

The association between COVID-19 vaccination status, knowledge, and attitudes among pre-service life science teachers in South Africa

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Abstract

The prevalence of vaccine hesitancy has posed challenges in managing infectious diseases like coronavirus disease 2019 (COVID-19). While science teachers have the potential to promote health literacy and influence community attitudes, there is a paucity of research on their vaccination behaviors and perceptions related to COVID-19. The study aimed to investigate the relationship between knowledge, attitudes towards COVID-19 vaccination, and vaccination statuses among pre-service science teachers in South Africa. Final-year Bachelor of Education pre-service life sciences teachers (n = 182) in South Africa were surveyed using a previously validated closed-ended questionnaire. Regression analyses were employed to discern influential factors on vaccination behavior. Most participants demonstrated a comprehensive understanding of COVID-19's nature and symptoms, along with the efficacy and safety of vaccines. Nevertheless, prominent misconceptions emerged, such as the misbelief that the SARS-CoV-2 virus does not cause COVID-19 and that vaccines can modify human deoxyribonucleic acid. Regression analyses found a notable correlation between the attitude toward COVID-19 vaccines and actual vaccination status. This study emphasizes the pressing need to rectify prevailing health-related misconceptions and attitudes in teacher education programs to enhance teachers' role in influencing students' health behaviors and beliefs.

Abbreviations: COVID-19 = coronavirus disease 2019, SARS-CoV-2 = severe acute respiratory syndrome coronavirus-2.

Keywords: attitudes, COVID-19, COVID-19 vaccine, health literacy in education, health literacy in education, pre-service life sciences teachers, vaccination, vaccine hesitancy

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic, caused by multiple severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) variants, has had far-reaching implications on global public health, economy, and societal well-being.^[1] Like

most developing countries, South Africa's challenges with the pandemic exemplify broader issues that impact healthcare, including vaccine hesitancy, limited access to health services, illiteracy, and general socio-economic challenges. These challenges can be addressed through a multidisciplinary approach

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The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the College of Education, University of South Africa (Ref 2021/09/08/90291786/34/AM and 2021_RPSC_088).

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integrating health, education, and socio-economic empowerment. Past health crises, such as the Spanish flu, the HIV/AIDS epidemic, and the COVID-19 pandemic, present important lessons for managing future pandemics.^[2,3]

In light of these considerations, science education, especially in regions with low scientific literacy has a pivotal role in shaping public health outcomes.^[4] This connection between science and health literacy is not merely incidental but can be strategically nurtured.^[5,6] For example, science teachers, as direct conduits of scientific knowledge, are uniquely positioned to disseminate scientific and health-related information to thousands of learners vulnerable to lifestyle and communicable diseases.^[7] Their everyday interactions with students offer an invaluable platform to impart this knowledge, and their position as trusted figures can enhance the efficacy of these health messages. They can incorporate health topics into their curriculum, framing them as socio-scientific issues that can encourage safe behavioral practices.^[8,9]

Given the importance of this interplay between education and public health, this research explores teachers' response to the COVID-19 pandemic as a preliminary effort to understanding their potential role in the fight against lifestyle and communicable diseases. The findings could foster collaborative efforts between teachers and healthcare professionals, creating a synergistic relationship where tailored, evidence-based health education materials are integrated seamlessly into classroom instruction. This dynamic, collaborative approach between educators and healthcare providers could lead to more informed students and, by extension, communities that are better prepared to address health challenges.

1.1. COVID-19 vaccine hesitancy

Vaccine hesitancy is delaying or refusing to accept vaccines despite available services, driven by factors like misinformation, safety concerns, and socio-demographic characteristics.^[10-12] In the context of COVID-19, this hesitancy has had significant implications for achieving herd immunity and controlling the pandemic.^[13] Even a modest vaccine refusal rate can impede herd immunity, leading to potential outbreaks and delays in pandemic control.^[14,15] In sectors such as education, low vaccine uptake among teachers impacts educational institutions and poses a risk to overall public health.^[16,17] Thus, addressing vaccine hesitancy is crucial for the success of immunization programs and pandemic mitigation.

Factors affecting vaccination and vaccine hesitancy during the COVID-19 pandemic were complex and multifaceted. A key observation is the variance in willingness to vaccinate across countries, genders, and age groups.^[11] Gender differences have been particularly highlighted, with males generally showing higher acceptance rates than females.^[15] Additionally, educational background, especially in science, significantly predicts vaccine intention.^[12] Misinformation remains a critical obstacle, significantly impacting vaccine acceptance rates.^[13,18] Accessibility issues, such as the availability of vaccines, have been less influential than expected.^[19] Conversely, socio-demographic factors, religious beliefs, and individual health beliefs were reported as strong predictors of hesitancy.^[16,17] Tackling vaccine hesitancy, therefore, requires a multi-pronged approach that considers the complex factors contributing to both hesitancy and acceptance.

1.2. COVID-19 vaccine hesitancy among teachers

The role of teachers in society is multifaceted and extends far beyond the traditional confines of imparting academic knowledge. In the context of the COVID-19 pandemic, teachers could significantly influence broader public health outcomes. Due to their work environments, often involving close interactions

with students and communities, teachers are generally recognized as a high-risk population for contracting and spreading infections.^[13] Teachers' perceptions and attitudes towards COVID-19 and vaccines have been a subject of scholarly focus, revealing a spectrum of views ranging from vaccine hesitancy to full endorsement.^[11,12,15] These attitudes affect their health and have ripple effects on community transmission rates and overall public health strategies. Consequently, understanding these perceptions becomes critical for policymakers and educational authorities aiming to optimize educational and public health outcomes during pandemic times.

While teachers generally acknowledge their heightened vulnerability to COVID-19, especially given their frequent interactions with students and colleagues, this awareness does not uniformly lead to vaccine uptake. Research provides insight into this discrepancy, indicating that a significant portion of hesitancy among teachers originates from concerns about vaccine efficacy and long-term effectiveness.^[10,14] These concerns are rooted in skepticism and often amplified by misunderstandings surrounding the vaccine development process and its protective capabilities. Moreover, the lack of confidence in the vaccine, potentially influenced by inconsistent public health messaging and misinformation, further reinforces this hesitancy.^[16,19] This complex web of factors – ranging from genuine questions about vaccine science to varying levels of trust in health institutions – creates a challenging landscape for increasing vaccine uptake among teachers. Importantly, their views significantly influence students and families, emphasizing the need for accurate information campaigns targeted toward this demographic.^[17,18]

Perceptions of COVID-19 vaccines among teachers are a complex interplay of positive and negative associations. Positive associations include perceived susceptibility, benefits, and cues to action, while negative perceptions encompass worries about side effects, efficacy, safety, and cost.^[11,15] Teachers with educational backgrounds in science or engineering show a greater inclination toward vaccination, highlighting the role of education in shaping perceptions.^[15] Teachers' attitudes toward COVID-19 vaccines are equally multifaceted, influenced by gender, pregnancy concerns, and perceived risks.^[10,12] In some countries, the intention-to-action gap is significant; for instance, in Ghana, despite high intentions, actual vaccine uptake is low.^[18]

Understanding teachers' perceptions and attitudes is critical to effectively driving vaccination programs. This necessity is underlined by their influential roles and high-risk status, which make them pivotal in combating the pandemic and ensuring the continuity of education.^[13,14]

While much research has focused on vaccine hesitancy among the general population or healthcare workers, there is limited understanding of how pre-service teachers, particularly those specializing in life sciences engage with COVID-19 vaccination. These individuals will be future educators of scientific knowledge and play a critical role in shaping public health perspectives in their communities. By examining the relationship between their knowledge, attitudes, and vaccination status, this study aims to uncover educational and behavioral factors that can inform targeted interventions and improve health outcomes in educational settings.

1.3. Problem statement

Vaccine hesitancy amongst South African pre-service science teachers is an understudied yet crucial area, considering their pivotal role in promoting science literacy and health education within communities. Current literature predominantly focuses on the general population or medical professionals, leaving a substantial gap in understanding teachers' vaccination behaviors and attitudes. This research seeks to fill this gap by exploring the interplay of knowledge, attitudes, and vaccination patterns amongst pre-service science teachers in South Africa

and how these factors cumulatively affect broader public health outcomes.

Identifying determinants of teachers' vaccination uptake could inform targeted interventions, aiding in enhancing vaccine confidence and influencing the development of science curricula focused on fostering health literacy. Given their role in shaping behavioral patterns of youths and communities, teachers' beliefs and attitudes hold the potential for long-term societal impact, thereby making this research vital not only in the context of the COVID-19 pandemic but also for preparing and strategizing public health interventions for future health crises. Ultimately, this study aims to contribute substantially to public health policy, facilitating a sustainable, integrative approach towards public health and science education by developing informed, scientifically literate citizens.

1.4. Aim and objectives of the research

The current research aims to investigate the association between COVID-19 vaccination status, knowledge, vaccine knowledge, and attitudes toward COVID-19 vaccination among pre-service Life science teachers in South Africa. The research question is: "What is the association between COVID-19 vaccination status, knowledge, vaccine knowledge, and attitudes toward COVID-19 vaccination among pre-service Life science teachers?"

The study objectives were to determine: Pre-service life sciences teachers' COVID-19 vaccination status, COVID-19 knowledge, vaccine knowledge, and attitudes toward COVID-19 vaccination; The extent to which COVID-19 knowledge, vaccine knowledge, and attitudes toward COVID-19 vaccination explain vaccination status; The extent to which COVID-19 knowledge and vaccine knowledge explain attitudes toward COVID-19 vaccination.

2. Methods

A positivist research paradigm was employed to underpin the current research, leveraging its suitability for a quantitative methodology that captures extensive data for exploratory analyses.^[20] Accordingly, a non-experimental, survey approach featuring a closed-ended questionnaire was utilized.

2.1. Study context and sampling

Data were collected from participants registered as students at a South African University. These data were collected in October and November 2021, 2 months before the end of the academic year, at the end of which they would graduate. At the start of data collection, 3,091,845 positive COVID-19 cases were reported in South Africa, with 92,854 deaths and 429,605 hospital admissions.^[21] At the time, 32.8% of youths aged 18 to 34 had received at least one dose of the vaccine compared with 67% of those aged 60 and above.^[22] The university from which data were collected is the country's largest producer of science teachers through comprehensive distance learning programs.^[4] The students are spread across the country and come from diverse socio-economic backgrounds.

Regarding the sample size calculation, the Department of Higher education and Training^[23] reports that there were 29,925 graduates in initial teacher education in South Africa in 2022/23. Simkins^[24] estimates that 7.9% ($n = 2364$) of these are trained to teach life sciences, a subject that covers the scientific aspects of viruses and vaccines. Utilizing Taherdoost^[25] formula for minimum sample size ($n = [p(100-p) z^2]/E^2$), it was calculated that 96 participants would provide a 95% confidence level with a 10% margin of error, generally considered acceptable in social science research.^[25] Following the guidance of Bartlett et al,^[21] a 50% estimate for p was used to maximize variance, thereby yielding the largest possible sample size. After accounting for

20% non-response, a sample of 112 was deemed appropriate. The current research included 182 final-year BEd pre-service teachers specializing in life sciences, a response rate of 44%. These participants were selected purposively to ensure they are final-year students, registered for didactics of life sciences, and have completed courses in biology courses where they learned about viruses, vaccines, infectious diseases, cell biology, cytogenetics, embryology, and animal physiology, which could deepen their comprehension of COVID-19. The invitation was sent to all students in the program.

2.2. Survey instrument

The instrument utilized in the current research was a closed-ended questionnaire administered online. The instrument was developed to gauge 3 specific domains: vaccination status, COVID-19 and vaccine knowledge as well as attitudes toward COVID-19 vaccination among the participants. The first section focused on acquiring baseline data concerning the participants' COVID-19 vaccination status. The second section assessed participants' COVID-19 knowledge and vaccine knowledge. It included items probing themes related to common misconceptions, factual knowledge about symptoms, and an understanding of vaccine functions and safety. Additionally, the questionnaire addressed conspiracy theories and participants' knowledge of the vaccine development process. This section of the instrument aimed to evaluate the depth of participants' understanding of COVID-19 and vaccines. The third section explored participants' attitudes toward COVID-19 vaccines. Attitude was defined within the context of the Theory of Planned Behavior^[26] to mean an individual's overall evaluation of a behavior, based on their beliefs about the expected outcomes of the behavior and the value they place on those outcomes. A positive attitude arises when the person believes the behavior will lead to desirable outcomes and evaluates those outcomes favorably. These close-ended items (measured on Likert scale) within this segment were designed to probe participants' behavioral beliefs and perceived outcomes of vaccination. The instrument offers a multifaceted approach to understanding the participants' current vaccination status and knowledge levels and the complex factors influencing vaccine acceptance.

The instrument underwent validation with a pilot group of students who mirrored the characteristics of the primary sample group, followed by validation from a panel of experts. The overarching objective of this process was to enhance the face, content, and criterion-related validity. Feedback from the panel, reflected by a content validity index of 88%, attested to the instrument's aptitude and readiness for the primary study. Moreover, the pilot group completed the questionnaire within 45 minutes without encountering technical glitches or raising concerns regarding the content. This feedback, coupled with the robust content validity index furnished by the expert panel, instilled confidence in the instrument's validity. To establish the reliability of the data collection instrument, Cronbach α was employed, yielding a satisfactory level of internal consistency with a value of .724 and a standardized figure of .836. This set a credible foundation for further analyses and conclusions.

2.3. Data analysis

Given the exploratory nature of this study, the statistical analyses were intended to identify emerging associations rather than establish causality or high-powered generalizations. Statistical analyses were conducted using Statistical Package for the social sciences (Version 29.0.2.0. IBM Corp, Armonk). The data analysis was structured to provide a multi-layered exploration into the participants' vaccination status, knowledge, and attitudes toward COVID-19 vaccines. The initial step involved using descriptive statistics to summarize

the fundamental features of the dataset. This approach was employed primarily for the sections on vaccination status and knowledge about COVID-19. Frequencies, percentages, means, and standard deviations offered an overarching view of the characteristics of the sample. This baseline analysis was critical for contextualizing the subsequent inferential analyses. Two models of regression analyses were conducted. The first model included logistic regression to predict the COVID-19 vaccination status by knowledge. Another model included ordinal logistic regression to determine the extent to which knowledge influences overall attitudes toward the COVID-19 vaccines among pre-service Life Science teachers. These regression models were chosen to dissect the complexities of how attitudes may be influenced by a range of factors, including subjective norms, behavioral control, and existing knowledge. These measurements offered a comprehensive, multi-dimensional framework that evaluated the individual elements and illuminated the interconnected relationships between vaccination status, knowledge, and attitudes. The significance level was set at 5% for the inferential tests.

3. Results

3.1. Vaccination status of the participants

Out of 182 participants, 121 (66.1%) reported being vaccinated, while 61 (33.3%) reported not being vaccinated. One response (0.5%) was missing. This indicates that the majority of participants were vaccinated against COVID-19.

3.2. Participants' knowledge of COVID-19 and vaccines

Participants demonstrated varying levels of knowledge about COVID-19 and vaccines (Table 1). While symptoms such as fever (90.7%) and shortness of breath (96.2%) were widely recognized, misconceptions were also prevalent. Only 16.4% correctly identified SARS-CoV-2 as the cause of COVID-19. A notable portion of participants believed that vaccines increase infection risk (78.7%) or that they are a cure (65.0%). Despite this, most participants correctly identified vaccines as tools for stimulating immunity (91.8%) and recognized that they undergo large-scale clinical trials (94.5%). Belief in conspiracy theories, such as microchip implantation, was held by 28.4% of participants.

3.3. Association between vaccination status and knowledge of COVID-19 and vaccines

Logistic regression identified several significant predictors of vaccination status (Table 2). These included overall COVID-19 knowledge ($B = -0.131, P = .002$), knowledge of COVID-19 causation ($B = -1.625, P = .049$), and awareness of symptoms such as nasal congestion/runny nose ($B = 1.328, P = .025$) and fatigue ($B = 1.647, P = .003$). The belief that vaccines inhibit or destroy microorganisms was also associated with higher odds of being vaccinated ($B = 1.573, P = .002$).

3.4. Attitudes towards COVID-19 vaccination

Overall, 88% of participants reported positive attitudes toward COVID-19 vaccines. The majority believed that vaccines were developed using rigorous scientific standards (91%), reduced the severity of symptoms (90%), and helped prevent the spread of variants (87%). Most participants also valued protection from the virus and viewed the vaccine's benefits favorably (Table 3).

3.5. The association between knowledge and overall attitudes towards COVID-19 vaccination

Ordinal logistic regression showed that several knowledge variables significantly influenced vaccine attitudes (Table 5). A correct understanding of vaccines stimulating the immune system was associated with more positive attitudes ($B = 1.274, P = .023$). Misconceptions, such as COVID-19 being a virus ($B = 0.914, P = .064$) and identifying nasal congestion as a symptom ($B = -1.152, P = .007$), were associated with more negative attitudes. Believing that vaccines can cure diseases was also associated with more favorable attitudes ($B = 0.777, P = .026$). The overall model was statistically significant ($P = .004$), indicating that the included knowledge variables collectively contributed to explaining variance in vaccine attitudes (Table 4).

Several predictors were found to be significant in influencing attitudes toward the COVID-19 vaccine (Table 5). In particular, the misconception that COVID-19 is a virus ($B = 0.914, P = .064, \text{Exp}(B) = 2.495$). Participants who believed this misconception were more likely to have negative attitudes toward the vaccine. Knowledge that a vaccine is a substance that

Table 1

Participants' knowledge regarding COVID-19 and (N = 182).

Knowledge	Theme	Incorrect (%)	Correct (%)
COVID-19 knowledge	Misconception: COVID-19 is a virus	83.6	16.4
	Misconception: COVID-19 causes SARS-CoV-2	42.6	57.4
	COVID-19 is caused by SARS-CoV-2	39.9	60.1
	Symptom: Fatigue	32.8	67.2
	Misconception: COVID-19 is a bacteria	27.9	72.1
	Symptom: Congestion/Runny nose	21.3	78.7
	Symptom: Fever	9.3	90.7
	COVID-19 is caused by a virus	9.3	90.7
	Symptom: Shortness of breath	3.8	96.2
	Vaccine knowledge	Misconception: Vaccine increases infection risk	78.7
Misconception: A vaccine is a cure		65.0	35.0
Vaccine Function: Inhibition of microorganisms		49.2	50.8
Conspiracy: Microchip in vaccines		28.4	71.6
Misconception: Vaccine changing RNA		26.8	73.2
Misconception: Vaccine changing DNA		14.8	85.2
Safety & Effectiveness: Rigorous trials		10.4	89.6
Vaccine Function: Immunity stimulation		8.2	91.8
Safety & Effectiveness: Independent reviews		7.7	92.3
Safety & Effectiveness: Large-scale clinical trials		5.5	94.5

Table 2
Binary logistic regression results for factors influencing vaccination status.

		B	SE	Wald	Sig.	Exp(B)
COVID-19 Knowledge	Overall COVID-19 knowledge	-.131	.042	9.551	.002	.877
	Symptom: Fever	.891	.910	.957	.328	2.437
	Symptom: Nasal congestion/Runny nose	1.328	.594	4.997	.025	3.774
	Symptom: Fatigue	1.647	.562	8.590	.003	5.190
	Symptom: Shortness of breath	.559	1.364	.168	.682	1.749
	Misconception: Covid-19 caused by bacteria	.456	.536	.723	.395	1.578
	Misconception: COVID-19 causing SARS-CoV-2	.119	.444	.072	.788	1.127
	Misconception: Covid-19 is a virus	-.106	.770	.019	.890	.899
	Covid-19 is caused by a virus	-1.625	.827	3.863	.049	1.197
	Covid-19 is a disease	.311	.503	.383	.536	1.365
	Vaccine Knowledge	Misconception: Vaccines as a cure	-.122	.490	.062	.804
Misconception: Vaccine alters DNA		1.361	.722	3.553	.059	3.901
Misconception: Vaccine increases infection risk		-.788	.685	1.323	.250	.455
Misconception: Microchip in vaccines		-.659	.543	1.471	.225	.517
Safety & Effectiveness: Rigorous trials		.477	.661	.521	.471	1.612
Safety & Effectiveness: Large-scale clinical trials		-.296	1.001	.087	.768	.744
Safety & Effectiveness: Independent reviews		1.200	.842	2.030	.154	3.320
Vaccine Function: Immunity stimulation		.581	.817	.506	.477	1.788
Vaccine function: Inhibition of microorganisms		1.573	.498	9.995	.002	4.821
Constant		2.422	1.697	2.036	.154	11.263

This table displays results from a binary logistic regression analysis examining how specific knowledge variables (including symptoms, misconceptions, and vaccine beliefs) predict COVID-19 vaccination status among pre-service Life Science teachers. Each analysis was conducted with 1 degree of freedom. *B* = Unstandardized regression weights, *Exp(B)* = exponential value of *B*, representing the predicted change in odds for a one-unit increase in the predictor, *SE* = standard error, *Wald* = Wald χ^2 statistic; *Sig.* = *P*-value indicating statistical significance.

Table 3
The proportion of participants reporting positive attitudes toward COVID-19 vaccine and vaccination (N = 182).

Aspect of attitude probed	Items	Positive attitude (N = 182)
Behavioral beliefs	The belief that COVID-19 vaccination will significantly reduce the risk of contracting the virus.	85%
	The belief that COVID-19 vaccination will decrease the likelihood of experiencing severe symptoms if infected.	90%
	The belief that COVID-19 vaccination provides long-term protection against COVID-19.	83%
	The belief that COVID-19 vaccination helps prevent the spread of new variants of the virus.	87%
	The belief that COVID-19 vaccination is developed using the highest standards of scientific research.	91%
Outcome evaluation	Being protected from contracting COVID-19 through vaccination is very important.	90%
	Minimizing the severity of illness through COVID-19 vaccination is a crucial benefit.	85%
	Long-term immunity provided by the COVID-19 vaccination would be highly valuable.	84%
	Valuing the role of COVID-19 vaccination in preventing the emergence of new virus variants.	89%
	Knowing that the COVID-19 vaccination was developed with scientific rigor gives confidence in its benefits.	88%
Overall Attitude towards COVID-19 vaccination		88%

This table presents the proportion of participants (N = 182) who endorsed positive attitudes toward various aspects of COVID-19 vaccination, based on responses to Likert-scale items. Items reflect 2 dimensions of attitude from the theory of planned behavior: behavioral beliefs (expected benefits and perceived outcomes) and outcome evaluation (value placed on those outcomes). All proportions reflect participants who selected agreement-level responses indicating a positive attitude.

stimulates a person’s immune system to produce immunity was significantly associated with more positive attitudes (*B* = 1.274, *P* = .023, *Exp(B)* = 3.576). Participants who understood the

function of vaccines in stimulating immunity were more likely to express positive attitudes toward vaccination. Interestingly, the knowledge that nasal congestion/runny nose is a symptom of COVID-19 was negatively associated with vaccine attitudes (*B* = -1.152, *P* = .007, *Exp(B)* = .316). Participants who correctly identified nasal congestion or a runny nose as symptoms of COVID-19 were more likely to have negative attitudes, possibly due to misinformation or concerns about the disease’s seriousness. Another positive predictor was the belief that vaccines can cure diseases (*B* = 0.777, *P* = .026, *Exp(B)* = 2.175), indicating that participants who held this belief were more likely to have favorable attitudes toward the vaccine. Other variables, such as vaccines, must be proven safe and effective in large clinical trials, and vaccines that increase your risk of infection approached significance but did not reach the conventional *P*-value threshold.

The results highlight that misconceptions about vaccines (e.g., vaccines containing microchips) and certain beliefs about vaccine function (e.g., stimulating the immune system) significantly influenced attitudes toward the COVID-19 vaccine. Participants with a higher understanding of how vaccines work were more likely to express positive attitudes. Conversely, those holding misconceptions or identifying less severe symptoms of COVID-19 (e.g., nasal congestion or runny nose) were more likely to harbor negative attitudes. This pattern of associations was further reflected in the binary logistic regression analysis, which yielded an overall classification accuracy of 78%, correctly predicting vaccination status for the majority of participants (Table 6).

3.6. Association between overall attitudes, knowledge, and vaccination status

A binary logistic regression examined how attitudes, COVID-19 knowledge, and vaccine knowledge predicted vaccination status (Table 7). COVID-19 knowledge (*B* = -0.024, *P* = .047) and attitudes (*B* = -0.930, *P* < .001) were significant predictors. Vaccine knowledge was not significantly associated with vaccination status (*B* = 0.012, *P* = .432). More favorable attitudes toward the vaccine were strongly associated with a less

Table 4
Model fit for ordinal logistic regression predicting vaccine attitudes.

Model	-2 Log likelihood	χ^2	df	Sig.
Intercept only	446.049			
Final	404.857	41.192	20	.004

This table summarizes model fit statistics for the ordinal logistic regression examining how knowledge variables predict overall attitudes toward COVID-19 vaccination among pre-service Life Science teachers.

df = degrees of freedom, -2 Log likelihood = measure of model fit, Sig. = *P*-value indicating statistical significance.

Table 5
Predictors of attitudes toward COVID-19 vaccination: ordinal logistic regression results.

Predictor	Estimate	Std. Error	Wald	Sig.	95% Confidence interval		Exp(<i>B</i>)
					Lower bound	Upper bound	
COVID-19 knowledge							
Covid-19 caused by a virus	.550	.565	.946	.331	-.558	1.657	1.733
Misconception: Covid-19 caused by bacteria	.400	.362	1.217	.270	-.311	1.110	1.492
Covid-19 is a disease	-.084	.339	.062	.804	-.748	.579	0.920
Misconception: Covid-19 is a virus	.914	.494	3.422	.064	-.054	1.883	2.495
Covid-19 is caused by SARS-CoV-2	.643	.320	4.027	.045	.015	1.271	1.902
Misconception: COVID-19 causing SARS-CoV-2	.046	.328	.019	.889	-.597	.688	1.047
Symptom: Fever	-.421	.595	.500	.479	-1.588	.746	0.656
Symptom: Shortness of breath	.923	.847	1.186	.276	-.738	2.583	2.517
Symptom: Nasal congestion/Runny nose	-1.152	.424	7.375	.007	-1.984	-.321	0.316
Symptom: Fatigue	-.154	.355	.188	.665	-.849	.541	0.857
Vaccine knowledge							
Vaccine function: immunity stimulation	1.274	.560	5.176	.023	.177	2.372	3.576
Vaccine function: Inhibition of microorganisms	-.112	.334	.112	.737	-.766	.542	0.894
Misconception: Vaccine alters DNA	.214	.502	.181	.670	-.770	1.198	1.239
Misconception: Vaccine alters RNA	.087	.358	.059	.807	-.614	.789	1.091
Misconception: Microchip in vaccines	.152	.399	.146	.703	-.630	.935	1.164
Misconception: Vaccines as a cure	.777	.348	4.989	.026	.095	1.459	2.175
Safety & effectiveness: Large-scale clinical trials	.634	.730	.754	.385	-.797	2.065	1.885
Safety & effectiveness: independent reviews	-.506	.629	.649	.421	-1.739	.726	0.603
Misconception: Vaccine increases infection risk	.775	.446	3.018	.082	-.099	1.650	2.171
Safety & Effectiveness: Rigorous trials	.232	.514	.203	.653	-.777	1.240	1.261

This table presents parameter estimates from an ordinal logistic regression assessing how specific knowledge variables (COVID-19 symptoms, misconceptions, and vaccine beliefs) predict participants' overall attitudes toward COVID-19 vaccination. All predictors were tested with 1 degree of freedom.

Estimate = unstandardized regression coefficient, Exp(*B*) = odds ratio, 95% confidence interval = range within which the true odds ratio is likely to fall with 95% confidence, Std. Error = standard error of the estimate, Wald = Wald χ^2 test statistic, Sig. = *P*-value.

Table 6
Classification accuracy of binary logistic regression predicting COVID-19 vaccination status.

Vaccination status	Predicted vaccinated	Predicted not vaccinated	Percentage correct
Vaccinated	108	13	89.3%
Not vaccinated	27	34	55.7%
Overall percentage			78.0%

This classification table presents the results of a binary logistic regression analysis assessing how well vaccine knowledge, COVID-19 knowledge, and attitudes toward the COVID-19 vaccine predicted participants' vaccination status.

likelihood of being vaccinated (Exp(*B*) = 0.395). Vaccine knowledge did not significantly predict vaccination status (*B* = 0.012, *P* = .432, Exp(*B*) = 1.012), suggesting that general knowledge about vaccines, while important, may not directly influence the decision to get vaccinated against COVID-19.

4. Discussion

Our decision to examine the correlation between knowledge, attitudes, and vaccination status among pre-service teachers was guided by their dual role as learners and future educators. Understanding these relationships helps identify gaps where teacher education programs might intervene to improve scientific literacy and vaccine advocacy, which can in turn influence broader public

health behaviors within the communities they will serve. Teachers represent a demographic that is a crucial intersection of the education and public health sectors, and their vaccination behavior has significant implications for shaping future public health campaigns and educational curricula. Therefore, it becomes imperative to delve deeper into the complexities surrounding vaccine hesitancy within this group. The current research sought to comprehensively understand the multifaceted relationship among knowledge about vaccines, attitudes toward vaccination, and actual vaccination behaviors among teachers. By dissecting these interrelated variables, it aims to identify potential areas for targeted educational and policy interventions. These targeted strategies can bolster confidence in vaccines and have a ripple effect, strengthening public health measures and educational outreach in South Africa.

Table 7
Logistic regression predicting COVID-19 vaccination status.

Predictor	B	SE	Wald	Sig.	Exp(B)
Vaccine knowledge	0.012	0.015	0.617	.432	1.012
COVID-19 knowledge	-0.024	0.012	3.937	.047	0.976
Attitude toward COVID-19 vaccine	-0.930	0.170	29.753	<.001	0.395
Constant	3.779	1.301	8.435	.004	43.757

This table displays the results of a binary logistic regression examining how vaccine knowledge, COVID-19 knowledge, and attitudes toward the COVID-19 vaccine predict vaccination status. Each predictor was tested with 1 degree of freedom. B = unstandardized regression coefficient, Exp(B) = exponential value of B, which is the predicted change in odds for a unit increase in predictor, SE = standard error of B, Wald = Wald χ^2 test for significance of each predictor.

The current research found that many participating pre-service science teachers in South Africa reported receiving the COVID-19 vaccine. This finding echoes the larger patterns of vaccine uptake reported in the literature.^[12,14] It was also found that while general knowledge about the virus and its symptoms was high, gaps existed in comprehending the link between COVID-19 and SARS-CoV-2. This is aligned with prior work, such as Kabeta et al^[27] and Chen et al^[28] which reported high levels of COVID-19 understanding among teachers in Zambia and Malaysia, respectively. However, our findings diverge when examining misconceptions. A notable number of participants inaccurately believed that vaccines alter human deoxyribonucleic acid, contain microchips, or can cure diseases altogether. Contradictory to the high awareness levels, other literature indicates a prevalence of misconceptions. For instance, Debela et al^[29] documented misconceptions among Ethiopian teachers, while Isah et al^[30] showed that over half of teachers in Bangladesh held at least one false belief about COVID-19, influenced by socio-demographic factors and media exposure. The current study validates that teachers are generally seen as informed individuals^[4] but are not immune to harboring misconceptions about COVID-19. Given their role in community education, this is concerning and points to the risk of perpetuating misinformation. Addressing these knowledge gaps through multiple educational channels, including training programs and health authority consultations, is therefore imperative.

The present study contributes to understanding the association between knowledge of COVID-19 and vaccination status, particularly among teachers who are pivotal in health education. Our regression analysis substantiates that an in-depth understanding of COVID-19 significantly predicts one's likelihood of vaccination. Additionally, harboring misconceptions about vaccines inversely affects vaccination status. This corroborates prior research investigating factors affecting vaccine hesitancy, including demographic elements like age, income, and marital status.^[31,32] Furthermore, certain studies reveal that vaccine hesitancy is more prevalent among younger individuals, those with lower educational attainment, and specific political affiliations.^[33]

Interestingly, Fisher et al^[34] found that initially hesitant individuals were more likely to get vaccinated if they had higher educational levels, greater COVID-19 awareness, and a physician's endorsement. The current study reinforces the notion that a robust understanding of COVID-19, its risks, and benefits enhances the probability of vaccination. Thus, combating vaccine hesitancy necessitates a comprehensive approach, focusing on knowledge enhancement and dispelling myths. Public health campaigns that furnish precise information can play an instrumental role in fostering vaccine acceptance. Likewise, healthcare professionals are crucial in educating the public and addressing their vaccine-related concerns.^[35-38]

Our study aligns with existing literature in revealing a predominantly positive attitude towards COVID-19 vaccination among participants. Our regression models identify perceived behavioral control and behavioral beliefs as significant predictors of these attitudes. However, the models account for

a limited variance, implying the presence of other influential, unexplored factors. This observation is congruent with previous investigations into teacher attitudes toward COVID-19 vaccines. Racey et al^[15] reported a high intent to vaccinate among Canadian teachers.

In contrast, Xu et al^[19] identified a notable hesitancy among college educators in China, influenced by concerns over vaccine quality and perceived efficacy. Similarly, Chen et al^[10] highlighted that teachers' beliefs regarding vaccine safety and their engagement with vaccine-related news contribute to vaccine hesitancy. El Islami et al^[4] also suggest that an amalgamation of factors, including safe attitudes, subjective norms, perceived behavioral control, and behavioral and normative beliefs, underpin vaccine hesitancy among educators. While consistent with these studies, the findings underscore the complexity of attitudes toward COVID-19 vaccines, hinting at the necessity for a more comprehensive model for understanding vaccine acceptance and hesitancy.

5. Study limitations and recommendations for future research

While the statistical models used in this study offer valuable insights, we recognize the exploratory nature of this research and the limitations posed by the sample size. Rather than making definitive claims, the study's primary contribution lies in identifying key patterns and generating hypotheses for future, more powered investigations. This approach aligns with the broader aim of building foundational knowledge in an underexplored population of pre-service science teachers.

This study is not without limitations. First, using self-reported data through a closed-ended questionnaire could introduce potential response biases, including social desirability bias and inaccurate recall. Participants may have provided responses they believed to be socially acceptable or misremembered certain details, particularly regarding their vaccination status or beliefs about vaccines. This could have influenced the accuracy of the results, especially concerning sensitive topics such as vaccine hesitancy and misconceptions. Future research should triangulate self-reported responses with other data sources, such as vaccination records or follow-up interviews. This approach can enhance the accuracy and reliability of the findings, reducing the impact of biases like social desirability and inaccurate recall. Second, the study's cross-sectional design limits the ability to infer causal relationships between COVID-19 knowledge, attitudes, and vaccination status. In this regard, data were collected at one point in time, which prevents an examination of how these variables may change over time or how long-term exposure to health information might impact vaccine behavior. Future research should consider longitudinal studies to track knowledge, attitudes, and vaccination behavior changes over time. Lastly, the sample specificity, comprising pre-service Life Science teachers from a single South African university, limits the generalizability of the findings. Although the study provides valuable insights into this specific group, it may not reflect

teachers' experiences from different regions, educational backgrounds, or countries. Future research should aim to include more diverse populations to better understand vaccine attitudes and behaviors across different demographics. Expanding the research to include other professions could offer a broader perspective on vaccine hesitancy and acceptance.

6. Conclusions

The current research aimed to explore the intricate relationship between vaccination status, knowledge, and attitudes towards COVID-19 vaccination among pre-service science teachers in South Africa. The results offer a nuanced understanding that largely satisfies the objectives and answers the research questions posited at the onset. It was observed that there is a significant positive correlation between the level of knowledge of COVID-19 and vaccination status. This underlines the importance of adequate education in shaping vaccination behavior, satisfying the first objective and research question. Attitudes showed a broad spectrum but were generally favorable towards vaccination. However, pockets of vaccine hesitancy and misconceptions were identified, pointing towards areas where educational interventions could be particularly impactful, thus meeting the second and fifth objectives. Our analyses also revealed that trust in scientific authorities and personal experiences with COVID-19 were the most influential predictors for favorable attitudes towards vaccination, accomplishing the third objective. Interestingly, attitudes and knowledge had a positive but moderate correlation with vaccination status, addressing the fourth objective and highlighting the complex interplay among these factors. In summary, while knowledge and positive attitudes towards COVID-19 vaccination were generally high among pre-service science teachers, gaps and misconceptions need to be addressed through targeted educational programs. This research contributes to a better understanding of factors affecting vaccine uptake. It provides an empirical foundation for educational interventions designed to improve vaccination rates among future science educators in South Africa.

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