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The Influence of a Scientific Investigation Workshop on In-service Biology Teachers' Attitudes Towards Scientific Investigations

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ABSTRACT

Biology teachers' attitudes play a vital role in successful scientific investigations. Some biology teachers situated in the central part of South Africa experience challenges that include a lack of the necessary scientific knowledge and skills, which hinders the presentation of scientific investigations. These challenges adversely influence these biology teachers' attitudes towards conducting scientific investigations. The result is that they conduct the minimum number of investigations with their learners, or don't conduct them at all. Professional, in-service training workshops allow biology teachers to develop the necessary scientific knowledge and skills to successfully conduct scientific investigations. This study aimed to understand how a scientific investigation workshop affected biology teachers' attitudes by measuring the ABC attitude model's affective, cognitive and behavioural components. Likert-type, five-point scale items were used for the 20 pre-surveys and the same for the 20 post-surveys that were completed and collected for analysis. This research provided information on how vital in-service training programmes such as this scientific investigation workshop are in fostering positive attitudes toward scientific investigations amongst biology teachers. The findings that emerged from this study imply that implementing this scientific investigation workshop has developed biology teachers' confidence in their science skills and knowledge to facilitate scientific investigations. The findings also indicate that this workshop caused a significant improvement in teachers' intended behaviours in implementing scientific investigations in the science classrooms, as they gained valuable knowledge and skills regarding the science apparatus and the use thereof in conducting scientific investigations.

KEYWORDS

Attitudes; behaviours; in-service training; inquiry-based; scientific investigations; biology teachers.

INTRODUCTION

Scientific investigations play a vital part in learning and teaching biology; in fact, they are critical for theory to be brought to life (Isozaki, 2017). Kambaila et al. (2019) posit that investigations in the science classroom can contribute to learners' appreciation of science, promote exploration and manipulation, and develop concepts. Educators and researchers have studied the value and importance of scientific investigation work since the beginning of the 18th century. According to Sshana and Abulibdeh (2020:199), studies have found that practical work offers advantages such as improving laboratory skills and scientific knowledge, and promoting an understanding of science theories and concepts.

Scientific investigations are processes of asking questions and testing possible answers through experiments, observations or dissections (Kambaila et al., 2019). These hands-on activities provide practical experience through which learners and teachers develop scientific skills (Kambaila et al., 2019). Sshana and Abulibdeh (2020, 199) and Heeralal (2014, 796) state that learners design better investigations when they conduct the scientific investigations themselves instead of observing or taking notes while others undertake investigations. Learners and teachers achieve a deeper level of comprehension by experimenting with different techniques and methods as they make discoveries themselves.

Scientific investigation activities also promote positive attitudes and motivate the effective learning and teaching of a science subject (Okam & Zakari, 2017). Positive attitudes toward scientific investigations might affect teachers' and learners' achievements in science (Hinneh, 2017).

Not much appears to have changed in biology teachers' practices, despite 21st-century classrooms being better equipped with technology and laboratory equipment. Current teaching follows a traditional step-by-step approach in which learners spend most of their time passively taking notes, working on worksheets and listening to the teacher (Constantinou, et al., 2018).

Many South African biology teachers (where the subject is named "life science"), unenthusiastic about experiments, limit the number of scientific investigations their learners perform (Mwangu & Sibanda, 2017). Although some South African biology teachers have access to the necessary laboratory equipment and resources, they have not acquired the essential knowledge and skills required to conduct scientific investigations with their learners (Ramnarain & Hlatswayo, 2018). Research conducted in the Gauteng province of South Africa a number of years ago revealed that only a few teachers involved their learners in scientific investigations because the teachers lacked confidence (Heeralal, 2014).

Mogofe and Kibirige (2017, 426) state that science is incomplete without practical application, which is why science syllabuses worldwide emphasise learners' involvement in scientific investigations. European countries such as the Netherlands, Romania, France and Ireland work under the umbrella of Science Education to Develop European Citizenship (SEDEC). This project has focused on evolving learners' scientific process skills by integrating scientific investigations into their lessons (Kibirige et al., 2022; Mogofe & Kibirige, 2017)

It seems that scientific investigations contribute to effective science learning, and therefore a variety of cognitive and scientific skills should be taught in the biology classroom (Okam & Zakari, 2017). South Africa's Department of Basic Education states in the biology Curriculum and Assessment Policy Statement (hereafter CAPS LS) that teachers must conduct scientific investigations with their learners to enhance their scientific skills.

According to studies, numerous countries, especially developing countries, have difficulty implementing scientific investigations effectively (Cossa & Uamusse, 2015). Cossa and Uamusse (2015, 154) argue that the reasons for this include a shortage of the necessary equipment and laboratory materials, problems with the safe disposal of the chemicals and tools, inadequate conditions, a lack of financial resources, poor preparation by the teachers, and most significantly, teachers' lack of scientific knowledge and skills.

Teachers' attitudes towards investigations must be positive when teaching a scientific subject (Cossa & Uamusse, 2015). Kibirige, Teffo and Singh (2022,9) and Mogofe and Kibirige (2017,427) argue that, as in many countries, South Africa's scientific investigation work is failing because of teachers' negative attitudes.

Teachers' lack of scientific skills, knowledge, and resources and conducive laboratory environments (Heeralal, 2014) lead to their being unenthusiastic about performing scientific investigation work or to doing so sparingly because of the unavailability of resources and lack of motivation. The teachers regard the practical part of the subject as not being as vital as the theoretical part; this does not promote positive attitudes towards scientific investigations in general (Cossa & Uamusse, 2015).

According to Omeodu and Amadi (2018, 2), science teachers are often perceived as lifelong learners because their scientific knowledge continues to develop, and they require support and opportunities to develop their professional education. In-service training workshops can present such opportunities. They are programmes that provide opportunities for teachers to develop their knowledge and skills, and to learn about the new developments in their area of expertise (Omeodu & Amadi, 2018). A study conducted in China found that in-service training and workshops lead to teachers' development and that teachers need regular training to develop their profession and foster positive attitudes toward their occupation (Donkor & Banki, 2017).

This research centred on one such professional development programme, designed by the Faculty of Education at the University of the Free State, situated in Bloemfontein, central South Africa. This professional development programme (workshop) aims to offer biology teachers the opportunity to advance and develop their scientific investigation knowledge and skills by integrating experiential activities. This study also aimed to examine biology teachers' attitudes towards scientific investigations before and after the workshop to determine its effect on those teachers' attitudes. We shall now present the theoretical foundation which underlies this study.

Attitude theory

According to Ukachukwu (2016, 24–29) and Drew (2021, 1), attitudes are defined as evaluation statements, unfavourable or favourable, concerning objects, people or events. In this context, one can evaluate a situation positively (happy and comfortable) or negatively (unsatisfied and uncomfortable). One's attitude is also linked to the readiness of the psyche to react and act in specific ways (Ramnarain & Hlatswayo, 2018; Vishal, 2014)

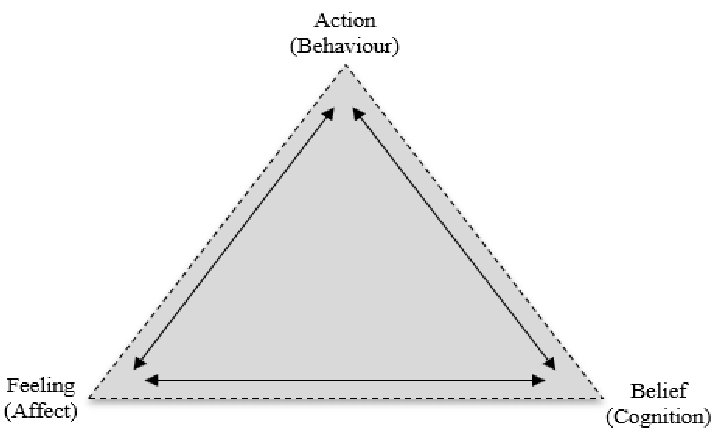
Vishal (2014, 1) posits that an attitude originates from an individual's world encompassed of other people, physical objects, different behaviours and policies. How individuals react to their environment determines their attitudes (Drew, 2021): attitudes are responses associated with mental state which affect interactions with an environment (Karim et al., 2017).

An individual's attitude can be a negative or positive perception, or a mental state of readiness to cope with a situation, person or object (Ukachukwu, 2016). This study argues that experience and the world in which some biology teachers find themselves define their attitudes and how they perceive the presentation of scientific investigations.

The ABC model of attitudes (see Figure 1) describes attitudes and the components thereof (Mzomwe, 2019; Vishal, 2014). It supports the comprehension process of an attitude and how attitudes affect everyday life (Mzomwe, 2019; Vishal, 2014) and is also one of the models cited most often when discussing attitudes (Vishal, 2014). This model proposes that attitudes comprise three main components: affective, behavioural and cognitive. Understanding these three components will aid in comprehending teachers' attitudes toward scientific investigations, and why they feel reluctant to conduct such investigations (see Figure 1).

Figure 1.

Components of an attitude, where the arrows indicate the mutual interactions between the components.



Sources: Drew (2021, 5) and Ukachukwu (2016, 28).

The cognitive component (see Figure 1) comprises one's beliefs; it also refers to an individual teacher's thoughts (Mzomwe, 2019; Vishal, 2014). Teachers' thoughts are deemed a crucial aspect of the cognitive component and are conveyed as either negative or positive observations held by teachers towards objects or situations, such as the facilitation of scientific investigations (Ukachukwu, 2016). However, it is essential to understand that individuals' attitudes concerning an object cannot be described by solely classifying their beliefs and thoughts, as feelings operate simultaneously with the cognitive process (Mzomwe, 2019; Vishal, 2014).

The affective component (see Figure 1) describes a person's (teacher's) emotional feelings. It reflects how one feels about something particular: disliking or liking it (Mzomwe, 2019; Vishal, 2014). In our study, the affective component referred to teachers' feelings about conducting scientific investigations in biology classrooms. Some teachers might feel they lack the relevant knowledge and skills to conduct scientific investigations (Kambaila, et al., 2019; Heeralal, 2014). Gecer and Zengin (2015, 144) posit that numerous challenges faced by biology teachers contribute to the reason teachers feel they cannot lead scientific investigations. According to Ukachukwu (2016, 26), when teachers cultivate negative feelings, such as self-doubt, towards any part of a subject, it significantly affects their behaviour (see Figure 1).

The behavioural component (see Figure 1) is the overt or verbal tendency that comprises observable responses and actions (Vishal, 2014). This component encompasses an individual's (teacher's) decision (unfavourable/favourable) to act (Ukachukwu, 2016). An example that illustrates the interaction between the three components of attitude is the positive/negative emotion or feeling an individual develops towards a particular situation. For example, the test for the presence of glucose in food might be seen as one such situation, and biology teachers who do not know how this experiment is conducted and/or do not have the necessary skills to use apparatus such as a Bunsen burner might cultivate negative feelings or feelings of uncertainty. The affective component influences the cognitive component: what the teachers think and believe. Teachers may believe that they are unskilled and think that they are not able to conduct a particular experiment successfully, which in turn influences the behavioural component, that is, how they behave. Teachers might then refrain from performing the test-for-glucose experiment and resort to showing their learners video clips of how the experiment is performed, or they might read through the experiment activity in the textbook (Ukachukwu, 2016).

It could be argued that one of the foremost obstacles to conducting scientific investigations in biology classrooms is teachers' attitude that they lack the necessary knowledge and skills, meaning that they make a cognitive decision to avoid presenting such investigations, resulting in that teacher using a lecture- or textbook-based teaching approach to scientific investigations.

Based on the above, we formulated our primary and secondary research questions.

Primary research question

What influence will a scientific investigation workshop have on biology teachers' attitudes toward scientific investigations?

Secondary research questions

- What effect will a scientific investigation workshop have on the affective component of biology teachers' attitudes?
- What effect will a scientific investigation workshop have on the behavioural component of biology teachers' attitudes?
- What effect will a scientific investigation workshop have on the cognitive component of biology teachers' attitudes?

METHODS

Research paradigm

The positivist paradigm informed the research design. Positivism focuses on the scientific research method and embodies a realist orientation (Okwara, 2021). According to Wang (2020, 725), positivists believe in objectivism and claim that knowledge exists independently of people's consciousness and experiences. Wang (2020, 725) states that researchers use the positivism paradigm because they believe that objective truth and meaning can be obtained and measured through scientific research. Okwara (2021, 98) states that positivist research has a realist orientation and focuses on scientific research methods.

Bloomfield and Fisher (2019, 27) argue that it is difficult for a researcher to observe a world of which they are a part and maintain an objective view. They suggest that a researcher can remain objective by using reliable, standardised measuring instruments to collect data, as they cannot otherwise completely detach themselves from the research (Bloomfield & Fisher, 2019). Consequently, we designed the standardised pre- and post-survey and controlled the items for use in the surveys.

Implementing the pre-experimental design in this study helped us control external factors that might impact the research outcomes and validity (Okwara, 2021) by keeping situational factors such as the location, and time of day in mind when setting up the scientific investigation workshop, as such factors can affect external validity (Cuncic, 2021). This study adopted a field-experiment setting, which is a study conducted in a natural setting, in this case, a biology laboratory at a secondary school in Bloemfontein, South Africa.

Research methodology

The quantitative research design is often used in educational and social research. The main features of the quantitative design, as implemented in this study, are to test theories to establish a connection between the dependent (possible change in the biology teachers' attitudes towards scientific investigations) and the independent (scientific investigation workshops) variables (Morgan, 2017). The quantitative research methodology was best suited for this study as it aims to explain phenomena through the collection of numerical data which is then analysed using a statistical method (Boru, 2018). The design of this study emphasised objectivity through constructs that can be measured, so the results obtained in the study did not depend on beliefs alone (Morgan, 2017).

As this study aimed to describe variables, test relationships and explore cause-and-effect relationships, we followed the quantitative, pre-experimental research design (Okwara, 2021). The pre-experimental design facilitated the establishment of a connection between the intervention (the use of biology investigation workshops) and the possible outcomes, a potential improvement in the teachers' attitudes towards scientific investigations.

The research methodology also defined the research procedure and the instruments used to obtain data (Ukachukwu, 2016). In this study, standardised pre- and post-surveys were employed as the research instruments. This research methodology ensured objectivity and the possibility of generalising the results to a broader population.

Population

The population is the group to which the research findings can be applied, defined as the target group from whom the researcher wishes to generalise (Shukla, 2020; Babbie, 2020). The population for this research were secondary-school biology teachers in the Free State Province of South Africa.

Sample

A total of 20 participants were involved in this study. All were secondary-school life science teachers, nine females and 11 males. Among them, 10 possessed a bachelor's degree in Life Science Education, three held a BED Honours bachelor's in education, and seven attained a B.Ed. Honours in a different field with a PGDE. Regarding experience, 12 participants had 0–5 years, three had 6–10 years, while one had each of 21–25 years, 16–20 years, and 26–30 years. Additionally, two participants boasted more than 30 years of experience. This diverse pool of participants offered a comprehensive perspective for the study's findings.

Research design

We employed the one-group pretest–posttest pre-experimental design. Participants received thae pre-survey prior to the biology scientific investigation workshop (the independent variable). The same group received a post-survey to complete after their exposure to the independent variable. These surveys were used to evaluate whether there was any change in the dependent variable (biology teachers' attitudes toward scientific investigations). Using the pretest–posttest pre-experimental design decreases the possibility that a factor other than the independent variable (the workshop) might cause a change in the teachers' attitude between the pre-test and post-test results (Babbie, 2020).

This study adopted the pre-experimental research design because conditions for a full-fledged experimental design were not favourable (Babbie, 2020). An invitation was sent to biology teachers in the Free State province to attend the registered workshop, where they could develop their scientific investigation knowledge and skills. Since only 20 of the teachers eligible responded and attended the one-day workshop, we decided against implementing the experimental design because randomised sampling would require that the participants be divided into two groups, one of which would be the control group and therefore not receive the same experience and training as the intervention group (Babbie, 2020). There were not enough biology teachers to apply a full experimental design. This is identified as a limitation of the current research and should be addressed in follow-up studies.

Data collection

Asenahabi (2019, 79) states that an attitude survey is a research instrument that offers a numeric explanation for attitudes, trends or beliefs by studying a sample population. Surveys are also data collection tools used to gather participants' responses to open- and closed-ended questions or items; these responses are easily translated into statistics for further analysis (Asenahabi, 2019; Kabir, 2016).

After designing the surveys, we approached a senior lecturer, the coordinator for the University of the Free State's statistical and consultation unit, to review the pre- and post-surveys used for this study. We also collaborated with field experts by performing a pre-test with the survey questions before administering the survey. One suggestion was that the researcher incorporate language more familiar to the target group instead of language used in a scientific setting. It was also advised that each participant be assigned a number to be used to link pre-survey with post-survey results for comparison so that differences could be detected. We ensured that there was consistency in the survey items between the pre-and post-surveys, which also maintained reliability.

In a pilot study, the first author asked five biology teachers that she knew to participate to ensure that the survey items were relevant to biology teachers and did not contain ambiguous questions (Babbie, 2020). According to Fraser, Fahlman, Arscott and Guillot (2018, 263), a researcher runs a pilot study to assess the clarity of the items used in the official research study, ensuring that the instrument is reliable and valid within the educational setting before undertaking the main study.

A Likert-type, five-point scale was used for the 20 pre-surveys and the same for the 20 post-surveys completed and collected for analysis. The participants were assured that their names and their schools' names would remain anonymous

The first part of the survey was divided into four sections and included a Likert-type scale to collect data about the teachers' attitudes towards their knowledge and skills in scientific investigations by choosing from the available options, namely strongly disagree, disagree, neither agree nor disagree, agree, strongly agree (McLeod, 2019).

Section A of the survey contained items concerning the affective component of the ABC attitude model which covered items that focused on emotions and feelings concerning a particular subject (Mzomwe, 2019; Vishal, 2014). Section B focused on items concerning the cognitive component (see Figure 1), which included the teachers' thoughts (Mzomwe, 2019; Vishal, 2014). Section C, the third section, contained items related to the behavioural component (see Figure 1), the tendency that comprises noticeable responses and actions (Vishal, 2014). This component included a teacher's decision to take action (Ukachukwu, 2016).

The fourth section of the survey harvested biographical data about the participants. According to Teelaw, et al. (2012, 281), placing the biographical questions at the end of a survey is advantageous as it might help the researcher to build rapport with the participants before encountering the "mundane" items. The biographical data in this case focused on the highest level of education that the teacher had achieved and the number of years they had been teaching biology, which was used to link to the responses to the survey items. The researcher used this data to ascertain if these aspects correlated with the participant's responses to the first part.

The workshop

This in-service training workshop, designed and presented by the second author, focused on scientific investigations in biology required by CAPS (the biology curriculum of South Africa) to be completed with learners in secondary schools. The workshop was approximately six hours in duration on a Saturday in May 2022 from 08: am to 14:00.

This workshop was structured around the inquiry-based teaching method. The teachers were guided to investigate scientific problems, explore possible solutions, observe, ask questions, test their ideas, and use their intuition to think creatively (Bulba, 2021; Constantinou et al., 2018). Inquiry-based science teaching focuses on performing science and, therefore, biology teachers must understand the significance of facilitating inquiry-based lessons (Kibirige, et al., 2022; Constantinou et al., 2018; Bulba, 2021).

Exploratory conversations are crucial in an inquiry-based approach to improve scientific reasoning and formulation; therefore, the teachers had the opportunity to engage in discussions and to collaborate throughout the workshop. Collaboration and communication can be addressed in the science classroom by assigning different responsibilities and roles to the learners during group activities and by collectively sharing findings and ideas (Alozie & Mitchell, 2019). The teachers were asked to arrange themselves in four groups of five teachers to collaborate and discuss their findings throughout the workshop in an informal group structure: teachers had the choice of who they would like to be in a group with.

Teachers had the opportunity to undertake different roles in their group during the workshop (see Figures 2 and 3). For instance, one teacher took responsibility for investigating, with the support of other group members, while another took the role of writing up the findings, and a third was responsible for presenting their findings to the other groups. In the next investigation, the teachers changed roles and responsibilities, ensuring that they could experience all the aspects of investigations. Socialising in the science classroom can support teachers in communicating openly, as they need to explain clearly their actions and decisions to their class (van Uum et al., 2016).

Figures 2 and 3.

Participants performing scientific investigations in groups.

Table 1.

Scientific investigations performed during the workshop.

Tests	Demonstration	Dissection
Test for the presence of glucose.	Demonstrate the phenomenon of osmosis in animal cells.	Dissect an eye.
Test for the presence of starch in a leaf.	Investigate the effect of different solution concentrations on the length, mass, osmotic potential and turgor of potato tissue.	Investigate a mammal's kidney through dissection.
Test for the presence of protein.	Prepare a wet mount of an animal cell.	Investigate a sheep's heart through dissection.

Test for the presence of lipids (fats, including oils).	Investigate the phenomenon of plasmolysis by ex-osmosis. Investigate the rate of transpiration of a plant under different environmental conditions with a photometer.	

The teachers received a workbook containing the biology investigation experiments to be conducted during the workshop. This workbook guided the teachers through each experiment, explaining the method, apparatus and steps. Each experiment had follow-up questions that guided the teachers to investigate, explain what they had observed and reflect on what they had found. These activities included experiments, microscope work and dissections (see Table 1).

RESULTS

The results of the pre- and post-surveys are presented in this section. The gender distribution of the participants in this study was nine females and 11 males. Ten had a B.Ed. degree with biology as their main subject, three had a B.Ed. Honours degree, and seven of the 20 participants had bachelor's degrees in another field with a post-graduate diploma in Education (PGDE). The participants were also asked to indicate the number of years that they had been teaching.

Of the 20 participants, 12 indicated that they had 1–5 years of teaching experience; three had 6–10 years of experience; no participants had 11–15 years of experience; one had 15–20 years of experience; one had 21–25 years of experience; one had 26–30 years of experience and two indicated that they had more than 30 years of teaching experience. This study did not contain any form of bias, as Simundic (2013, 13) indicated that a study should include all age groups, male and female participants, and participants with various years of experience in different schools.

We chose to analyse the three components of attitudes (cognitive, affective and behavioural) separately to facilitate an understanding of each component of teachers' attitudes toward scientific investigations (see Figure 1 earlier) and how the components influence one another. The results are discussed according to these components, in line with the secondary research questions.

Descriptive statistics encompassing the count, mean, standard deviation, and minimum and maximum for demographical measures related to age, years of experience and qualifications were implemented (Loeb, et al,. 2017). For each Likert scale statement, a t-test was performed to test the null hypothesis, where the mean differences between the paired data were considered significant when the results were less than or equal to the alpha set or *p* value of 0.05. The Holm-Bonferroni method was applied.

By cross-referencing the responses to the demographic items, the assumption was made that the expected number of responses in every category (agree, disagree, etc.) was not affected by the demographic factors (Loeb et al., 2017).

We also analysed the data by calculating the probability of seeing differences in the categories as large as, or more significant than, observed under the assumption. If this probability was small, the conclusion was that there was evidence of grouping and dependence. However, no significant statistical difference was found, so it was assumed that no further discussion was needed.

Discussion of the items measuring the affective components of the biology teachers' attitudes

These results are presented in Table 2 (see appendix).

Not all the item results in Section A were significant, so no further discussion is required. For instance, if one analyses item 3, *Practical work is important in teaching science*, there was no statistically significant improvement in the post-survey response compared to the pre-survey. The average increased by 0.15 from 4.7 to 4.85 (p value 1). We concluded that teachers knew the importance of practical work in teaching science before attending this workshop.

A similar conclusion was made in the other items with p values > 0.05. We concluded that this scientific investigation workshop did not have a statistically significant effect on the participants' feelings regarding motivation to teach scientific investigations. The results also indicated no statistically significant improvement in teachers feeling that scientific information is gained through experimentation. These results similarly indicated no statistically significant change in teachers' feelings that practical work is important in teaching science and that tactile modes are the best way to understand science content.

In contrast, in item 4, *I enjoy carrying out scientific investigations,* one can see a statistically significant difference when comparing the average of the pre-survey result, (4), to the average of the post-survey result, which increased by 0.8 to an average of 4.8 (p value 0.019, < 0.05), meaning that the participants enjoyed carrying out scientific investigations more after than before they had attended this workshop.

As the results for items 4, 8, 10 and 18 in Table 2 all showed p values < 0.05, one can assume with 95% certainty that there were statistically significant differences in the before and after workshop responses to these items.

Since in-service training programmes are personal and professional opportunities for teachers to improve their teaching, facilitation, knowledge and skills, their enjoyment might also improve. The biology teachers who attended this workshop had an opportunity to develop new skills and knowledge regarding specific investigation activities that might have improved their motivation and perceptions regarding scientific investigations (Zulkifli, 2014).

The results of item 8 indicate that, after the workshop, there was a statistically significant increase in the respondents' perceptions concerning their skills to facilitate a scientific investigation, as the average increased by 0.6 from 3.9 to 4.5. The t-test indicated that the observed difference between the two groupings was statistically significant (p = 0.036, p value < 0, 05); therefore, we rejected the null hypothesis and concluded that the workshop caused a statistically significant improvement in the participants' perceptions of their science skills.

The findings signify that attending this scientific investigation workshop developed the biology teachers' confidence in having the necessary science skills to facilitate scientific investigations. Therefore, the conclusion can be made that learning and improving scientific investigation skills through in this workshop contributed significantly to biology teachers having positive attitudes toward scientific investigations.

The results of item 10 indicate an increase in the perception of support from colleagues during this scientific investigation workshop, as the average increased by 1.55 from 2.9 to 4.45. The t-test indicated that the difference between the two groupings was statistically significant (p =.002); therefore, the null hypothesis was rejected, and a conclusion reached that the workshop did cause a significant improvement in the teachers' perceptions about being supported by colleagues. It can, therefore, be assumed with 98.2% certainty that there was a statistically significant difference in their perceptions about being supported by their colleagues during and after this workshop, as the p value was < 0.05.

These findings seemingly support Nursianawati and Winarno's (2019, 840) statement that collaboration among biology teachers can enable them to discover new strengths and weaknesses, and work together to encourage, support and learn from one another. The findings also seem to align with Harman, et al. (2016), who argue that cooperative learning activities might encourage teachers to learn from one another.

The results of item 18 indicate an increase in the affective component of the participants' attitudes towards having sufficient content knowledge to conduct scientific investigations after the workshop. The average increased by 0.94 from 3.62 to 4.6. The t-test indicated that the observed difference between the two groupings was statistically significant (p = 0.021, p value < 0. 05); therefore, the null hypothesis was rejected, and we concluded that the workshop caused a significant improvement in the participants' content knowledge. The findings imply that educational experiences, such as this biology scientific investigation workshop experience, might positively influence teachers' perceptions regarding their content knowledge. It was observed that the teachers did indeed share their content knowledge with each other.

Kibirige, et al. (2022, 2) and Mwangu and Sibanda (2017, 48) state that some South African biology teachers do not have the necessary knowledge to conduct scientific investigations successfully, which might explain why they are unenthusiastic about the practical part of biology. The findings seem to support Zulkifli's (2014) statement that in-service training programmes can improve teachers' knowledge of scientific investigations, and that attending in-service workshops might play a part in overcoming the challenges encountered in the classroom.

It seems fair to conclude that scientific investigation workshops can enhance some of the affective components of teachers' attitudes, where numerous changes in their emotional states were found in the post-survey compared to the pre-survey. However, to determine if the teachers' overall attitudes improved after attending the workshop, it was necessary to also analyse the cognitive and behavioural components of their attitudes.

Discussion of the cognitive component (section B of the attitude survey)

These results are presented in Table 3 (see appendix).

Not all item results in section B were significant, so required no further discussion. For instance, item 6, *I know all the scientific method steps.* There was no statistically significant improvement in the post-survey responses compared to the pre-survey responses. The average increased by 0.5 from 3.55 to 4.05 (p value 1 > 0.05). Therefore, we concluded that the teachers knew the scientific method steps before participating in this workshop.

In contrast, the responses to item 8, *I know the function of each chemical used in scientific investigations prescribed in CAPS*, indicated a statistically significant difference when comparing the pre-survey average (3.4) to the post-survey average of 4.25, an increase of 0.85 (p value 0.009, < 0.05). According to this data, the teachers gained more knowledge of the chemicals used in scientific investigations during this workshop.

As the p values for items 1, 2, 8 and 11 were < 0.05, one can assume with 95% certainty that there were statistically significant differences in the responses before and after the workshop.

The results of item 1 indicate an increase in the teachers' perceptions concerning learning scientific investigation skills when working with other biology teachers, as the average increased from 4.05 to 4.65. The t-test indicated that the observed difference between the two groups of responses was statistically significant (p = 0.036); therefore, the null hypothesis was rejected, and a conclusion was reached that the workshop caused a significant improvement in the cognition of these teachers' scientific investigation skills when working with other biology teachers.

The results of item 2 indicate that, after the workshop, there was more positivity in the teachers' perceived ability to conduct the scientific investigations required by the CAPS curriculum, as seen in the average increase from 3.4 to 4.3. The t-test indicated that the detected difference between the two groups was statistically significant (p = 0.015, p value < 0.05); therefore, the null hypothesis was discarded, and a conclusion was made that the workshop caused a significant improvement in the teachers' perceived knowledge about how to conduct scientific investigations.

The teachers who participated in this scientific investigation workshop had the opportunity to work with the basic science equipment necessary to conduct scientific investigations with their learners. Kibirige, et al. (2022, 9) stated that a lack of resources might also hinder the demonstration of scientific investigations. During this workshop, the teachers received a basic set of scientific equipment that could be used during the workshop activities and in their classrooms. Teachers who might not have been able to utilise this equipment successfully before had the chance to such acquire knowledge and skills.

The results of item 11 indicate that, after the workshop, there was a statistically significant increase in the teachers' perceptions of their ability to formulate a hypothesis for a scientific investigation, as the average increased from 4.15 to 4.6. The t-test indicated that the observed difference between the two groupings was significant ($p = 0.036, < 0.05$); therefore, the null hypothesis was rejected, and a conclusion was made that the workshop caused a significant improvement in the teachers' perceptions about their ability to formulate a hypothesis for a scientific investigation.

A hypothesis can be defined as a proposed explanation for a phenomenon based on limited evidence that serves as a starting point for further investigation (Anupama, 2018). As this workshop incorporated the inquiry-based teaching approach, participants were required to apply their science process skills during the investigations, including the creation of a hypothesis. Creating a hypothesis is crucial in understanding the relationship between two variables; it guides teachers through the inquiry process, as it provides them with the plan to test their presumption by applying their newly acquired skills and knowledge (Anupama, 2018).

Discussion of the behavioural component (Section C)

Mzomwe (2019, 210) stated that the behavioural component contains an individual's decision or intention to act. As mentioned earlier, the three components of the attitude theory do not function independently, but in an integrated manner. The affective component can influence the cognitive component, which can influence the behavioural component. Since statistically significant improvements in aspects of the participants' cognitive and affective components were observed, it seems reasonable to expect a similar improvement in the behavioural component.

This section aligns with answering the last secondary research question, namely whether the workshop would influence the behavioural components of the biology teachers' attitudes. These results are presented in Table 4 (see appendix).

When considering the results in this section, it should be pointed out that it did not measure or determine the actual behaviour of the participants, but only the *intended* behaviour. As such, we would be the first to admit that the statistically significant improvements in no less than eight of the twenty sections in this section should be considered and interpreted with caution. We also recommend a follow-up study at the schools where the participants teach. This would determine the extent to which the intended changes in behaviour have indeed occurred.

The responses to item 3, for example, *I will use scientific apparatus to perform experiments,* indicated a statistically significant difference between the average of the pre-survey responses, (3.4, an increase of 1.05) and the average of the post-survey responses of 4.45 (p value 0.019, which is < 0.05). The data in this item, teachers' behaviour, includes the use of scientific apparatus when performing experiments after attending this workshop.

Further discussions concerning items 1, 3, 4, 5, 8, 13, 18, 20 is warranted. As the p values of all eight items were < 0.05, one can assume with 95% certainty that there was a statistically significant difference in the responses before and after the workshop.

The results of item 1 also indicate a statistically significant increase in the teachers' possible behaviour regarding the demonstration of scientific investigations to their learners after attending this workshop, as the average increased from 3.5 to 4.5. The t-test indicated that the observed difference between the two groupings was significant (p = 0.023, p value < 0.05).

In view of the above, the participants showed statistically significant improvements in the following:

- They intended to perform more demonstrations of scientific investigations for their learners.
- They intended to make more use of scientific apparatus to perform experiments.
- They intended to create more opportunities for their learners to participate in scientific investigations.
- They intended to attend more in-service training workshops.
- They decided to include more preparation time for practical classes in their schedules.
- They would allow their learners to be more actively involved when presenting scientific investigations.
- They would perform more reflections with their learners at the end of scientific investigations.
- They would conduct more scientific investigations in their laboratories.

We regard this as encouraging and significant progress. According to Zulkifli (2014, 1), in-service training workshops are opportunities for teachers to learn, develop and improve the science skills and knowledge they are required to transfer to their learners in the classroom. Teachers need to use scientific knowledge and skills in science lessons when they demonstrate investigations such as experiments and dissections. According to Constantinou, et al. (2018, 2), the inquiry-based teaching method emphasises the process of performing science; thus, teachers should understand that it is vital to demonstrate scientific investigations in lessons rather than using the lecture-style teaching method. This occured during the workshop. The data presented in this study correlates with the above-mentioned discussion. The findings of this study signify that, after attending the workshop, the teachers were more willing to attend in-service training workshops where they could improve their scientific knowledge and skills. According to Zulkifli (2014, 1), attending workshops is crucial for improving the quality of science education. Teane (2019) supports this statement and urges teachers to participate in workshops to enhance their skills and knowledge, which encourages positive attitudes and assists in overcoming challenges.

This study is in line with Boslisani and Bratianu’s (2018) assertion that knowledge and skills lay the foundation for performing scientific investigations. According to Kassema (2019, 5), teachers first need to gather knowledge regarding the apparatus during workshops and develop and practice their skills in utilising the apparatus thereafter. Throughout the workshop, the teachers learned about the different apparatuses and related experiments, and they had the opportunity to use them to practice their skills. The findings presented in this study support the conclusion that workshops can lead to significant improvement in teachers’ intended behaviours concerning implementing the use of scientific apparatus in the classroom, as they gain valuable knowledge and skills regarding the equipment.

SUMMARY

This study's results show a connection between the biology teachers' attitudes and the scientific investigation workshop. Teachers' attitudes toward scientific investigations are informed by their perceptions, feelings, and intended behaviour concerning their scientific investigations knowledge and skills. Positive attitudes can enhance teachers' confidence when conducting scientific investigations with their learners in the science classroom and can be developed through acquiring the necessary scientific skills and knowledge.

It seems fair to conclude that the inquiry-based teaching approach implemented during this workshop generated positive attitudes amongst the participants; they indicated that they developed their science skills and knowledge through collaboration with other biology teachers during the workshop in which they were actively involved. They had the opportunity to use scientific equipment to carry out investigations, supporting the notion that the hands-on approach accompanied by the inquiry-based teaching method successfully enhances confidence and encourages positive attitudes. However, we recommend that a workshop such as this one be conducted over several days to provide more time for reflection and discussion amongst the participants; This might also help with the teachers' memory retention and comprehension of newly acquired scientific knowledge and skills.

It has become necessary for biology teachers to attend regular biology scientific investigation workshops to remain current with scientific developments, develop skills, and have opportunities to collaborate with and learn from one another. Professional development programmes such as this in-service training workshop are a strategy that can be used to support teachers in acquiring the necessary scientific skills and knowledge to successfully demonstrate and engage in scientific investigations with their learners. However, to truly measure this scientific investigation workshop's success, future researchers might find it valuable to continue data collection with the learners in the classrooms of the life science teachers who have attended the workshop. This would ascertain whether the positive change in the teachers' attitudes is carried over and implemented in their science classrooms with their learners.

A qualitative research method might also be added to the surveys for a more comprehensive study, since relying solely on a Likert-type survey can be limiting: it offers a finite number of response options, which could potentially restrict respondents from expressing nuanced opinions or feelings. By incorporating interviews as a qualitative data collection method, we believe the research can be improved.

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APPENDIX

Table 2.

The results from Section A: The affective component of the ABC attitude model.

Survey questions	Pre-survey	Post-survey	Difference
1. I am motivated to teach scientific investigations.			
Average	4.05	4.7	0.65
StdDev	0.999	0.571	0.933
t-test (*p* value)			0.183
2. Scientific information is gained through experimentation.			
Average	4.55	4.75	0.2
StdDev	0.686	0.444	0.696
t-test (*p* value)			1
3. Practical work is important in teaching science.			
Average	4.7	4.85	0.15
StdDev	0.923	0.366	1.04
t-test (*p* value)			1
4. I enjoy carrying out scientific investigations.			
Average	4	4.8	0.8
StdDev	0.795	0.523	0.834
t-test (*p* value)			<u>0.019</u>
5. Tactile modes are the best to understand science content.			
Average	4.05	4.4	0.35
StdDev	0.759	0.681	0.813
t-test (*p* value)			1
6. Professional development workshops developed my scientific investigation knowledge.			
Average	4.25	4.8	0.55
StdDev	1.333	0.41	1.356
t-test (*p* value)			1
7. I have enough science resources for scientific investigations.			
Average	2.45	3.6	1.15
StdDev	1.234	1.046	1.565
t-test (*p* value)			0.136
8. I have the science skills to facilitate a scientific investigation.			
Average	3.9	4.5	0.6
StdDev	0.553	0.607	0.681
t-test (*p* value)			<u>0.036</u>

9. Reflection is a valuable part of scientific investigations.			
Average	4.2	4.4	0.2
StdDev	0.894	0.681	1.005
t-test (*p* value)			1
10. My colleagues support me in scientific investigation lesson-planning.			
Average	2.9	4.445	1.55
StdDev	1.252	0.945	1.317
t-test (*p* value)			0.002
11. Inquiry is a successful method of gaining scientific investigation skills.			
Average	4.55	4.5	-0.05
StdDev	0.605	0.513	0.605
t-test (*p* value)			1
12. Professional development workshops develop my scientific investigation skills.			
Average	4.25	4.7	0.45
StdDev	1.02	0.571	1.146
t-test (*p* value)			1
13. My pre-service course prepared me to perform scientific investigations at a high school level.			
Average	4.2	4.2	0
StdDev	1.056	0.696	0.918
t-test (*p* value)			1
14. Life Science is best taught through a lecture-style teaching method.			
Average	2.65	2.8	0.15
StdDev	1.182	1.105	1.089
t-test (*p* value)			1
15. Oral questioning is enough when developing learners' inquiry.			
Average	2.75	2.7	-0.05
StdDev	1.209	1.455	1.504
t-test (*p* value)			1
16. Our laboratory is used as a storeroom for science materials.			
Average	3.25	3.45	0.2
StdDev	1.41	1.05	1.281
t-test (*p* value)			1
17. Group work amongst learners is important when performing scientific investigations.			
Average	4.15	4.6	0.45
StdDev	1.182	0.821	1.468
t-test (*p* value)			1

18. I have enough content knowledge to conduct scientific investigations.			
Average	3.632	4.6	0.947
StdDev	1.012	0.503	0.97
t-test (*p* value)			0.021

Notes: p *value 1.*

Table 3.

Results of the items measuring the cognitive components of teachers' attitudes.

Survey Questions	Pre-Survey	Post-Survey	Difference
1. I learn scientific investigation skills when working with Life Science teachers.			
Average	4.05	4.65	0.6
StdDev	0.826	0.489	0.681
t-test (*p* value)			0.036
2. I know how to conduct all scientific investigations required in CAPS.			
Average	3.4	4.3	0.9
StdDev	0.821	0.657	0.912
t-test (*p* value)			0.015
3. I know how to use all the scientific equipment at my school.			
Average	3.3	4	0.7
StdDev	0.801	0.725	0.979
t-test (*p* value)			0.161
4. The lecture-style teaching method is suited to teaching scientific investigations.			
Average	2.6	3.05	0.45
StdDev	1.273	1.191	1.395
t-test (*p* value)			1
5. I learn scientific investigation knowledge when working with Life Science teachers.			
Average	4.15	4.6	0.45
StdDev	0.587	0.503	0.605
t-test (*p* value)			0.127
6. I know all the steps of the scientific method.			
Average	3.55	4.05	0.5
StdDev	0.945	0.686	1.192
t-test (*p* value)			1
7. I know how to interpret data after a scientific investigation.			
Average	4.05	4.45	0.4
StdDev	0.605	0.51	0.598
t-test (*p* value)			0.233

8. I know the function of each chemical used in scientific investigations prescribed in CAPS.			
Average	3.4	4.25	0.85
StdDev	0.94	0.716	0.813
t-test (*p* value)			<u>0.009</u>
9. Scientific investigation is a learner-centred process.			
Average	3.8	4	0.2
StdDev	1.105	1.214	0.951
t-test (*p* value)			1
10. Science educators need to have both science skills and content knowledge.			
Average	4.684	4.85	0.158
StdDev	0.671	4.689	0.834
t-test (*p* value)			1
11. I know how to formulate a hypothesis for a scientific investigation.			
Average	4.15	4.6	0.45
StdDev	0.587	0.598	0.51
t-test (*p* value)			<u>0.036</u>
12. I analyse data after a scientific investigation.			
Average	4	4.3	0.3
StdDev	0.649	0.571	0.657
t-test (*p* value)			1
13. I can provide explanations to support my scientific conclusions.			
Average	4.05	4.45	0.4
StdDev	0.605	0.605	0.681
t-test (*p* value)			0.463
14. Science is a set of procedures to be memorised.			
Average	3.05	2.8	-0.25
StdDev	1.05	1.361	1.41
t-test (*p* value)			1
15. Scientific investigations, practical work and inquiry are synonymous.			
Average	3.05	3.3	0.25
StdDev	0.999	0.979	0.91
t-test (*p* value)			1
16. Every hands-on practical is a scientific investigation.			
Average	3.4	3.895	0.474
StdDev	0.94	0.937	0.841
t-test (*p* value)			0.662

17. Learners use the cognitive process to solve scientific investigation problems.			
Average	3.842	4.2	0.368
StdDev	1.015	0.696	0.761
t-test (*p* value)			1

Notes: p *value 1.*

Table 4.

Results of the items measuring the cognitive components of attitudes.

Survey Questions	Pre-Survey	Post-Survey	Difference
1. I will demonstrate scientific investigations to my learners.			
Average	3.5	4.5	1
StdDev	1.051	0.607	1.076
t-test (*p* value)			0.023
2. My learners conduct scientific investigations themselves.			
Average	2.45	2.8	0.35
StdDev	1.234	1.105	1.348
t-test (*p* value)			1
3. I will use scientific apparatus to perform experiments.			
Average	3.4	4.45	1.05
StdDev	1.188	0.605	1.099
t-test (*p* value)			0.019
4. I will create opportunities for my learners to participate in scientific investigations.			
Average	3.7	4.5	0.8
StdDev	0.733	0.607	0.834
t-test (*p* value)			0.019
5. I have subject meetings with my colleagues to plan scientific investigations.			
Average	3.05	4.35	1.3
StdDev	1.146	0.988	0.979
t-test (*p* value)			0.001
6. I attend Life Science in-service training workshops.			
Average	3.9	4.6	0.7

StdDev	0.968	0.503	0.865
t-test (*p* value)			0.069
7. I only use textbooks to teach scientific investigations.			
Average	2.9	2.25	-0.65
StdDev	0.912	1.118	1.424
t-test (*p* value)			1
8. I include preparation time for practical lessons in my schedule.			
Average	3.25	4.25	1
StdDev	1.118	0.716	1.026
t-test (*p* value)			0.017
9. I only use the Teacher Edition textbook when planning scientific investigations.			
Average	3.15	2.35	-0.08
StdDev	0.933	0.988	1.473
t-test (*p* value)			0.662
10. I design worksheets for my learners to complete during scientific investigations.			
Average	3.55	4.25	0.7
StdDev	0.945	0.639	1.129
t-test (*p* value)			0.351
11. The lack of scientific investigation equipment discourages me from improvising.			
Average	3.3	3.4	0.1
StdDev	1.302	1.188	1.21
t-test (*p* value)			1
12. My learners conduct scientific investigations in groups.			
Average	3.35	4.4	1.05
StdDev	1.387	0.503	1.317
t-test (*p* value)			0.076
13. My learners are actively involved when I present scientific investigations.			
Average	3.6	4.6	1
StdDev	1.046	0.681	0.973
t-test (*p* value)			0.01

14. I often walk around to monitor my learners as they perform scientific investigations.			
Average	3.7	4.8	-0.05
StdDev	1.174	0.41	1.504
t-test (*p* value)			1
15. I use digital devices to teach scientific investigations.			
Average	3.5	4.3	0.8
StdDev	1.357	0.865	1.281
t-test (*p* value)			0,349
16. My learners passively listen when I teach scientific investigations.			
Average	3.25	3.45	0.2
StdDev	0.967	1.191	1.005
t-test (*p* value)			1
17. I perform scientific investigations in a normal classroom.			
Average	3.45	3.4	-0.05
StdDev	1.05	1.188	1.276
t-test (*p* value)			1
18. I will perform reflections with my learners at the end of scientific investigations.			
Average	3.684	4.5	0.789
StdDev	1.108	0.688	0.855
t-test (*p* value)			0.033
19. The lack of resources does not stop me from conducting scientific investigations.			
Average	3.45	4.4	0.95
StdDev	1.234	0.754	1.356
t-test (*p* value)			0.181
20. I conduct scientific investigations in a laboratory.			
Average	2.65	3.86	1.2
StdDev	1.226	1.137	1.005
t-test (*p* value)			0.002

Notes: p *value 1.*