Influence of culture on secondary school students' learning of stoichiometry: A case of a Guruve district school, Zimbabwe

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ABSTRACT

The study was carried out after realising that students had presented persistent learning problems in stoichiometry. The research was a case study of a purposively sampled 2018-2019 'O' Level Chemistry class of 45 students. Interpretive analysis techniques were used to determine the relative impact of selected aspects of culture on students' learning of stoichiometry at a rural secondary school in Guruve District of Zimbabwe. The aspects of culture considered in the study were: language and symbols, values and attitudes and scientific culture. The study employed the convergent parallel mixed research approach. Data generation methods used was: stoichiometry class tasks, questionnaire for students, reflective discussions on class tasks and follow-up semi-structured interviews. Most students exhibited an inability to explain phenomena; lack of logical scientific reasoning, and an inability to explain phenomena in the stoichiometric processes and determinations, which compromised critical thinking skills development among the students. The three aspects of culture, namely; language and symbols, values and attitudes, and scientific culture, were all found to influence students' learning of stoichiometry in an interrelated manner. For instance, the use of English as a medium of instruction was found to be problematic. A low scientific culture was also observed among the students. It was however noted that students performed better and showed more understanding on stoichiometry tasks that included processes with practical value and importance in real-life A fit-for-purpose classroom language blend with the local dialect was suggested as a way to solve the communication challenge and enhance understanding of concepts. It was also recommended that there be an integration of cultural practices and experiences that involve quantification of substances so as to leverage students' conceptual understanding of stoichiometry.

Keywords: *Stoichiometry; learning for conceptual understanding; aspects of culture*

Introduction

Reaction stoichiometry is that part of chemistry concerned with the evaluation of results of quantitative measurements in chemical reactions (Schmidt & Jigneus, 2003). Knowledge of stoichiometry is fundamental in chemistry as it forms the base for learning and understanding of other chemistry concepts such as acids, bases and salts, electrochemistry, chemical bonding, chemical equilibrium and solution chemistry (Mpofu, Kusure, Nhenga, & Zishiri, 2007). However, conceptual understanding of reaction stoichiometry also requires knowledge on particulate nature of matter, mole and Avogadro's number, conservation of matter, laws of definite proportions, chemical reactions and algebraic skills (Niaz & Montes, 2012; Wagner, 2001).

Reaction stoichiometry develops abilities in students to be able to make predictions about chemical reactions and decision-making basing on the quantification of substances. For example, predicting the amounts of fertilizers required on a piece of land after some nutritional analyses, amounts of pharmaceutical drugs to be taken by patients, and volumes of pollutant gases emitted from combustion of fuels, among others, are important abilities. Therefore, reaction stoichiometry knowledge enhances the optimal utilisation of chemical substances in chemical reactions.

Despite being a difficult learning area in chemistry, reaction stoichiometry has attracted the attention of many chemistry educators and researchers because it is key. A lot of studies such as those carried out by Kazembe and Musarandega (2012), Chandrasegaran, Treagust, Waldrip and Chandrasegaran (2009), Pekdag and Azizoglu (2013) and Pekdag and Azizoglu (2013), among others, report on students' difficulties in reaction stoichiometry. Problem solving strategies have also been studied (Mandina & Ochonogor,2017; BonJaoude & Barakat, 2003; Bodner & Bhattacharyya, 2005). These studies have even proposed algorithmic problem-solving strategies but have not focused on students' conceptual understanding of the underlying chemistry concepts.

Besides the emerging evidence pointing towards culture as likely to influence students' learning of science (Okere, Keraro, & Anditi, 2012), in Zimbabwe, however, the influence of culture on science learning has not been adequately considered when developing science curricula for both the primary and secondary school. The present study, therefore, attempted to fill the gap by establishing how the three selected aspects of culture which are: language and symbols, values and attitudes and scientific culture impacted on the Guruve secondary school learners' conceptual understanding of reaction stoichiometry. The three selected aspects of culture were selected because they are among the key cultural attributes that define a scientific community which Aikenhead (2001) identified to be language, beliefs, values, conventions, expectations and technology.

Statement of the problem

There has been an observation of recurrent low pass rates and poor quality of passes in Chemistry especially among Zimbabwean rural secondary schools that are exposed to the 'western education curriculum'. That scenario raises both pedagogical and social justice questions that affect the quality and relevance of local education. These problems exist despite the availability of local knowledge, practices and socio-cultural experiences. The paper thus explores the ways in which local cultures could be exploited to leverage students' learning for conceptual understanding of the challenging reaction stoichiometry.

Research question

The study sought to establish the extent to which cultural experiences and practices could inform how secondary school students learn reaction stoichiometry. The study was guided by the following research question:

How do the selected aspects of culture (language and symbols, values and attitudes, scientific culture) influence students' conceptual understanding of stoichiometry?

Methodology

The study employed a case study of a rural secondary school in Guruve District in Mashonaland Central Province, Zimbabwe, where a 2018-2019 O' Level Chemistry class of 45 students was purposively sampled. The case study design was found appropriate for the study as it afforded an in-depth and contextual investigation (Yin, 2009) of a school in the locality of the indigenous Korekore people of Guruve. This was done to yield thick descriptions of phenomena relating to the relative impact on students' learning of the identified aspects of culture, through inductive analysis (Nyawaranda, 2014; Bell & Bryman, 2007). The data were gathered in situ over a twelve-month engagement with participants, that is, from May 2018 to April 2019.

In order to understand how the socio-cultural experiences and practices influence students' conceptual understanding of reaction stoichiometry, the study utilised the convergent parallel mixed methods approach with the predominance of the interpretive approach. According to Semali and Mehta (2012), a study on culture of a particular populace cannot be adequately dealt with by applying one method. The study therefore employed the following techniques: stoichiometry diagnostic test, stoichiometry class tasks, questionnaire for students, focus group interviews and reflective discussions on class tasks. In addition to the qualitative nature of the data gathered using these instruments, there were some descriptive statistics (frequencies, percentage frequencies, means and standard deviations) which were used on the stoichiometry diagnostic test to determine the prevalence and variability of students' conceptions, students' questionnaire for the students' held views on the influence of the three aspects of culture on their learning of reaction stoichiometry and on stoichiometry class tasks. Such statistics were used to index students' performance on stoichiometry concepts. A second level purposive sampling was conducted to select 12 students for follow-up semi-structured interviews in order to get further explanations on their responses that required to be further elaborated. The semi-structured interviews also served as data validation technique. Interpretive analysis techniques were used to determine how the three selected aspects of culture (language and symbols, values and attitudes, scientific culture) impacted students' learning of reaction stoichiometry concepts.

Findings and discussion

Influence of language on students' learning for conceptual understanding of reaction stoichiometry

The study revealed that the use of English language complicated students' learning of stoichiometry, as English is a foreign language and rather difficult to understand for the Korekore speaking rural dwellers of Guruve district. It was observed that in most cases the students could not interpret the stoichiometry concepts or the demands of the problems due to the complexity of English as both a language for communication and language of instruction in science learning in Zimbabwe. The finding corroborates Moyo's (2019) study which was carried out in the rural district of Binga in Zimbabwe whose findings were that those students had challenges with English language.

The students' questionnaire responses in Table 1 below show that students had problems with subject matter (chemistry) language. The overall mean rating on the statements in Table 1 is 2.57, an inclination towards students either not knowing or agreeing to the incorrect statements LS1 to LS10. There was evidence of incorrect representations of chemical formulae and balancing of chemical equations as revealed during class tasks. For example on a task to represent the equation for the burning of firewood, the following were some of the students' responses:

$C + 2O = CO_2$ *(STR 1, 2, 21)* $C + C_2 = CO_2$ *(STR 3)*

$2C + O_2 = 2CO$ *(STR 28)* $C + O = CO_2$ *(STR 41)*

This could be because the chemistry language has its peculiarities in terms of rules and structure which are different from the other languages used in daily communication. In support, Manahan (2011) notes that, in chemistry, what might seem a slight mistake in representing symbols, formulae and chemical equations misleads.

Table 1: Students' responses to questionnaire: Language and symbols

	STATEMENT	RATING					Mean	S.D
		Strongly Agree 4	Agree 3	I do not know 0	Disagree 2	Strongly Disagree 1		
	Language and symbols							
LS1	Magnesium reacts with oxygen as in the equation: $Mg + O_2 = MgO_2$	15 (37.5%)	5 (12.5%)	0 (0%)	13 (32.5%)	7 (17.5%)	2.70	1.159
LS2	The formula for potassium dichromate is KCr_2O_7	8 (20.0%)	11 (27.5%)	6 (15.0%)	11 (27.5%)	4 (10.0%)	2.28	1.320
LS3	The ionic equation, $H^+ + OH^- = H_2 + O$ represents the acid-base neutralization reaction	4 (10.0%)	22 (55.0%)	2 (5.0%)	7 (17.5%)	5 (12.5%)	2.53	1.012
LS4	The number of moles is the amount of substance consumed in a chemical reaction.	9 (22.5%)	19 (47.5%)	2 (5.0%)	10 (25.0%)	0 (0.0%)	2.83	0.958
LS5	Sodium reacts readily with air to produce an oxide, NA_2O	5 (12.5%)	15 (37.5%)	2 (5.0%)	11 (27.5%)	7 (17.5%)	2.35	1.075
LS6	Taking one-sip doses of a medicine three times a day equals three moles of the substance consumed.	3 (7.5%)	16 (40.0%)	2 (5.0%)	12 (30.0%)	7 (17.5%)	2.28	1.012
LS7	When gold is mined it is not pure. The gold ore would contain half gold metal and the other half constitutes impurities.	13 (32.5%)	18 (45.0%)	0 (0.0%)	5 (12.5%)	4 (10.0%)	3.00	0.934

LS8	A solution of wood ash contains Na_2CO_3.If it the solution is taken orally to control heartburn caused by excess gastric acids, the ionic chemical equation is: $2H^+ + CO_3^{2-} = CO + H_2O$	2 (5.0%)	13 (32.5 %)	4 (10.0 %)	18 (45.0%)	3 (7.5%)	2.15	1.001
LS9	The equation: KCO_3 (aq) + $CaNO_3$ (aq) = $CaCO_3$ (s) + KNO_3 (aq) represents the reaction of potassium carbonate with calcium nitrate.	21 (52.5%)	14 (35.0 %)	0 (0.0%)	5 (12.5%)	0 (0.0%)	3.40	0.709
LS10	The theoretical yield is the amount of product obtained from a chemical reaction when the limiting reagent is in excess.	6 (15.0%)	16 (40.0 %)	9 (22.5 %)	5 (12.5%)	4 (10.0%)	2.15	1.424

Findings from focus group discussions with students revealed that participants perceived English as a comparably more effective language of instruction for science concepts and particularly stoichiometry than their mother tongue. This was despite their having rated it as too difficult to understand. The students viewed their local Korekore (dialect of Shona language) as having some limitations when it came to explaining some rather more technical subject matter/concepts in reaction stoichiometry. Asked during the FGIs whether it was possible to contexualise their language for use in the learning of stoichiometry concepts, the students responded as follows:

> *No, because some words used are difficult to translate into other languages like stoichiometry is not easy to be translated to Shona (Korekore) (FGI/Q3/G1).*

> *Not possible, because some other scientific words are meaningless when translated to Shona (Korekore) e.g. empirical formula (FGI/Q3/G3).*

It was also observed that students tended to use both English and the Korekore dialect in the form of code-switching or used alternative local language equivalent terminologies in explaining phenomena. The following are students' responses from FGDs:

> *Yes, the teachers should teach us in English and explain using the local language (FGI/Q3/G2).*
>
> *Home language helps to understand other scientific terms. Instructional language assists in having a deep understanding of some concepts e.g. percentage purity (FGI/Q4/G3)*

Such code switching was seen to be effective in enabling learners to understand reaction stoichiometry. Code-switching as a viable option confirms Gudhlanga's (2005) view that no language is more expressive than the other. This is despite the fact that the local languages have been relegated to Basil Bernstein's restricted code status (Jones, 2013). Babaci-Wilhite (2019) also notes that if children use a language which they already know, an effective education is achieved as the community's own language is embedded with both local linguistic and cultural knowledge wealth.

Influence of values and attitudes on students' learning for conceptual understanding of reaction stoichiometry

The study findings show that students held the view that the knowledge gained from the socio-cultural practices and experiences could enhance their conceptual understanding of reaction stoichiometry if these aspects were integrated in their learning. When further probed participants acknowledged that there were differences in the way quantification of substances were done in the socio-cultural setups and in chemistry. Results from focus group discussions with students revealed that stoichiometry knowledge was relevant to day-to-day living. The students were able to identify socio-cultural practices that applied knowledge on the quantification of substances. These practices were aligned to the underlying chemistry concepts being applied in the processes involved. Sincero (2019) also found that students' immediate environment and the cultural contexts provide learning through direct social interaction among individuals.

The students also provided explanations to stoichiometry class tasks that were directly linked to their socio-cultural practices. For example, the results showed that although the students had problems in writing a balanced equation for the reaction on rusting of iron, $4Fe_{(s)} + 3O_{2\,(g)} = 2Fe_2O_{3\,(s)}$, they all knew that rusting of iron occurs in the presence of moisture. Therefore, regardless of the mistakes in the chemical equation representations, students were aware that water was part of the reactants in the equations. Examples of such students' responses were as follows:

$$Fe_2 + H_2O = Fe_2O_3 + H_2O \text{ (SRN 1)}$$

$$2Fe + 3H_2O = Fe_2O_3 + 3H_2 \text{ (SRN 38)}$$

Table 2: Students' responses to questionnaire: Values and attitudes

	STATEMENT	**RATING**					**Mean**	**Standard Deviation**
		Strongly Agree 4	Agree 3	I do not know 0	Disagree 2	Strongly Disagree 1		
	Values and attitudes							
VA11	Traditional practices and experiences can be adapted/ integrated in science learning.	9 (22.5%)	14 (35.0%)	2 (5.0%)	9 (22.5%)	6 (15.0%)	2.55	1.154
VA12	The way we do substance quantity measurements and determinations at home contradicts with and inhibits my understanding of stoichiometry concepts in chemistry.	7 (17.5%)	21 (52.7%)	3 (7.5%)	7 (17.5%)	2 (5.0%)	2.68	1.071
VA13	Stoichiometry concepts	4	3	1	21	11	1.95	0.932

	are just abstract and irrelevant to life outside school.	(10.0%)	(7.5%)	(2.5%)	(52.5%)	(27.5%)		
VA14	Socio-cultural contexts have no impact on the way students learn scientific concepts such as stoichiometry in chemistry.	5 (12.5%)	15 (37.5%)	4 (10.0%)	13 (32.5%)	3 (7.5%)	2.35	1.122
VA15	IK practices e.g. plant healing of ailments are just superstitions and have no place in explaining science phenomena.	4 (10.0%)	1 (2.5%)	7 (17.5%)	21 (52.5%)	7 (17.5%)	1.70	1.114
VA16	The major difficulty in learning science concepts that include stoichiometry in chemistry is learning the language of science.	8 (20.0%)	16 (40.0%)	0 (0.0%)	13 (32.5%)	3 (7.5%)	2.73	0.877
VA17	Scientific and technological knowledge is value free.	5 (12.5%)	11 (27.5%)	4 (10.0%)	15 (37.5%)	5 (12.5%)	2.20	1.137
VA18	Scientific and traditional worldviews are incompatible in explaining phenomena.	1 (2.5%)	19 (47.5%)	8 (20.0%)	7 (17.5%)	5 (12.5%)	2.00	1.240
VA19	Learning scientific concepts such as stoichiometry in chemistry is an imposition of a foreign	1 (2.5%)	8 (20.0%)	2 (5.0%)	16 (40.0%)	13 (32.5%)	1.83	0.903

	worldview, making it even difficult to understand.							
VA20	Using examples of known chemical processes in contexts helps in learning and understanding underlying scientific concepts.	15 (37.5%)	21 (52.5%)	2 (5.0%)	1 (2.5%)	1 (2.5%)	3.15	0.975

The students viewed reaction stoichiometry as relevant in their day-to-day living. During FGDs, the students managed to identify the socio-cultural practices that utilised reaction stoichiometry knowledge, the artefacts used as well as the underlying chemistry involved in the practices, as summarised in Table 3 below.

Table 3: Students' FGDs responses: practices, processes, experiences with stoichiometry use and determinations

Group	**Practices, processes, experiences**	**Artefacts and materials used**	**Underlying Chemistry concept**	**Stoichiometry concept(s) linked to the cultural practices/experiences**
1	Beer brewing	Brewers' yeast, bucket, water	Fermentation	Put 20 ml of yeast in 5 litre-bucket of water then put one bucket of mealie-meal.
	Bread making	Yeast, flour, water	Fermentation	Put the dough in warm place to allow to rise.
	Purifying water	Fire, water	Distillation	Percentage purity
2	Purifying muddy water	Distillation pot kit, muddy water	Simple distillation	Percentage purity
	Gold panning	Mercury, sieve, gold ore, Sulphuric acid, water, fire,	Purification	Percentage purity

		pestle and mortar		
3	*Kubika chimodho(baking home-made bread)*	Spoons, cooking sticks, pan	Suspension, expansion, evaporation	Quantifications
	Wound healing	Tree leaves and roots	Skin recovering	Chemical reactions
	Kurima*(farming)*	Seeds, herbicides, plough	Germination, spraying	Percentage yield, concentration
	Kutsatsa mukaka*(preparing fermented milk)*	Clay pots, sieving pan	Fermentation	Percentage purity
	Gold panning	Sieve, bowel	Purification	Percentage purity
4	Salt and sugar solution	Teaspoon	Neutralization	
	Purifying dirty water	Filter paper	Filtration	Separation
	Beer brewing	Chimera, water	Brewing	Fermentation

Influence of scientific culture on students' learning for conceptual understanding of reaction stoichiometry

From the findings in Table 4 below, it can be observed that the students' scientific culture (literacy) was very low as evidenced by the majority either agreeing to the false statements or indicating that they did not know. This shows that the students did not know the explanations to the *how* and *why* some scientific phenomena happen the way they do. The findings from the stoichiometry class tasks also showed students leaving blanks on spaces where they were supposed to write supporting explanations to their answers. This was despite the fact that scientific literacy is linked to the development of critical thinking skills. According to Onwu and Mosimege (2004), lack of explanations results from accepting cultural-based knowledge claims without interrogating or questioning for meanings.

Table 4: Students' responses to questionnaire: Scientific culture

STATEMENT	**RATING**					**Mean**	**Standard Deviatio**
	Strongly Agree	Agree	I do not know	Disagree	Strongly		

	Scientific culture	4	3	0	2	Disagree 1		**n**
SC21	Sprinkling wood ashes on sweet potato plantations increases their sweetness.	0 (0.0%)	10 (25.0%)	5 (12.5%)	20 (50.0%)	5 (12.5%)	1.88	0.939
SC22	To reduce the production of soot during a combustion reaction of burning wood in the fireplace we add more firewood.	2 (5.0%)	11 (27.5%)	6 (15.0%)	14 (35.0%)	7 (17.5%)	1.90	1.128
SC23	Drinking a wood ash solution controls heartburn by increasing the acidity levels of the gastric juices.	3 (7.5%)	21 (52.5%)	5 (12.5%)	10 (25.0%)	1 (2.5%)	2.40	1.105
SC24	During the process of fermentation in the production of traditional beer, if the containers are left open the beer tastes sour because of the increase in % of alcohol produced.	10 (25.0%)	11 (27.5%)	0 (0.0%)	14 (35.0%)	5 (12.5%)	2.65	1.001
SC25	A smoky vehicle would be producing more of carbon dioxide.	6 (15.0%)	14 (35.0%)	1 (2.5%)	12 (30.0%)	7 (17.5%)	2.43	1.035
SC26	If very big maize cobs are produced from a field that had been	10 (25.0%)	21 (52.5%)	0 (0.0%)	8 (20.0%)	1 (2.5%)	3.00	0.751

	applied *mufudze* obtained from the cattle kraal, this means that the *mufudze* will be containing more nitrogen.							
SC27	The charcoal *(marasha)* put into the furnace together with the mined iron ore eats up the impurities when heated and pure iron is obtained for moulding hoes and other hunting and farming tools.	6 (15.0%)	18 (45.0 %)	6 (15.0%)	7 (17.5%)	3 (7.5%)	2.38	1.275
SC28	Bio-gas can be used to provide energy for cooking according to the reaction: C_3H_8 (g) + $5O_2$ (g) = $3CO_2$ + $4H_2O$ (g). If a lot of soot is observed to be produced, this is because oxygen is in excess and therefore to reduce the soot is to close all vent holes to prevent oxygen from entering the system.	5 (12.5%)	21 (52.5 %)	2 (5.0%)	9 (22.5%)	3 (7.5%)	2.60	0.982
SC29	The actual yield of a chemical process is always more than the theoretical yield.	5 (12.5%)	9 (22.5 %)	1 (2.5%)	19 (47.5%)	6 (15.0%)	2.28	0.960

SC30	A limiting reactant is the substance whose amount of matter is the smallest.	12 (30.0%)	19 (47.5 %)	0 (0.0%)	8 (20.0%)	1 (2.5%)	3.05	0.783

In most cases the students could not provide reasons or adequate reasons to justify the answers for the stoichiometry class tasks as well as during the reflective discussions on the tasks. Some of the students' responses to follow-up reflective discussions on statement SC24 were as follows:

> *The fermentation clay pots with the brew are kept air-tightly closed because they wanted not to allow carbon dioxide to enter the clay pots. (SRN 19)*
>
> *Not to allow CO_2 to get in. (SRN 8)*

The students' failure to provide adequate explanations and justifications exposed the gaps in the development of their critical thinking skills and logical reasoning. According to Erduran and Jimenez-Aleixandre (2008), argumentation is essential in developing scientific thought systems of learners through making claims about phenomena and providing empirical data as evidence and supporting statements as justifications for the claims.

Relationship between language and symbols, values and attitudes and scientific culture on students' learning of stoichiometry

The study findings under the selected aspects of culture as presented above have shown that an understanding of language as either the language of instruction or subject matter language was directly related to whether students were able to explain phenomena (scientific culture). It was also directly related to the utility value placed by the society on the subject matter knowledge (values and attitudes). Figure 1 summarises the linkages between the three aspects of culture and how they influenced students' learning of stoichiometry.

The findings have shown evidence of the relationship of culture and learning of stoichiometry. It has been established that in cases where students would have shown an understanding of stoichiometry through an explanation of its phenomena and their value in their(students') socio-cultural practices and experiences they would often be able to represent the chemical formulae and chemical equations and perform related stoichiometry determinations of the chemical processes involved.

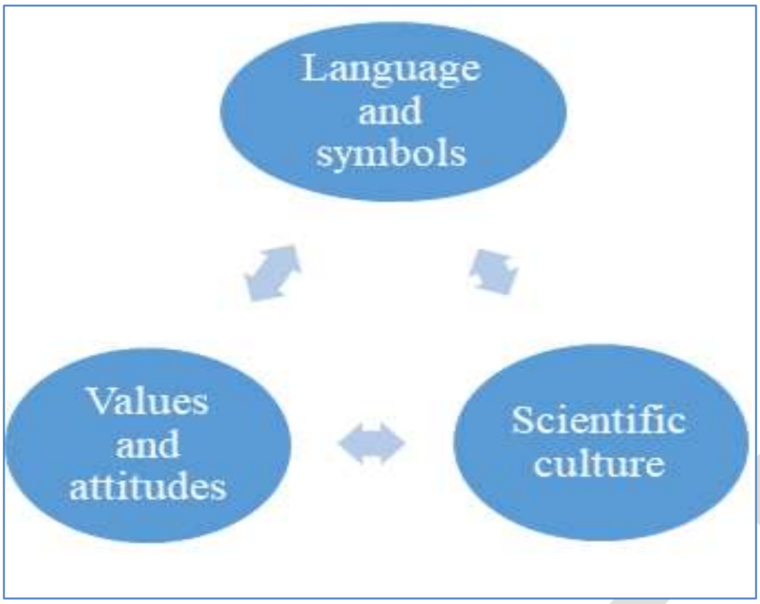

Figure 1: Relationship between the three aspects of culture of students' learning of stoichiometry

The findings have shown that learning stoichiometry is not value free. As presented in Figure 1 above, the three aspects of culture considered in this study influence students' learning of stoichiometry in different but interrelated manner. The nature of the established relationship relates to Lederman & Niess's (2001) interlocking, concentric and cyclical linkages. Therefore, by taking into account students' socio-cultural characteristics such as language, values and attitudes and scientific culture in the curriculum and instruction, addresses issues of inclusivity by taking care of the needs (Commonwealth of Learning, 2000) and cultural rights (Soto, 2015) of local indigenous populace. Acknowledging and using situated socio-cultural knowledge on quantification of substances enhance students' learning of stoichiometry by reducing science knowledge abstraction, thereby increasing epistemological access.

Conclusions and recommendations

The study concluded that aspects of local culture affected the way Chemistry students in a school in Guruve appreciated concepts in reaction stoichiometry. It was concluded that language as a cultural aspect had a bearing on students' understanding of stoichiometry. That is, the use of English as an instructional language was problematic and students ended up code-switching between Korekore, a Shona dialect, and English, an action they considered fit-for-purpose. According to Babaci-Wilhite (2019) already known languages enhance comprehension of concepts as they are embedded with both linguistic and cultural knowledge wealth.

The study also concluded that knowledge embedded in the students' socio-cultural experiences and practices involving quantification of substances has been found useful in explaining and understanding stiochiometry phenomena. However, it was also established that students' scientific culture was relatively low as they could hardly explain the underlying knowledge behind the activities they did on a daily basis as they solved socio-scientific problems. Based on these findings the study recommends that educational institutions draw from socio-cultural instructional methods to enhance Chemistry students' conceptual understanding of stoichiometry. This means that secondary school teachers should allow students to conceptualise issues and develop their arguments in an environment that respects students' local knowledges including language.

REFERENCES

Aikenhead, G. S. (2001). Integrating western and aboriginal sciences: Cross-cultural science teaching. *Research in Science Teaching*, *31*(3), 337–355.

Babaci-Wilhite, Z. (2019). Educational tools to teach STEAM subjects: Integrating linguistic rights, collaborations, and critical thinking. In Babaci-Wilhite (Ed.), *Promoting language in STEAM as human rights in education*. Singapore: Springer. https://doi.org/https://doi.org/10.1007/978-981-13-2880-0_1

Bell, M. and Bryman, A. (2007). The ethics of management research: An exploratory content analysis. *British Journal of Management*, *18*(1), 63–77. https://doi.org/10.1111/j.1467-8551.2006.00487.x

Bodner, G. M. and Bhattacharyya, G. (2005). A cultural approach to problem solving. *Educacion Quimica*, *16*(2), 222–229.

BonJaoude, S. and Barakat, H. (2003). Students' problem solving strategies in stoichiometry and their relationships to conceptual understanding and learning approaches. *Electronic Journal of Science Education*, *7*(3), 1–42.

Chandrasegaran, A. L., Treagust, D. F., Waldrip, B. G. and Chandrasegaran, A. (2009). Students' dilemmas in reaction stoichiometry problem solving: Deducing the limiting reagent in chemical reactions. *Chemistry Education Research*, *10*, 14–23.

Commonwealth of Learning. (2000). *Curriculum theory, design and evaluation*. London: Commonwealth of Learning.

Erduran, S.and Jimenez-Aleixandre, M. P. (Eds.). (2008). *Argumentation in science education: Perspectives from classroom-based research*. New York: Springer Publishing Co.

Gudhlanga, E. S. (2005). Promoting the use and teaching of African languages in Zimbabwe.

Zimbabwe Journal of Educational Research, *17*(1), 54–68.

Jones, P. E. (2013). Bernstein's "codes" and linguistics of "deficit." *Language and Education*, *27*(2), 161–179.

Kazembe, T. C. and Musarandega, A. (2012). Student performance in A-level chemistry in Makoni district, Zimbabwe. *Eurasian Journal of Physics and Chemistry Education*, *4*(1), 2–29.

Lederman, N. G. and Niess, M. L. (2001). Curriculum and instruction: Whose life is it anyway? *School Science and Mathematics*, *101*(3), 113–116.

Manahan, S. E. (2011). *Fundamentals of environmental chemistry* (3rd ed.). London: CRS Press.

Mandina, S. and Ochonogor, C. E. (2017). Problem solving instruction for overcoming students' difficultites in stoichiometric problems. *Acta Didactica Napocensia*, *10*(4), 69–78.

Moyo, R. (2019). Can interactive methods enhance oral communication in English language: An insight of two Zimbabwean rural secondary schools in Binga South. In *Sustainable Rural Learning Ecologies Conference* (pp. 47–48). Lupane: Lupane State University.

Mpofu, V., Kusure, L., Nhenga, J.and Zishiri, G. (2007). Advanced level chemistry students' understanding of stoichiometry: Evidence from four schools in Zimbabwe. *Southern African Journal of Education Science and Technology*, *2*(2), 90–100.

Niaz, M. and Montes, L. (2012). Understanding stoichiometry: Towards a history and philosophy of chemistry. *Educacion Quimica*, *23*(2), 290–297.

Nyawaranda, V. (2014). Qualitative and quantitative paradigms: Intimate lovers or distant cousins? *Zimbabwe Journal of Educational Research*, *26*(2), 169–185.

Okere, M. I. O., Keraro, F. N. and Anditi, Z. (2012). Pupils' beliefs in cultural interpretations of "heat" associated with anger: A comparative study of ten ethic communities in Kenya. *European Journal of Educational Research*, *1*(2), 143–154.

Onwu, G. and Mosimege, M. (2004). Indigenous knowledge systems and science and technology education : A dialogue. *African Journal of Research in Mathematics, Science and Technology Education*, *8*(1), 1–12. https://doi.org/10.1080/10288457.2004.10740556

Pekdag, B. and Azizoglu, N. (2013). Semantic mistakes and didactic difficulties in teaching the "amount of a substance" concept: A useful model. *Chemistry Education Research and Practice*, *14*, 117–129. https://doi.org/10.1039/c2rp20132a

Schmidt, H.-J. and Jigneus, C. (2003). Students' strategies in solving algorithmic stoichiometry problems. *Chemistry Education: Research and Practice*, *4*, 305–317.

Semali, L. M. and Mehta, K. (2012). Science education in Tanzania: Challenges and policy responses. *International Journal of Educational Research*, *53*, 225–239.

Sincero, S. M. (2019). Ecological system theory. Retrieved January 21, 2019, from https://explorable.com/ecological-systems-theory

Soto, S. T. (2015). An analysis of curriculum development. *Theory and Practice in Language*

Studies, *5*(6), 1129–1139.

Wagner, E. P. (2001). A study comparing the efficiency of a mole ratio flow chart to dimensional analysis for teaching reaction stoichiometry. *School Science and Mathematics*, *101*(1), 10–22.

Yin, R. (2009). *Case study research: Design and methods* (4th ed.). Califonia: SAGE Publications Ltd.