Preservice science teacher preparation and scaffolding (PSTPS) model for first experience with outcome-based education in Botswana

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ABSTRACT

Outcome-Based Education (OBE) has evolved as a transformative approach to education that emphasises clearly defined learning outcomes, competency acquisition, and learner-centred learning. Drawing on multidisciplinary literature, the review indicates that Outcome-Based Education enhances student engagement, motivation, critical thinking, and employability by aligning curriculum design, instructional approaches, and assessment practices around clearly articulated learning outcomes. Empirical review points to notable gains in learner achievement, skill development, and the practical application of knowledge. Nevertheless, the review highlights implementation challenges, including faculty resistance, complexities in assessment design, limitations in institutional capacity, and the need for continuous professional development. Curriculum reforms in Botswana have prioritised the effective implementation of Outcome-Based Education (OBE), particularly in science education. However, newly trained teachers often struggle to translate preservice teacher preparation into exemplary instructional methods and performance-based assessments aligned with OBE during their early years of teaching. To address this gap, this study developed and tested a Preservice Science Teacher Preparation and Scaffolding (PSTPS) model that establishes structured collaboration between teacher training institutions and schools. Using a collaborative design-based research approach, the model was developed, implemented, and refined within selected institutions. The PSTPS model emphasises sustained mentorship, joint planning, coaching, and reflective practice to support the transition from preservice training to early-career teaching. Findings from implementation indicate that the model enhanced teacher confidence, improved lesson coherence and OBE alignment, and strengthened the use of inquiry-based and performance-oriented assessment practices. Continuous scaffolding bridged the theory-practice divide and strengthened school-institution partnerships. The study recommends scaling the model, strengthening mentor preparation, integrating digital tools, and testing the PSTPS model across diverse contexts and subject areas.

Keywords: Exemplary Instructional Methods, Outcome-Based Education, Performance-Based Assessments, Preservice Teacher Preparation, Scaffolding

I. INTRODUCTION

In response to increasing demands for critical thinking, problem-solving, and learner autonomy, education systems globally have shifted from traditional teacher-centred instruction toward student-centred pedagogies. Outcome-Based Education (OBE) has emerged as a central framework guiding this transformation. It emphasises clearly articulated learning outcomes, active engagement, and the development of higher-order competencies such as inquiry, reasoning, and collaboration (Spady, 1994). Researchers in different parts of the world have argued that when implemented effectively, OBE supports deeper learning and aligns with contemporary research in science education (Crespo et al., 2010; Gurukkal, 2018; Keo et al., 2025), which advocates for exemplary instructional methods and performance-based assessment practices. Botswana's science education reforms reflect this global shift. Historically characterised by rote learning and examination-oriented instruction, the system has progressively adopted learner-centred approaches grounded in OBE principles. Initial implementation began in the early 2000s within Technical and Vocational Education and Training (TVET) institutions. It was later expanded through the Education and Training Sector Strategic Plan (ETSSP 2015-2020), which mandated the phased implementation of OBE across all levels of education, beginning with senior secondary schools in 2015 (Ministry of Education and Skills Development, 2015). These reforms emphasised competency development, active learning, alignment with 21st-century workforce demands, and were also consistent with recommendations of the Revised National Policy on Education (Republic of Botswana, 1994).

Extensive research in science education provides clear guidance on the instructional practices necessary to support these reform goals. High-quality science teaching is characterised by engagement in meaningful investigations,

the use of real-world contexts to motivate learning (Wellington, 2006), sustained development of core scientific ideas, and the integration of assessment with instruction (Taebi et al., 2025). These features are commonly associated with exemplary instructional methods and performance-based assessments and are supported by a strong empirical base demonstrating their effectiveness for student learning, motivation, and equity. However, the successful enactment of such practices depends not only on curriculum policy but also on teachers' capacity to interpret, adapt, and implement OBE principles in real classroom contexts. Preservice and early-career science teachers play a pivotal role in sustaining reform. Yet their ability to enact learner-centred pedagogy is shaped by the nature and structure of their preparation. Increasingly, research suggests that one-off coursework or short-term teaching practice is insufficient; instead, teachers require sustained, practice-embedded support that bridges university learning and classroom enactment through collaboration, reflection, and iterative refinement of practice (Lederman & Lederman, 2015; Sturges et al., 2024). These insights point to the need for preparation models that are closely connected to school contexts and responsive to teachers' developing practice.

1.1 Statement of the Problem

Despite strong policy commitments to Outcome-Based Education (OBE) and its alignment with science education research, OBE's implementation in Botswana's science classrooms remains uneven and limited (Motlhabanyane & Tsheko, 2023; Tau et al., 2025). This persistent challenge reflects a research-practice gap in which exemplary instructional methods and performance-based assessments are promoted in policy and teacher education discourse but are inconsistently enacted in classroom practice. A central contributor to this gap is the structure of existing preservice science teacher preparation. While preservice programs introduce prospective teachers to OBE principles, inquiry-based instruction, and alternative assessment strategies, Marpa (2022) argues that these elements are often addressed at a theoretical level or within isolated coursework. Limited opportunities exist for preservice teachers to iteratively plan, enact, reflect on, and refine these practices in authentic classroom settings with sustained guidance. Consequently, many preservice teachers complete their training with a conceptual understanding of OBE but lack the practical coherence and confidence needed to implement it effectively. The transition from preservice preparation to early-career teaching further exacerbates this problem. Evidence from Botswana indicates that novice teachers frequently experience discontinuity between university-based learning and school-based expectations, leading them to revert to familiar, teacher-centred practices despite awareness of OBE ideals (Motlhabanyane & Tsheko, 2023). This regression is often linked to the absence of structured mentoring, limited opportunities for collaborative reflection, and weak partnerships between teacher education institutions and schools during the early years of teaching.

Although research underscores the importance of developing specific components of science teacher knowledge, such as pedagogical content knowledge, assessment literacy, and reflective practice, there remains limited guidance on how these components can be systematically integrated and supported over time within preservice teacher education (Luvanga et al., 2025; Tau et al., 2025). There is a lack of models that provide sustained scaffolding across institutional and school contexts and that are responsive to teachers' evolving instructional needs through iterative refinement. This study addresses this gap by developing and evaluating a Preservice Science Teacher Preparation and Scaffolding (PSTPS) model through a collaborative partnership between teacher education institutions and schools. The PSTPS model is explicitly designed to support preservice and early-career science teachers through sustained planning, mentorship, coaching, and reflective practice. By embedding these supports within authentic teaching contexts and refining them through collaborative inquiry, the model aims to enhance teachers' capacity to implement exemplary instructional methods and performance-based assessments aligned with Outcome-Based Education.

1.2 Research Objectives

(i) To develop a structured Preservice Science Teacher Preparation and Scaffolding (PSTPS) model based on empirical findings and established learning theories.
(ii) To test the PSTPS model and evaluate its effectiveness in enhancing collaboration between teacher training institutions and schools and improving preservice science teachers' instructional competence.

II. LITERATURE REVIEW

2.1 Theoretical Review

The development of the Preservice Science Teacher Preparation and Scaffolding (PSTPS) model was anchored in Bandura's (1977) Social Learning Theory, which emphasises learning through observation, modelling, imitation, and social interaction. The theory asserts that individuals acquire new behaviours and competencies not only through direct instruction but also by observing others and internalising their actions, particularly in social and collaborative settings. Central to this theoretical perspective is the concept of self-efficacy, which describes individuals' beliefs about their ability to accomplish tasks. Bandura (2005) proposed four primary sources of self-efficacy: mastery experiences,

vicarious experiences, verbal persuasion, and emotional and physiological states. This theory provides a valuable framework for teacher education to address the gap between preservice science teacher training and classroom practice, particularly in navigating new educational reforms such as the Outcome-Based Education (OBE) curriculum. The transition into OBE in Botswana has left newly trained teachers struggling to translate theoretical training into exemplary classroom instruction and assessment. The Preservice Science Teacher Preparation and Scaffolding (PSTPS) model was developed as a direct response to this challenge, with Bandura's theory shaping both its conceptual foundation and practical design.

The PSTPS model integrates the four sources of self-efficacy to ensure a well-rounded developmental experience for preservice teachers. Mastery experiences are promoted through opportunities for preservice teachers to engage in real teaching tasks during their training, thereby building competence and confidence. Vicarious experiences are supported through structured classroom observations and mentorship, in which preservice teachers observe experienced educators modelling effective science instruction and conducting performance-based assessments. Verbal persuasion is incorporated through feedback and encouragement from mentors, peers, and teacher educators, which, according to Nicol and Macfarlane-Dick (2006), reinforces their belief in their own teaching abilities. Finally, the model addresses emotional and physiological states by providing a supportive environment that reduces anxiety and stress, fostering a positive mindset towards teaching. By grounding the PSTPS model in Social Learning Theory, the study ensures that preservice teacher development is rooted in theoretical knowledge and enhanced by social interaction, modelling, and reflective practice. This approach fosters a stronger transition from coursework in teacher preparation institutions to effective classroom practice, ultimately supporting the implementation of OBE-aligned, exemplary science teaching in Botswana. Thus, Bandura's (1977) Social Learning Theory was not only a theoretical lens but a practical guide in shaping a responsive and sustainable teacher preparation and scaffolding model.

2.2 Empirical Review

2.2.1 Teacher Preparation and Outcome-Based Education

Globally, research on teacher preparation and implementation of student-centred pedagogies has consistently emphasised the importance of structured, practice-embedded support for preservice teachers. Empirical studies from higher education and professional disciplines have also demonstrated the effectiveness of sustained scaffolding and collaboration in promoting inquiry-based teaching and performance-based assessment. Kaliannan and Chandran (2012) employed a one-group pretest-posttest design with 44 students in Malaysia, using two sets of questionnaires, and found that the introduction and implementation of OBE at the faculty and university levels were timely, in accordance with employers' demand for graduates with requisite competencies. Milon et al. (2024) conducted a qualitative study with science teachers-trainers in Bangladesh to investigate their attitudes regarding the implementation of Outcome-Based Education (OBE). They reported that structured coaching improved teachers' use of collaborative and inquiry-based pedagogy, though time constraints and large class sizes limited consistency. Akramy (2021) conducted a qualitative study with ten instructors in Afghanistan, combining lesson observations and interviews, and concluded that OBE enhanced reflective practice and fostered higher-order thinking in learners; however, gaps persisted when institutional support was weak.

In the African context, Bwembya et al. (2024) employed a descriptive survey design and a desk review of literature, policies, and reports in Zambia. They found that awareness of authentijc assessment strategies did not translate into practice due to limited training and inadequate resources. Luvanga et al. (2025) adopted a qualitative study using semi-structured interviews and classroom observations with secondary school chemistry teachers in Tanzania, reporting that teacher-centred strategies persisted despite positive attitudes toward inquiry-based learning. Bainton et al. (2016) argue that sustained guided practice and reflective feedback were key enablers of inquiry-based teaching competence.

In Botswana, Motlhabanyane and Tsheko (2023) used a survey design with 480 teachers across schools in the southeast region, revealing that while conceptual understanding of OBE existed, practical implementation of collaborative, inductive, and experiential teaching was inconsistent. Tau et al. (2025) similarly highlighted limited opportunities for iterative practice and reflection, as well as weak partnerships between teacher-training institutions and schools. Findings from Makwinja (2017) revealed that resource shortages, large class sizes, and pressure to complete syllabi constrained the enactment of contemporary pedagogies. Motlhabanyane and Tsheko (2023) corroborated these findings, emphasising that theory-practice gaps persisted despite positive attitudes toward OBE principles. Collectively, these studies underscore the urgent need for structured, contextually grounded models that provide sustained mentoring, reflective practice, and collaborative engagement to enhance preservice teachers' competence in implementing exemplary instructional methods and performance-based assessments that are aligned with Outcome-Based Education.

2.2.2 Exemplary Instructional Methods

Science education research consistently emphasises instructional approaches grounded in empirical research on how people learn. Such approaches have been variously described as reform-based (Modebelu & Ogbonna, 2014),

inquiry-based (Guerrero & Bautista, 2023; Luvanga et al., 2025), or constructivist teaching (Gautam & Agarwal, 2024). In this study, the term "exemplary instructional methods" is deliberately used to capture a coherent set of instructional principles that closely align with the core tenets of Outcome-Based Education (OBE). First, exemplary instructional methods prioritise the sustained development of a limited number of core scientific ideas and practices over time, rather than superficial coverage of content. This focus directly supports OBE's emphasis on depth of understanding and demonstrable learning outcomes. Second, these methods situate learning within connected explorations of meaningful phenomena and problems, enabling learners to engage with science in context rather than as isolated facts. Third, exemplary instruction fosters a "need to know" by helping learners recognise how new ideas support sense-making around central phenomena, thereby promoting motivation and conceptual coherence. Importantly, exemplary instructional methods position students as active agents in the learning process, responsible for connecting activities, ideas, and evidence (Wei & LeSage-Clements, 2019). This learner-centred orientation is foundational to OBE, which requires students to demonstrate learning through observable performance rather than passive recall. Exemplary instructional methods blend inductive, collaborative, and experiential learning approaches with authentic, formative, and differentiated assessment practices. Together, these approaches support learners in demonstrating intended outcomes while accommodating diverse learning needs (Wellington, 2006). However, while the principles underlying exemplary instructional methods are well established in the literature, their enactment in classroom practice is complex. Implementing such approaches requires careful instructional design, responsive assessment practices, and ongoing reflection. These are capacities that preservice teachers often struggle to develop without sustained guidance and structured scaffolding. This challenge is particularly salient in OBE realities, where misalignment between instructional methods and assessment practices can undermine reform goals.

2.2.3 Inductive Teaching and Learning Methods

Inductive teaching and learning methods are central to exemplary science instruction and closely align with OBE's emphasis on learner engagement and the demonstration of understanding. These approaches shift the focus from direct transmission of knowledge to active sense-making, requiring learners to construct understanding through exploration, investigation, and reasoning. Inquiry-Based Learning (IBL), for example, engages students in authentic scientific practices such as questioning, hypothesising, and evidence-based explanation, thereby supporting the development of outcomes related to scientific literacy and problem-solving (Luvanga et al., 2025). Similarly, Discovery Learning encourages learners to explore concepts and derive principles through experimentation, often supported by digital tools. Project-Based Learning (PBL) further extends inductive learning by immersing students in complex, real-world tasks that promote autonomy, collaboration, and application of knowledge over time (Ketlhoilwe & Silo, 2016). While these approaches align well with OBE principles, research suggests that preservice teachers often struggle to design and manage inductive learning environments effectively (Marpa, 2022; Tau et al., 2025). Challenges include aligning activities with intended outcomes, facilitating productive student inquiry, and assessing learning processes and products. Without explicit modelling, guided practice, and feedback, inductive methods risk being implemented superficially, thereby limiting their potential to support meaningful outcomes. These challenges highlight the need for structured scaffolding within teacher preparation programs to support preservice teachers in enacting inductive pedagogies with fidelity.

2.2.4 Collaborative Learning Methods

Collaborative learning methods play a critical role in exemplary instruction by promoting social interaction, shared sense-making, and collective problem-solving, which are key dimensions of learner-centred education and OBE. Strategies such as the Jigsaw Method, Peer Instruction, and Think-Pair-Share (TPS) have been shown to enhance engagement, deepen understanding, and surface misconceptions through structured peer interaction. From an OBE perspective, collaborative learning supports outcomes related to communication, teamwork, and reasoning, while also providing opportunities for formative assessment through dialogue and peer feedback. However, effective collaborative learning requires careful orchestration, including clear task design, explicit expectations, and responsive facilitation. Research indicates that novice teachers often struggle to manage group dynamics, maintain cognitive focus, and assess individual learning in collaborative contexts (Major & Mulvihill, 2018). These challenges underscore the importance of mentoring and coaching in helping preservice teachers move beyond procedural use of collaborative strategies toward purposeful implementation aligned with intended learning outcomes. Without such scaffolding, collaborative methods may be reduced to surface-level interaction rather than serving as vehicles for deeper learning and assessment.

2.2.5 Experiential Learning Methods

Experiential learning, grounded in the principle of learning through action and reflection (Healey & Jenkins, 2000), is another cornerstone of exemplary science instruction. Approaches such as simulations, problem-based learning, and field trips create opportunities for learners to engage with complex, authentic situations that mirror real-

world scientific practices. Simulations offer risk-free environments in which learners can test ideas, make decisions, and collaborate, supporting outcomes related to systems thinking and applied knowledge (Lim et al., 2011). Problem-Based Learning (PBL) requires students to integrate knowledge across disciplines while collaboratively addressing ill-structured problems (Major & Mulvihill, 2018), thereby aligning closely with OBE's emphasis on transferable skills and performance. Field trips further extend experiential learning by connecting classroom instruction to real-world contexts, enabling learners to observe and engage directly with scientific phenomena. Despite their potential, experiential learning methods are often underutilised or poorly implemented due to logistical constraints, limited planning skills, and uncertainty about assessment. For preservice teachers, these challenges are compounded by limited opportunities to practice experiential approaches under guided conditions (Retallick & Miller, 2010). Structured scaffolding through joint planning, reflective dialogue, and iterative refinement is therefore essential to support meaningful implementation of experiential learning within OBE-aligned science instruction.

2.2.6 Performance-Based Assessments

Performance-based assessment is a core feature of school-based assessment in Outcome-Based Education, requiring learners to demonstrate competencies through authentic, real-world tasks rather than solely through selected-response formats. Nicol and Macfarlane-Dick (2006) conceptualisation of principles of feedback and criteria-referenced assessment supports performance tasks that foreground meaning, application, and complex reasoning. Reports by Sitto-Kaunda et al. (2023) work also intersects with performance assessment through their emphasis on feedback loops that inform instruction and learner self-regulation. In performance assessment, students may engage in science investigations, projects, presentations, portfolios, or contextual problem-solving tasks that provide richer evidence of ability and deeper learning. Taebi et al. (2025) highlight that performance-based assessments are better suited than traditional tests for capturing the full range of intended learning outcomes, especially in domains such as science, where practical skills, investigative reasoning, and collaborative problem-solving are valued. Performance assessments shift the focus from correct responses to demonstration of competence, enabling teachers to observe processes such as planning, inquiry, reflection, and synthesis. Effective performance assessment also requires well-defined criteria and standards, enabling both teachers and learners to understand performance expectations and to engage in quality feedback practices. This aligns with OBE's emphasis on transparency of learning goals and learner responsibility.

2.2.7 The Role of Teacher Education in Promoting Exemplary Instructional Methods

Many years of classroom experience are typically required for teachers to develop the deep, interconnected knowledge and skills that characterise expert teaching. However, teacher education plays a pivotal role in placing novice teachers on a trajectory toward this level of expertise. Expertise in teaching is defined by well-structured knowledge systems in which ideas are connected around a few central concepts (Marpa, 2022), as well as adaptive expertise that allows teachers to respond effectively to novel and complex classroom situations. The recent implementation of Outcome-Based Education (OBE) curriculum in Botswana has increased the demand for exemplary instruction and performance-based assessments. Such instruction focuses on the progressive development of core disciplinary ideas, contextual learning through meaningful phenomena, and student-led engagement in constructing scientific understanding (Suduc et al., 2015; Wei & LeSage-Clements, 2019). To support this kind of instruction, teachers need more than a strong grasp of science content; they require a unique blend of pedagogical knowledge that allows them to translate curriculum expectations into effective classroom practices. This specialised knowledge is often referred to as pedagogical content knowledge (PCK). Pedagogical content knowledge encompasses understanding how students learn specific concepts, which representations and instructional approaches are most appropriate, and how to sequence instruction to support long-term understanding. Research has shown that PCK plays a significant role in enabling teachers to plan and deliver meaningful and outcome-aligned instruction (Darling-Hammond et al., 2005). Effective teaching also depends on teachers' affective and motivational dispositions, such as their beliefs, values, and situational judgment (Tikly, 2010). These factors influence not only how teachers interpret curriculum goals, but also how they respond to classroom challenges, engage with students, and reflect on their teaching. Teachers' beliefs and goals serve as amplifiers or filters of instructional decisions and are especially critical during the early stages of a teacher's career (Keo et al., 2025). For preservice teachers, navigating the dual roles of student and school-based teacher often leads to tensions between theoretical ideals and practical realities, which can impede the enactment of exemplary science instruction and assessment.

To mitigate these shortcomings, science teacher education programs must be designed not only to build knowledge but also to shape dispositions and develop the situational awareness needed for effective teaching. This includes structured opportunities to plan, teach, and reflect within authentic teaching environments, as well as exposure to models of effective teaching that exemplify the principles of the enacted curriculum and research-based science instruction (de Rivas et al., 2025). By doing so, teacher education can foster both the professional competence and confidence required for preservice teachers to engage in instructional practices that promote scientific literacy, learner-

centred pedagogy, and the achievement of clearly defined learning outcomes. Preparing teachers for exemplary instructional methods and performance-based assessments within an OBE framework requires a holistic approach that integrates content knowledge, pedagogical reasoning, and reflective practice, while attending to the complex motivations and beliefs that shape teaching. Teacher preparation that addresses these interrelated components is essential for cultivating teachers who can implement instruction that is not only effective but also transformative for student learning. Therefore, teachers are the primary agents in enacting intended standards and curricula, and professional learning opportunities play a substantial role in how teachers design or adapt instructional materials to meet their students' needs (Reiser et al., 2021). Within preservice science teacher education, professional learning opportunities play a critical role in shaping new teachers' instructional dispositions and their capacity to adapt instructional materials to classroom contexts. Thus, the design of science teacher education and scaffolding models plays a crucial role in determining whether and how exemplary instructional methods are implemented in classrooms.

2.2.8 Teacher Beliefs and Goals

Teachers' beliefs influence classroom practice by shaping how teachers interpret information and approach instructional decision-making. However, research consistently shows that teachers' beliefs and observed practices are frequently misaligned, particularly among novice teachers (Decoito & Myszkal, 2018). New teachers may articulate learner-centred or inquiry-oriented beliefs yet enact teacher-centred practices once they enter the classroom. Although science teacher education is well positioned to support coherence between beliefs and practice, preservice teachers often struggle to translate theoretical ideas encountered in coursework into classroom practice (Motlhabanyane & Tsheko, 2023; Tau et al., 2025). This challenge persists even when preservice science teachers initially adopt pedagogical beliefs aligned with research-based consensus. Studies indicate that such beliefs are often weakened or abandoned during the transition into in-service teaching, as novice teachers confront contextual pressures and competing demands within school environments (Widiyatmoko et al., 2024). These findings suggest that belief change alone is insufficient to support sustained instructional reform. Preservice teachers' goals may centre on meeting university expectations or demonstrating theoretical understanding, whereas practising teachers' goals are often shaped by institutional demands such as curriculum coverage, classroom management, or standardised assessment performance. When goals shift during the transition into professional practice, previously held beliefs about effective instruction and authentic assessment may remain dormant or be overridden.

Supporting belief-practice alignment requires more than exposure to reform-oriented ideas; it requires structured support that helps teachers reconcile competing goals and enact their beliefs in authentic classroom contexts. The present study proposes an integrative model that directly addresses this challenge by embedding mechanisms that support the activation and refinement of beliefs over time. Through sustained mentorship, collaborative planning with in-service teachers, guided classroom enactment, and structured reflective practice, preservice teachers are supported in aligning their instructional goals with OBE-oriented beliefs. By positioning belief development as an iterative, practice-embedded process rather than a purely cognitive outcome of coursework, the model provides a coherent conceptualisation through which teachers' beliefs about exemplary instruction and assessment can be activated, tested, and sustained in classroom practice. This alignment between beliefs, goals, and enacted practice is essential for the successful implementation of Outcome-Based Education in science classrooms.

2.2.9 Science Teacher Education

Science teacher education programs play a pivotal role in preparing preservice teachers to enact desired pedagogies and assessments that emphasise deep understanding of core scientific ideas, inquiry-oriented learning, and the application of knowledge to authentic, real-world contexts. To support the development of pedagogical content knowledge and instructional competence, science teacher education must offer a coherent and scaffolded learning trajectory that consistently communicates a shared vision of high-quality science teaching across coursework and clinical practice. However, research indicates that many programs struggle to meaningfully connect university-based learning with school-based experiences, limiting preservice teachers' ability to translate theoretical knowledge into student-centred practice (Mikkilä-Erdmann et al., 2024). Scholars argue that stronger alignment between theory and practice requires intentionally structured opportunities that scaffold preservice teachers' engagement with authentic teaching tasks, promote continuity between coursework and field experiences, and support progressive development toward independent practice (Jacobs, 2001; Tikly, 2010). When science teacher education programs deliberately integrate these elements, they can foster instructional practices that promote deep learning, critical thinking, and the attainment of intended learning outcomes. Accordingly, a model of teacher preparation that emphasises systematic scaffolding and alignment across learning contexts has the potential to prepare preservice science teachers better to meet the complex demands of contemporary science classrooms and advance broader goals of educational quality and student success.

III. METHODOLOGY

3.1 Research Design

This study employed a multi-phase, collaborative design-based research approach to develop and test the Preservice Science Teacher Preparation and Scaffolding (PSTPS) model (Figure 1). The design was collaborative, iterative, and practice-based, integrating elements of design-based research and developmental evaluation. The model was developed in response to persistent challenges faced by newly trained science teachers in Botswana, particularly difficulties in implementing exemplary instructional methods and in aligning performance-based assessments with the Outcome-Based Education (OBE) framework. The research unfolded in two major phases: (1) model development and refinement, and (2) pilot implementation and testing. Rather than relying solely on pre-post measures, the evaluation emphasised practice-based evidence, including changes in lesson coherence, instructional decision-making, and reflective capacity over time. Iterative cycles of planning, enactment, observation, reflection, and revision informed the progressive refinement of the PSTPS model.

3.2 Study Area

The study was conducted across three teacher preparation institutions in Botswana, in Gaborone, Molepolole, and Tonota. These institutions collaborate with surrounding secondary schools where preservice science teachers undertake practicum experiences. The school contexts provided authentic classroom environments for observing instructional practices, mentoring processes, and implementation of Outcome-Based Education (OBE). Each Campus offered a unique demographic and academic focus, contributing to a diverse context and resulting in varied outcomes and a representative sample. The integration of university coursework and school-based teaching practice within these institutions and partner schools provided a suitable context for examining instructional coherence, assessment alignment, and mentorship practices in real-world settings.

3.3 Target Population

The target population consisted of preservice science teachers, school-based mentor teachers, and science teacher educators involved in teacher preparation programs at the participating institutions. These groups were selected for their direct involvement in science teacher preparation and for their roles in bridging theory and practice.

3.4 Sampling Procedures and Sample Size

A purposive sampling strategy was employed to select participants who were directly engaged in science teacher preparation and mentoring processes. The sample included 18 preservice science teachers, 10 school-based mentor teachers, and 12 science teacher educators. Participants were selected based on their active participation in teaching practice supervision, curriculum implementation, and instruction in science pedagogy. Their involvement ensured that multiple perspectives informed the design and refinement of the PSTPS model.

3.5 Data Collection Instruments and Procedures

Multiple data sources were generated and systematically analysed during both development and testing phases. Data collection procedures included structured workshops, school visits, practicum observations, and collaborative planning sessions. Lesson plans, scheme books, classroom observation guides, and reflective journals were reviewed. Participants engaged in structured, iterative workshops that brought together teacher educators, mentor teachers, and preservice teachers to examine national curriculum expectations, discuss OBE implementation challenges, and explore strategies for strengthening the transition from preservice preparation to classroom practice. School visits and practicum engagements enabled the research team and teacher educators to observe classroom instruction and mentoring practices. These observations supported shared reflection on instructional coherence, assessment alignment, and learner-centred pedagogy. Preservice teachers implemented lessons designed using PSTPS-aligned tools during teaching practice. Mentor teachers and teacher educators provided ongoing feedback. Classroom observations, reflective discussions, and follow-up planning sessions were conducted to examine the enactment of exemplary instructional methods and performance-based assessments.

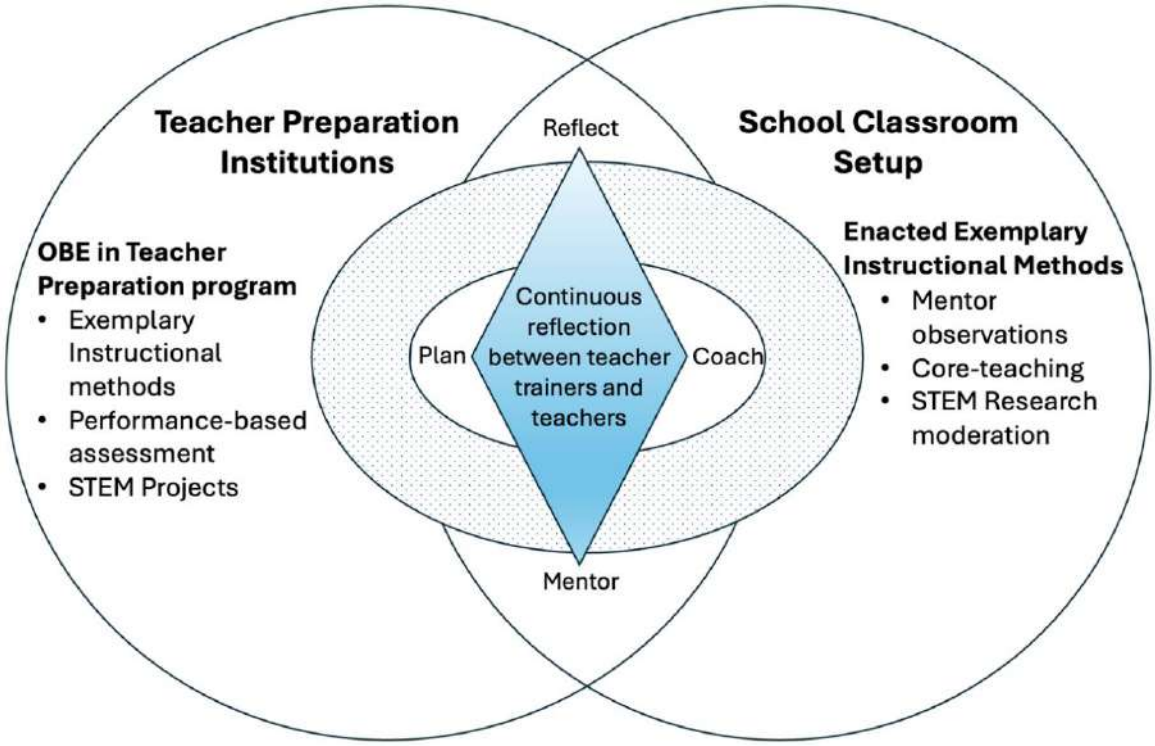

Figure 1
The Preservice Science Teacher Preparation and Scaffolding (PSTPS) Model

3.6 Data Analysis

Document analysis was used to examine the alignment between intended learning outcomes, instructional strategies, and assessment practices. Data from lesson plans, reflective journals, and observation records were analysed to identify recurring patterns related to instructional coherence, assessment alignment, and pedagogical decision-making. An iterative analytical process was employed, consistent with the study's design-oriented nature. Evidence from classroom enactment, mentoring interactions, and reflective discussions informed progressive refinement of the PSTPS model. Emphasis was placed on practice-based indicators, including coherence of lesson planning, alignment between instruction and assessment, quality of reflective practice, growth in pedagogical content knowledge (PCK), and development of teaching self-efficacy. Findings from each cycle informed modifications to the model, leading to the identification of critical features necessary for effective science teacher preparation.

3.7 Ethical Considerations

Ethical principles were observed throughout the study. Participants were informed about the purpose of the research and their voluntary involvement. Informed consent was obtained from preservice teachers, mentor teachers, and teacher educators before participation. Confidentiality and anonymity were maintained by ensuring that participants' identities and institutional affiliations were not disclosed in reporting. Data collected from lesson plans, observations, and reflective journals were used strictly for research purposes. Participants were assured that their professional evaluations and academic standing would not be affected by their involvement in the study. Permission to conduct the study was obtained from the participating teacher preparation institutions and relevant school authorities.

IV. FINDINGS & DISCUSSION

4.1 Findings

The purpose of this study was to develop, implement, and refine the Preservice Science Teacher Preparation and Scaffolding (PSTPS) model as a contextually grounded framework for strengthening science teacher preparation in Botswana. Consistent with the research's design-oriented, practice-based nature, the findings are presented qualitatively and thematically. Data were generated through classroom observations, reflective journals, lesson plan analyses, structured workshops, and semi-structured interviews with preservice teachers, mentor teachers, and science teacher educators. The findings reveal interconnected transformations in preservice teachers' instructional alignment, pedagogical content knowledge, teaching confidence, collaborative professional engagement, and integration of STEM-oriented practices. These themes illustrate how the PSTPS model functioned as both a structural and relational scaffold bridging university coursework and school-based practice.

4.1.1 Alignment of Beliefs and Classroom Practice

A central finding of the study was the gradual alignment between preservice teachers' stated pedagogical beliefs and their enacted classroom practices. At the beginning of the practicum period, many preservice teachers expressed strong commitment to inquiry-based, learner-centred teaching approaches. However, classroom observations and reflective journals revealed that several initially defaulted to teacher-directed methods when confronted with classroom realities such as time constraints, curriculum pacing, and classroom management pressures. Through structured mentoring, joint lesson planning, and reflective dialogue embedded within the PSTPS model, preservice teachers began translating theoretical commitments into actionable instructional practices. This shift was not immediate; rather, it emerged progressively through cycles of planning, enactment, feedback, and revision. One preservice teacher reflected on this transition:

> *"Before PSTPS, I wanted to do inquiry lessons, but in the classroom, I defaulted to lectures. The mentoring and planning meetings helped me try it out successfully."*
> *(Preservice Teacher 7, 12 July 2025)*

This statement illustrates how mentoring served as a confidence-building scaffold, enabling risk-taking and experimentation with student-centred strategies. The collaborative planning sessions reduced uncertainty by providing structured support and shared responsibility.

Another participant emphasised the value of observing modelled practice:

> *"Observing my mentor and getting feedback made me realise that active learning strategies are not just theory; they actually work in class. I tried them with my students and got so comfortable with repeated attempts."*
> *(Preservice Teacher 3, 18 July 2025)*

Mentor teachers also observed a noticeable transformation. One mentor commented:

> *"The preservice teachers were able to link what they learned in coursework directly to lab activities and projects. We could see them growing more confident in using inquiry methods."*
> *(Mentor Teacher 4, 25 July 2025)*

Classroom observations confirmed that lessons increasingly included structured investigations, guided questioning, collaborative problem-solving tasks, and opportunities for students to articulate scientific reasoning. Rather than focusing solely on content delivery, preservice teachers began designing learning experiences that foregrounded conceptual understanding and application. These findings suggest that the PSTPS model reduced the fragmentation between belief and practice by embedding sustained mentorship and reflective processes within authentic teaching contexts.

4.1.2 Development of Pedagogical Content Knowledge (PCK)

The findings also indicate substantial qualitative growth in preservice teachers' pedagogical content knowledge. Early lesson plans often demonstrated adequate content knowledge but lacked strategic alignment between scientific concepts, learner misconceptions, and instructional approaches. Over time, however, preservice teachers became more intentional in sequencing content, anticipating student difficulties, and selecting strategies that supported conceptual understanding. Collaborative lesson revision played a pivotal role in this development. Preservice teachers described how feedback conversations prompted deeper pedagogical thinking rather than superficial adjustments.

One participant stated:

> *"Working on lesson revisions with feedback helped me organise ideas better and think about how students would actually engage."*
> *(Preservice Teacher 11, 1 August 2025)*

Another reflected:

> *"I now plan activities that help students discover concepts themselves instead of me just telling them the answers."*
> *(Preservice Teacher 5, 8 August 2025)*

These reflections reveal a shift from transmission-oriented instruction toward constructivist engagement. Lesson observations demonstrated that preservice teachers increasingly used probing questions, facilitated student discussion, and incorporated real-life examples to contextualise abstract scientific ideas.

Teacher educators also noted growth in pedagogical intentionality:

> *"They became more thoughtful and intentional about linking learning outcomes to classroom activities. You could see them thinking carefully about why they were choosing certain strategies."*
> *(Teacher Educator 6, 15 August 2025)*

Reflective journals further revealed deeper analytical thinking. Initial reflections were often descriptive accounts of what occurred during lessons. Later entries, however, demonstrated critical examination of instructional decisions, analysis of student responses, and consideration of alternative strategies. The iterative nature of the PSTPS

model, where planning, enactment, feedback, and reflection were continuously interwoven, appeared central to strengthening pedagogical reasoning. Rather than viewing teaching as a fixed routine, preservice teachers began to see it as an adaptive and reflective practice.

4.1.3 Confidence and Teaching Self-Efficacy

Another prominent theme was the growth of teaching confidence and professional self-efficacy among preservice teachers. At the outset of the practicum, several preservice teachers expressed anxiety about classroom management, inquiry facilitation, and the design of performance-based assessments. These concerns were particularly evident when preservice teachers were required to deviate from traditional lecture-based instruction. Through consistent mentorship and collaborative support, participants gradually developed a stronger sense of professional agency. Confidence emerged not from isolated success but from repeated cycles of guided experimentation and constructive feedback. One preservice teacher explained:

> *"At first, I was nervous about letting students lead investigations, but working with my mentor helped me trust my own ability."*
> *(Preservice Teacher 2, 20 August 2025)*

Another noted:

> *"Collaborating with the mentor teacher gave me confidence to try new teaching strategies without fear of failure."*
> *(Preservice Teacher 14, 22 August 2025)*

Mentor teachers observed increasing independence in lesson facilitation and classroom leadership:

> *"I noticed that their ability to plan and lead lessons improved as they gained experience and feedback. They became more independent."*
> *(Mentor Teacher 8, 30 August 2025)*

Classroom observations supported these perceptions. Preservice teachers demonstrated greater comfort facilitating group discussions, allowing productive struggle during investigations, and adjusting instruction in response to student questions. Rather than rigidly adhering to lesson scripts, they exhibited flexibility and responsiveness. The relational dimension of the PSTPS model, particularly the emphasis on supportive feedback rather than evaluative judgment, appeared instrumental in cultivating professional confidence.

4.1.4 Collaborative Reflection and Professional Learning

The PSTPS model fostered a collaborative professional learning culture among preservice teachers, mentor teachers, and teacher educators. Structured reflection sessions provided a shared space for discussing instructional challenges, analysing student learning, and generating collective solutions. Preservice teachers described reflection sessions as transformative moments for professional growth.

One participant stated:

> *"Reflecting with my peers and mentor helped me think critically about why students struggled and how I could adjust lessons."*
> *(Preservice Teacher 9, 5 August 2025)*

Another added:

> *"Sharing challenges with other preservice teachers showed me different strategies I hadn't considered."*
> *(Preservice Teacher 16, 6 August 2025)*

Mentor teachers emphasised that reflection deepened pedagogical awareness:

> *"It wasn't just about teaching the lesson; it was about understanding how students are learning. The reflection sessions made a real difference."*
> *(Mentor Teacher 1, 11 August 2025)*

These collaborative engagements reduced isolation and encouraged shared ownership of instructional improvement. Teacher educators reported that joint supervision strengthened coherence between university coursework and school-based mentoring, ensuring consistent pedagogical messaging. Reflection sessions evolved from surface-level discussions of lesson flow to more sophisticated analyses of student misconceptions, engagement patterns, and assessment alignment. This shift illustrates how the PSTPS model cultivated reflective practitioners capable of examining teaching through both practical and theoretical lenses.

4.1.5 Integration of STEM-Oriented Instruction

An additional theme was enhanced integration of STEM-oriented principles within science instruction. Teacher educators serving as STEM project champions guided preservice teachers in designing lessons that incorporated inquiry, problem-solving, and interdisciplinary connections. Preservice teachers reported that structured scaffolding made cross-

disciplinary planning more accessible and meaningful. Lessons increasingly incorporate real-world applications, collaborative design tasks, and problem-based investigations that link science, mathematics, and technology.
One teacher educator observed:

> *"Embedding STEM principles within the planning process encouraged preservice teachers to think beyond content coverage toward problem-solving and innovation."*
> *(Teacher Educator 3, 11 July 2025)*

Mentor teachers also noted heightened student engagement during these lessons, particularly when activities involved authentic problems and collaborative exploration. The integration of STEM principles within the PSTPS framework reinforced alignment with both Outcome-Based Education and contemporary 21st-century learning goals. Rather than treating STEM as an additional requirement, preservice teachers began incorporating interdisciplinary thinking as a natural extension of inquiry-based science teaching.

Table 1
Triangulation of Data Sources Across Themes

Theme	Lesson Observations	Reflective Journals	Lesson Plans	Interviews / Workshops
Alignment of Beliefs & Practice	Inquiry lessons observed	Reflections on shifting from lectures to inquiry	Planned inquiry activities	Mentors confirmed the adoption of strategies
PCK Development	Lesson sequencing & task integration	Reflection on engagement strategies	Integrated performance assessments	Teacher educators noted improved planning
STEM Integration	Collaborative investigations & authentic tasks	Reflections on real-world applications	Interdisciplinary lesson designs	Mentors & educators confirmed problem-solving emphasis
Collaborative Reflection	Joint planning sessions observed	Critical reflections on student learning	Notes on lesson revisions	Workshop discussions reinforced shared solutions

4.2 Discussion

The findings of this study provide preliminary yet compelling support for a practice-based, socially mediated model of preservice science teacher preparation that foregrounds the interconnected roles of planning, reflection, coaching, and mentoring as summarised in Table 1. Consistent with contemporary research in science teacher education, the Preservice Science Teacher Preparation and Scaffolding (PSTPS) model demonstrates how structured integration of university coursework and school-based experiences reduces the persistent theory-practice divide that has long characterised teacher education programs (Darling-Hammond et al., 2005). The outcomes of this study align strongly with Bandura's (1977) Social Learning Theory, which emphasises learning through observation, modelling, guided practice, feedback, and social interaction. Within PSTPS, preservice teachers engaged in repeated cycles of vicarious learning through observing mentor teachers, mastery experiences through co-teaching and independent teaching, mentor feedback that was verbally persuasive, and reflective dialogue. These processes collectively contributed to enhanced instructional competence and self-efficacy, echoing findings from prior studies that identify social learning as a critical mechanism for developing inquiry-oriented teaching practices in science education (Guerrero & Bautista, 2023; Gutiérrez & Vossoughi, 2010).

A central contribution of the PSTPS model lies in its ability to align preservice teachers' pedagogical beliefs with their enacted classroom practices. Prior research consistently reports that preservice teachers often espouse learner-centred or inquiry-based beliefs yet revert to teacher-centred instruction during practicum experiences due to contextual pressures, limited pedagogical content knowledge, and lack of support (Decoito & Myszkal, 2018). In this study, mentor modelling collaborative lesson planning and guided reflection served as critical mediating structures that enabled preservice teachers to translate inquiry-oriented beliefs into practice. Classroom observations indicating increased use of inquiry-driven tasks, student engagement strategies, and performance-based assessments mirror findings from research on cognitive apprenticeship and instructional coaching models, which emphasise learning through supported participation in authentic teaching practices (de Rivas et al., 2025). The emphasis on collaborative planning and co-teaching within PSTPS also strengthened preservice teachers' pedagogical content knowledge (PCK), a core construct in science teacher education research. Through iterative lesson design, enactment, and revision, preservice teachers developed greater coherence among learning objectives, instructional activities, and assessments. This finding resonates with studies highlighting the effectiveness of lesson study, professional learning communities, and practice-based teacher education models in fostering deliberate instructional decision-making and alignment (Hayes et al., 2016). Importantly, the structured feedback cycles embedded in PSTPS enabled preservice teachers to move beyond procedural lesson delivery toward responsive and adaptive teaching informed by student learning evidence. The strong impact of

PSTPS on preservice teachers' confidence in implementing outcomes-based education (OBE) principles is particularly significant given policy expectations that emphasise competency development, authentic assessment, and learner-centred pedagogy. OBE frameworks, widely adopted in science curricula globally, require teachers to design instruction that supports higher-order thinking, inquiry, and performance-based assessment, which novice teachers often find challenging. The reported gains in self-efficacy observed in this study align with research demonstrating that confidence is a key predictor of teachers' willingness to sustain inquiry-based and innovative instructional practices, a finding similar to that of the recent review by Bwembya et al. (2024). By providing structured mastery experiences and social support, PSTPS addresses a critical gap in traditional teacher preparation programs that often emphasise theoretical knowledge over supported practice.

The PSTPS model's facilitation of STEM-oriented instruction resonates with existing research that underscores the value of interdisciplinary, real-world learning experiences in science education. Scholars argue that integrating STEM elements supports deeper cognitive engagement and helps students apply scientific concepts in authentic contexts (Major & Mulvihill, 2018). Within this study, structured scaffolding and mentorship guided preservice teachers in adopting such practices, aligning with evidence that sustained professional learning communities and collaborative planning are essential for translating innovative instructional ideas into classroom practice (Darling-Hammond et al., 2005).

Embedding STEM principles within inquiry-based pedagogy further aligns with the literature, which affirms that authentic, student-centred tasks enhance scientific reasoning and conceptual understanding. Rather than treating STEM as an add-on, the PSTPS framework positioned STEM integration as a natural extension of inquiry practices, supporting coherence between learning activities, curriculum standards, and performance tasks. Mentor and teacher educator support helped preservice teachers navigate the complexity of interdisciplinary design, reinforcing research that coaching and reflective dialogue are critical for teacher learning and instructional change (Tau et al., 2025). Overall, the findings suggest that structured, mentored integration of STEM within science teacher preparation can foster meaningful innovation and alignment with contemporary educational goals.

The collaborative and reflective dimensions of PSTPS further contributed to the development of a professional learning community among preservice teachers, mentor teachers, and teacher educators. Shared reflection and collective problem-solving promoted deeper pedagogical reasoning and supported reflective decision-making beyond individual lesson enactment. This finding is consistent with research on communities of practice, which highlights the role of collective inquiry and shared expertise in professional learning and identity development (Campbell et al., 2015). The social coherence fostered by PSTPS contrasts with more fragmented models of teacher preparation, where limited coordination between universities and schools often undermines professional growth. Despite these positive outcomes, the study also revealed contextual constraints, including large class sizes, limited instructional time, and resource shortages, which at times hindered the full implementation of inquiry-based and performance-oriented instruction. These findings align with existing literature documenting the influence of structural and environmental factors on teachers' instructional choices, particularly in resource-constrained settings (Mulenga & Ng'andu, 2022; Tau et al., 2025). From a social learning perspective, such constraints limit opportunities for mastery experiences; however, the structured mentoring and reflective scaffolds within PSTPS mitigated these challenges by supporting adaptive decision-making without compromising learning objectives. This underscores the importance of institutional support and coherent mentoring structures in enabling preservice teachers to navigate complex classroom realities.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

The PSTPS model enabled teacher preparation institutions to reflect on and improve their programs by fostering collaboration between teacher training institutions and schools. Preservice teachers gained practical experience and reflective guidance, enhancing their use of exemplary instructional methods and performance-based assessments in classrooms. While full alignment was not always achieved, the model provided a valuable framework for addressing fragmentation, promoting continuity across learning environments, and building a more coherent system for preparing future science teachers.

5.2 Recommendations

Future efforts should focus on expanding PSTPS to additional institutions, investing in comprehensive mentor training, leveraging digital tools to support reflective practice, and conducting empirical research to monitor effectiveness across diverse contexts. Beyond science education, the model's core components can be adapted for other subject areas by aligning mentorship, coaching, and assessment strategies with discipline-specific pedagogical needs. International adaptation is also feasible, provided the framework aligns with local curriculum standards, teacher certification requirements, and cultural expectations for teaching and learning. By strategically addressing mentor

capacity, institutional support, and contextual variability, PSTPS has the potential to evolve into a versatile, scalable framework for improving preservice teacher preparation and advancing learner-centred, performance-based teaching in diverse educational settings.

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