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Using a constructivist teaching approach to enhance life sciences learners' understanding of line graphs

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ABSTRACT

This study explored the use of a constructivist teaching approach to enhance grade 10 Life Sciences learners' understanding of line graphs, where social constructivism served as a lens through which the findings were interpreted. The study made use of a qualitative research approach where a single case study and purposive sampling were used as research design and sampling technique, respectively. In a population of 54 Grade 10 Life Sciences learners, 19 learners were sampled to participate in the study, where the study used both participant observations and document review to collect data. The findings from both classroom observations and document analysis show that learners had limited knowledge of line graphs. However, through a constructivist approach, the learners' graph creation skills and engagement, where their articulation of graphing processes, such as proper point charting along the axes of x and y, as well as knowledge of the relationships between variables, were enhanced. Amongst other things, the study recommended that researchers consider exploring interdisciplinary and longitudinal studies, as well as studies that would explore Life Sciences learners' cultural experiences and how prior knowledge influences their interpretation and building of line graphs. This study extends scholarship on science in South Africa by exploring Grade 10 Life Sciences learners' understanding of line graphs, thereby addressing a gap in the literature where graphing has been studied largely in mathematics rather than disciplinary science contexts.

Keywords: Constructivist teaching approach, Life sciences, Line graph, Social constructivism

INTRODUCTION

Graphs are part and parcel of Life Sciences and part of everyday life.[1] Thus, the ability to use graphs is of great importance in today's world, for academic achievement, mathematical literacy and scientific literacy.[2] Hence, learners are taught graphing from the intermediate phase right up to the Further Education and

[1] Aakanksha Angra and Stephanie Gardner, "Reflecting on Graphs: Attributes of Graph Choice and Construction Practices in Biology," *CBE—Life Sciences Education* 16, no. 3 (2017): ar53, https://doi.org/10.1187/cbe.16-08-0245; Joseph A. Harsh and Mikaela Schmitt-Harsh, "Instructional Strategies to Develop Graphing Skills in the College Science Classroom," *The American Biology Teacher* 78, no.1(2016): 49–56, https://doi.org/10.1525/abt.2016.78.1.49.

[2] N. Remziye Ergül, "Pre-Service Science Teachers' Construction and Interpretation of Graphs," *Universal Journal of Educational Research* 6, no. 1 (January 2018): 139–44, https://doi.org/10.13189/ujer.2018.060113.

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Training (FET) phase to master graphing skills from a younger age.[3] Line graphs are the type of graphs used to present quantitative data that shows a continuous relationship between two variables.[4] Furthermore, they are found and used everywhere;[5] as a consequence, there is a need for Life Sciences learners to deeply understand graphs, for their role within and outside the classroom.[6]

It is assumed that learners are more exposed to graphing concepts in mathematics class and should be able to use the knowledge in other content areas, such as Life Sciences.[7] As with Life Sciences, graphs are intensively taught in Grade 10 as part of the introduction, and learners are expected to use the knowledge throughout. Correspondingly, similar information about graphing is also found in different Life Sciences study materials.[8] Life sciences learners are required to draw or use already drawn line graphs concerning the content learned; to extract, analyse and interpret information from the graph. Life Sciences learners, therefore, shall see patterns, make predictions and draw conclusions from the graph.[9] However, based on the diagnostic report in South Africa, Life Sciences learners are not able to interpret line graphs correctly, determine variables, and these learners struggle with transposing of exes as well as selecting the correct scales.[10] Furthermore, Hassan et al. explored Grade 10 science learners' understanding of line graphs and found that errors with graph interpretation were due to virtual features of the graph referred to as scaling, variable identification, and data points, which learners could not identify.[11] As with graph drawing, learners could not transfer information into a line graph and could not apply their mathematical knowledge of graphs to a science context. This issue of failing to integrate graphing knowledge from one content area to another was also emphasised by Phage and Lemmer.[12]

The constructivist teaching approach allows teachers to provide meaningful experiences and make conclusions that will sharpen and deepen learners' understanding by using different teaching methods and materials.[13] Furthermore, learners can develop new understanding and ways of solving problems, thus any misconceptions and difficulties can be addressed.[14] Hence, a comparative study by Aslan et al. on the effect of biology teaching based on a constructivist learning approach on learner attainment and permanence of knowledge revealed that teaching with concept cartoons had a positive effect on enabling learners to learn biology knowledge compared to the traditional method.[15] Another comparative study on the effect of a constructivist teaching approach on learners' achievement in science found a significant difference between the achievements of the two groups, where the experiment group performed better than the control group.[16]

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3 Banu Inan, "Teacher Revoicing in a Foreign Language Teaching Context: Social and Academic Functions," *Australian Journal of Teacher Education (Online)* 39, no. 9 (2014): 53–75.

4 Harsh and Schmitt-Harsh, "Instructional Strategies to Develop Graphing Skills in the College Science Classroom."

5 E. M. Glazer, " A Constructivist Perspective on Leadership," *Revista de Administração de Empresas* 51, no. 2 (2011): 139–49; Harsh and Schmitt-Harsh, "Instructional Strategies to Develop Graphing Skills in the College Science Classroom."

6 A E Hassan, Essa Ali Adhabi, and Lauren Wright Jones, "The Impact of Inclusion Setting on Social Interaction and Psychological Adjustment of Students with Disabilities," *International Journal of Scientific Research in Science and Technology* 4 (2017): 121–28; Corrie Stone-Johnson, "Not Cut Out to Be an Administrator," *Education and Urban Society* 46, no. 5 (July 10, 2014): 606–25, https://doi.org/10.1177/0013124512458120.

7 Samantha Govender, "South African Teachers' Perspectives on Support Received in Implementing Curriculum Changes," *South African Journal of Education* 38, no. 1 (2018).

8 Lena von Kotzebue, Mariele Gerstl, and Claudia Nerdel, "Common Mistakes in the Construction of Diagrams in Biological Contexts," *Research in Science Education* 45, no. 2 (April 16, 2015): 193–213, https://doi.org/10.1007/s11165-014-9419-9.

9 Department of Basic Education, *Life Sciences Curriculum and Assessment Policy Statement (CAPS)* (Pretoria: Government Printers, 2011).

10 Department of Basic Education, *Life Sciences Curriculum and Assessment Policy Statement (CAPS)*.

11 Hassan, Adhabi, and Jones, "The Impact of Inclusion Setting on Social Interaction and Psychological Adjustment of Students with Disabilities."

12 J. Phage and E. Lemmer, " Difficulties in Graphing: Problems of Learners Transferring Mathematical Graphing Knowledge to Science," *South African Journal of Education* 37, no. 4 (2017): 1–11.

13 B. Barman and S. Bhattacharyya, "Constructivism: A Paradigm for Teaching and Learning," *International Journal of Advanced Research in Education & Technology* 2, no. 3 (2015): 146–51.

14 R. Oliver, "Constructivism: An Overview," The University of Auckland, New Zealand, 2000, https://www.learningdesign.psu.edu.

15 S. Aslan, S. Doğan, and M. Yılmaz, "The Effect of Biology Teaching Based on Constructivist Learning Approach Using Concept Cartoons on Student Achievement and Retention of Knowledge," *Journal of Biological Education* 55, no. 3 (2021): 295–308.

16 A. Noureen, A. Malik, and R. Khalid, "Impact of Constructivist Teaching Approach on Student's Achievement in Science," *Journal of Educational Research* 23, no. 2 (2020): 108–17.

The authors also claimed that constructivism improves the learners from being passive to active participants in the teaching and learning environment.

Again, constructivists acknowledge that learners are not passive receivers of knowledge but active constructors of their knowledge based on their existing conceptions.[17] It is suggested that the new information to be learned can only make sense when it is related to the previous one.[18] From this, it is clear that knowledge cannot be imparted without learners making sense of it concerning their current perceptions. Therefore, it is argued that learning occurs best when learners are allowed to experience things and reflect on those experiences,[19] to build their understanding individually and collectively[20] as they make connections between old and new experiences. It is for this reason that we sought to explore the use of a constructivist approach to enhance Grade 10 Life Sciences learners' understanding of line graphs.

This study aims to contribute to this literature gap by exploring the use of a constructivist teaching approach to enhance Grade 10 Life Sciences learners' understanding of line graphs. The following research questions guided this study:

1. What are Grade 10 Life Sciences learners' understanding of Line graphs?
2. How does the use of a constructivist teaching approach enhance Grade 10 Life Sciences learners' understanding of Line graphs?

LITERATURE REVIEW

Understanding graphs implies being able to draw and examine graphs to infer interpretations about the issue of interest.[21] Hence, graphing is regarded as a key competence for aspiring scientists and educated citizens. However, Gioka revealed that 'graphs are not easy'.[22] Thus, research indicates that most learners struggle with drawing and interpreting graphs,[23] which is pinned on unsatisfactory classroom instructions.[24] Therefore, this raises global concerns about the aim of developing learners who can comprehend and utilize graphs.[25]

Drawing Line Graphs

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[17] J. J. Connors, "Constructivism in Education," in *Handbook of Educational Psychology*, ed. P. A. Alexander and P. H. Winne (London: Routledge, 2007), 83–102; S. McLeod, " Constructivism as a Theory for Teaching and Learning," Simply Psychology, 2019, https://www.simplypsychology.org/constructivism.html.

[18] N. C. Ihejiamaizu, C. E. Okonkwo, and C. I. Onah, " Influence of Prior Knowledge on Students' Academic Performance in Biology," *Journal of Education and Practice* 9, no. 11 (2018): 12–18; B. A. Israel et al.., *Methods in Community-Based Participatory Research for Health* , 2nd ed. (Jossey-Bass, 2013).

[19] Steve Olusegun, Bada and Steve Olusegun, "Constructivism Learning Theory: A Paradigm for Teaching and Learning," *Journal of Research & Method in Education* 5, no. 6 (2015): 66–70; D. Bhattacharjee, " Constructivism Learning Theory: A Paradigm for Teaching and Learning," *International Journal of Multidisciplinary Research and Development* 2, no. 1 (2015): 82–86.

[20] Connors, "Constructivism in Education"; J., Keengwe and G. Onchwari, " Technology and Constructivism," in *Technology-Enhanced Learning: Best Practices* , ed. J. Keengwe (IGI Global, 2011), 65–81.

[21] H. Ozmen, E. Erdem, and S. Aydin, " Students' Difficulties in Interpreting Scientific Graphs and the Role of Instructional Intervention," *International Journal of Science Education* 42 (2020): 1312–1330–1330.

[22] Olga Gioka, "Assessment for Learning in Teaching and Assessing Graphs in Science Investigation Lessons.," *Science Education International* 18, no. 3 (2007): 189–208.

[23] Ozmen, Erdem, and Aydin, " Students' Difficulties in Interpreting Scientific Graphs and the Role of Instructional Intervention"; S. W. Zucker, " Learning to Interpret Graphs: Challenges and Instructional Supports," *Journal of Educational Psychology* 105, no. 4 (2013): 1035–49.

[24] C., Matuk and M. C. Linn, " Designing Modeling Tools to Support Graph Interpretation and Construction," *Journal of Science Education and Technology* 25, no. 3 (2016): 343–59; Y. Xiong, M. C. Linn, and J. L. Chiu, " Enhancing Graph Interpretation Skills through Dynamic Visualizations," *Educational Technology Research and Development* 67, no. 5 (2019): 1145–62.

[25] Harsh and Schmitt-Harsh, "Instructional Strategies to Develop Graphing Skills in the College Science Classroom"; I. R. Meisadewi, A. Sutawidjaja, and D. Puspitasari, "The Effectiveness of Teaching Materials Based on Constructivism for Improving Students' Ability in Graph Interpretation," *Journal of Physics: Conference Series* 895, no. 1 (2017): 012063.

Two decades ago, the ASE-King's Science Investigations in Science (AKSIS) project team found that more than 75% of line graphs were incorrectly drawn. Similar findings were reported by Lai et al. and Ozmen et al., who investigated learners' overall graphing literacy, graph comprehension, critique and construction in science.[26] These studies concluded that low graphing abilities are caused by learners not being explicitly taught how to draw graphs, and they rarely use graphs as a tool to communicate investigation results, as well as sources to create rich classroom discussions. Thus, learners' difficulties persist because they are not accustomed to working with graphs. Furthermore, a study on learners' ability in graph understanding for mastering Natural Science by Andalia et al. found that the improvement of learners' understanding of graphs is dependent on concept mastery.[27] This is because learners' understanding of graphs cannot be separated from their mastery of the concepts involved. That is to say, when learners lack concept mastery, they lack the know-how in terms of graph plotting.

Gardner et al. caution that graphs are multifaceted tools in science that afford learners the opportunity to examine data patterns and communicate findings.[28] That is to say, due to their multifaceted nature, they may appear difficult to some learners. Hence, a study on grade 11 Physical Sciences' difficulties in constructing and interpreting graphs by Kibirige and Ngobeni revealed the learners' difficulties, such as plotting the graph and writing the title of the graph.[29] Similarly, another study on learners' graph skills and affective state about common graph types by Bursal and Polat revealed the learners' lack of skills.[30] Furthermore, the findings of the study revealed that the learners preferred bar graphs, because they are easy to draw as opposed to pie graphs and others, which reflect the challenges learners encounter when drawing line and other graphs.

Interpreting Line Graphs

Hassan et al. explored science learners' understanding of line graphs and discovered that errors in graph interpretation were due to virtual elements of the graph, such as scaling, variable identification, and data points, which learners could not identify.[31] Also, Tairab and Al-Naqbi highlighted that learners will never grasp graphs if they fail to see the relationship between variables and how they relate to the graph at hand.[32] As a result, learners tend to perceive graphs as just visuals rather than scientific tools for communication.[33] Moreover, other studies report that prior knowledge on graphing, concepts represented in the graph, inadequate familiarity with the language and rules of graphs, as well as describing trends and identifying patterns in the data, all contribute to graph interpretation difficulties.[34]

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[26] M. Y. Lai, A. S. Yeung, and X. Hu, " A Meta-Analysis of the Effects of Conceptual Change Instruction on Students' Science Learning," *International Journal of Science and Mathematics Education* 14, no. 4 (2016): 673–701; Ozmen, Erdem, and Aydin, " Students' Difficulties in Interpreting Scientific Graphs and the Role of Instructional Intervention."

[27] Nurlena Andalia, Burhanuddin AG, and Muhammad Zulfajri, "The Student Ability in Graph Understanding for Mastering Natural Science Concepts through the Process Skills Approach.," *International Journal of Instruction* 13, no.4 (2020): 145–60.

[28] Stephanie M. Gardner, Aakanksha Angra, and Joseph A. Harsh, "Supporting Student Competencies in Graph Reading, Interpretation, Construction, and Evaluation," *CBE—Life Sciences Education* 23, no. 1 (March 2024), https://doi.org/10.1187/cbe.22-10-0207.

[29] I., Kibirige and S. Ngobeni, "Exploring the Effectiveness of a Scientific Literacy Strategy in Promoting the Development of Graphing Skills in Grade 10 Learners," *South African Journal of Education* 30, no. 4 (2010): 553–66.

[30] Murat Bursal and Fuat Polat, "Middle School Students' Line Graph Skills and Affective States about Common Graph Types Used in Science Courses.," *International Journal of Education in Mathematics, Science and Technology* 8, no. 4 (2020): 290–303.

[31] Hassan, Adhabi, and Jones, "The Impact of Inclusion Setting on Social Interaction and Psychological Adjustment of Students with Disabilities."

[32] Hassan H Tairab and Ali K Khalaf Al-Naqbi, "How Do Secondary School Science Students Interpret and Construct Scientific Graphs?," *Journal of Biological Education* 38, no. 3 (2004): 127–32.

[33] C Hadjidemetriou and J S Williams, "Children's Graphical Conceptions. Research in Mathematics Education, 4, 69-87," 2002.

[34] Stacy K. Boote, "Assessing and Understanding Line Graph Interpretations Using a Scoring Rubric of Organized Cited Factors," *Journal of Science Teacher Education* 25, no. 3 (April 30, 2014): 333–54, https://doi.org/10.1007/s10972-012-9318-8; Andalia, AG, and Zulfajri, "The Student Ability in Graph Understanding for Mastering Natural Science Concepts through the Process Skills Approach."; Sunyono Sunyono, "Science Process Skills Characteristics of Junior High School Students in Lampung," *European Scientific Journal, ESJ* 14, no. 10 (April 30, 2018): 32, https://doi.org/10.19044/esj.2018.v14n10p32.

Furthermore, a study on assessing and understanding line graph interpretations revealed that learners with less mathematical ability are less likely to be able to interpret graphs.[35] While the very same study on grade 11 Physical Sciences' difficulties in constructing and interpreting graphs by Kibirige and Ngobeni revealed that some of the difficulties learners experienced were reading of variables on the x and y axes. [36] To address the dilemma of graphing, Gardner et al. conducted research to determine instructional adjustments that can aid in the enhancement of graphing competencies. They suggested (a) the use of data to engage learners, (b) teach graphing based on the subject, (c) adopt explicit education, (d) deploy real-world "messy" data, (e) employ collaborative work, and (f) emphasize reflection.[37] In the context of this study, it implies that if one wants to improve Grade 10 learners' understanding of line graphs, one must meaningfully present and provide them with experiences that will allow them to learn how graphing tasks (drawing and interpretation) are being done to the fullest extent possible.

Constructivist Teaching Approach

This teaching approach enables teachers to use different methods and materials to support and enrich learning, thus promoting meaningful learning,[38] while learners are encouraged to take an active role in the learning process. [39] In agreement, Burrowers study found that constructivist teaching provides many opportunities for learners to strengthen their graphing abilities through a range of in-class activities.[40] This approach is crucial for filling the gaps and facilitating desirable changes in the teaching and learning process, as graphing appears to necessitate long-term guidance and reflective practice.[41] Another study on the impact of the constructivist teaching model in enhancing reading skills by Seh found statistically significant differences in the performance of the experiment group, suggesting the effectiveness of the constructivist learning strategy in improving reading comprehension.[42] As such, through a constructivist approach, learners are able to enjoy deeper and more meaningful learning. [43] Hence constructivist teaching approach is considered in this study to improve learners' understanding of line graphs.

THEORETICAL FRAMEWORK

The theory underpinning this study is the social constructivism theory by Lev Vygotsky, who posited that knowledge is internalized as learners interact with each other in a social setting where they collaborate by engaging in group activities for meaningful learning.[44] The said theory was used to interpret the findings of this study; as such, it is necessary to briefly deliberate on the tenets considered specifically for this study. This theory is dependent on several tenets, including Zone of Proximal Development, scaffolding, mediation, language, and culture, to mention a few.

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[35] Boote, "Assessing and Understanding Line Graph Interpretations Using a Scoring Rubric of Organized Cited Factors."
[36] Kibirige and Ngobeni, "Exploring the Effectiveness of a Scientific Literacy Strategy in Promoting the Development of Graphing Skills in Grade 10 Learners."
[37] Gardner, Angra, and Harsh, "Supporting Student Competencies in Graph Reading, Interpretation, Construction, and Evaluation."
[38] Barman and Bhattacharyya, "Constructivism: A Paradigm for Teaching and Learning."
[39] Karimova Umida, Akhmedova Dilora, and Ergashev Umar, "Constructivism in Teaching and Learning Process," *European Journal of Research and Reflection in Educational Sciences* 8, no. 3 (2020): 134.
[40] Patricia A. Burrowes, "A Student-Centered Approach to Teaching General Biology That Really Works: Lord's Constructivist Model Put to a Test," *The American Biology Teacher* 65, no. 7 (September 2003): 491–502, https://doi.org/10.2307/4451548.
[41] Angra and Gardner, "Reflecting on Graphs: Attributes of Graph Choice and Construction Practices in Biology."
[42] Maisa Seh, "The Effectiveness of the Constructivist Learning Model in Enhancing the Motivation of Fourth Grade Students towards Reading among Arab Students in Israel.," *Journal of Positive School Psychology* 6, no. 5 (2022).
[43] K. Sumitha, "Constructivist Teaching Strategies to Enhance Academic Outcomes of Learners," *Conflux Journal of Education* 11, no. 2 (2023).
[44] Lev S Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*, vol. 86 (Harvard university press, 1978).

However, among these components, this study considered only culture and language.[45] Culture is viewed as a set of languages, symbols and signs that are included in the process of communication as they are transmitted by community members.[46] In the context of this study, culture was used as a mode of communication through which learners were able to interpret and make meaning of what they meant during their social interactions.

Language, according to Vygotsky, develops from social interactions and is the greatest tool for communication with the world; as such can be seen as a set of written or spoken symbols that serve as the foundation for thinking, reasoning, and comprehension developed from social interactions.[47] Therefore, in the context of this study, the learners were able to communicate through thinking, reasoning, and comprehension to communicate their understanding of graphs and ways in which they interpreted them.

METHODOLOGY

Research approach, sampling and research design

This study used a qualitative research approach. The rationale for using this approach was to ensure that the collected data is presented as words combined into meanings, to describe and interpret phenomena. This followed a single case study design. The case in the context of this study was the Grade 10 learners who had Life Sciences as one of their major subjects. This study used a purposive sampling technique to sample 25 Grade 10 learners on the basis that they belonged to a Life Sciences classroom at a particular school within Sekhukhune Circuit. Although the study targeted a sample of 25 learners within the population of 57 Grade 10 learners, only 19 learners agreed to participate.

Quality Criteria and Ethical Considerations

This study used data triangulation, where participant observations and document reviews were in the form of learners' written responses. To reach data saturation, this study conducted participant classroom observations and carried out a document review in the form of learners' written responses.

Data Collection

In an attempt to respond to this study's research questions, data was collected in the form of participant classroom observations as well as document review. When and how each tool was used to collect the data is explained below.

Classroom Observations

This study used participant classroom observations, which allowed the researchers to engage in some of the events that occurred at the place where the research took place. In the context of this study, the second author served as the participant observer, where she played this role on two occasions.

Documents Review

The researchers used document review, which afforded them the latitude to be in parity with the language and words of the learners who participated in this study. The documents that were reviewed were in the form of participating learners' written responses, which were written towards the end of each of the two lessons observed.

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[45] K. N. J. Musafer, " Investigation of the Correlation between the Leptin Gene and Type II Diabetes Mellitus-Related Biochemical Parameters in the Iraqi Population" (Universiti Teknologi Malaysia, 2021); Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*.

[46] Siyaves Azeri, "Activity, Labour, and Praxis: An Outline for a Critique of Epistemology," *Critique* 47, no. 4 (October 2, 2019): 585–602, https://doi.org/10.1080/03017605.2019.1678267.

[47] L. S. Vygotsky, *Thought and Language* (MIT Press, 1962).

Data Analysis

The data analysis process was driven by "giving meaning to first impressions as well as to final compilations", where the researchers synthesised data and participants' experiences into components where they assign meaning. Furthermore, categorical aggregation were chosen where instances or patterns from the data collected were assessed to draw conclusions. Also, an inductive approach was used, which allowed the examination of textual material from the data sets, namely, classroom observations and document review. Lastly, all of the collected data were inspected and searched for resemblances and variances before they were categorised and inferred. Once the data was analysed, social constructivism was used as a lens to interpret the findings.

Ethical Considerations

In this study, an ethical certificate was obtained from the relevant body and permission to conduct the study at the circuit was also granted by the provincial Department of Education. The learners who participated in this study were requested to complete the assent and informed consent forms. Hence, the learners' biographical data (see Table 01) is provided below, where they were provided pseudonyms to protect their identity to strengthen the anonymity and confidentiality in the following manner: learners (L) were named L01 to L19.

Table 1: Biographical details of the participants

Participant	Gender	Age
L01	Female	16
L02	Female	16
L03	Female	16
L04	Male	16
L05	Female	16
L06	Male	16
L07	Female	16
L08	Male	16
L09	Male	17
L10	Male	17
L11	Female	16
L12	Female	16
L13	Female	16
L14	Male	16
L15	Male	16
L16	Male	16
L17	Female	17
L18	Male	16
L19	Male	16

PRESENTATION OF FINDINGS

This section presents the data gathered from the classroom using the data collection instruments that were discussed previously. The presentation of data begins with classroom observation and document review on day one. This is followed by the presentation of the data collected on day two through classroom observations and document review. The theme that emerged from data analysis for day one was *interpreting line graphs*, and the theme for day two was *drawing the line graph*.

Presentation and Analysis of Data collected from the first session (day 1)

During this session, the teacher used the whole class discussion as a teaching method, which allowed her to carry out observations, while the activity used for document review required the learners to work in groups of 5 learners per group. The theme for this session is *interpreting line graphs.*

Classroom Observations

- **Interpreting line graphs**

The first question asked during the observation was to determine if the learners understood what a line graph is, and below is a conversation between the teacher and the learners.

1 - **Teacher**: *How do you understand a line graph?*

2 – **L04**: *Line graphs show results that are continuous for two variables that influence one another and are represented in the form of a line*.

3 – **L08**: *Line graphs are graphs which show lines.*

4 - **Teacher**: *Anyone who wishes to expand the answers provided by the two learners?*

5 – **Learners**: *Were silent and none answered.*

Drawing from the conversation between the learners and the teacher, it can be deduced that the learners had an idea of what a line graph is. This is drawn from **L04,** whose response highlights the presence of two variables that influence one another, while **L08** highlighted that these graphs are represented in the form of a line. The views shared by Slutsky, who define a line graph as a graph that is used to present quantitative data that shows a continuous relationship between two variables.[48] Although other learners remained silent after they were asked if there was anything they wanted to add, it can still be deduced from what **L04** and **L08** said that the learners are familiar with a line graph.

This question sought to get an idea of what the learners do in order to draw a line graph.

1 - **Teacher**: *Okay, what do you do when you draw a line graph?*

2 – **L15**: *I write a title and, choose variables and assign them to axes with units.*

3 – **L11**: *I draw the cartesian plane, look at the table of results.*

4 – **L01**: *I check the pattern of the values so that I can come up with a scale and use ruler to place and arrange data points so that I can join them.*

Drawing from this conversation between the learners and the teacher, it can be deduced that although most of the learners had an idea of what to do when they draw a graph, these learners somehow reflect misconceptions to a certain extent. This is because there is no learner who speaks of independent or dependent variables which play a significant role in determining the values on the axes. In other words, these learners seem to struggle in terms of determining the variable.[49] This is evident with **L15,** who speaks about choosing variables, **L11** starting with the Cartesian plane, while **L01** starts with the pattern of values, which may lead to learners being unable to scale or transfer information into the graph. Furthermore, **L11**'s response is silent about the data set and the information about the data set. The trend that emerges from the learners' responses is similar to a study on learners' understanding of line graphs by Hassan et al., which found that, among other things, learners could not transfer information into a graph and could not apply their mathematical knowledge of graphs into a science context.[50]

This question sought to find out what the learners include in the title of their line graph

1 - **Teacher**: *What do you include in the title of your graph?*

2 – **L08**: *Most of the time, I just copy the question and make it the title.*

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[48] David Slutsky, "The Effective Use of Graphs," *Journal of Wrist Surgery* 03, no. 02 (May 17, 2014): 067–068, https://doi.org/10.1055/s-0034-1375704.

[49] Department of Basic Education, *Life Sciences Curriculum and Assessment Policy Statement (CAPS)*.

[50] Hassan, Adhabi, and Jones, "The Impact of Inclusion Setting on Social Interaction and Psychological Adjustment of Students with Disabilities."

3 – **L19**: *It is difficult for me to come up with a title, so most of the time, I do not even bother to write the title when constructing a graph*.

Drawing from the learners' responses, it can be deduced that learners do not know what to include in the title of their line graphs. This is evident from both **L08** and **L19**, where one copies the question, while the other does not even bother to generate a title for the line graph. Researchers attributed this trend to inadequate awareness of the language and rules of graphs, as well as relating trends, which all contribute to graph interpretation difficulties.[51]

This question aimed to find out how the learners read the line graph to get the general trend.

1 - **Teacher**: *How do you read off the line graph to get the general trend?*
2 – **L15**: *I check the line of the direction of the line and relate it to the variables.*
3 – **Teacher**: *What do you mean?*
4 – **L15**: *If the line goes up, it means an increase, and when it goes down, it means a decrease.*
5 – **Teacher**: *So, the graph reflects growth and decline?*
6 – **L11**: *No ma'am, when the line is flat and straight, it means it is constant.*

The trend emerging from the teacher and learners' conversation suggests that the learners know and measures used to read the general trend of a line graph. This is evident from **L15**'s response, where the learner is interested in the direction of the line and the use of variables, while **L11** shows that she is familiar with what it means for a graph to be constant. These responses show that these learners are able to interpret most of the aspects of a drawn line graph. Lastly, the ability for **L11** to counter the teacher with a response to a question that was asked to **L15** is a reflection that these learners, through a constructivist approach, are not passive receivers of knowledge, but dynamic constructors of their knowledge grounded on their prevailing conceptions.[52]

Documents Review

This section generated data from the learners' written responses to the questions based on Figure 1 below. The 19 learners were grouped, where each group was made up of five learners, except for one group that had four learners. This activity was intended for the assessment of the learners' line graph interpretation skills.

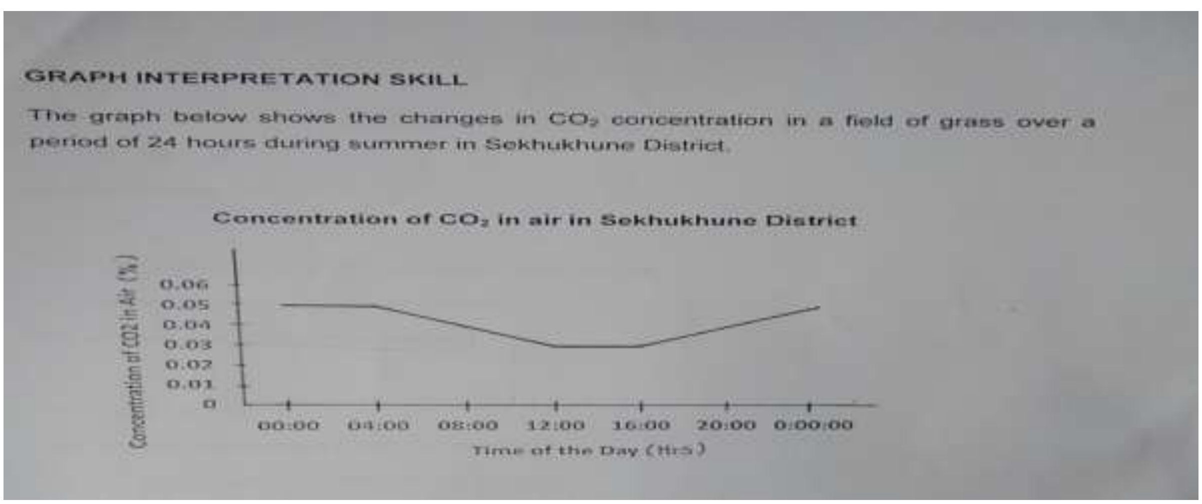

Figure 1: Graph interpretation skill

[51] Kamarudin, Abdullah, and Aziz, "Examining ESL Learners' Knowledge of Collocations"; Andalia, AG, and Zulfajri, "The Student Ability in Graph Understanding for Mastering Natural Science Concepts through the Process Skills Approach."
[52] Connors, "Constructivism in Education"; McLeod, " Constructivism as a Theory for Teaching and Learning."

1. Between which hours is the concentration of CO_2 a) the least? b) below average?
   Group 1; Group 2 and Group 3: *a) 12h00 to 16h00 b) 08h00 to 20h00*
   Group 4: *a) 12h00 to 16h00 b) 12h00 to 16h00*

This question required these groups of learners to reflect on their understanding of this question by examining the relationship between the dependent and independent variables. Therefore, out of the four Groups of learners, only three of the groups were able to provide the correct interpretation of the graph by providing the correct answers related to the question. However, Group 4 provided the wrong information related to the concentration of the CO_2, which was below average. Instead of providing the answer as 08h00 to 20h00, the Group provided 12h00 to 16h00 as the answer; as such, it can be deduced that 75% of the Groups provided the correct answer, as opposed to 25% that provided the wrong answer. This trend corroborates the findings by Kibirige and Ngobeni, who found that learners had difficulties plotting and reading variables on the x and y axes.[53]

2. Between which two hours did the percentage of CO_2 a) drop the most? b) rise the most?
   Group 1; Group 2; Group 3 and Group 4: *a) 8h00 to 12h00 b) 16h00 to 00h00*

This question, just like the previous question, required all four Groups of learners to reflect an understanding of graph interpretation, where the knowledge of the role of both independent and dependent variables is important. All four Groups provided correct answers to this question; as such, 100% of the Groups provided correct answers. This trend reflects the opposite trend to a study on assessing and understanding line graph interpretations by Boote, which revealed that learners with less mathematical ability are less likely to be able to interpret graphs.[54] However, on this question, all the Groups of learners reflected the high mathematical abilities which allowed them to interpret the graph in question.

3. What was a) the highest concentration of CO_2 recorded? b) the lowest concentration of CO_2 recorded?
   Group 1; Group 2 and Group 3: *a) 0.05 b) 0.03*
   Group 4: *a) 00h00 to 04h00 b) 12h00 to 16h00*

This question required the four Groups to provide the reading of both the highest and lowest CO_2 concentrations. Groups 1 to 3 were able to reflect an understanding of the question, which required the readings, not time frames. However, Group 4 provided answers reflecting time frames which reflect a misunderstanding of the question or the Group's inability to interpret the graph; as such, this is the only Group to provide an incorrect answer under this question. Hence, 75% of the four Groups managed to provide the correct answers as opposed to 25% that provided incorrect answers. This trend reflects the study on assessing and understanding line graph interpretations by Boote, which revealed that learners with less mathematical ability are less likely to be able to interpret graphs.[55] Therefore, it can be deduced that Group 4 learners are likely to have less mathematical ability.

At what time was the concentration of CO_2 in the air 0.4%?
   Group 1; Group 2 and Group 3: *08h00*
   Group 4: *04h00*

This question required the four Groups of learners to focus their answers on the x-axis of the line graph, and the answers provided by the four Groups reflect a trend that emerged from both questions 1 and 3, where Group 4 provided a wrong answer. Although under this question, the Group reflected an understanding of what the question required, their interpretation of the graph was poorly done. This is evident from the answer they provided, where they provided 04h00 instead of 08h00. Hence, three out of four Groups

[53] Kibirige and Ngobeni, "Exploring the Effectiveness of a Scientific Literacy Strategy in Promoting the Development of Graphing Skills in Grade 10 Learners."
[54] Boote, "Assessing and Understanding Line Graph Interpretations Using a Scoring Rubric of Organized Cited Factors."
[55] Boote, "Assessing and Understanding Line Graph Interpretations Using a Scoring Rubric of Organized Cited Factors."

provided the correct answers. This trend reflects the study on learners' graph skills and affective state about common graph types by Bursal and Polat, which found that learners struggled with variables and graphing skills. This is evident in the answer provided by Group 4.[56]

Presentation and Analysis of Data Collected from the Second Session (Day 2)

This section presents and analyses data drawn from classroom observations, which is followed by a document review in the form of the participating learners' written work, which was done during the second session or day 2. During this session, the teacher used the whole class discussion as a teaching method, which allowed her to carry out observations, while the activity used for document review required the learners to work in groups of 5 learners per group. The theme for this session is *drawing a line graph.*

Day 2 - Classroom Observations

- **Drawing the line graph**

This question is intended to find out how the learners determine data points on a line graph.

1 - **Teacher**: *How do you determine data points on a line graph?*
2 – **L06**: *I use a ruler and draw dotted lines from the number from the x-axis and another one from the y-axis until the two dotted lines meet.*
3 – **L04**: *Where the two dotted lines meet is a point that is needed.*
4 – **L08**: *I just look at the graph and guess the answer.*

Drawing from the three responses, it is evident that two of the learners' responses (**L06** and **L04**) suggest that the learners know what they need to do in order to plot a line graph, while **L08**'s response suggests that the learner is lost. The two learners seem to have figured out a way of generating points on the Cartesian plane. This is drawn from **L06,** who uses a ruler and draws the dotted lines, while **L04** highlights the importance of where the dotted lines meet. Hence, studies suggest that it is anticipated that learners are more exposed to graphing principles in mathematics class and should be able to use their knowledge in other subject areas, such as Life Sciences, where they can spot patterns, make predictions, and draw conclusions from graphs.[57] Although the two learners reflect the exposure to graphing principles, **L08** seem lost, and this is a trend that was visible in the previous lesson.

This question sought to determine how learners determine the variable and how they decide which values should be placed on the *x-axis* and *y-axis*.

1 - **Teacher**: *How do you determine the variables? Which one do you put on the x-axis and y-axis?*
2 – **L02**: The *Independent variable belongs to the x-axis and the dependent variable belongs y-axis.*
3 – **L10**: *I just chose any variable from the data table and put it anywhere.*
4 – **L08**: *Me too.*

The learners' responses to this question reflect two opposite trends: one that shows that some of the learners have an understanding of how variables are determined. It is evident from **L02** who highlights that independent variables belong to the x-axis, while dependent variables belong to the y-axis. Such an informed response from the learner is in contrast to what both **L10** and **L08** reflected. That is to say, it is evident that the two learners are familiar with what variables entail and the role they play in line graphs. However, they do not know how to use them. Hence, certain scholars have stated that learners will never grasp graphs if they do not understand the relationship between variables and how they relate to the graph at hand.[58] As a result, learners tend to perceive graphs as mere visuals rather than scientific communication tools.

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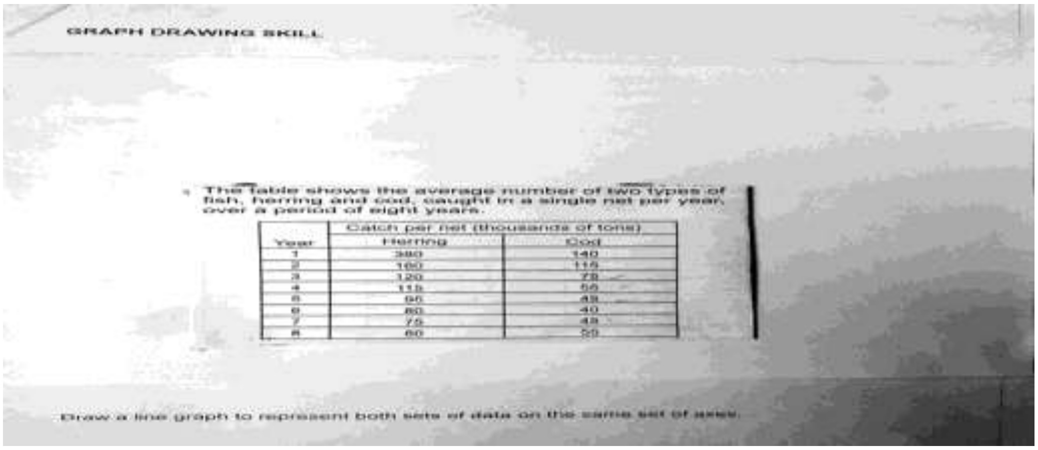
[56] Bursal and Polat, "Middle School Students' Line Graph Skills and Affective States about Common Graph Types Used in Science Courses."
[57] (DBE) Department of Basic Education, *Life Sciences Curriculum and Assessment Policy Statement (CAPS)*; Govender, "South African Teachers' Perspectives on Support Received in Implementing Curriculum Changes."
[58] Hadjidemetriou and Williams, "Children's Graphical Conceptions. Research in Mathematics Education, 4, 69-87"; Tairab and Khalaf Al-Naqbi, "How Do Secondary School Science Students Interpret and Construct Scientific Graphs?"

Documents review

This section generated data from the learners' written responses to the questions based on Figure 2 below. The 19 learners were grouped, where each group was made up of five learners, except for one group that had four learners.



GRAPH DRAWING SKILL

The table shows the average number of two types of fish, herring and cod, caught in a single net per year, over a period of eight years.

Year	Catch per net (thousands of tons)	
	Herring	Cod
1	380	140
2	160	115
3	120	78
4	115	55
5	95	45
6	80	40
7	75	45
8	60	50

Draw a line graph to represent both sets of data on the same set of axes.

Figure 2: Graph drawing skill

The following figures represent the line graphs drawn by each of the four Groups of learners. Each figure of the graph is deliberated upon. This activity was intended for the assessment of the learners' line graph drawing skills.

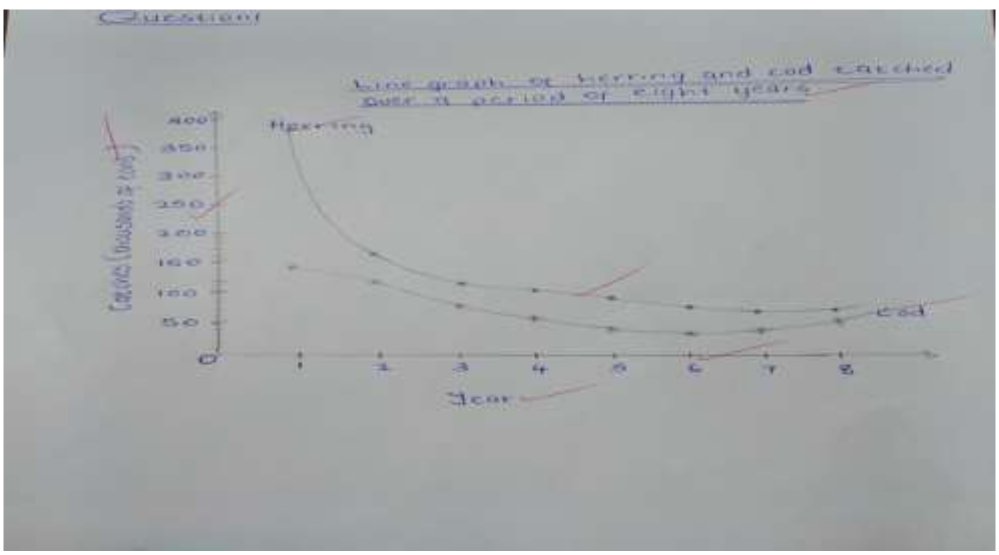


Figure 3: Group 1 response

It can be deduced from Figure 3 above that the line graph reflects several key aspects, such as the title of the graph, the correct use of scaling, and the correct use of the axes, where time is under the x-axis and dependent variables on the y-axis. Although it can be argued that the Group could have used different colours to draw the graphs and provided keys to reflect the difference between the two-line graphs, the necessary information was correctly written. As such, it can be concluded that Group 1 followed the proper channel to construct the correct line graph. The accuracy of the graph drawn resonates with a study on learners' ability in graph understanding for mastering Natural Science by Andalia et al., which found that the improvement of learners' understanding of graphs is dependent on concept mastery, which suggests that the learners' understanding of graphs cannot be separated from their mastery of the concepts involved.[59] Therefore, it can be deduced that this Group's concept mastery played an important role in the answer they provided.

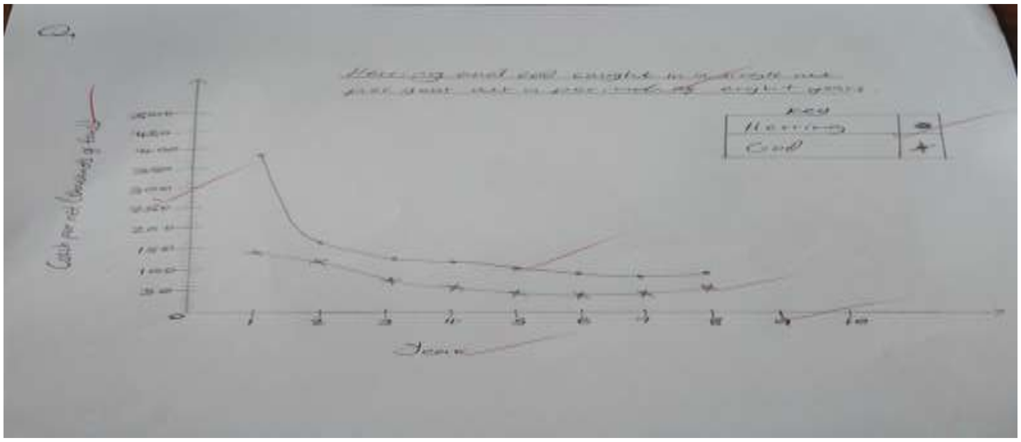


Figure 4: Group 2 response

The graph drawn by Group 2 also shows a few important aspects, such as the title, the correct labelling, scaling, and the correct use of the variables, where time is on the x-axis. Furthermore, the Group went a step ahead of Group1, where they managed to highlight keys; although the graphs are constructed using the same colour, the points are highlighted differently. Therefore, it can be deduced from Figure 4 above that Group 2 managed to correctly draw the line graph. While a study on grade 11 Physical Sciences' difficulties in constructing and interpreting graphs by Kibirige and Ngobeni revealed the learners' difficulties, such as plotting the graph and writing the title of the graph.[60] This was not the case with this Group, which was able to correctly plot the graph and write a title. As such, reflecting a trend that is consistent with concept mastery, high mathematical abilities.

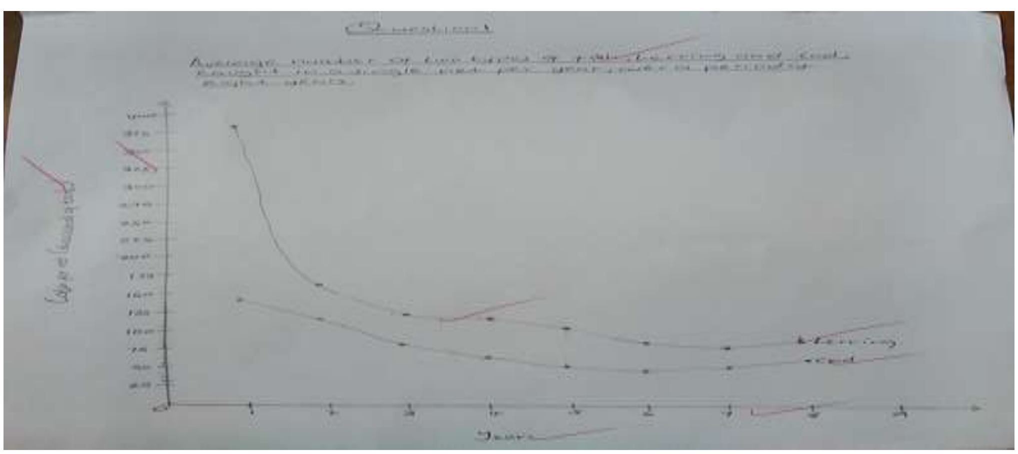


Figure 5: Group 3 response

[59] Andalia, AG, and Zulfajri, "The Student Ability in Graph Understanding for Mastering Natural Science Concepts through the Process Skills Approach."

[60] Kibirige and Ngobeni, "Exploring the Effectiveness of a Scientific Literacy Strategy in Promoting the Development of Graphing Skills in Grade 10 Learners."

Similarly, Group 3 managed to correctly include several key aspects in their drawing, which shows that they understand the necessary aspects needed to draw the line graph. Although the line graph has no keys, the line graphs are drawn using the same colour. It can be argued that, similar to Group 1, the graphs have been labelled as such; it can be concluded that Group 3, just like Groups 1 and 2, managed to correctly draw the two line graphs. This is the opposite reflection of research study by Ozmen et al.. who investigated learners overall graphing literacy, graph comprehension, critique and construction in science where the study concluded that low graphing abilities are caused by learners not being explicitly taught how to draw graphs, and they rarely use graphs as a tool to communicate investigation results as well as sources to create rich classroom discussions.[61] As such, the Group 3 drawing and plotting of the graph reflect their high graphing abilities.

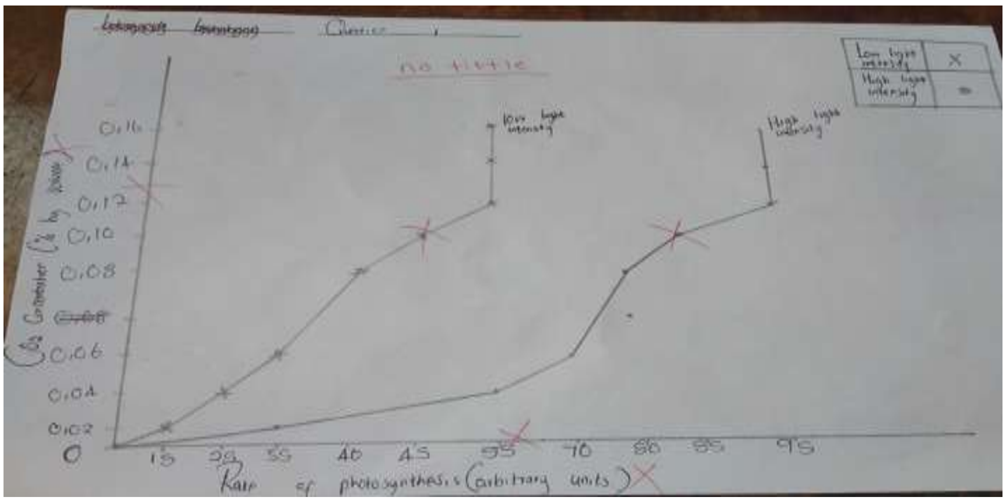


Figure 6: Group 4 response

The last line graph drawn by Group 4 reflects a few positive aspects and a few wrong aspects that contributed to the graph being wrongly drawn. The one positive aspect gathered from the graph is that the Group managed to provide keys, and they can also be seen on the two graphs. The wrong aspects are that the Group did not write the title for the graphs, and the Group did not use the information that belongs to the x-axis, which is time represented by *years*. Furthermore, the Group did not construct the graphs correctly, which was due to the incorrect plugging of variables. Therefore, it can be deduced that the graphs drawn by Group 4 are incorrectly constructed, and this trend is a continuation that began on day 1 (first lesson), where this Group managed to obtain only one correct answer from the activity that was written. The answers reflected from Group 4 are the reflection of the studies that found that concept mastery in graphing, graphing skills such as plotting the correct variables and naming of the graph title, are important in line graph understanding.[62]

DISCUSSION

This section deliberates on the findings of this study, interpret the findings through the social constructivism tenets, namely, culture and language.

[61] Ozmen, Erdem, and Aydin, " Students' Difficulties in Interpreting Scientific Graphs and the Role of Instructional Intervention."

[62] Andalia, AG, and Zulfajri, "The Student Ability in Graph Understanding for Mastering Natural Science Concepts through the Process Skills Approach."; Bursal and Polat, "Middle School Students' Line Graph Skills and Affective States about Common Graph Types Used in Science Courses."; Kibirige and Ngobeni, "Exploring the Effectiveness of a Scientific Literacy Strategy in Promoting the Development of Graphing Skills in Grade 10 Learners."

Research Question 1:
What are Grade 10 Life Sciences learners' understanding of line graphs?
The findings from both classroom observations and document analysis show that learners had limited knowledge of line graphs. However, some learners were able to correctly define a line graph by detecting continuous data and line representation. Other learners provided confusing or misleading descriptions. While the majority of learners could sketch basic graph creation techniques, such as using a ruler and plotting points, a few learners struggled to identify essential concepts, such as independent and dependent variables. The trend of inconsistency emerged during graph interpretation, with 75% of the groups able to identify trends and values, but Group 4 continued to misinterpret the data, implying that while most of the learners demonstrated basic understanding of interpreting line graphs, Group 4 struggled with deeper conceptual understanding. As a result, common errors included inaccuracy in differentiating variables, depending on question wording, as well as graph titles, and misinterpretation of questions.

Research Question 2:
How does the use of a constructivist teaching approach enhance Grade 10 Life Sciences learners' understanding of line graphs?
The findings from classroom observations and document analysis show that learners' graph creation skills and engagement have improved. Furthermore, the constructivist approach enhanced learner articulation of graphing processes, such as proper point charting along the axes of x and y, as well as knowledge of the relationships between variables. The technique increased learner engagement during class discussions, as they corrected and expanded on each other's and the teacher's remarks, demonstrating active knowledge development. Finally, three of the four groups displayed improved graph drawing skills, including proper scale, axes labelling, and variable placement. However, some of the learners did not profit from these advantages, particularly Group 4, which continued to struggle with essential concepts and graph accuracy, emphasising the need for more assistance.

The interpretation of the findings through social constructivism
The sections below interpret the findings through social constructivism by using the tenets, namely, culture and language, as mediating tools for understanding.

Culture as a mediating tool for understanding
Culture, in social constructivism, refers to the common practices, tools, norms, and values that influence how knowledge is built in specific circumstances. In the context of this study, learners' knowledge of line graphs was heavily influenced by their previous experiences with graphing activities, particularly in Mathematics and Life Sciences, as well as the cultural norms of their learning environment. Many learners demonstrated narrow conceptual knowledge, with their engagement motivated by procedural or rote learning, such as copying questions for titles or plotting points without interpreting trends. Such techniques represent cultural learning habits that value performance above real learning. The learners' difficulties in revealing variable relationships or interpretations of graph axes highlight inadequacies in how line graphs have been culturally transmitted throughout their educational experience.

However, by implementing a constructivist approach that included whole-class discussion and group work, the classroom became a cultural community of practice in which learners engaged with line graphs as a collaborative scientific practice rather than a technical competence. This improved their performance because they were able to design graphs and use the proper resolutions, such as titles, keys, and labelling axes, reflecting learners' adoption of disciplinary cultural tools through social engagement and directed involvement. Importantly, the diversity among groups, particularly Group 4's ongoing challenges, demonstrates that access to cultural tools is not fairly distributed. Learners from various origins or with varied prior experiences may require individualised assistance to fully engage with scientific graphing as a cultural activity.

Language as a mediating tool for understanding

Language serves as both a medium of communication and a foundation for thought. Thus, in the context of this study, language was critical in moulding and demonstrating the learners' comprehension of line graphs. Initially, the learners struggled to articulate line graph-related concepts using scientific language. That is, their responses were generally ambiguous and duplicated the teacher's phrases and enquiries, implying that the learners had a limited grasp of language, which was critical for their reasoning regarding line graphs. However, the implementation of a constructivist approach enabled learners to verbally interact, participate, and cooperate through discussion, which aided their cognitive development. Peer-to-peer talks and dialogues allowed learners to externalise their ideas, which encouraged meaning negotiation and helped to clear up certain misconceptions. As a result, the interaction between **L15** and **L11** about line graph trends demonstrates an engagement that facilitated comprehension. Furthermore, **L11** was able to correct the teacher, demonstrating increasing confidence in language use in knowledge construction. Furthermore, the four groups worked together to create line graphs, which allowed for shared meaningful language acquisition. The groups were given the opportunity to verbalise judgements such as axes labelling and line graph draughting methods. These interactions provided learners with the opportunity to practise and internalise line graph terminology in an authentic environment.

RECOMMENDATIONS

Based on the findings of this study, the following practical and actionable recommendations are made to improve the teaching and learning of line graphs in Grade 10 Life Sciences classrooms.

To begin, Life Sciences teachers should explicitly teach graphing as a scientific technique, rather than presuming that learners will transfer their graphing expertise from Mathematics to Life Sciences. The data revealed that many learners struggled to identify variables, scales, and create meaningful names. Life Sciences teachers should thus demonstrate the step-by-step process of creating line graphs, emphasising the relationship between independent and dependent variables, appropriate scaling, and the scientific significance of graph titles in Life Sciences contexts. In addition, teachers are urged to use a constructivist teaching approach that emphasise learner involvement and conversation, such as whole-class debates, group projects, and peer explanations. The study found that giving learners opportunities to clarify their thoughts, correct one another, and negotiate meaning throughout graphing assignments enhanced their learning. Structured group activities in which learners collaborate, interpret and build line graphs should be integrated into day-to-day classroom pedagogy.

Secondly, Life Sciences teachers should intentionally provide scaffolding and individualised support for learners who continue to struggle with graphing concepts. The continuous challenges encountered by some learners in this study suggest that a single teaching strategy may not be adequate for all learners. There should be a consideration for teachers to provide targeted support, such as guided worksheets, visual stimuli, and language support, to help learners with limited conceptual or mathematical foundations. Life Sciences teachers should emphasise the use of scientific terminology while teaching graph interpretation and building. The results showed that learners initially struggled to communicate graphing concepts using suitable terminology. Furthermore, teachers should purposefully model and reinforce graph-related vocabulary, including phrases such as ‘independent variable,’ ‘dependent variable,’ ‘trend,’ and ‘constant’, and provide chances for learners to utilise this language during conversations and written activities.

Finally, curriculum planners and subject advisors are encouraged to improve the linkage of mathematics and life sciences curriculum in terms of graphing skills. Line graphs are a cross-disciplinary tool; coordinated teaching strategies and common expectations across topics may improve learners' capacity to transfer graphing skills meaningfully between settings.

CONCLUSION

This study explored Grade 10 Life Sciences learners' understanding of line graphs and how a constructivist teaching strategy could improve that understanding. According to the findings, most learners struggled at first with reading and creating line graphs, and they typically had a limited understanding of core concepts such as variable connections and trend analysis. Their interaction with graphs was primarily procedural, suggesting rote learning, which prioritises memorisation over comprehension. The implementation of a constructivist teaching approach enabled learners to participate in meaningful learning through dialogue, collaboration, and hands-on activities. This strategy promotes meaningful interaction with line graphs. Furthermore, learners were able to employ accurate graphing conventions more consistently and showed improved comprehension in both individual and group assignments.

When seen through the lens of social constructivism, the findings highlight the critical importance of culture and language as mediating resources for learning. The two tenets emphasised that learners' challenges were rooted in cognitive gaps and unequal access to the cultural and linguistic resources required for scientific reasoning, notably graphing. The two tenets enabled the classroom to function as a culturally rich environment in which learners applied appropriate disciplinary procedures, such as line graphs, through social interaction and group activities. Furthermore, language was important as a means for transmitting thought in order to facilitate meaningful learning. Thus, this study shows that a constructivist strategy based on cultural sensitivity and explicit language support can significantly improve learners' understanding of complicated representations such as line graphs. However, the study emphasises the importance for Life Sciences teachers to understand and address the diverse cultural and language experiences that learners bring to their classrooms, as a constructivist approach may benefit a few learners while leaving others behind.

Recommendations for further studies

For further research, firstly, this study suggests that researchers conduct studies that explore how Life Sciences learners' cultural experiences and prior knowledge influence their interpretation and building of line graphs. Such research could help to provide insights into how learners' scientific thinking is influenced by their local and daily experiences, as well as how culturally relevant pedagogies can improve understanding. Second, given the small population and number of participants in this study, it is advocated to do a longitudinal study to investigate how the constructivist approach influences Life Sciences learners' graphing skills over time. Such research could assist in evaluating whether the learners' improved comprehension is retained and how their ideas evolve throughout grades. Finally, given the cross-disciplinary nature of line graphs, this study suggests that future research compare how learners engage with graphs in Life Sciences content to how they engage with line graphs in mathematics, which could aid in skill transferability.

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