforced through hands-on demonstrations in the science center. Therefore, these data demonstrated a collective understanding of most teachers (n = 6) that teaching in the science center is not only connected to classroom curriculum but enriches and reinforces the broader curriculum covered in the classroom. Some of these teachers' responses were as follows.

> *"I think that the science center's lessons and teaching in the classroom are related. because what we say in the classroom can be seen by the students." (Mrs Rose)*
> *"Everything we have already taught in the classroom is improved by the science center. Our students can see that at the science center and say wow, this is what my teacher was saying." (Mr Xolani)*
> *"Yes, science center teaching supports lessons in the classroom. For instance, I may teach students about chemical reactions and demonstrate to them at the science center." (Mr Mzo)*

However, it is worth noting that not all teachers held the perspective that teaching in the science center links to classroom curriculum. There were teachers (n = 2) who viewed science center teaching as having a more indirect impact. They suggested that while the science center may not align perfectly with the academic curriculum, its primary role is to spark interest and guide students toward potential career choices. This viewpoint acknowledges the importance of the science center in offering tangible experiences that may not strictly mirror classroom content but contribute to shaping students' interests and career paths. One of the teacher's responses was as follows.

> *"No, but it's just to arouse interest because there are things that they see physically when they are at the science center because what is offered by the center is not correct or 100% in line with the curriculum in class or back at school, but it can direct them in terms of the career choices." (Mr Oliphant)*

Science Center Grade Level Inclusivity

In our investigation into teachers' perspectives on science education within the science center, we examined their beliefs regarding the most suitable grades for science center visits. Notably, a diversity of opinions emerged among teachers regarding the grade levels deemed appropriate for science learning and teaching experiences in this setting. Specifically, a majority of the surveyed teachers (n = 6) expressed the viewpoint that the science center should cater exclusively to Grade 12 learners. Their rationale centered on the idea that, at this critical stage, learners are on the verge of transitioning from secondary education to university, compelling well-informed decisions about their academic paths. These teachers contended that the science center provides a unique opportunity for Grade 12 learners to deliberate and make informed choices regarding their future careers. The following excerpts show some teachers' responses.

> *Mr Mzo: "Mostly it's the Grade 12 I take to the science center because they are about to exit High School… So, I need them to see for the career guidance part, so the exhibition is key to them for visual learning, so they know what is happening outside the world and can choose careers wisely."*
> *Mr Eliot:* "*We typically take learners who are in Grade 12. Since they are going to graduate from school, I think they are the most appropriate.*"
> Mrs Rose: "*The facilitators at the science center mainly teach about the various science-related careers. The learners from Grade 12 should always go there. At my school we always prefer to take the higher grades."*

In contrast, a minority of teachers (n = 2) held the viewpoint that the science center should be accessible to learners across all grades, including the lower ones. According to this perspective, they argued that since science is a subject undertaken by learners in every grade, the science center should be open to all when teaching science. Notably, Mr. Sean advocates for a more inclusive approach, asserting that learners from every grade should have the opportunity to visit the science center, emphasizing the diverse educational benefits it offers. Mr Sean clarified his stance by specifying, "*this year it will be Grade 9 and Grade 12,*" aligning with his current role as a teacher for both Grade 9 and Grade 12 students. Similarly, Miss Noni maintains the belief that the primary focus of science education in a science center should be extended to encompass all learners in all grades, including lower levels. She articulated this perspective with the following statement:

> *Miss. Noni: "I believe from learners doing grade 4 to Grade 12 because natural science and technology begin in grade 4 and natural sciences and technology has theory and practical components."*

Findings of the Second Research Question Analysis

Our next investigation in this study revolved around understanding how teachers perceive their roles in facilitating teaching within the science center, as outlined in our second research question. Through a thorough examination of the collected data, we identified distinct categories representing teachers' self-perceived roles. These categories encompass those who do not view themselves as facilitators, those managing learners' behaviors, acting as guides, and those adopting an observational role. This discussion, grounded in empirical evidence, examines the degrees of these roles, offering understandings into teachers' diverse perspectives on their responsibilities in the science center.

Not as Facilitators

The obtained data indicate a common perception among all participating teachers (n = 8) that their roles within the science center did not align with the facilitator standard. In every observed instance at the science center, teachers consistently refrained from assuming the role of facilitators for their learners. This was notably evident as teachers abandoned their responsibilities to the science center facilitators, abstaining from active participation in the presented lessons. Their passive approach extended to the neglect of encouraging learners to independently engage with exhibits or conduct experiments, tasks that were exclusively delegated to the science center facilitators. A recurrent theme emerged in the observed behaviors, highlighting the teachers' inability to adapt to the visit and capture teachable moments. Across the five distinct sessions attended by teachers and learners, a visible absence of encouragement for learners to explore and interconnect different exhibits was noted. Furthermore, there was a clear absence of any substantial discussion initiated by the teachers with their learners during these science center visits. Table 4 summarizes the observed behaviors revealing that teachers do not express the facilitator role during their science center visits:

In certain observed sessions, there were evident instances where teachers (n = 2) had clear opportunities to actively facilitate the teaching, potentially linking it to their classroom instruction. Regrettably, they did not capitalize on these opportunities. An illustrative example can be drawn from Mr. Eliot's sessions, where the science center facilitator tried to involve him in the lesson, but he did not seize the opportunity. The observed conversation unfolded as follows:

> Science center facilitator: [Presenting a lesson on safety at sea]. "*…so, this is how such content aligns with real-world scenarios. Mr Eliot, your insights are valuable. Would you like to perhaps add how these scenarios may relate to your classroom*?'
> *Mr. Eliot:* [Absorbed in his phone]. "*No, the learners already know that topic. Right?*" [Addressing the learners].

Despite the explicit invitation to contribute to the lesson and relate it to his classroom context, Mr. Eliot's engagement was limited, focusing on his phone rather than actively participating

Table 4: Teachers observed behavior at the science center

Behavior	Number of participants
Teachers did not interact with their learners during sessions	7/8
Teachers were seated at the back, busy with their phones	7/8
No interaction with science center facilitators	7/8
Failure to prepare or present a lesson during visits	8/8

in the collaborative discussion. This represents a missed opportunity for him to connect the science center experience with his learners' prior knowledge and potentially enrich the learning experience through real-world applications. In addition to the observational data, perceptions from interviews further confirmed that all participating teachers (n = 8) did not have intentions of conducting formal lessons or any lessons during their visits to the science center. The agreement among them was that they refrained from lesson preparation, as they considered it the sole responsibility of the science center facilitators. Below are some of the teachers' responses.

> *Mr. Mzo: "…I will not be taking up any lessons at the science center."*
> *Mrs. Rose: "We let the science center facilitators teach the learners when we are there. Our job is to let them educate our learners, not to share knowledge as we would in a physical science classroom."*
> *Mr. Sean: "The moment I step into the science center, the facilitators are the ones responsible for teaching our learners. That is their role, and we trust them with it."*

Act as Guides and Managers of Learners' Behavior

The collected data illustrate that the eight participating teachers perceived themselves as behavior managers and guides during their visits to the science center. Observational data captured instances where teachers actively intervened to guide their learners' conduct within the science center environment. Particularly, teachers issued instructions to maintain silence and attentiveness, supplemented by non-verbal cues such as meaningful looks to foster compliance. For instance, Mr. Eliot was observed articulating clear instructions in Zulu: "*Hlala phansi ulalele, angifune ukuzwa umuntu ekhuluma, kungenjalo, ngizokuxosha*" [Sit down and listen, I do not want to hear anyone talking, otherwise, I will throw you out]. In a different context, Mrs Lily and Mr Sean demonstrated their managerial roles by organizing learners into groups for collective exploration of the science center exhibits. Simultaneously, Mrs Rose consistently guided her learners on appropriate behavior, actively reprimanding those who deviated during the facilitators' sessions.

During interviews, the teachers (n = 8) repeated their commitment to improving a conducive learning environment by actively managing learners' behavior and providing guidance throughout their science center engagements. Some noteworthy excerpts from these conversations include the following:

> *Mr. Xolani's perspective: "...my roles will be different because now my role will be managing the learners, as I mentioned that maintaining discipline will be my role in order for all learners to participate, give them all the required materials that we've developed so I have to make sure that all learners pay attention and there will be no distractions…"*
> *Miss. Noni concurred, stating: "…I will be managing learners' behavior because learners become excited in an environment that differs from the classroom and lose focus, guide them into all seminars in the science center, and provide learners with refreshments."*

Act as Observers

Teachers' conduct at the science center reflected their perception of the role as observers (n = 7), evident in the passive engagement displayed during the visits, as depicted in Table 4. The teachers maintained a passive stance, refraining from active participation in presented lessons and avoiding direct engagement with exhibits alongside their learners. Observation data highlighted a tendency among teachers to minimize interaction with learners, often resorting to sitting at the back and being occupied with their phones, revealing an observational rather than participatory approach. Furthermore, the teachers exhibited an unwillingness to engage with science center materials, and they abstained from posing questions to seek clarity or participating actively in the inquiry process, aligning with their more observant role. In addition, insights from interviews provided further confirmation of this observational stance among teachers: Some of these teachers' responses were as follows.

> *Mr. Oliphant: "I will not present any lesson at the science center, but I will be observing the activities and content being presented to ensure that we don't go away or divert from what is required by the curriculum."*
> *Mr. Sean: "The moment I step into the science center, the facilitators are the ones responsible for teaching our learners. That is their role, and we trust them with it."*
> *Mr. Mzo: "…I will not be taking up any lessons at the science center."*

DISCUSSION, CONCLUSIONS, AND IMPLICATIONS

First Research Question

The first research question aimed to examine teachers' knowledge of teaching science in the science center. Teachers' knowledge of teaching science in the science center was examined under the categories: Teaching methods, science center concept, curriculum alignment, and science center grade level inclusivity. It was determined that teachers expressed a range of preferences regarding teaching methods in the science center. While the majority favored hands-on approaches, few teachers highlighted the significance of demonstrations. This diversity underlines the varied pedagogical strategies employed by teachers in science education, aligning with the contemporary emphasis on experiential learning (Aaron Price and Chiu, 2018; Bereiter and Scardamalia, 2018). Even though teachers could express their preference of teaching methods in the science center, the results revealed one teacher who exhibited inadequate understanding of teaching in the science center. This highlights the importance of targeted professional development to ensure a comprehensive grasp of the science center concept among teachers, in line with the broader literature emphasizing the comprehensive role of science centers (Darling-Hammond et al., 2020; Eren-Şişman et al., 2020).

This insufficient understanding among some teachers may stem from limited formal exposure to the pedagogical use of science centers and a lack of training on how to integrate such venues into their teaching practice. Research shows that many teachers are simply unaware of the educational advantages that science centers offer (Eshach, 2007; Gumede, 2023; Gumede and Photo, 2024), which can lead to underutilization of these resources. Consequently, when teachers do not fully grasp the science center concept, they tend to adopt a more passive or hands-off role during visits, as was observed in our study. This finding is echoed by Gumede and Photo (2024), who report that without adequate teacher preparation and understanding, visits to science centers often fail to produce lasting improvements in learners' scientific understanding. In other words, conceptual gaps in teachers' knowledge can translate into missed learning opportunities for students. Photo (2024) likewise found that teachers with an insufficient understanding of how to plan effective informal learning experiences negatively influenced their learners' outcomes. Learners in such cases could not link the experience at the science center with the science curriculum in the classroom, resulting in knowledge gains that were limited and short-term (Gumede and Photo, 2024). These examples illustrate how teachers' conceptual gaps about science centers directly impact teaching effectiveness. Ennes et al. (2020) note that a teacher's knowledge and confidence in informal settings significantly affect their decision-making and level of instructional effort. Therefore, if a teacher lacks a clear concept of the science center as a learning environment, they are less likely to actively engage students or connect exhibit content to curriculum topics. Addressing these conceptual gaps is crucial, doing so would empower teachers to take on a more facilitative role and fully exploit the educational potential of science centers.

In terms of curriculum alignment, most teachers emphasized the connection between science center teaching and classroom curriculum. They viewed the science center as a valuable supplement to formal classroom instruction, reinforcing concepts covered in traditional settings. This aligns with literature advocating for coherence and integration between formal and informal science learning (National Research Council, 2009). However, a minority perspective suggested a more indirect impact, emphasizing the complex role of science centers in shaping students' interests and career choices (Falk and Needham, 2011). For instance, some teachers in our study noted instances of misalignment between certain science center activities and the school curriculum, which hindered their ability to directly reinforce classroom lessons during the visit. Photo (2024) observed that learners often could not link their science center experiences with the science topics that they had learned in class when teachers did not explicitly draw those connections. This gap emphasizes the need for deliberate strategies to bridge informal and formal learning. Teachers and science center staff should collaborate in planning visits and aligning exhibits with curriculum objectives to ensure coherence (Photo, 2022). Teachers can also implement structured pre-visit orientation and post-visit debriefing activities to help students integrate their out-of-classroom experiences with classroom content (Eshach, 2007). Such steps would strengthen curriculum alignment and maximize the educational impact of science center visits.

In addition, teachers held diverse opinions on the most suitable grade levels for science center visits. While a majority of teachers advocated for a focus on Grade 12 learners, citing their imminent transition to higher education, a minority argued for inclusivity across all grades. This discrepancy emphasizes the need for a comprehensive approach, considering the diverse educational benefits that science centers can offer to learners at different academic stages.

The implications of these findings emphasize the importance of recognizing and addressing the varied perspectives and practices among teachers when it comes to science education in the science center. Professional development initiatives should aim to enhance teachers' understanding of the science center concept and promote alignment with formal curricula. Moreover, acknowledging the diversity in preferred teaching methods reinforces the need for flexible and adaptable pedagogical strategies within the science center environment. Therefore, to maximize the potential of science centers as educational resources and to design successful professional development programs, it is imperative to comprehend teachers' perspectives on teaching science in the science center. Within the dynamic setting of the science center, the specific interaction of teaching strategies, conceptual knowledge, curriculum alignment, and grade-level considerations highlights the richness and complexity of science education.

Second Research Question

The second research question sought to investigate how teachers perceive their roles in facilitating teaching within the science center. Understanding teachers' roles within the science center environment is crucial for optimizing the educational potential of such visits. Our analysis of teachers' perceptions and behaviors during science center visits revealed distinct categories: Those who perceive themselves as non-facilitators, those managing learners' behaviors while acting as guides, and those adopting an observational role. All participating teachers (n = 8) consistently perceived their roles within the science center as not aligning with the facilitator standard. The observed behaviors demonstrated a passive approach, with teachers refraining from active participation in lessons and delegating responsibilities to science center facilitators. This lack of engagement included a failure to encourage learners to interact with exhibits, adapt to teachable moments, or initiate substantial discussions during the science center visits. This finding is consistent with literature emphasizing the need for teacher involvement in guiding and facilitating student learning in informal settings (Falk and Needham, 2011; Photo, 2022; Salmi, 2003). Moreover, the missed opportunity for teachers to actively contribute to presented lessons highlights a potential gap in realizing the collaborative and integrative potential of science center's experiences with classroom teaching (Tang and Zhang, 2020; Weitze, 2003). The data indicated that teachers perceived themselves as guides and managers of learners' behavior during science center visits. They actively intervened to guide learners' conduct, issued instructions for attentiveness, and organized them for collective exploration. This managerial role aligns with the literature on the importance of teachers as guides and mentors in informal learning environments (Photo, 2024). Teachers further exhibited an observational role. They maintained a passive stance, refraining from active participation in lessons, and minimizing interaction with learners. This aligns with literature emphasizing the need for teachers to actively engage with exhibits and participate in the learning process to enhance the educational impact of science center visits (Carvalho, 2021).

The findings highlight the need for targeted professional development to enhance teachers' understanding of their roles within the science center. Training programs could focus on fostering a more active and facilitative approach, emphasizing the integration of science center experiences with classroom teaching. Clear communication channels could help teachers understand the potential for aligning science center experiences with classroom content, ensuring a more integrated and impactful learning experience.

RECOMMENDATION

Building on this study's findings, several specific recommendations can be made for the structure and implementation of professional development programs. First, teacher training should be structured as an ongoing, collaborative process rather than a one-off event. For example, a series of workshops spread throughout the academic year, combined with follow-up coaching or peer discussion sessions would allow teachers to gradually build their skills and reflect on their practice in informal environments. Such a sustained model could ensure that teachers have the time to internalize new strategies and receive feedback as they apply them. Second, the content of these programs should directly target the identified conceptual gaps and pedagogical techniques needed for effective science center teaching. Sessions should include an orientation to the science center's exhibits and resources, demonstrations of how to facilitate student engagement with hands-on displays, and guided planning on linking those experiences to specific curriculum objectives. By focusing on concrete strategies for connecting informal activities to classroom topics, the training can improve teachers' confidence and effectiveness in using science centers as extension classrooms (Ennes et al., 2020). For instance, teachers might learn how to design pre-visit activities that prime students on relevant concepts and post-visit assignments that reinforce what was learned, thereby tightly weaving the informal experience into the curriculum.

Finally, effective professional development in this area requires strong support and partnerships. Education authorities, school administrators, and science center staff should collaborate to create opportunities for teachers to practice and refine their skills in real informal learning settings. One recommended approach is to hold joint teacher development workshops at the science centers themselves, where museum educators and experienced teachers can model best practices. Such immersive training could allow teachers to experience the exhibits from a learner's perspective and develop lesson plans on-site, bridging theory and practice. Studies have shown that well-designed, museum-based training programs can significantly improve teaching outcomes, for instance, a science center professional development initiative in the United States led to measurable gains in teachers' instructional practices and their students' science performance (Aaron Price and Chiu, 2018). Drawing on these best practices, local professional development efforts should incorporate elements such as collaborative planning with science center educators, peer mentoring, and reflective sessions to discuss what approaches worked during actual field trips. Policy-level support is also important, as Photo (2024) noted, a lack of coordination among departments of education, schools, and science center staff can impede the success of such programs. Therefore, educational authorities should consider endorsing and funding formal partnerships with science centers as part of teachers' ongoing professional development.

STATEMENTS AND DECLARATIONS

I have no conflicts of interest to disclose.

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