Okwara, V. U. (2024). The impact of puppetry as a teaching tool on Grade 9 learners' applied conceptual understanding of ecological concepts: A STE(A)M context. *Educational Research: Theory and Practice, 35*(4), 158-174.

The Impact of Puppetry as a Teaching Tool on Grade 9 Learners' Applied Conceptual Understanding of Ecological Concepts: A STE(A)M Context

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The author declares that this article is an extract from his PhD study.

Abstract: *Understanding ecological concepts is crucial in tackling environmental issues like climate change, pollution, and habitat destruction. These concepts also serve as a teaching framework, encouraging learners to effect positive change. This research was conducted with grade 9 learners from three schools in Bloemfontein, South Africa, randomly assigned to experimental and control groups. It used a positivist paradigm and Ajzen's theory of planned behaviour as a theoretical framework, incorporating a quantitative experimental research design. The Colorado Learning Attitudes about Science Survey (CLASS), a standardised attitude survey, was administered to experimental and control groups as a pre-and post-test. Data analysis involved descriptive and analytical statistics. Results show a positive influence on learners' applied conceptual understanding of ecological concepts, favouring the experimental group post-intervention [$F(1,350) = 36.45$, $p <.0001$] at a 5% significance level. Puppetry, therefore, can create dynamic, interactive learning environments as a teaching tool, enhancing learner engagement, understanding, and appreciation of ecological concepts. It aids in information retention by associating them with unique experiences. This teaching tool can boost learners' positive perspectives on ecology, enabling learners to make informed decisions and contribute to a sustainable environment. This paper aims to contribute to the scholarship of innovative teaching methods and an interdisciplinary approach to science teaching and learning.*

Keywords: STEAM education, applied conceptual understanding, Puppetry, art in science education

INTRODUCTION

The integration of arts into the teaching and learning of science, known as STE(A)M (Science, Technology, Engineering, Arts, and Mathematics), has been gaining popularity as a means to foster creativity and a hands-on approach in problem-solving (Katz-Buonincontro, 2018). Despite its growing acceptance, scholars caution against making causal claims about the beneficial

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academic effects of the arts on non-arts subjects like Science, Technology, Engineering, and Mathematics (STEM) (Katz-Buonincontro, 2018).

The challenge lies in the fact that while STE(A)M is seen as an alternative to traditional STEM pedagogy, there is a need for empirical evidence to support its effectiveness in promoting creativity, collaborative learning, and experiential learning (Feng & Qiong, 2023). This is crucial for preparing learners to become future leaders and fostering innovative and transformative educational approaches.

The integration of 'arts' in STE(A)M aims to make science more engaging through teacher-learner collaboration (Shashidhar, Bhesh,Wandee, Hassan, Munkhjargal, & Adeeb 2022). It provides learners with cognitive tools to explore creative educational methods, such as visualisation, thereby broadening their perspectives. However, the question remains: how practical is this approach in enhancing learners' engagement and applied understanding of ecological concepts?

The use of arts, such as Puppetry, in teaching ecological concepts within the STE(A)M context has been shown to deepen understanding and aesthetic learning (Marmon, 2019). While research indicates improved performance among learners, especially those at risk, when arts are used as a pedagogical tool in science education, there is a need to investigate further its impact on learners' attitudes towards science and their career choices in the field (Fasasi 2017; Hillman, Zeeman, Tilburg, & List, 2016).

In light of these challenges, it is proposed that the application of appropriate instructional tools and diverse teaching approaches, which promote an active learning environment in science lessons (Sasway & Kelly 2020), might help learners develop critical thinking skills and habits, such as problem-solving, creativity, collaboration, and perseverance (Wilson, Song, Johnson, Presley & Olson, 2021). The effectiveness of these strategies in improving learners' understanding of scientific concepts needs to be empirically validated.

PROBLEM STATEMENT

The integration of Puppetry into educational settings has garnered attention for its potential to enhance learning experiences, particularly in STE(A)M (Science, Technology, Engineering, Arts, and Mathematics) contexts (Chu, Martin & Park, 2019). However, it has become imperative to investigate how Puppetry affects learners' engagement and their applied conceptual understanding of ecological concepts within the STE(A)M context.

RESEARCH QUESTION

How does Puppetry as a teaching tool in ecology influence learners' engagement and their applied conceptual understanding of ecological concepts in the context of STE(A)M education?

Hypothesis. Applying Puppetry as a teaching tool to teach ecology can enhance learners' engagement and applied conceptual understanding of ecological concepts in natural sciences.

Null hypothesis. Applying Puppetry as a teaching tool to teach ecology does not enhance learners' engagement and applied conceptual understanding of ecological concepts in natural sciences.

THEORETICAL FRAMEWORK

Ajzen's theory of planned behaviour suggests that a learner's decision to participate in learning activities, such as Ecology and understand the concepts taught is shaped by three main elements: their attitude towards learning, societal expectations related to the instruction, and their perceived control over the learning process (Ajzen, 2015). Ajzen (2019) further explains that to instil new beliefs and enhance applied conceptual understanding, it's crucial to address the power of existing beliefs that learners may have. This can be achieved through strategies aimed at fostering the development of fresh ideas. Puppetry, within the framework of the STEAM educational approach, is one of the teaching methods that could be employed to challenge the power of old beliefs and facilitate the emergence of new thoughts, as Ajzen (2019) recommended. This approach could potentially foster new beliefs on cognitive, normative, and behavioural levels, thereby enhancing learners' engagement with the subject matter.

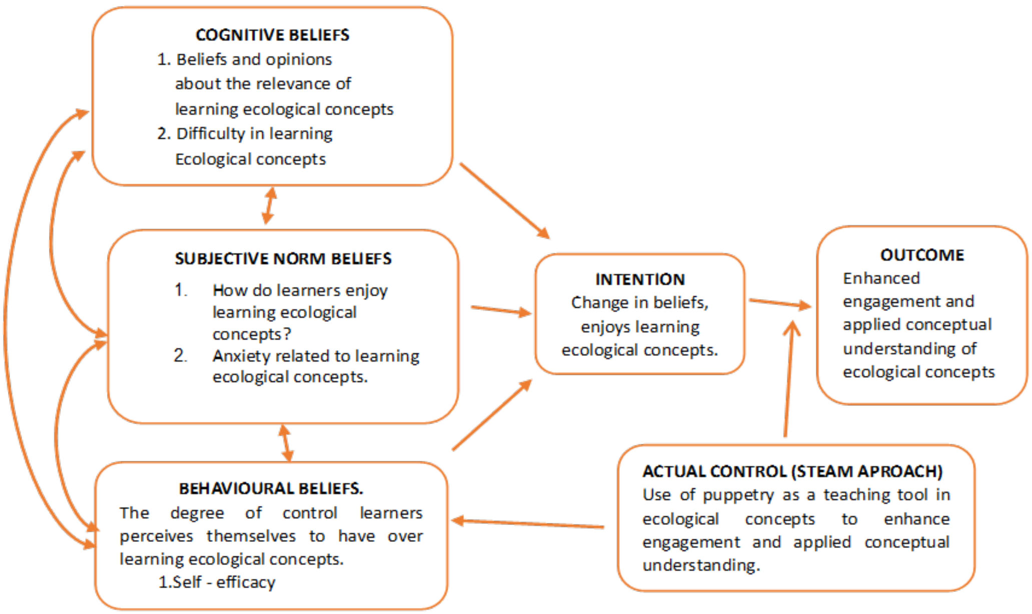
Puppetry, as a teaching tool in natural sciences, can boost learners' sense of control over their engagement and comprehension of ecological concepts by offering interactive and hands-on learning experiences (McGregor & Knoll, 2015). It can introduce fresh ideas that tackle learners' low self-efficacy, enabling them to carry out communication activities driven by knowledge and emotional motives that transcend the limits of real and imagined worlds (Perignat & Katz-Buonincontro, 2019). Ahlcrona (2012) highlights puppets' potential in science education to trigger learners' emotions, thoughts, and associations, which could positively influence their attitudes. This could also lead to memory recall, reinforcing their learning. Such an approach could enhance their self-efficacy, making learning natural sciences more engaging and meaningful (Perignat & Katz-Buonincontro, 2019).

The process of empowerment aids in fostering confidence and self-belief in learners, enabling them to apply ecological knowledge through engaging learning experiences. Puppetry allows learners to interact and engage dynamically with ecological concepts, creating a practical learning environment. Learners who participate directly in puppetry performances or activities gain a sense of control over their learning journey (Marmon, 2019). This leads to heightened engagement and motivation. Participation in puppetry-based activities empowers learners, boosting their confidence in comprehending and applying ecological knowledge.

The interactive aspect of Puppetry allows learners to experiment, explore, and establish connections between various ecological concepts. This results in a more profound understanding of the subject (Tornikoski & Maalaoui, 2019). As learners become more actively involved in puppetry-based learning experiences, they grow more confident in applying ecological knowledge in real-world situations. This increased self-belief motivates learners to take proactive steps towards environmental stewardship and conservation, as they feel capable of making a positive impact. The integration of Puppetry into the teaching process aligns with Ajzen's theory. It shapes a positive outlook, reinforces social norms, and enhances perceived control, ultimately fostering improved engagement and applied conceptual understanding of ecological concepts among learners.

Perceived Behavioural Control, as defined by Yung, Zhu, Wong, Cheng, & Lo (2013), refers to the learners' belief in their ability to regulate their behaviour in a given situation. This belief is crucial to the learning process, as it influences the learners' engagement and motivation. According to Ajzen (2019), applying Puppetry as a teaching tool in natural sciences might produce these possible outcomes in their cognitive, normative, and behavioural beliefs, as shown in the figure below.

Figure 1
Theoretical framework on learners' engagement with ecological concepts (Ajzen, 2019).



LITERATURE REVIEW

Artistic approaches like Puppetry can potentially enrich the teaching and learning of ecology in natural sciences, making it more engaging and meaningful than traditional methods (Sousa & Pilecki 2013). Integrating Puppetry into ecology lessons can promote collaboration and creativity, enhancing learners' experiences (Liao 2019). As a creative art form, Puppetry can be an effective teaching tool that increases learners' motivation (Sousa & Pilecki 2013) and reduces the perceived complexity of learning ecological concepts (Lindquist, James-Hassan & Lindquist, 2017).

Puppetry can positively impact learners' attitudes towards learning ecological concepts by making the process enjoyable and engaging. This fosters a deeper understanding of ecological concepts (Tornikoski & Maalaoui, 2019). As a dynamic and interactive educational tool, Puppetry captivates learners' attention and imagination. It can introduce new beliefs relevant to the subject and a different style of interpersonal relationships, which benefits science learning. It also supports instructional scaffolding (Lindquist et al. 2017), which can positively influence the perceived relevance of the subject. This is important for guided knowledge construction (Perignat & Katz-Buonincontro, 2019) and can provide learners with various opportunities for cognitive development during peer interactions. This can reduce the perceived difficulty in learning ecological concepts, leading to increased engagement with the content.

Incorporating Puppetry into ecology education can ignite learners' curiosity and desire to learn by providing a multisensory experience (Perignat & Katz-Buonincontro, 2019). This approach fosters a vibrant, interactive learning environment that captures learners' attention and encourages active participation. Puppets serve as tools for role-playing, enabling learners to actively explore ecological concepts, thereby increasing their engagement (Tornikoski & Maalaoui, 2019). The entertaining nature of Puppetry makes learning enjoyable and memorable.

Learners develop positive attitudes towards the ecological concepts presented through Puppetry, enhancing their enjoyment and satisfaction. This positive outlook motivates learners to delve deeper into the subject outside the classroom, cultivating a profound understanding and appreciation of nature's interconnectedness and ecological concepts.

Puppetry can be an effective educational tool, especially in fostering an understanding and appreciation for environmental stewardship and ecological conservation. It can expose learners to new ecological concepts and encourage responsible behaviour, making the learning process pleasurable (Ajzen, 2015). Puppets' unique appearance, movement, speech, and action can captivate learners and shape their perceptions about ecology (Perignat & Katz-Buonincontro, 2019). Interacting with puppets during lessons can stimulate learners' thoughts, feelings, and intentions. These experiences can leave lasting impressions (Ahlcrona 2012), potentially enhancing learners' enjoyment of the lessons.

In other words, puppets can influence learners' emotions, including feelings that can be transformed into actions, thoughts, or interactions (Sloan 2018). This transformation can significantly enhance learners' enjoyment of the lessons. It can aid them in quickly understanding new concepts, developing skills (Toma et al., 2019), and overcoming any fears they might have about learning ecological concepts.

Several studies have highlighted the importance of implementing more engaging teaching methods to counter the ongoing decrease in learners choosing science as a subject in school (Sasway & Kelly, 2020). Wilson et al. (2021) suggest that incorporating arts into the learning process can serve as a platform to engage learners, foster connections, enhance the learning environment to stimulate thought, support struggling learners, and extend the learning of those succeeding. Therefore, merging arts with science education could introduce fresh ideas, inspire learners to approach problems from various angles, engage in diverse thinking processes, and gain a deeper understanding of ecological concepts in natural sciences. The literature review also suggested that using suitable teaching tools in science classes could improve learners' attitudes towards the subject (Sasway & Kelly, 2020).

Furthermore, Puppetry is a vibrant tool for instilling new ecological beliefs and cultivating a positive attitude towards ecology lessons. This makes the learning process both captivating and pleasurable. It incorporates case studies highlighting the significance of preserving the environment and living harmoniously with nature. These case studies serve as powerful channels for conveying social norms related to ecological conservation. This conveyance occurs during puppetry performances or group activities, facilitating peer interactions. Such interactions can reinforce social norms about responsible environmental behaviour (Perignat & Katz-Buonincontro, 2019).

Positive engagement among peers motivates learners to adopt behaviours that support ecological conservation. Teachers are crucial in guiding discussions and reflections on ecological topics introduced through Puppetry. They can help learners understand the importance of ecological knowledge and encourage responsible actions through classroom discussions and activities.

Materials and Methods

This study employed the quantitative research methodology. Quantitative research methodology is a systematic approach used in research to gather and analyse numerical data. The study used this methodology to quantify learners' engagement and applied conceptual understanding of ecological concepts. Statistical analysis was used to interpret the data and draw conclusions.

RESEARCH PARADIGM

The study employs the positivist paradigm, which posits that a single, objective reality can be known and accurately described (Miller 2011). Positivists seek to gain knowledge through empirical, sensory observations. They can test their hypotheses against this objective reality to ascertain their validity. However, it's important to note that the positivist approach does not necessarily restrict researchers from collecting and interpreting data from an unbiased perspective (Leung & Shek 2018). Instead, it emphasises the need for objectivity and replicability in research, often leading to a preference for quantitative research methods. The potential limitation is that it may overlook individuals' subjective experiences and interpretations, frequently explored through qualitative research methods.

RESEARCH DESIGN

The research employed a quantitative experimental design, including control and experimental groups, with pre and post-tests (Mujis 2011). The participants were split into two categories: experimental and control. The experimental group was taught ecological concepts through Puppetry as an innovative teaching method. Conversely, the control group was taught the same ecological content using the traditional method (Leung & Shek 2018). A brief overview of the research design can be found in Table 1.

Table 1
The summary of the quantitative experimental design (Mujis 2011)

Groups	Pre-test	Treatment (application of Puppetry as a teaching tool)	Post-test
Experimental	YES	YES	YES
Control	YES	NO	YES

Duration of the Study

The study timeline was from April to September 2019 per the Free State Department of Education policy. The schedule of work is included in Table 2 below:

Table 2
The work schedule

Week 1	13-20 April	Proposal finalisation/selection of schools
Week 2	4-11 May	Selection/workshop for natural science teachers and puppeteers
Week 3	18-25 May	School visit planning
Weeks 4-13	27 July-28 September	Intervention/Data collection- and pre-test post-test administration

POPULATION AND SAMPLE

Simple random sampling, a type of probability sampling, was employed in selecting the subjects. This technique was chosen because every individual in the sampling frame (i.e., the desired population) had an equal and independent chance of being selected for the study (Onwuegbuzie & Collins 2007). The main limitation of this sampling method is that it is rather costly and time-consuming (Tye-Williams 2018; Bergan 2018). The researcher overcame this limitation by suggesting that research should be planned to be as efficient as possible by minimising the expenditure of effort, time, and money. This was done by studying in selected high schools in the Motheo District of the Free State. Therefore, the researcher did not travel long distances during the data collection process, and the cost of travelling from one school to another was significantly reduced. The advantages of this sampling method, which included the known probability of drawing each sample, allowed for unbiased estimates of important population parameters. It also enabled the calculation and reporting of the sampling error, making it easier to generalise the results to the larger population of ninth-grade learners. This approach aligned with Tye-Williams's (2018) and Bergan's (2018) recommendations.

The study involved 355 ninth-grade learners (170 males and 185 females) from schools A, B, and C. These learners were selected using a random number table, a method suggested by Fritz & Morgan in 2012. Each learner was assigned a unique number from 1 to 355. Using the random number table, the researcher selected the learners participating in the study. This was done by choosing an arbitrary starting point on the Table and then moving down the column. The first numbers on the Table with their first digits between 1 and 355 were chosen. This method led to the selecting of 180 learners for the experimental group and 175 for the control group.

The selection process was systematic. If a number on the Table matched one of the assigned numbers, that learner was chosen as a participant for a specific group. Any numbers that did not match the assigned numbers were ignored. This method ensured that the selected learners were representative of the larger population, thereby improving the generalizability of the findings. The distribution of the learners was as follows: School A had 119 learners (60 in the experimental group and 59 in the control group), School B had 118 learners (60 in the experimental and 58 in the control group), and School C also had 118 learners (60 in the experimental and 58 in the control group).

It's important to note that the number of participants was less than initially estimated because some learners chose not to participate. The researcher respected their decisions, adhering to the ethical considerations in educational research outlined by Herrera (2012) and Alferes (2013).

DATA COLLECTION TOOLS/INSTRUMENTS

The study used the Colorado Learning Attitudes about Science Survey (CLASS) questionnaire to collect data and measure learners' engagement levels and applied understanding of ecological concepts. The standardised questionnaire, which has passed validity and reliability tests, differentiates between the beliefs of experts and novices (Madsen et al., 2020). Puppetry-based lessons were designed, implemented, and tailored to the STE(A)M curriculum. These lessons covered ecological concepts such as balance in the ecosystem, conservation of the ecosystem, and feeding relationships. The experimental group received these lessons through Puppetry facilitated by professional puppeteers, while the control groups were taught the same concepts using traditional methods.

Learners were tested before and after the lessons to measure any changes or "shifts" in their beliefs. The CLASS attitude survey was used to measure the potential impact of teaching ecological concepts using Puppetry on learners' engagement and applied conceptual understanding. This survey was administered to the experimental and control groups as a pre-and post-test, where they choose an option on a Likert scale between 1 to 5, where 1=strongly disagree, 2=disagree, 3=neutral, 4=agree and 5=strongly agree (Madsen et al. 2020). After the post-test, descriptive statistics were used to determine if there were any effects due to the experimental stimulus (Mujis 2011). If the post-test positively influenced the overall level of engagement and applied conceptual understanding, it might indicate that the intervention was effective (Barbie, 2010).

DATA ANALYSIS

The researcher utilised descriptive statistics and the SAS/STAT software to analyse the data, which allowed for a comprehensive understanding of the data set's main characteristics. This analysis included pre-and post-tests for the experimental and control groups, providing a foundation for further data interpretation. The study involved comparing the responses of 355 Grade 9 learners from both groups to expert reactions on the same 42 statements/questions, using the Colorado Learning Attitude about Science Survey (CLASS) Expert Response Key. This comparison helped streamline the data for statistical analysis and facilitated the extraction of insights from the observed patterns.

Each learner's performance was evaluated based on the average number of questions they answered similarly to an expert, represented by the percentage favourable score. The percentage of unfavourable scores indicated the number of questions the learners responded to differently from those of experts. Neutral responses were not counted as either agreement or disagreement with the expert. If a learner left questions unanswered, the average percentage favourable score was adjusted accordingly. The class's average percentage favourable score was then calculated by averaging the learners' scores.

The study involved a repeated process to determine the class average of the percentage of unfavourable scores, representing the count of questions learners didn't answer like an expert would. Descriptive statistics were used to calculate the mean score for each statement in the attitude survey, with the scores divided by study period (pre- and post-test) and group (experimental and control). This mean score represented the fraction of learners who answered like an expert, and when multiplied by 100, it gave the percentage of expert-like or favourable responses (Madsen, McKagan, & Sayre, 2020).

Further descriptive statistics, including total (n), mean, standard deviation, minimum, median, and maximum, were calculated for these mean scores, again divided by study period and group. These statistics were also calculated for different schools (A, B, C), study periods, and groups (Leung & Shek, 2018). Lastly, the Analysis of Covariance (ANCOVA) was employed to compare the outcomes between the experimental and control groups. ANCOVA is a statistical procedure used in experimental design to eliminate the effect of one or more confounding variables (Sim, 2018). The SAS software program and the GLM procedure were used for this analysis. This method helped reduce unexplained outcome variance, thereby enhancing the power of the treatment test effect and narrowing its confidence interval (Van Breukelen, 2012). It also increased the sensitivity of the statistical test of the experimental factor in the statistical model (Sim, 2018).

It was applied to reduce error variance, remove sources of bias, and obtain adjusted estimates of population means (Kirk, 2014).

The Analysis of Covariance (ANCOVA) is a statistical method that offers significant benefits, including a decrease in error variance, an increase in power, and a reduction in bias due to differences among experimental units unrelated to the independent variable manipulation (Kirk 2014). The study used ANCOVA to compare experimental and control groups across various questionnaire categories. The dependent variable was the mean score (post-test survey) of a category, and the independent variables included the school (with three categories: A, B, C), the group (two categories: experimental and control), and the corresponding mean score (pre-) as a covariate.

The ANCOVA analysis yielded the least square means post-intervention mean scores for each group (experimental and control), the difference in mean scores between the experimental and control groups, the 95% confidence interval for the mean difference, and the p-value for the test of the null hypothesis that the mean difference is zero, implying no difference between the experimental and control groups (Leung & Shek 2018). The dependent variable was adjusted using ANCOVA to eliminate the effects of uncontrolled sources of variation represented by the concomitant variable. This adjustment reduces error variance, increases the power to reject the null hypothesis, and decreases bias caused by differences among the experimental units not attributed to manipulating the independent variable (Kirk 2014).

Ethical Consideration

The parents/guardians of the learners who were part of this project were issued permission and informed consent letters. The details of the research were outlined in the letters, and the possible consequences of participation were highlighted. Although no ethical issues were anticipated during this research, action was taken to follow all the necessary steps.

Presentation of Results

The statistical null hypothesis posits no significant link between dependent and independent variables (Bloomfield & Fisher 2019). It is tested using a sample of Grade 9 learners, using the Analysis of Covariance (ANCOVA). The outcome of this test determines if we accept or reject the null hypothesis.

We have two similar groups: the experimental and the control group. Both undergo a pre-test to assess their initial understanding. The experimental group receives an intervention, and a post-test measures its effect. The control group does not receive the intervention. This process helps to validate or refute the null hypothesis.

Applied conceptual understanding (all schools)

For the pre-and post-survey, Table 3 below shows that 24.7% (0.247 × 100) of the subjects in the experimental groups and 31.0% (0.31 × 100) of the subjects in the control groups responded as experts would in the pre-survey. In the post-survey, 22.0% (0.22 × 100) of the subjects in the experimental groups and 35.2% (0.352 × 100) of the subjects in the control groups responded as experts would, post-experimental intervention with the experimental groups.

Table 3
Descriptive statistics for expert-like responses for applied conceptual understanding in all schools A, B, and C (pre- and post-survey)

Domain		Period			
		Post- Groups		Pre- Groups	
		Control	Experimental	Control	Experimental
Applied conceptual understanding	Total	175	180	175	180
	Mean	0.352	0.22	0.31	0.247
	Std. Dev.	0.18	0.18	0.17	0.18
	Minimum.	0	0	0	0
	Median	0.33	0.29	0.29	0.29
	Maximum.	1	0.71	0.86	0.86

Comparing the impact of Puppetry as a teaching tool on learners' engagement and applied conceptual understanding of ecological concepts in natural science

Research question: How does Puppetry as a teaching tool in ecology influence learners' engagement and their applied conceptual understanding of ecological concepts in the context of STE(A)M education?

Ho: Applying Puppetry as a teaching tool to teach ecology does not influence learners' engagement and applied conceptual understanding of ecological concepts in the context of STE(A)M education.

The ANCOVA results for testing this hypothesis show a difference at a 5% significance level between the post-test mean scores of the experimental and control groups [F (1,350) =36.45, p <.0001; Table (4)] in favour of the experimental group. According to these results, the experimental group performed significantly better than the control group after applying Puppetry as a teaching tool to teach ecology to the experimental group. This indicates that Puppetry as a teaching tool greatly influenced learners' applied conceptual understanding of ecological concepts and their engagement with the content taught. Therefore, the null hypothesis that applying Puppetry as a teaching tool to teach ecology does not influence learners' applied conceptual understanding was rejected. This indicates that Puppetry as a teaching tool positively influenced learners' applied conceptual understanding. See Table 4 below.

Table 4
ANCOVA results for applied conceptual understanding

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Group	1	0.67429002	0.67429002	36.45	<.0001
School	2	0.05024762	0.02512381	1.36	0.2585

Table 5
Comparison of experimental and control groups by group means and mean difference.

Category	Group Means[1]		Mean difference[1]: Experimental – Control		
	Experimental	Control	Point Estimate	95% Confidence Interval	P-value[2]
Applied conceptual understanding	0.242	0.330	-0.089	-0.117 to -0.060	<.0001

The information in Table 5 above summarises the p-value from the t-test. This test was conducted to verify the null hypothesis, which states no significant difference (mean difference is 0) between the experimental and control groups. This hypothesis was tested using the Analysis of Covariance (ANCOVA) method for the category specified in the research question.

In Table 5, the ANCOVA results summary reveals significant differences in the p-values of the post-test scores between the experimental and control groups. These differences emerged after the experimental groups were taught ecological concepts using Puppetry as an intervention method. The statistical significance of these differences is indicated by the p-value ($p < .0001$), suggesting a significant improvement in the experimental group's understanding of ecological concepts.

Discussion of Findings

The study aimed to evaluate the effectiveness of Puppetry, a teaching tool used to instruct learners on various ecology topics. These topics included ecosystem balance (focusing on habitat loss, species loss, and climate change), ecosystem conservation (emphasising biodiversity and sustainability), and feeding relationships (covering food chains and webs). The context for this teaching method was the STE(A)M educational approach, which integrates Science, Technology, Engineering, Arts, and Mathematics. The study aimed to understand how Puppetry might enhance learners' engagement and their ability to apply conceptual understanding. The results of ANCOVA analysis showed that the experimental group taught using Puppetry performed significantly better than the control group, which was taught using traditional methods. The post-test mean score for the experimental group was significantly higher [Experimental $F\ (1,350)=36.45$, $p = <0.0001$].

These results suggest that the improved performance of the experimental group could be attributed to the use of Puppetry in teaching ecology. This finding aligns with previous research, which found that the STE(A)M educational approach helps learners deepen their learning and consolidate their understanding of scientific theories and concepts (Lindquist et al. 2017). These concepts include habitat loss, species loss, climate change's impact on ecosystem balance, the importance of biodiversity and sustainability in ecosystem conservation, and the role of food chains and webs in the feeding relationships among ecosystem organisms.

As an educational tool, Puppetry significantly boosts learners' comprehension of ecological concepts, enabling them to apply them in various situations and contexts. This method is vital for science education (Hoft, Bernholt, Blankenburg, & Winberg, 2018). The STE(A)M approach encourages learners to see themselves as creators and designers (Cook, Bush & Cox, 2017), fostering their creativity and independent thinking (Jamil, Linder & Stegelin, 2017). Puppetry is anticipated to aid learners in actively constructing knowledge in natural sciences. Studies have shown that groups taught with arts integration outperformed those taught without. This underscores the importance of integrating arts into science education. Applied conceptual understanding, as defined by Aydin Ceran & Ates (2020) and Macanas & Rogayan (2019), is the ability to grasp and apply knowledge to new situations and contexts, evident in the learners' responses to the teaching methods used in the study.

Complex concepts cannot be mastered merely through memorisation. They require deep understanding, which can be achieved through reflective thinking and learner-focused teaching methods such as STE(A)M. This method enhances the learners' ability to apply learned concepts in various situations. Studies have indicated the importance of this practical application of concepts in science education. For instance, learners can see the connections and similarities among concepts in fields like ecology, which can be used to solve problems (Macanas & Rogayan 2019).

The STE(A)M method employs project-based learning to impart scientific concepts (Bush & Cook 2019), ensuring that learners are actively involved and meaningfully engaged with the content (Pino-Pasternak & Volet 2018). A study found that using Puppetry as a teaching tool in an experimental group brought out emotional aspects such as motivation, passion, and personal significance in learning (Park, Byun, Sim, Han & Baek, 2016). This could have served as a bridge between arts and science disciplines, influencing learners' engagement and their practical understanding of the concepts taught.

This finding aligns with Marmon's (2019) research, which suggests that Puppetry provides a platform for presenting natural science lessons in a way that leads to practical and meaningful knowledge construction and application. Other research has confirmed that significant knowledge construction occurs when learners actively engage with the content (Chi & Wylie 2014), are cognitively involved, and participate in learning (Pino-Pasternak & Volet 2018). This suggests active learner participation can be achieved when lessons are delivered via a learner-centred approach. This approach positively influences learners' engagement and helps them feel they understand and can effectively use the concepts taught. This was evident in a study where experimental groups responded significantly better than control groups. Furthermore, appropriate teaching tools like Puppetry can enhance instructional quality and promote an active learning environment (Sasway & Kelly, 2020).

The research indicates that rote learning does not improve scientific process skills. Instead, these skills are enhanced when learners actively engage with the content and apply their understanding of the concepts. This involves recognising the significance of scientific knowledge, its applicability, and its cross-domain usage. These elements contribute to the superior performance of experimental groups over control groups. According to Ajzen's Theory of Planned Behaviour (TPB), learners' attitudes towards natural sciences are shaped by their beliefs, which include expectations of studying outcomes, emotional responses, and perceptions of facilitating or hindering factors. Therefore, it's suggested that learners' applied conceptual understanding likely influences their behaviour towards natural sciences.

The study's results align with previous research. For instance, Najami, Hugerat, Khalil, & Hofstein (2019) found that using Puppetry as a teaching tool for tenth-grade chemistry learners positively impacted their learning and understanding of various chemistry concepts. Learners taught with Puppetry scored higher and exhibited a more positive attitude towards learning chemistry than those taught using traditional methods. This supports the findings of Belohlawek, Keogh & Naylor (2010) and Simon, Naylor, Keogh, Maloney & Downing (2008), who found that Puppetry engaged learners in lessons and stimulated discussions involving reasoning and arguments, fostering a productive learning environment for science education. The results of this study confirm these findings.

The STE(A)M educational approach enabled learners in the experimental groups to develop their grasp of ecological concepts through hands-on learning and discovery. This implies that a practical comprehension of these concepts requires profound understanding, which can be achieved by structuring these concepts (Aydin Ceran & Ates 2020). On the other hand, the outcomes of the control groups might be attributed to less effective teaching strategies that could make science seem more complicated, thereby impacting learners' interaction with the subject matter (Turner & Ireson, 2010). The study's findings and prior research suggest that a teacher-centric teaching approach, which relies heavily on textbooks, lectures, and rote learning, could lead to a negative response towards science among learners (Toma, Greca & Orozco Gómez, 2019). This could explain the control group's lack of significant engagement and comprehension of ecological concepts.

CONCLUSIONS AND RECOMMENDATIONS

This study aims to develop design principles enabling science teachers to apply a specific teaching method in their classrooms, as outlined in the recommendations section. Additionally, it will validate the use of puppetry art as an effective teaching tool. This tool is expected to enhance learners' interest and applied understanding of ecological concepts within the STE(A)M educational framework. The study will contribute both to the field of epistemology and methodology.

CONCLUSIONS

In conclusion, the study demonstrated that the experimental and control groups had comparable foundational knowledge of ecology before the intervention. However, Puppetry's teaching of the experimental group resulted in a significantly improved engagement and understanding of ecological concepts compared to the traditional teaching approach used with the control group. The learners in the experimental group expressed that the incorporation of Puppetry made the ecology lessons more stimulating and enjoyable. The learners identified this hands-on, engaging, and enjoyable method as the key factor in their enhanced post-test performance.

On the other hand, the traditional teaching approach, characterised by a lack of active learner participation, such as discussions, debates, and constructive feedback, may have contributed to the less favourable response from the control group. This suggests that more interactive and engaging teaching methods, like Puppetry, can enhance learners' understanding and engagement in the subject matter.

RECOMMENDATIONS

Further research should investigate the sustained impact of Puppetry as a teaching tool on learners' engagement and applied conceptual understanding over an extended period to determine if the benefits persist over time. Explore the role of teacher training in optimising Puppetry as a teaching tool, including developing instructional strategies and techniques for integrating Puppetry effectively into the senior phase curriculum. Limited participant numbers may restrict the generalisability of the findings. Future studies could involve more extensive and diverse participant groups to enhance the study's representativeness and validity.

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