LEVELS OF INQUIRY FOCUSED IN THE EXAMINATION COUNCIL OF ZAMBIA (ECZ) SCHOOL CERTIFICATE CHEMISTRY PAPER 3 (5070/3) EXAMINATION

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ABSTRACT

In science education, the inquiry has two distinct sides: 1) teaching and learning science by inquiry, 2) Science as inquiry. Teaching and learning science by inquiry involves the means by which students acquire scientific knowledge. On the other hand, science as inquiry focuses on science as a method by which facts are obtained. This study focused on teaching and learning science by inquiry. Specifically, the purpose of this study was to determine inquiry levels in the Examination Council of Zambia chemistry 5070/3 practical examinations for the period ranging from 2008 to 2018. Both questions in chemistry 5070/3 practical paper for each year were analyzed for levels of inquiry using analysis framework and procedures. Analysis framework and procedures involve two processes; categorizing sentences as experiential and further analyzing the experiential sentences for inquiry potential by considering the four levels of inquiry (confirmation, structured, guided, and open inquiry). An inter-rater agreement coefficient for analysis of the chemistry 5070/3 practical examination was calculated using Cohen's Kappa (Cohen, 1960). The percentage agreement between the two raters for the chemistry 5070/3 practical examination past papers analyses ranged from 75 to 100% with the corresponding Kappa values from 0.421 to 1.00. This means that there was a high degree of agreement between the two raters in categorizing the levels of inquiry. The results showed that the experiments in chemistry practical examinations were mostly at the structured level of inquiry. The period under review had no experiments focusing on higher levels of inquiry such as open inquiry. These results have implications on science teaching, learning, assessment, and teacher education. *[African Journal of Chemical Education—AJCE 11(1), January 2021]*

INTRODUCTION

The desire to produce a scientifically literate society has been at the heart of science education worldwide [1]. With the current exponential increase in scientific knowledge, new technologies and more complex societal challenges the world over, much demand is placed, and the emphasis is laid on the teacher, the learner, the curriculum and the environment in the entire process of teaching and learning of science. Science education curriculum reform efforts around the world emphasize the importance of developing abilities to do inquiry [2]. Studies show that chemistry is a very important school subject in the context of science education and its importance in the scientific and technological development of any nation has been widely reported [3, 4]). Other than natural resources, the development of any country relies on the scientific literacy of its citizenry.

Chemistry plays a major role in solving the challenges that face our planet and the development of every nation [5]. Hence, adequate preparation of learners in chemistry classes is required so as to have future chemists that will be able to offer solutions to existing and new problems in society. This means developing a new curriculum and new methods of teaching chemistry so that citizens can become chemically literate and be able to provide solutions to societal issues. The inquiry appears to be one way to learn both skills and curriculum [6, 7]. It is quite promising that most African countries have changed and revised their curriculum from a content-based curriculum to a competency-based (CBC) or Outcome-based curriculum (OBC). The justification for this change is to make the curriculum more effective and responsive to societal needs by providing relevant knowledge, skills, and real-life competencies for the learners [8].

The Zambian education curriculum was revised in 2013 in a bid to produce learners who are life-long learners, creative, innovative, analytical, productive, and cooperative in their

communities and the nation [9]. The new curriculum was themed 'Empowering Learners by Putting Theory into Practice'. One of the education guiding principles in this document is outcome-based (or competency-based) education. This means learners must be provided with practical experiences during the teaching and learning process that assist them to gain life skills [10]. While this change is appreciated, it is important to realize that the actualization of the curriculum depends on the conformity of assessment goals and learning outcomes in the national examinations and school-based assessments and syllabus to its goals. Besides, its implementation largely depends on teachers, though other stakeholders are equally important as well.

To date, the new national chemistry syllabus and chemistry practical examinations (5070/3) have undergone six cycles of implementation since their introduction in secondary schools. However, chemistry 5070/3 practical examinations, in particular, have not been evaluated to determine which of the four levels of inquiry emphasized in science education they conform to: Confirmation, Structured, Guided, or Open inquiry level. This lack of evaluation of the national chemistry (5070/3) practical examination papers for the four levels of inquiry justifies this study.

Literature shows that inquiry has four different levels. The lowest level of inquiry is confirmation. During confirmation inquiry level activities, learners are required to confirm or verify concepts by providing them with a question, procedure, and a known solution or answer to the question. Structured inquiry level activities require learners to find the answer to a given problem by following a given procedure. Guided inquiry level activities require learners to design their procedures in order to answer a given question. Finally, Open inquiry level activities allow learners to formulate their questions or problems or hypotheses, procedure, and conclude the data collected.

Studies show that practical examinations (Physics, Chemistry & Biology) are dominated by structured inquiry while inquiry activities in science textbooks are dominated by confirmation [11]. The advantages of lower levels of inquiry as reported by many authors include: Learners experience less confusion and frustrations when the question and procedure are given [12]; learners acquire procedural knowledge and manipulative skills which are necessary for advanced inquiry activities [13]; easy to grade learners' reports in that standard marking keys can be used by teachers [14]; motivates learners to learn science [15] and less time consuming thereby enabling learners to complete inquiry activities on time [12,16]. However, the teaching and learning that focuses on higher levels of inquiry is effective in helping learners understand concepts and support their success [17]. Thus, finding out the inquiry levels in Zambian secondary school chemistry examinations is significant to both Zambian science educators and to other science educators worldwide who intend to implement or are already implementing similar chemistry practical examinations at the senior secondary school level.

PROBLEM STATEMENT

The motive behind the current chemistry curriculum is well-intended and is in line with Zambia's vision 'Becoming a Prosperous Middle Income Country by 2030'. Therefore, increased effective inquiry teaching, learning, and assessment in chemistry are important if Zambia is to meet this aspiration [10, 18]. Studies show that a conceptual understanding of chemistry is enhanced if learners are taught through inquiry [19-21]). Bell and Wheeler [17] accentuate that teaching and learning that focuses on higher levels of inquiry is effective in helping learners understand concepts and support their success. Also, inquiry teaching, learning and assessment that focus on higher levels of inquiry allow learners to develop sophisticated inquiry skills such as

hypothesizing [22]. Both the lower and higher levels of inquiry can be reflected in the assessment activities given to learners.

However, the levels of inquiry focused in the Examination Council of Zambia school certificate chemistry practical 5070/3 for the years ranging from 2008 to 2018 are still unclear amid the implementation of the new curriculum. In particular, the primary purpose of this study was to determine the levels of inquiry focused in ECZ chemistry practical (5070/3) examinations and the extent to which the inquiry levels are examined. In addition, it sought to determine whether there was a balanced representation of inquiry levels in chemistry practical (5070/3) examinations.

Research Questions of the Study

This study was guided by the following research questions:

1. What are the levels of inquiry focused in chemistry 5070/3 practical examination for the period ranging from 2008 to 2018?
2. To what extent are levels of inquiry in chemistry (5070/3) examined?
3. Is there a balanced representation of inquiry levels before and after implementation of the new national chemistry curriculum?

METHODOLOGY

A case study approach employing a mixed methodology for purposes of data triangulation was the research design adopted [23]. A case study is a single entity such as a program or a course [24]. It is a design where a researcher may be involved in the analysis of documents [24-26]. A case study design was suitable in this study in that the study involved the analysis of chemistry course materials (chemistry 5070/3 practical examination past papers).

The research instruments were chemistry 5070/3 practical examination past papers which were administered to secondary school learners between 2008 and 2018. Chemistry 5070 paper 3 examination consists of two experimental-based questions. Thus, it is a laboratory-based examination. A total of 22 experimental-based questions were analyzed to determine the levels of inquiry that are focused in the examination. Inquiry levels in the chemistry 5070/3 practical examination past papers were determined by using analysis framework and procedures. Analysis framework and procedures was developed by Tafoya, Sunal and Knecht [27]. Since then, many researchers have used this tool to determine the inquiry levels in curriculum materials. Analysis framework and procedures involve two main processes; categorizing sentences or assertions as experiential and further analyzing the experiential sentences for inquiry potential by considering the four levels of inquiry (confirmation, structured, guided and open inquiry).

Questions, procedures, tables, and content statements were analyzed for inquiry potential. Two experienced chemistry teachers were taught how to use analysis framework and procedures. Thereafter, the two chemistry teachers separately analyzed the chemistry paper 3 examination past papers to determine the levels of inquiry. An inter-rater agreement coefficient for analysis of the chemistry 5070/3 practical examination was calculated using Cohen's Kappa [28]. This coefficient factor represents a measure of inter-rater reliability. The percentage agreement between the two raters for the chemistry 5070/3 practical examination past papers analyzed ranged from 75 to 100% with a corresponding range of kappa values from 0.421 to 1.00. This means that the agreement between the two raters was high. Values above 75% suggest that percentage agreement between two raters was excellent while kappa values below 0.4 denote a poor inter-rater coefficient [29].

RESULTS OF THE STUDY

Levels of Inquiry focused in ECZ chemistry practical (5070/3) examinations

Table 1 presents data that was obtained after the analysis of ECZ chemistry practical paper 3 (5070/3) for the years 2008 to 2018.

Table 1. *Percentage of Inquiry Levels per Year*

Year	Levels of Inquiry			
	Confirmation	**Structured**	**Guided**	**Open**
2008	27	73	0	0
2009	27	73	0	0
2010	44	56	0	0
2011	36	64	0	0
2012	36	64	0	0
2013	40	60	0	0
2014	23	77	0	0
2015	27	73	0	0
2016	36	64	0	0
2017	36	64	0	0
2018	44	50	6	0
Average	**34.2**	**65.3**	**0.5**	**0**

Source: ECZ chemistry paper 3 (5070/3) past papers

Table 1 shows that Experiments in chemistry practical examinations were mostly at structured inquiry level (65.3%), followed by confirmation level of inquiry (34.2%) and guided inquiry only had an average of 0.5%. However, there were no activities at the open inquiry level. These results suggest that the ECZ has not considered an equal proportion of inquiry levels in chemistry 5070/3 practical examinations. Generally, the focus is on the lower levels of inquiry (confirmation & structured). Furthermore, Table 1 reveals that the inclusion of structured inquiry from 2008 to 2018 has been above 50.0% while confirmation inquiry has been below 50%.

The Extent to which the Inquiry levels are examined

Table 2 shows the levels of inquiry levels that are examined in Chemistry 5070/3 practical examinations and their corresponding overall percentages.

Table 2. *Overall Percentage of Inquiry Levels for the Period Ranging From 2008 to 2018*

Levels of Inquiry	**Percentage**
Confirmation	34.2
Structured	65.3
Guided	0.5
Open	0

From Table 2, the results show that confirmation and structured inquiry levels have been consistently covered for the period under review. However, the focus has been more on structured inquiry and less on confirmation inquiry level. Generally, the results in Table 2 suggest that the inquiry levels are being examined up to structured inquiry in the chemistry 5070/3 practical examinations.

The Representation of Inquiry Levels Before and After Implementation of the New National Chemistry Curriculum

Table 3 shows the representation of inquiry levels before and after the implementation of the new chemistry curriculum.

Table 3. *Representation of Inquiry Levels in Chemistry Practical Examination Under the Old and New Curriculum*

Inquiry level	Representation (%)	
	Old curriculum (2008 -2013)	New curriculum (2014-2018)
Confirmation	35	33.2
Structures	65	65.5
Guided	0	1.2
Open	0	0

In Table 3, the inquiry levels that were represented before implementation were confirmation and structured inquiry without there being the representation of guided and open inquiry. This means that the representation of these inquiry levels was unbalanced. In addition, Table 3 shows that only confirmation, structured, and guided inquiry were represented after implementation of the new curriculum. This means that after the implementation of the new curriculum there was still an unbalanced representation of the levels of inquiry emphasized in science education.

DISCUSSION AND IMPLICATIONS

The primary objective of this study was to find out the levels of inquiry focused in ECZ chemistry paper 3 (5070/3) examination for the period ranging from 2008 to 2018. The results in Table1 have revealed that experiments in chemistry paper 3 practical examinations were mostly at confirmation and structured inquiry levels. These findings agree with the views of Chabalengula & Mumba [11] who reported that Zambia's practical exams lack both curriculum and instructional validity concerning the inquiry levels emphasized in science education. On the other hand, they contradict the views of Wheeler and Bell [17] that inquiry activities that focus on higher levels of inquiry are effective in helping learners understand concepts and support their success.

For example, results in Table1 indicate that the ECZ chemistry paper 3 (5070/3) examination does not include practical activities at open inquiry level and barely includes practical activities at the guided inquiry level. This means that the focus is more on the lower levels of inquiry than the higher levels of inquiry.

Furthermore, inquiry teaching, learning and assessment that focus on higher levels of inquiry allow learners to develop sophisticated inquiry skills [22]. However, inadequate coverage or complete absence of higher levels of inquiry in chemistry 5070/3 practical examinations, as revealed in this study, has the potential of influencing inquiry teaching and learning of chemistry in the classroom as learners are prepared for examinations. There is likelihood that teaching and learning may focus on lower levels of inquiry thereby denying learners opportunities to develop higher-level inquiry skills.

The findings in Table 3 show the unbalanced representation of inquiry levels in Zambian chemistry practical examinations before and after implementation of the new chemistry curriculum. The findings indicate that there has been more representation of lower levels of inquiry and barely any representation of higher levels of inquiry. However, the appearance or the representation of the lower levels of inquiry was consistent before and after the implementation of the new national chemistry curriculum except in 2018 where there was an inclusion of guided inquiry level in 2018. These findings are similar to the findings of the previous study by Mumba, Chabalengula and Hunter [30]. For the period ranging from 2001 to 2006, the aforementioned authors also found that there was an unbalanced representation of inquiry levels in chemistry 5070/3 practical examinations. Therefore, the findings of this study imply that the chemistry 5070/3 practical examinations are not fully aligned with the four levels of inquiry emphasized in science education.

According to the findings of this study, the period under review had no experiments focusing on higher levels of inquiry such as open inquiry. Mumba, Pottmeyer and Chabalengula [22] point out that such finding suggests that learners are having no opportunities to develop hypothesizing or questioning skills and other higher-level inquiry skills. Besides, such findings imply that learners may lack a deep understanding of concepts [17]. For this reason, ECZ and science educators must strive to include all the four levels of inquiry in their assessments so as to deepen learners' understanding of chemistry concepts.

CONCLUSIONS

It can be concluded that structured inquiry is the main level of inquiry focused in the Examination Council of Zambia (ECZ) School Certificate Chemistry Paper 3 (5070/3) Examination. This is followed by confirmation. Other levels of inquiry receive little or no focus. Also, the study revealed that a structured inquiry level is an extent to which inquiry levels are usually examined in chemistry practical examination. Hence, there has been an unbalanced representation of the four levels of inquiry.

RECOMMENDATIONS FOR FUTURE STUDY

The research should be extended to other practical examinations such as Science 5124/3, Biology 5090/3, Physics 5054/3 and other teacher-developed practical assessments. This will bring to light the depth to which inquiry levels are covered in teaching, learning, and assessment of chemistry by inquiry. In addition, this will confirm whether the four levels emphasized in science education are being appreciated or embraced by ECZ and science educators in all subject areas.

REFERENCES

1. International Institute for Capacity Building in Africa (IICBA). (2008). Contextualizing Science Education in Africa: *The case of Malawi, 2*(10), 1-5. Retrieved from http//www.unesco-iicba.org
2. Dudu, T., & Vhurumuku, E. (2012). Teachers' Practice of Inquiry When Teaching Investigation. *Journal of Science Teacher Education*, *6*(23), 579-600.
3. Odawa, O. C. (2011). *Factors Influencing Performance of Students in Chemistry in Public Secondary Schools in Kajiado North District, Kenya (Masters' thesis, The University of Nairobi, Nairobi, Kenya).* Retrieved from http://erepository.uonbi.ac.ke/bitstream/handle/11295/7149/Ouma_Factors.
4. Adesoji, F.A., & Olantunbosun, S. M. (2008). Student, Teacher and School Environment Factors as Determinants of Achievement in Senior Secondary school Chemistry in Oyo State, Nigeria. Uluslararasi Sosyal Aratirmalar Dergisi. *The Journal of International Social Research, 2*(1), 14-34.
5. Lerman, Z. M. (2014). The Challenges for Chemistry Education in Africa. *AJCE*, *2*(4), 80-90.
6. McMahon, M.M., O'Hara, S.P., Holliday, W.G., McCormack, B.B., & Gibson, E.M. (2000). Curriculum with a common thread. *Science and Children, 7*(37), 30-35, 57.
7. Holliday, W.G. (2001). Critically considering inquiry teaching. *Science Scope, 24*(7), 54, 56-57.
8. Mulenga, I. M., & Kabombwe, Y. M. (2019). A Competency-Based Curriculum for Zambian Primary and Secondary Schools: Learning from Theory and some Countries around the World. *International Journal of Education and Research*, *7*(2), 117-127.
9. Ministry of General Education. (2013). *The Zambia Education Curriculum Framework*. Lusaka: Curriculum Development Center.
10. Ministry of General Education. (2014, February). *Ministerial Statement Presented to Parliament on the Revised National Education Curriculum Framework by the Honourable Minister of General Education*. Lusaka, Zambia: Ministry of General Education. Retrieved from http://www.parliament.gov.zm/node/570
11. Chabalengula, V. M., & Mumba, F. (2012). Inquiry-based science education: A scenario on Zambia's high school science curriculum. *Science Education International, 4*(23), 307-327.
12. Mumba, F., Mejia, W.F., Chabalengula, V.M., & Mbewe, S. (2010). Resident scientists' instructional practice and their perceived benefits and difficulties of inquiry in schools. *Journal of Baltic Science Education, 9*(3), 187-195.
13. Woolnough, B., & Allsop, T. (1985). *Practical Work in Science*. Cambridge: Cambridge University Press.
14. Mumba, F., Chabalengula, V.M., & Wise, K (2007). Analysis of new Zambian high school physics syllabus and practical examinations for levels of inquiry and inquiry skills. *Eurasia Journal of Mathematics, Science and Technology Education,* 3(3), 213-220.
15. Brown, P. L., Abell, S. K., Demir, A., & Schmidt, F. (2006). College science teachers' views of classroom inquiry. *Science Education*, 90, 784-802.
16. Soyibo, K. (1998). An Assessment of Caribbean integrated science textbooks' practical tasks. *Research in Science and Technology Education*, 16(1), 31-41.

17. Wheeler, L., & Bell, R. (2012). Open-Ended Inquiry: Practical ways of implementing inquiry in the chemistry classroom. *The Science Teacher, 6* (79), 32-39.
18. Ministry of General Education. (2018, January). *Statement by the Minister of General Education, Honourable Dr. Dennis M. Wanchinga, MP on the Release of the 2017 Grade 12 Examination Results*. Lusaka, Zambia: Ministry of General Education. Retrieved from http://www.moge.gov.zm/dow
19. Ibrahim, M. S., Hamza, M. Y., Bello, M., & Adamu, M. (2018). Effects of Inquiry and Lecture Methods of Teaching on Students' Academic Performance and Retention Ability Among N.C.E 1 Chemistry Students of Federal College of Education, Zaria. *Open Access Journal of Chemistry, 3*(2), 1-8.
20. Ezazi, M., & Nourian, M. (2016). A Study on Chemistry Teaching Methods, Experimental Analysis by Student-Teacher in internship Lessons. *Journal of Current Research Science, 2*(5), 496-504.
21. Villagonzalo, E. C. (2014). Process Oriented Guided Inquiry Learning: An Effective Approach in Enhancing Students' Academic Performance. *Paper Presented at Philippines DLSU Research Congress.* Manila. Retrieved from https://pdfs.semanticscholar.org/6df4/19f58f5c2189dc0fb6267f1fcbdb8dfd6a70.pdf
22. Mumba, F., Pottmeyer, L.O., & Chabalengula, V.M. (2019). Analysis of Articles in the American Biology Teacher for Essential Features of Inquiry Representation. *Research in Science Education,* 1-21.
23. Opie, C. (2004). Doing Educational Research: A guide to First-Time Researchers. London: SAGE publications.
24. Tichapondwa, S. (2013). *Preparing Your Dissertation at a Distance: A Research Guide.* Vancouver:Virtual University for small states of the collon wealth.
25. Denzin, N.K., & Lincoln, Y.S. (2004). *A Book of Qualitative Research.* Thousand Oaks, C.A: Sage.
26. Creswell, J.W. (2007). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches (2nd edition).* Thousand Oaks, C.A: Sage.
27. Cohen, J. (1960). A coefficient of nominal scales. *Educational and Psychological Measurement, 1*(20), 37-46.
28. Tafoya, E., Sunal, D. W., & Knecht, P. (1980). Assessing inquiry potential: A tool for curriculum decision makers. *School Science & Mathematics,* (80), 43-48.
29. Chiappetta, E. L., Fillman, D. A., & Sethna, G. H. (1991). A method to quantify major themes of scientific literacy in science textbooks. *Journal of Research in Science Teaching*,*28*(8),713-725.
30. Mumba, F., Chabalengula, V.M., & Hunter, W. (2007). Inquiry Levels and Skills in Zambian High School Chemistry Syllabus, Textbooks and Practical Examinations. *Journal of Baltic Science Education, 6* (2), 1-8.