

Factors Influencing Science Teachers' Uptake of Virtual Laboratories in Resource-Constrained Rural Schools of the Global South: A PLS-SEM Analysis

Research Overview

This study investigates factors influencing rural science teachers' adoption of virtual laboratories (VLs) in South Africa. Using an extended Technology Acceptance Model (eTAM), it examines how technological, pedagogical, and contextual factors shape behavioural intention. The study contributes evidence on digital science education adoption in resource-constrained Global South contexts.

Purpose

Laboratory-based inquiry is central to science education, yet many rural schools in the Global South face persistent constraints such as inadequate infrastructure, limited laboratory equipment, and lack of trained personnel. These constraints significantly reduce opportunities for practical experimentation, thereby undermining conceptual understanding and inquiry-based learning in science subjects. Virtual laboratories (VLs) have emerged as innovative digital tools capable of simulating experimental environments and providing scalable access to practical science learning. However, the effectiveness of VLs is not solely dependent on availability, but on teachers' willingness, competence, and pedagogical readiness to integrate them into classroom practice. In rural and under-resourced contexts, adoption decisions are further shaped by professional isolation, limited technical support, and uneven access to digital infrastructure. This study, therefore, aims to examine the determinants of behavioural intention (BI) among rural Life Sciences teachers in South Africa to adopt virtual laboratories. Specifically, it extends the Technology Acceptance Model (TAM) by incorporating Technological Pedagogical Content Knowledge (TPACK), social influence (SI), and facilitating conditions (FC) as contextual variables influencing perceived usefulness (PU), perceived ease of use (PEOU), and attitudes (ATT). The study seeks to advance understanding of how established technology acceptance mechanisms operate under conditions of structural disadvantage.

Methods

A quantitative research design was employed, grounded in an eTAM. The model integrates classical TAM constructs, PU, PEOU, and ATT, with BI as the dependent variable. To contextualise adoption in rural education settings, three external constructs were incorporated: TPACK, SI, and FC. These constructs were hypothesised to influence PU, PEOU, ATT, and BI either directly or indirectly. Data were collected from a sample of 287 Life Sciences teachers working in rural schools in South Africa. A structured questionnaire using validated Likert-scale items was administered. Data analysis was conducted using Partial Least Squares Structural Equation Modelling (PLS-SEM), which is appropriate for complex predictive models and non-normal data distributions. The analysis assessed both the measurement model (reliability and validity) and the structural model (path relationships, effect sizes, and explanatory power).

Results / Discussion

The findings demonstrate that ATT, PU, FC, and TPACK significantly predict BI. Among these, TPACK emerges as the most influential determinant, exerting both direct effects on BI and indirect effects through PU and ATT. This highlights the central role of teachers' integrated technological, pedagogical, and content knowledge in shaping digital innovation uptake in science education. PEOU significantly influences both PU and ATT, confirming its foundational role in shaping technology perceptions. However, PEOU does not directly predict behavioural intention, suggesting that ease of use alone is insufficient to drive adoption unless it translates into perceived instructional value and positive attitudes toward integration. SI significantly affects both PU and PEOU, indicating that collegial networks, leadership encouragement, and professional discourse play a critical role in shaping teachers' perceptions of virtual laboratories. This finding is particularly relevant in rural contexts characterised by professional isolation, where peer and institutional support structures become key drivers of innovation uptake. In contrast, FC do not directly influence BI or attitudes. Instead, FC operates indirectly through its effect on usability-related perceptions, suggesting that infrastructure and technical support are necessary but not sufficient conditions for adoption. Overall, the results reveal a scarcity-driven adoption pattern in which teacher knowledge integration (TPACK) and socially embedded professional environments outweigh infrastructural factors in shaping technology acceptance. The study contributes to theory by demonstrating that while the Technology Acceptance Model remains robust in explaining adoption behaviour, the relative importance of its determinants shifts in resource-constrained rural contexts. These findings have important implications for policy and practice. They suggest that investment in infrastructure alone is insufficient to ensure successful VL adoption. Instead, targeted professional development to strengthen TPACK, along with the cultivation of collaborative professional communities, is essential to support meaningful integration of virtual laboratories in rural science classrooms.