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Science teachers' perspectives and prior practices for science centre visit: strategies development

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Abstract
In ongoing science education, utilising informal learning environments such as science centres has emerged as a crucial strategy to enhance learners' engagement and understanding of complex scientific concepts. However, despite their evident benefits, out-of-school learning environments often fail to produce lasting improvements in learners' understanding of scientific concepts, largely due to inadequate integration with classroom teaching and a lack of strategic planning. This qualitative study, grounded in a moderate constructivist framework, investigates the perspectives of high school science teachers regarding the significant influence and strategic optimization of science centre visits. Through interviews and document analysis, informed by thematic analysis methodology, the study examines teachers' perceptions and their prior practices when visiting the science centre. Teachers articulate a compelling narrative of how science centre visits serve as catalysts for active, experiential learning, and bridging the gap between theoretical knowledge and practical application. Furthermore, the study identifies and describes five strategic imperatives aimed at enhancing the effectiveness of science centre visits in science education. These imperatives encompass pre-visit curriculum integration, differentiated learning activities, teacher-led guided exploration, parental involvement, and continuous evaluation and improvement. Grounded in constructivist principles and contemporary educational theories, these strategies offer an inclusive framework to enrich learners' learning experiences, cultivate their scientific curiosity, and foster a profound and enduring appreciation for the details of science. These findings highlight how crucial it is for teachers to have access to continual professional development opportunities and institutional support to enable them to fully utilise the pedagogical potential of science centre visits in science curricula.

Keywords Science centre visits, Science education, Constructivist pedagogy, Experiential learning, Educational strategies

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Introduction

Visits to science centers offer learners a distinctive and engaging way to interact with various scientific ideas and concepts (DeWitt & Osborne, 2007). Science centres can be defined as places that often include interactive displays, performances, and educational activities suitable for a broad spectrum of age groups and passions (Mujtaba et al., 2018; Photo, 2022). Through investigating these facilities, learners can develop a sense of wonder and curiosity about the world around them in addition to expanding their knowledge of scientific subjects (Photo, 2024). Additionally, visits to a science centre give learners a chance to interact with practical applications of scientific theories and discoveries (Barbosa et al., 2018). By utilising a practical approach, science can be made more approachable and captivating for learners from diverse backgrounds and difficult ideas can be clarified (Thomas et al., 2022). Ultimately, visiting a science centre is a great way to inspire the next generation of scientists, engineers, and innovators and to promote STEM education (Christian et al., 2021; Stevens et al., 2016). By participating in interactive exhibits and engaging in hands-on experiments, learners can gain practical knowledge and skills that can be applied in various fields (DeWitt & Osborne, 2007). Furthermore, visiting science centres fosters critical thinking and problem-solving skills, which are vital for success in a world that is becoming more and more dependent on technology (Suwono et al., 2023). As a result, these educational experiences can spark a lifelong interest in science and technology, leading to a more informed and innovative society (Mujtaba et al., 2018). Fundamentally, science centres serve as invaluable resources for promoting scientific literacy and fostering a passion for learning in individuals of all ages (Simon et al., 2012).

Science teachers play a crucial role in enhancing the visit experience to science centres (Photo, 2024). Their perspectives and prior practices can greatly impact the way learners engage with the exhibits and activities at these facilities (Dunleavy et al., 2009). Through guidance and context, teachers can assist learners in drawing connections between their classroom learning and what they observe at the centre (Levstik & Barton, 2022). Teachers can also help learners understand and value the scientific ideas being presented by facilitating discussions and reflections (Photo, 2022). Their expertise and enthusiasm can inspire learners to ask questions, seek out further information, and continue their exploration of science long after the visit has ended (Suwono et al., 2023). Moreover, their ability to connect classroom learning to real-world applications helps learners see the relevance and importance of the scientific concepts they are studying (Christian et al., 2021). Teachers can create a passion for learning and exploration that goes beyond the confines of the science centre by promoting curiosity and critical thinking (Thomas et al., 2022). In the end, their direction and assistance can foster in learners a lifelong fascination with the sciences and a greater understanding of the world around them.

However, despite the apparent benefits of these out-of-school learning environments, there is growing evidence that such visits do not necessarily lead to long-term improvements in students' understanding of scientific concepts. Research has shown that engaging with exhibits in science centers alone may not be sufficient for learners to develop a deep comprehension of science concepts (Bahufite et al., 2023; Falk & Storksdieck, 2005; Raven & Wenner, 2023; Rennie & McClafferty, 1996). Out-of-school activities, including science center visits, may not always result in sustained educational benefits unless they are carefully integrated with formal classroom learning (Eshach, 2007; Hutmacher et al., 2020). Lee et al. (2020) and Tal (2012) emphasize that the success of these visits often depends on the degree of pre-visit preparation and post-visit reflection, further supporting the need for structured learning materials and teacher guidance.

Given these limitations, it becomes crucial to systematically embed science center visits into the school curriculum to maximize their educational potential. Teachers play a key role in this integration process, as they can provide learners with the necessary context to connect their classroom experiences with the exhibits, they encounter during science center visits (Levstik & Barton, 2022). Previous studies have highlighted the importance of teacher involvement in ensuring the success of such visits (Cigdemoglu & Köseoğlu 2019; Mujtaba et al., 2018). Faria and Chagas (2013) argue that structured learning materials are decisive in successfully embedding these experiences into formal education, reinforcing the notion that teacher preparation and post-visit activities are critical to the effectiveness of these excursions.

Despite the existing literature on the role of teachers in science center visits, there remains a significant gap in understanding the best strategies for maximizing the educational impact of these visits, particularly in the context of science education. This study aims to address this gap by exploring strategies that science teachers can adopt to enhance the learning experience during science center visits. By investigating the following research questions, this study seeks to contribute to a more systematic and impactful approach to science center visits in formal education:

- How do science teachers perceive the importance of science center visits?
- What are the prior practices adopted by science teachers to enhance science center visits?

Theoretical framework

Theoretical frameworks for science centre visits provide a foundation for understanding the impact of different learning strategies on visitor engagement and learning outcomes (Schcolnik et al., 2006). One key framework is constructivism, which emphasises the importance of hands-on, experiential learning in fostering a deeper understanding of scientific concepts (Schcolnik et al., 2006). This study adopts a moderate constructivist framework, which acknowledges the existence of an objective reality but emphasizes that learners construct their understanding through active engagement with their environment. By participating in hands-on activities and inquiry-based tasks, learners engage in a process of knowledge construction, aligning with the principles of constructivism (Bada & Olusegum, 2015).

By actively engaging with exhibits and programs, visitors can construct their knowledge and make meaningful connections between theory and practice (Schcolnik et al., 2006). Additionally, socio-cultural theories highlight the role of social interactions and collaboration in the learning process, suggesting that group activities and discussions can enhance learning outcomes (Bada & Olusegum, 2015). By reviewing and synthesizing existing literature on these theoretical frameworks, we can gain insights into how to design and implement effective learning strategies at science centres. These strategies may include interactive exhibits that promote hands-on experimentation, guided discussions led by knowledgeable staff members, and collaborative projects that encourage learners to work together to solve real-world problems (Ah-Nam & Osman, 2017). By incorporating these elements into science centre programs, teachers can create an immersive and engaging learning environment that fosters curiosity and critical thinking skills. Ultimately, by integrating socio-cultural theories into the design and implementation of science centre activities, we can enhance learners' understanding of scientific concepts and inspire a lifelong appreciation of learning science.

Within this framework, science centre visits offer a unique opportunity for learners to engage in hands-on exploration and inquiry-based learning, aligning with Constructivist principles of active engagement and knowledge construction (Bada & Olusegum, 2015). According to Bada and Olusegun (2015), constructivism suggests that individuals develop their understanding of the world through their experiences. Rather than behaviorist strategies as reviewed by Mustafa (2021), constructivist principles emphasize learning through experience and reflection (Schcolnik et al., 2006). When applied to the context of science centre visits, this theoretical framework implies that learners can enhance their learning by actively participating in hands-on activities and engaging in inquiry-based tasks during their visit (Ah-Nam & Osman, 2017).

Methodology

Research strategy

This research adopted qualitative methods as its primary aim was to explore the teachers' perceptions of the importance of the science centre visits and the prior practices, they adopt to enhance the visits. Furthermore, the study focused on identifying effective strategies for facilitating meaningful learning experiences at the science centre. According to McMillian and Schumacher (2014), a qualitative approach is considered most appropriate for understanding individuals' perspectives within their specific contexts. Utilising a case study design, as suggested by Cresswell (2009) as a research approach for obtaining a comprehensive understanding of a complex subject in its natural environment, aligns with the objective of this study. This design enabled an in-depth analysis of teachers' perceptions of the importance of science centre visits. The best way to describe this study is as interpretive qualitative research. The interpretive approach focuses on comprehending the world through the subjective experiences of participants, utilising methods such as interviews and document analysis (Akar, 2016). However, according to Henning (2004), the interpretive approach suggests that knowledge is constructed not only by investigating phenomena but also by descriptions of people's self-understanding, meanings, reasons, values, beliefs, and intentions.

Participants

The research study was targeted at specific schools, and to make the study's goals clearer, these schools were contacted by phone and invitation letters. One of the conditions for participation was that the high schools needed to be situated in King Cetshwayo district in the KwaZulu-Natal province. This criterion was established following a thorough evaluation of geographical accessibility to a varied spectrum of communities within the district. Additionally, this choice was informed by its congruence with the educational aims of the study and the demographic composition of the targeted population. Moreover, the participating high schools had to include teachers teaching science and whose schools had scheduled visits to a science centre. The focus on science teachers was chosen because science, such as physics and chemistry, often require hands-on, practical learning experiences that can be limited by resource constraints in many schools. Science centre visits provide a unique opportunity for these teachers to enhance their students' understanding of complex scientific concepts through interactive, real-world applications, making this group particularly relevant for exploring the educational value of such visits

(DeWitt & Osborne, 2007). The purposive sampling criteria focused on selecting teachers with experience in teaching science and who were actively involved in the integration of science centre visits into their curriculum. These criteria ensured that participants could provide meaningful insights into the study's objectives.

Eight teachers from eight different schools participated among the King Cetshwayo district's schools that met these requirements. All participants were purposefully selected. According to Cohen and Marrison (2007), purposive sampling is used to gather data from individuals who possess in-depth knowledge regarding a specific issue. While the selective criteria may have reduced the number of participants, it ensured that those involved could offer relevant and focused perspectives on the integration of science centre visits into teaching practice. The limited sample size may lead to wonder if the results can be applied outside of the setting of the chosen schools. Despite this limitation, the qualitative insights gathered from these teachers give the research depth and useful context-specific information (Creswell, 2013). Furthermore, sample sizes in qualitative research are typically small, with the size selection primarily based on the particular goals of the study (Maree, 2017).

Participants demonstrated an interest in the study and willingly agreed to take part, exhibiting a range of teaching backgrounds and experiences. Particularly, all participants were actively engaged in teaching roles within the King Cetshwayo district, focusing primarily on Natural Sciences and Physical Science subjects. Detailed biographical information for each participant is presented in Table 1 and pseudonyms were used for the participants. The table includes details such as the participant's gender, age, affiliated school, teaching experience in years, and the specific grade levels they teach. This diverse cohort comprises both male and female teachers, ranging in age from 28 to 52 years old. Their teaching experience spans from 5 to 18 years, with each participant actively engaged in teaching learners across grades 8 to 12. Such variability in demographics and experience enriches the scope of perspectives brought to the study.

Table 1 Participants' biographical information

Teacher	Gender	Age	School	Teaching Experience	Grade/s Teaching
Mrs Rachel	Female	49	A	14 years	8–12
Mr Edward	Male	36	B	8 years	8–12
Mr Samuel	Male	32	C	6 years	8–12
Mr Oscar	Male	37	D	10 years	8–12
Mr Walter	Male	31	E	8 years	8–12
Miss Nora	Female	31	F	6 years	8–12
Mrs Leah	Female	52	G	18 years	8–12
Mr Mike	Male	28	H	5 years	8–12

Data collection

Data collection for this research occurred in two folds. The first involved semi-structured interviews, wherein the researchers scheduled appointments with selected science teachers and conducted interviews at their respective schools. The comprised documents were collected on the same day of the interviews.

Semi-structured interviews

At the initial stage of data collection, the study used semi-structured interviews to collect data from the science teachers. These interviews were face-to-face, lasting approximately 20 min each. The questions posed were open-ended, enabling teachers to respond based on their perceptions rather than being confined to predetermined options (Cresswell, 2009; Meier, 2018). To comprehensively explore teachers' views on the educational value of science centre visits and their adopted prior practices, the interview schedule was divided into three sections addressing demographic information, perspectives on the value of science centre visits, and their prior practices for such visits. The carefully designed interview schedule aimed to explore teachers' perspectives on the educational value of science centre visits and how these perceptions align with constructivist principles such as active learning; social interaction; authentic contexts and knowledge construction. Throughout the interviews, participants were asked about their planning strategies in alignment with science curriculum objectives and how they integrated visit experiences into their classrooms. While the interviews were relatively short, they were structured to focus on key areas of inquiry, ensuring the depth of responses within the time frame. Data saturation was reached within these interviews, but additional follow-up interviews were an option if the responses had not been sufficient to answer the research questions. For a summary of the questions, refer to Table 2.

Table 2 Sample of questions from the semi-structured interview schedule

Demographics questions	Educational values questions	Adopted practice questions
How long have you been teaching?	What is your thinking regarding the teaching of physical sciences, particularly in a science centre environment?	What do you do before taking learners to the science centre visit?
Which Grade are you currently teaching?	Is the science centre relevant to the classroom curriculum of physical sciences?	What is your goal for visiting the science centre?
	What role does the science centre play in the curriculum of physical sciences?	What are your preparatory prior practices when visiting the science centre with your learners?

Document analysis

At the second and last stage of data collection, document analysis was implemented. Document analysis is a well-reputable research method that has been used for many years in qualitative studies (Morgan, 2022). In this research, documents were obtained from science teachers following interviews conducted at their respective schools. The primary focus of the document analysis revolved around documents detailing teachers' preparations and prior practices for visits to science centres. The examined documents included eight lesson plans related to the visits to the science centre and eight worksheets and all of them were analysed. Analysing these documents aimed to offer perceptions of the prior practices aligned with constructivism and how they are implemented in the context of science centre visits. The selection of mentioned documents for this research was guided by four key factors as outlined by Flick (2018). These factors cantered on authenticity; for instance, the handwritten lesson plans on their daily use template ensured the genuineness of the documents. Credibility merged as another imperative consideration, emphasising the reliability and trustworthiness of the selected documents. Additionally, the documents were assessed for representativeness, aiming to capture a diverse range of perspectives and experiences relevant to the research topic such as identifying the objectives of the visit to the science centre. Lastly, the significance of the documents, in terms of the perceptions they could offer to the study objectives, was carefully assessed. Through this careful selection process, the chosen documents were believed best suited to contribute meaningfully to this research study.

Data analysis

This study employed an inductive thematic analysis approach to identify and examine significant patterns in the dataset (Maree, 2017). The data consisted of interview transcripts and documents, which were thoroughly transcribed. The transcription process was guided by a set of established rules to ensure accuracy and completeness. Specifically, all non-verbal cues such as pauses and emphasis were noted, while maintaining participant anonymity through assigned codes (Maree, 2017). This process followed ethical standards, safeguarding the confidentiality of participants (Cresswell, 2009).

During the coding process, the researchers followed a systematic approach inspired by Braun and Clarke's (2006) method of thematic analysis. Two coders independently analyzed the data, generating initial codes based on recurring patterns and in vivo codes derived directly from participant responses (Glaser & Strauss, 1967). The initial codes were iteratively grouped into larger categories, such as perceptions of educational value and prior teaching practices. This process was collaborative, with both coders working together to refine the categories. The researchers also engaged in regular discussions to ensure that the coding scheme accurately reflected the data.

To ensure intercoder reliability, a subset of transcripts was reviewed by both coders and agreement was calculated. Initially, an agreement rate of 85% was reached, with subsequent discussions resolving discrepancies and refining the coding categories. This process increased the reliability of the coding framework, ensuring consistency across the dataset. The themes were developed inductively, with no pre-determined codes, allowing the data to shape the categories organically. As more transcripts were analyzed, additional codes were created and sorted into conceptual categories such as "Science Centre Educational Value" and "Teacher Adaptation Practices". Subcategories were also developed to capture more nuanced aspects of the data. This approach ensured that the coding was thorough and flexible, allowing for constant comparison across transcripts (Glaser & Strauss, 1967). Finally, the categories and subcategories were transformed into a coding matrix for further analysis, ensuring consistency and accuracy in the interpretation of the data.

Trustworthiness

In line with the principles of qualitative research, this study adhered to rigorous procedures to ensure its trustworthiness. The following steps were taken to address the key criteria: credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985).

Credibility

Credibility, which refers to confidence in the truth of the findings, was ensured through multiple strategies. First, the research methods used in this study were grounded in well-established qualitative approaches, including inductive thematic analysis (Braun & Clarke, 2006). Furthermore, member checking was employed, where participants were asked to review and confirm the accuracy of the transcriptions and the initial themes derived from their interviews (Cresswell, 2009). This approach allowed us to ensure that the participants' voices were accurately captured. Additionally, prolonged engagement with the data and the research context helped deepen our understanding of participants' perspectives, further enhancing the credibility of the findings (Maree, 2017).

To strengthen the credibility of the coding process, we utilized peer debriefing and intercoder reliability checks. Two independent coders participated in the analysis, and after initial coding, discrepancies were resolved through discussions. Intercoder agreement reached 85%, and after subsequent discussions, it increased to 96%, reflecting a robust coding process (Cresswell, 2009). Frequent debriefing sessions among the researchers also ensured the consistency and coherence of the coding framework.

Transferability

To promote transferability, which concerns the applicability of the findings to other contexts, we provided a detailed and thick description of the research setting, the participants, and the procedures used in data collection and analysis (Lincoln & Guba, 1985). Although the sample size was small (eight participants), this study focused on providing rich insights into teachers' experiences rather than generalizing findings to a wider population. The detailed descriptions provided allow readers to judge the potential relevance of the findings to their contexts.

Dependability

To ensure dependability, we kept an audit trail that documented the entire research process, including decisions made during data collection, coding, and analysis. The audit trail includes notes on the iterative process of developing codes and themes, as well as the steps taken to refine the coding framework after intercoder discussions (Lincoln & Guba, 1985; Maree, 2017). Additionally, code-recode strategies were employed, with the same data being coded at different points in time to check for consistency in the application of codes. This iterative process ensures that the findings are dependable and grounded in the data.

Confirmability

Confirmability ensures that the findings are shaped by the participants' responses and not by researcher bias. In this study, reflexive practices were adopted, with the lead researcher maintaining a reflexive journal throughout the data collection and analysis phases. This journal documented thoughts, decisions, and potential biases, which allowed for ongoing reflection on how the researcher's background and assumptions might influence the study (Cresswell, 2009).

Findings

Teachers' perceptions on the importance of science centre visits

Practical engagement and real-world application

Participants in this study pointed out the transformative impact of science centre visits on learners' understanding of scientific concepts, emphasizing the theme of practical engagement and real-world application. Mr Oscar highlighted the importance of hands-on experiences, noting that through the science centre, learners gain a better understanding of scientific phenomena such as chemical reactions and the motion of bodies. He emphasised the role of interactive videos in capturing learners' interest and fostering a deeper appreciation for the subject. Similarly, Mr Edward and Mr Walter contributed to this theme by contrasting the practical aspect of science centre visits with the theoretical approach in school. Mr Edward emphasised that learners benefit from witnessing practical demonstrations and activities at the science centre, as opposed to solely relying on theoretical learning from textbooks. He believed that this hands-on experience allows learners to gain insights into real-world applications of scientific principles, thereby enhancing their comprehension. Furthermore, Mrs Rachel highlighted the significance of laboratory settings in science centre visits, emphasizing the value of providing learners with access to equipment and resources not readily available in their school laboratories. She emphasised that such exposure allows learners to explore a wide range of scientific concepts and become familiar with using specialized equipment, contributing to their practical engagement, and understanding of real-world applications. Some of these teachers' responses were as follows.

> *Mr Oscar: "Through the science centre, learners can gain a better understanding of scientific concepts such as chemical reactions and the motion of bodies. The videos they watch in the centre can help to engage their interest and foster a deeper appreciation for the subject".*
> *Mr Edward: "The benefit is they see things at a practical level, and whereby opposed at school everything is done theoretically, its only books, but when they come to the science centre, they see more practical things rather than theoretical".*
> *Mrs Rachel: "Being in a laboratory setting allows learners to gain valuable insights and explore a wide range of scientific concepts. Additionally, it provides an opportunity for them to become familiar with using equipment that may not be available in our school laboratory".*

Collaborative learning and social interaction

The participants' responses detailed the theme of collaborative learning and social interaction as significant outcomes of science centre visits. For example, Mr Samuel emphasised the strengthening of learner-to-learner relationships, noting that such visits provide opportunities for learners to connect more deeply with their peers and teachers. Miss Nora further contributed to this theme by highlighting the benefits of group work during science centre visits. She observed that learners tend to excel and learn effectively when working collaboratively in groups, indicating the positive impact of peer interaction on learning outcomes. Additionally, Mrs Leah emphasised the inclusive nature of group work during science centre visits, emphasising the importance of allowing learners to work together to ensure that no one is left behind. She believed that promoting collaborative learning experiences during science centre visits creates opportunities for their learners to support each other's learning and enhance their understanding through peer interaction. Evidence of these findings is shown in the following excerpts below:

> *Mr Samuel: "Learner-to-learner relationships get stronger, and they also connect more with their teachers".*
> *Miss Nora: "Other learners learn well when working in groups, so in the science centre exhibits and other lessons are done or performed in groups".*
> *Mrs Leah: "Aaahhh … going to the science centre, we always allow our learners to work together, in that way, no one is left behind since they can work with their friends". (**Used native language, Zulu**). "Lapho besebenza ndawonye, bayafunda komunye nomunye, futhi ayikho indlela ongeke uyiqonde lapho usebenza nofunda naye". (When they work together, they learn from each other, and there is no way you will not understand when working with your classmate).*

Career aspirations and STEM engagement

From the interview data, the participants' replies converge on the theme of career aspirations and STEM engagement as significant outcomes of science centre visits. For instance, Mr Walter highlighted the role of teaching in the science centre to ignite learners' interest in their subjects and future careers. He emphasised the positive impact of science centre visits on learners' enthusiasm toward science-related fields. Similarly, Mr Mike contributed to this theme by emphasising how exposure to real-world applications of science during science centre visits inspires learners to consider pursuing careers in STEM fields. He noted that interactive experiences in science centres provide learners with tangible examples of how scientific principles are applied in various contexts, sparking their interest and motivation to explore STEM disciplines further. Furthermore, Mrs Rachel emphasised the unique learning environment and experiential nature of science centre visits, highlighting the transformative effect it has on learners' perceptions and aspirations. She underlined the value of the adventure of being in a lab and experiencing firsthand the wonders of science, suggesting that such experiences shape learners' career courses and lifelong interests. The following excerpts reveal this:

Table 3 Summary of teachers' perceptions of the importance of science centre visits that are consistent with constructivist principles

Constructivist Principles	Teachers' perceptions
Active learning	Learners are believed to actively construct understanding and interest in subjects and careers through hands-on engagement and exploration within the science centre environment. For instance, Mr Samuel noted how learners receive help and develop an interest in subjects and careers through their interactions within the science centre environment.
Social interaction	Science centres, as noted by participants such as Mr Samuel and Mrs Leah, promote social interaction and collaboration among learners, fostering a sense of community and shared exploration. Exposure to real-world applications of science in these settings motivates learners to explore STEM career paths (e.g. As stated by Mr Mike and Mr Walter).
Authentic Contexts	The authentic context provided by science centre laboratories, according to Mrs Rachel and others, offers learners immersive experiences that mirror real-world scientific practices. Additionally, Mrs Rachel highlighted how the hands-on experience of being in a science centre laboratory contributes to shaping learners' experiences and aspirations.

> *Mr Walter: "Through teaching learners get help and they get interested towards their subjects and careers when they are in the science centre".*
> *Mr Mike: "The exposure of learners to real-world applications of science through interactive experiences in science centres inspired learners to consider pursuing careers in STEM fields in higher institutions".*
> *Mrs Rachel: "Yes, the environment and exposure, the adventure of being in a lab teaches them a lot. To be in a science centre alone, it's an experience on its own".*

Table 3 presents extracts highlighting aspects from the results that display an alignment between teachers' perceptions of the importance of science centre visits with constructivist principles.

Prior practices adopted by teachers for their science centre visits

Uniform Planning procedures

In examining teachers' interviews, the study identified a standardized sequence of steps observed across participating teachers' planning processes. Notably, all teachers acknowledged a common framework encompassing activities such as informing parents about forthcoming visits, coordinating trip funding, completing necessary excursion documentation, and liaising with school management to obtain approvals. Additionally, pre-visit assessments to secure scheduling and communication of educational objectives to science centre facilitators were integral components of this uniform planning approach. Some of the excerpts to show these are shown below.

> *Mr Oscar: "You must organise with the parents, firstly the SMT of the school, you have to report about the excursion you fill out the form, you involve the parents because they have to support financially their children, you organise transport then you have to submit to the circuit manager about your planning".*
> *Mr Edward: "First, you have to brief the learners that they are going to go, then you have to write a letter to the parents, to let them know about the visit. Let the headmaster of the school know and the HODs know of the trip to the science centre. You then have to organise transport that's going to take the kids to the science centre, including the driver, he has to be well-known and well-informed about the location of the science centre".*
> *Miss Nora: "I talk to the parents, and they contribute especially towards food and transport fees because the school is very far from the science centre".*

Integration of objectives in the planning

While some teachers did not plan any objectives for their learners' visits to the science centre, the examination of document data and interviews with other teachers revealed that some had included objectives in their preparation. However, an analysis of these objectives indicated a deficiency in their formulation, particularly a lack of depth in reflecting on learning outcomes and problem-solving skills. The objectives tended to focus more on logistical or general exposure purposes rather than clearly defined educational goals that would enhance inquiry-based learning, reflection, or deeper engagement with scientific concepts. The following excerpts reveal this:

> *Mrs Rachel: "My goal is to build a learner, maybe the learners will understand another person when they are explaining a concept, especially when they demonstrate it practically".*
> *Mr Water: "The goal of visiting the centre is just to give my learners that exposure, since they are about to exit high school, I wish them not to just see things when they get to the university that those things become new to them, at least they must have that little knowledge about them".*
> *Mrs Leah: "The goal is for the learners to learn on knowledge and assessments, a practical task for this year".*
> *Mr Mike: "It is to do the practical part of it… resources are limited in our school; thus, learners don't get to know the practical part of their science subject. That's the reason we take them to the science centre because other resources are not there. In my school, our lab is not well equipped".*

Furthermore, some teachers who planned worksheets and lesson plans to be used in the science centre did not include objectives in their preparations (see Figs. 1 and 2). In some instances, learners were provided with the worksheet to fill out when at the science centre, but no objectives. Examples of some of these extracts are shown below.

However, there was an exception of only one teacher (see Fig. 3) who included an aim in their preparations. An example of this extract is shown below.

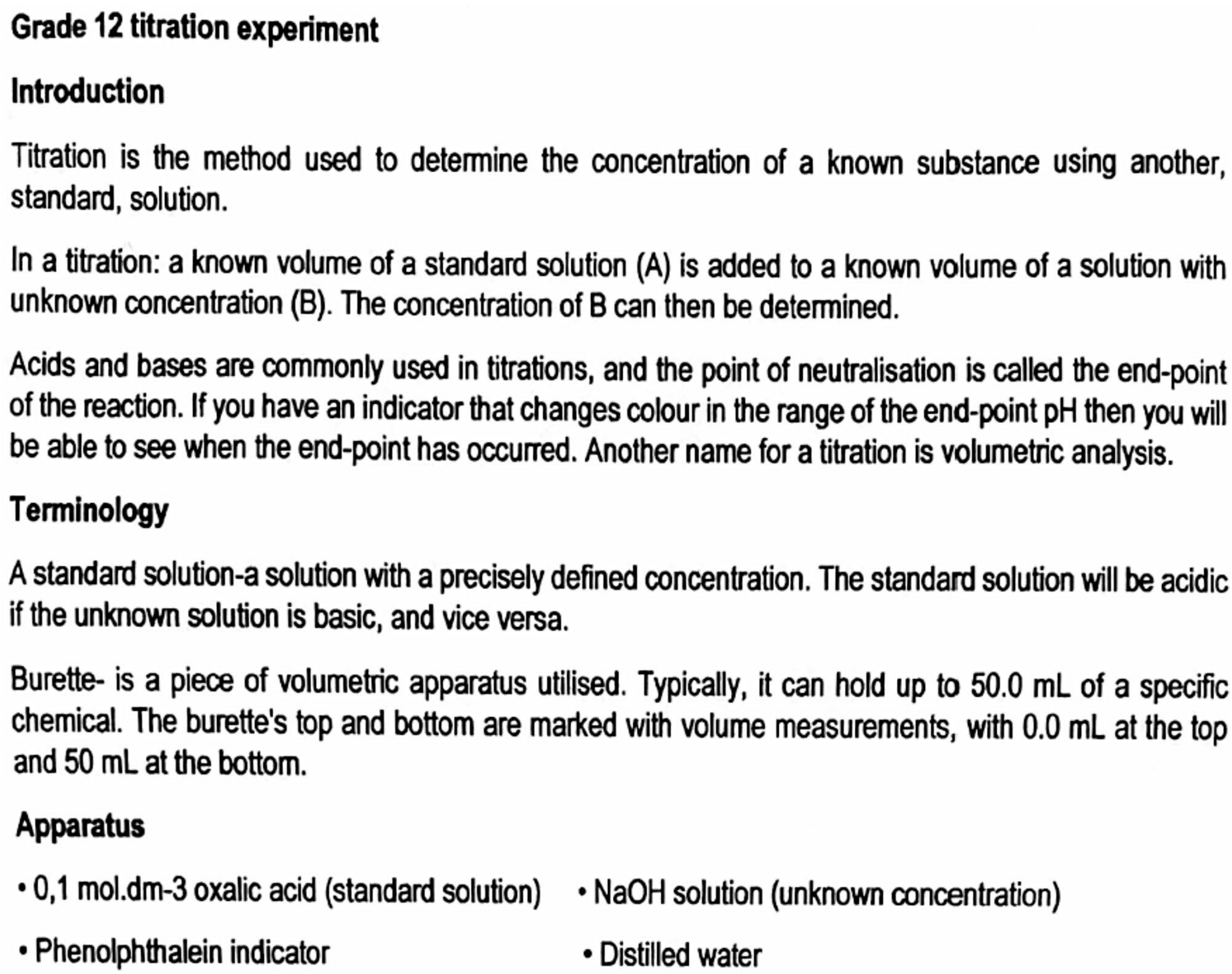
Individualized preparatory approaches

The interview data demonstrated that some teachers' preparatory prior practices were tailored to their instructional contexts and pedagogical preferences. For example, Mr Mike and Mr Samueal emphasised the explanation of learning objectives aligned with curriculum expectations. Mrs Leah highlighted meticulously pre-visit planning informed by the annual teaching plan for the subject. The following reflections attest to this:

> *Mr Mike: "As a teacher who is appointed with a prescribed curriculum, I develop objectives of that visit because I know what I need to achieve because we have something called learning outcomes so in each and every visit that we do I set out the learning outcomes objectives as to what my learners need to know at the end of the visit because they will be exposed particularly if we dealing with stereochemistry so I look at my curriculum to what my learners are expected to know and inform those in the science centre to what I want to achieve with that kind of visit".*
> *Miss Nora: "Before I visit to science centre with learners, I check the annual teaching plan and the topic that I wish my learners to learn at the science centre then I inform science centre teachers about the topic to touch on when teaching".*

Discussion

The exploration of science centre visits within the context of science education is integral to understanding their pedagogical significance and optimizing their potential as educational tools (Roehrig et al., 2021). As such, this study investigated the perceptions of science teachers regarding the importance of science centre visits, the methodologies they employ to enhance these experiences, and the strategies that can be formulated to ensure



Grade 12 titration experiment

Introduction

Titration is the method used to determine the concentration of a known substance using another, standard, solution.

In a titration: a known volume of a standard solution (A) is added to a known volume of a solution with unknown concentration (B). The concentration of B can then be determined.

Acids and bases are commonly used in titrations, and the point of neutralisation is called the end-point of the reaction. If you have an indicator that changes colour in the range of the end-point pH then you will be able to see when the end-point has occurred. Another name for a titration is volumetric analysis.

Terminology

A standard solution-a solution with a precisely defined concentration. The standard solution will be acidic if the unknown solution is basic, and vice versa.

Burette- is a piece of volumetric apparatus utilised. Typically, it can hold up to 50.0 mL of a specific chemical. The burette's top and bottom are marked with volume measurements, with 0.0 mL at the top and 50 mL at the bottom.

Apparatus

- 0,1 mol.dm-3 oxalic acid (standard solution)
- NaOH solution (unknown concentration)
- Phenolphthalein indicator
- Distilled water

Fig. 1 Extract of worksheet with no objective (Mr Mike)

their effectiveness. Science centre visits represent immersive and experiential learning opportunities that have the potential to profoundly impact learners' understanding and engagement with science concepts. By providing hands-on experiences, interactive demonstrations, and real-world applications of scientific principles, these visits offer a dynamic complement to traditional classroom instruction (Coll & Coll, 2018). Understanding how science teachers perceive the value of these visits was paramount in leveraging their potential to enhance learners' learning experiences and foster a deeper appreciation for the subject matter. Moreover, the methodologies employed by teachers to optimize science centre visits play a crucial role in shaping the quality and effectiveness of these experiences.

The study revealed that teachers, as evidenced by their perspectives, perceive these visits as transformative opportunities for learners to immerse themselves in hands-on experiences and interactive demonstrations, thereby deepening their understanding and appreciation of science. These perceptions resonate with existing literature, which points out the paramount importance of practical engagement and real-world relevance in science education (Hofstein et al., 2011; Phillips et al., 2019). Furthermore, teachers highlighted the invaluable contribution of collaborative learning and social interaction facilitated by science centre visits, emphasising the positive impact of peer-to-peer engagement on learning outcomes. By providing opportunities for learners to work together, exchange ideas, and collaborate on projects, science centre visits foster a sense of community and shared exploration, thereby enhancing the overall learning experience (Micari & Pazos, 2021). These findings align with contemporary theories of social constructivism, which posit that learning is a social process that occurs through interaction with others (Vygotsky, 1978). In essence, the perspectives shared by teachers in this study highlight the complex benefits of science centre visits in promoting active, collaborative, and authentic learning experiences for learners. By integrating these insights into

LESSON PLAN FORMAT

TOPIC Chemical Reaction		GRADE: 12	
Term	3	Week	5
Duration	60 Minutes	Weighting	
Sub-topics	Titration		
RELATED CONCEPTS/ TERMS/VOCABULARY	Indicator, Buret Standard Solution		
PRIOR-KNOWLEDGE/ BACKGROUND KNOWLEDGE			
Titration and indications Should be taught to learners so they have Underly iy knowledge needed.			
RESOURCES			
Burret, Erlenmeyer flask, White paper dropper, funnel, Pipette beaker, buret stand and Clamp			

Fig. 2 Extract of a lesson plan with no objective (Mrs Leah)

INSTRUCTIONS:

1. Pay careful attention during the pre-prac talk and take notes so that you are sure what you must do when you carry out the investigation.
2. All work must be done in the spaces provided in these sheets.

AIM: To demonstrate titration accuracy and determination of unknown concentration

Learners to demonstrate an ability to handle apparatus.

Preparation of a standard solution

Apparatus

1. Digital balance
2. Watch glass / filter paper
3. Spatula
4. 250 ml Volumetric flask
5. Dropper

Chemicals

1. Oxalic acid crystals

Method

1. Tare or Zero the digital balance with watch glass on it.
2. With the use of spatula add crystals of oxalic acid

Fig. 3 Extract of worksheet with an objective (Mr Samuel) pedagogical practice, teachers can effectively influence science centre visits to enhance learners' understanding and engagement with science concepts, ultimately fostering a deeper and more lasting appreciation for the subject.

This investigation showed a common thread of uniform planning procedures among the participating teachers, highlighting the paramount importance placed on detailed pre-visit planning and the integration of objectives into the planning process. However, notable variations emerged in the inclusion and emphasis of objectives, with some teachers prioritizing practical tasks while others focused on broader learning goals. Moreover, our analysis revealed the presence of individualised preparatory approaches, wherein teachers tailored their planning practices to align with curriculum expectations and instructional preferences. These findings underline the necessity for standardized planning frameworks that provide a foundation for effective science centre visitation, while also allowing flexibility for teachers to adapt strategies to their specific contexts (Cigdemoglu & Köseoğlu, 2019). Furthermore, our findings align with contemporary literature emphasizing the importance of comprehensive planning processes in educational settings (Wang et al., 2020). By outlining the various approaches employed by teachers in preparing for science centre visits, our study indicated the complex relationship between pedagogical goals, curriculum requirements, and instructional practices. This in-depth understanding emphasises the necessity of continuing professional development programs and provides teachers with the skills and knowledge to successfully plan and carry out science centre visits in an efficient manner.

Authors' conclusions

The primary objective of our study was to formulate preliminary strategies aimed at enhancing the effectiveness of science centre visits for teaching science. Understanding science teachers' perspectives on the importance and their prior practices adopted for their science centre visits played a pivotal role in shaping these strategies. Existing literature has highlighted a significant gap in specific strategies designed to assist science teachers in maximizing the educational potential of science centre visits (Cigdemoglu & Köseoğlu, 2019; Mujtaba et al., 2018; Souza et al., 2023). Despite the proven benefits of such visits in enriching learners' understanding of science concepts, the absence of personalised strategies highlights the need for comprehensive strategies to support teachers in implementing these experiences effectively. The findings of our study, informed by thematic analysis, led to the identification of five key strategies, as detailed in Fig. 4; Table 4. While not all strategies (S1–S5) emerged exclusively from the interview data, they are informed by a combination of teacher perspectives, existing practices, and relevant literature, making them both evidence-based and theoretically grounded.

The strategies identified in this study offer practical guidance for enhancing the effectiveness of science centre visits in science education. Pre-Visit Curriculum Integration (S1) aligns with research emphasising the importance of integrating out-of-classroom experiences with formal curriculum objectives to promote meaningful learning outcomes (Beames et al., 2020). This approach ensures that science centre visits complement classroom instruction, providing learners with opportunities to apply theoretical knowledge in authentic contexts, thereby fostering deeper conceptual understanding and retention of scientific principles. Differentiated Learning Activities (S2) reflect the principles of learner-centred pedagogy and personalized learning, which have been shown to enhance learner engagement and achievement in science education (National Research Council, 2012). By adapting learning activities to cater to diverse learning needs and preferences, teachers create inclusive learning environments where all learners have the opportunity to succeed.

Teacher-Led Guided Exploration (S3) empowers teachers to take an active role in guiding learner exploration during science centre visits, promoting meaningful discussions and critical thinking. This approach aligns with research highlighting the importance of teacher facilitation in promoting deeper learning experiences (Photo, 2022, 2024). Parental Involvement and Support (S4) recognizes the valuable role of parents in supporting their child's learning experiences. Involving parents in the planning and execution of science centre visits foster parental engagement and strengthens the home-school partnership, enhancing the overall impact of such visits on learner-learning outcomes (Epstein, 2013). Continuous evaluation and improvement (S5) ensure the ongoing effectiveness of science centre visits by collecting feedback from stakeholders and identifying areas for enhancement. This data-driven approach allows teachers to refine the planning framework continuously, maximizing the impact of science centre visits on learner-learning outcomes (Cigdemoglu & Köseoğlu, 2019).

Implications and final conclusion

This small study contributes to the field of science education by interpreting the perceptions of science teachers regarding the importance of science centre visits and describing methodologies to enhance their effectiveness. Even though this study is restricted to the individual interviews and documents of each participant, there are not many established strategies for teaching science subjects in informal learning settings such as a science centre. Therefore, it is essential to consider teachers'

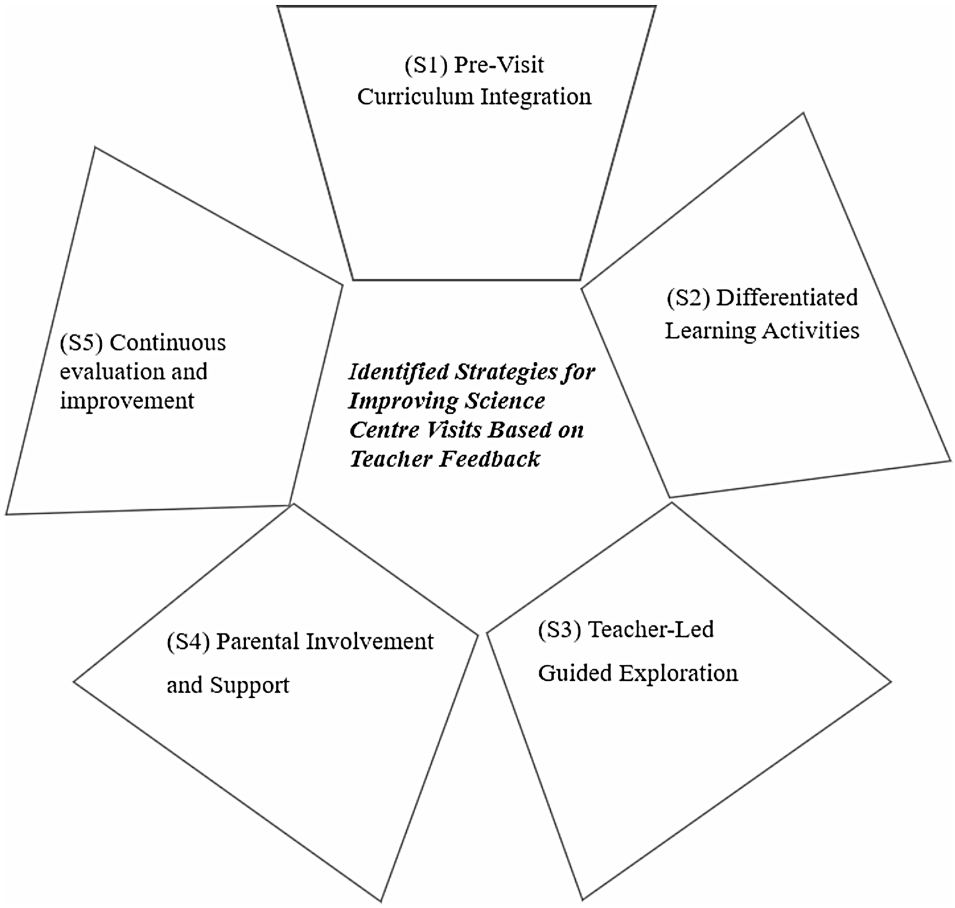


Fig. 4 Identified Strategies (S) for Improving Science Centre Visits

Table 4 Identified strategies for improving Science Centre visits

Strategy (S)	Description
(S1) Pre-Visit Curriculum Integration	Effectively integrate science centre visits into the curriculum, aligning visit objectives with learning outcomes and topics covered in physical science lessons. This has the ability to ensure that the visit complements classroom instruction and reinforces key concepts, enhancing learners' understanding and retention of scientific principles.
(S2) Differentiated Learning Activities	Design learning activities at the science centre that cater to diverse learning needs and preferences. Provide opportunities for hands-on experimentation, interactive demonstrations, and collaborative group work, allowing learners to engage with physical science concepts in ways that resonate with their individual learning styles and abilities.
(S3) Teacher-Led Guided Exploration	Empower teachers to take an active role in guiding learner exploration during science centre visits. Equip teachers with resources and training to facilitate meaningful discussions, pose thought-provoking questions, and scaffold learning experiences, encouraging learners to delve deeper into scientific inquiry and critical thinking.
(S4) Parental Involvement and Support	Foster parental engagement by involving parents in the planning and execution of science centre visits. Provide families with information about the visit objectives, suggested activities, and ways to support their child's learning before, during, and after the visit.
(S5) Continuous evaluation and improvement	Establish a system for evaluating the effectiveness of science centre visits. Collect feedback from teachers, learners, and parents to identify strengths, challenges, and areas for improvement. Use the evaluation findings to refine the planning framework continuously for future visits.

perspectives about these informal learning environments when developing effective teaching strategies for science subjects in these contexts.

One significant finding from the study is the emphasis on tactical strategies such as organizing logistics, contacting parents, and managing student groups primarily aimed at ensuring the smooth execution of the visits. However, the study revealed a gap in strategies specifically designed to enhance learning outcomes, such as pre-departure exercises, group discussions during the visit, and post-visit reflection sessions. These aspects, though less emphasized by teachers, are critical in maximizing the educational value of science centre visits by linking hands-on experiences with classroom-based learning. Pre-visit preparation could involve discussing the goals of the visit and reviewing relevant scientific concepts, while post-visit reflections might include activities such as group debriefing or reflective writing, helping learners consolidate their understanding of the science concepts encountered at the centre.

While this study focused on science teachers in a specific district, its findings hold broader relevance for the science education curriculum. The study emphasises the importance of comprehensive planning and ongoing professional development to optimize the effectiveness of such visits within science curricula which is also highlighted in the literature (Bada & Olusegum, 2015; Mustafa, 2021). However, it must be acknowledged that the strategies developed in this study remain preliminary and should be regarded as hypotheses at this stage. Their actual relevance and effectiveness in ensuring successful science centre visits must be further examined in future studies, including statistical analyses and broader empirical investigations.

In conclusion, through an exploration of teachers' perspectives, it becomes evident that science centre visits represent transformative opportunities for learners to engage in hands-on experiences, interactive demonstrations, and collaborative learning, thereby deepening their understanding and appreciation of science concepts. By integrating perceptions from this study, teachers can strategically influence science centre visits to foster active, collaborative, and authentic learning experiences, ultimately nurturing a deeper and more enduring appreciation for the subject among learners.

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Author contributions
LP was responsible for collecting, analyzing, and interpreting the data. P led the design of the interview questions and the development of the document checklist. Both authors were responsible for contextualizing the paper. They both reviewed and approved the final manuscript.

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Data availability
The interview protocol and data are available upon request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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