Effect of a Hands-On Chemistry Intervention on the behavioural and effective attitudes of learners from low socio-economic high schools

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ABSTRACT

This research focused on the effect that three easily accessible, cost-effective, and hands-on chemistry experiments which are aligned to Curriculum Assessment Policy Statements (CAPS), had on Grade 9 learners from low socio-economic high schools. These experiments were conducted in an after-school science club format at two quintile-1 high schools situated in Gqeberha, South Africa. The learners' behavioural and affective attitudes were examined using group interviews (n = 6) and a survey (n = 61). The findings from this study showed that learners wanted to share knowledge with their peers and community after learning new scientific skills at the science-club. Learners also recognized the economic and practical importance of science related careers. Responses revealed that learners lose interest if the science does not actively connect or engage with their current circumstances. This study also showed that learners were further motivated to pursue studies in Physical Science in Grades 10 to 12.

KEYWORDS

affective attitudes; behavioural attitudes; CAPS Curriculum; hands-on chemistry; low socio-economic schools

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INTRODUCTION

The authors of this paper set out to determine how and whether a Hands-on Chemistry Intervention (HoCI) would influence learners from quintile-1 high schools affective and behavioural attitudes toward science. Quintile categorisation refers to the poverty distribution of public schools with the consideration that poverty is unequally spread across South Africa with '1' being the poorest and '5' the richest.[1] This paper is based on the main research question "What effect do Hands-on Chemistry Interventions have on grade 9 learners from lower-socio economic schools affective and behavioural attitude toward science?". The rationale of the research question stemmed from the steady decline (34% to 30%) in Physical Sciences enrolment in public South African high schools from 2012 to 2016.[2] The decline was noted both during and after high school.[3,4] In the international context, a similar general trend toward a decrease in both positive attitudes and enrolment in science-based subjects was observed in the literature. These countries were conducted in Canada,[5] Denmark,[6] Turkey,[7] United Kingdom[8] and United States of America.[9]

The cause of this decline may be due to factors such as low interest and relatability[10,11] which could be attributed to a change in attitudes. With reference to this statement, this current study focused on the effect that easily accessible and relatable chemistry experiments had on the learners from lower quintile schools. We aimed to identify how three experiments designed for this study could affect learners' attitudes and to focus on the aspects which positively and negatively influenced them.

Behavioural Attitudes (BAs) were measured by examining learners' levels of: motivation; encouragement; career aspirations; boredom and; awareness of science in their daily lives. This was followed by examining whether learners had an interest in science or not, referred to as Affective Attitudes (AAs).

The purpose of selecting quinitile-1 schools was due to these schools still having limited resource and infrastructure development, a direct impact of post-Apartheid South Africa. As stated in the Department of Basic Education's Action Plan to 2024,[12] the legacy of division is still reinforced by economic inequality. Although the formal institutions of Apartheid such as educational inequality were abolished, the effects of it such as educational inequality at lower quintile schools still remained mostly unchanged.[13]

Therefore, the rationale for this paper was to utilise three experiments designed for this study as the Hands-on Chemistry Intervention. These included; combustion, pH, and mixtures and separation (see supplementary document A) and were based on the Curriculum Assessment Policy Statements (CAPS) for Natural Sciences document.[14] Table 1 shows the sections of the CAPS document for Natural Sciences on which the HoCI experiments were based.

The HoCI sessions were based on the CAPS curriculum for three main reasons, firstly it provided a realistic reflection of the current school level science. Secondly, the curriculum format utilised in this study allowed lower quintile school learners to relate more easily to the topics under discussion during school hours and potentially foster their interest toward science. Lastly, the CAPS curriculum sometimes has shortcomings pertaining to real world connections which are more noticeable at lower quintile schools.[15,16]

The absence of relatability and application-based examples in chemistry syllabi (and other sciences) may in turn cause a decline in interest from learners, as reported in a 2017 study which made use of a socio-cultural background to teach Natural Sciences in three South

Table 1. CAPS syllabus alignment with the Hands-on Chemistry Intervention (HoCI) topic used in study.

CAPS term	CAPS strand	CAPS Topic	CAPS page no.	HoCI topic
2	Matter and Materials	Combustion	65	1: Combustion
1	Life and Living	Test for CO_2 when exhaling	35	2: pH
2	Matter and Materials	The pH of CO_2 and types of indicators	67	
2	Matter and Materials	Separating mixtures	22	3: Mixtures and separation

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African township schools.[17] Subsequently, this may cause a decrease in participation in the scientific work force emerging from these lower economic or predominately Black communities.[18] As reported in a study conducted in Germany, the decline may also have the potential to directly affect public scientific literacy through learners no longer pursuing scientific careers.[19] Within South Africa, the low level of pursuit of scientific careers is already a reality, with a combined enrolment rate of just below 3% for Physical Sciences, Mathematics and Life Sciences.[4]

We aimed to address the gap between classroom and real world by bringing the static, pre-dominantly theoretical lessons to life by making use of HoCI. The simple experiments described in supplementary document A were designed to allow for uncomplicated reproducibility. These experiments made use of affordable materials and included socio-culturally relatable discussions during the sessions. The after-school science club setting also provided a more relaxed learning environment than the traditional quintile-1 school classroom and allowed for open discussions amongst like-minded peers, and, most importantly, using their language of choice. In the case of this study, code switching, the act of using multiple languages within the same conversation[20], for example between isi-Xhosa/English and Afrikaans/English, was a common practice.

BACKGROUND

Importance of understanding attitudes

The term, attitude, can be classified as a tendency to evaluate an entity in a favourable or unfavourable manner. This tendency cannot be directly observed and is inferred from the learners' responses or their attitude to an entity (science). These main attitude components may be defined as: (1) a feeling about the object, like or dislike component (affective); (2) a tendency-towards-action, the objective component (behavioural) and (3) a knowledge of the object, ideas component (cognitive).[21]

Since attitudes are based on one's beliefs, and those beliefs influence behaviour (tendency toward), it is important to effectively measure the driving factors behind these influences. Therefore, learners' attitudes toward science need to be understood by using suitable measurement and observation tools.[22] The research reported in this paper focuses on learners' affective and behavioural attitudes.

Hands-on chemistry intervention as a factor on influencing learners' attitudes

The social setting in an after-school science club is less formal than a conventional classroom. It therefore offers opportunities for productive and cooperative learning amongst learners providing the latent potential to promote a positive learning environment.[23] A Hands-on Chemistry Intervention (HoCI) provides a positive alternative environment for learners to acquire new knowledge while bridging the gap between theory and practice. This may subsequently have a positive influence on the learner's Behavioural Attitudes (BAs) and Affective Attitudes (AAs) towards science.

Similar studies done in the Eastern Cape, South Africa have emphasised that learners are greatly influenced by the extent of how enjoyable, useful, and relevant science experiments are to them as an individual and to society.[24] Usefulness and relevance are highly applicable to learners from lower socio-economic backgrounds. These learners tend to rank career importance according to what it can do and/or provide in order to improve themselves and help others.[25] This viewpoint aligns with a study conducted at Harmony Public High Schools in Texas, United States of America, which revealed that environments play an integral role for career choice.[26] Some studies have also shown that school science could cause a loss of interest and a decline in attitudes if the following are not achieved: (1) practical relevance within their own environment; (2) linkage (engagement) with their circumstances or enthusiasms.[7]

The development of the link between school science and learners' socio-economic circumstances and environment is culturally dependent and transforming. Some studies in the USA engage with these groups (cultural and socio-economic) separately. For instance, research on the cultural aspects[27] and on the rural relatability[28] for science engagement are normally viewed and studied separately. For the South African setting however, it is preferable for culture and socio-economic setting to be mutually inclusive. These types of characteristics, in addition to the relative flexibility of informal science education programmes, may allow the youth to develop identities positively in relation to science and connect those identities to the rest of their lives.[29]

Vygotsky's social learning theory[30] was used as a framework for this research study. His theory argues that learning is a social transactional process which is socio-culturally specific and influenced by the learning environment in which the learners find themselves in.[31] The two main perspectives of Vygotsky's socio-cultural learning theory, encapsulates activity and community of practice.[32] The key aspects being that learning environments actively influence learners and learners actively influence their learning environments.[32]

METHODS

Research design

A mixed methods research design was employed for this study. The research was classified as such because it made use of both qualitative and quantitative data collection methods and took a pragmatic approach to the data analysis.[33,34]

A pilot study was conducted using the topic of combustion. The methods tested were the experiments, worksheets and survey. The pilot study was also used to estimate the ideal amount of time needed to complete the Hands-on Chemistry Intervention, worksheet and to answer one survey. In addition to confirming time parameters, the pilot study was used to identify any issues with the survey such as readability of questions and whether the learners could understand the instructions provided and formatting. The learners' queries and feedback were taken into account to make the necessary adjustments to inform the design and implementation of the HoCIs.

The study followed a constructive-positivistic philosophy with an inductive-deductive approach to data analysis. The data collection techniques used were group interviews (GIs) shown in Table 3 and individual surveys (see supplementary document B). The research statements were developed from the main research question "*What effect do hands-on chemistry interventions have on grade 9 learners from lower-socio economic schools affective and behavioural attitudes toward science?*" (Table 2).

The Hands-on Chemistry Intervention (HoCI) consisted of three topics, namely, combustion, pH, and mixtures and separation based on the Natural Sciences matter and materials section of the CAPS document. Each session started with a short explanation of the topic and the underlying theory (supplementary document A). The topic was then taught using an interactive HoCI, where learners interacted in small groups of three to four. For each session, the learners were encouraged to ask questions throughout the lesson. The research design and methodology followed for the GIs and surveys, shaded in grey, are in shown in Figure 1.

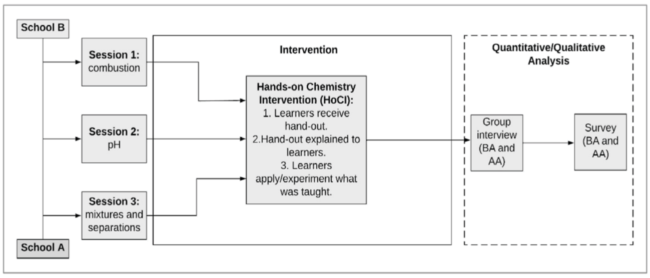

Figure 1. Flow diagram showing research design and methodology.

Table 2. Research statements, corresponding measuring tool and item used to study Behavioural Attitude (BA) and Affective Attitude (AA) in this study.

Attitude	Research Statements (RS)	Measuring tool and item
AA	Grade 9 learners from low socio-economic schools have an interest in science.	Survey item C3: '*Does science interest you?*'. GI questions 2, 3, 6 and 8.
BA	Hands-on chemistry experiments motivate grade 9 learners to select Physical Sciences in grade 10.	Survey item C6a: '*Do science demonstrations and experiments make you want to choose Physical Science in grade 10?*'. GI question 6.
BA	Hands-on chemistry experiments encourage grade 9 learners to want to follow a career in science and/or chemistry.	Survey item C6b: '*Do science demonstrations and experiments make you want to follow a career in science?*'. Survey items C3 and C6c: '*Does science interest you?*' and '*Do science demonstrations and experiments make you want to follow a career in chemistry?*'. GI question 6.
BA	Hands-on chemistry experiments encourage grade 9 learners to become excited about science.	Survey item C6d: '*Do science demonstrations and experiments make you excited about science?*'. GI question 7.
BA	Grade 9 learners find Hands-on chemistry experiments uninteresting.	Survey item C6e: '*Do science demonstrations and experiments bore you?*'. GI question 2.
BA	Hands-on chemistry experiments make grade 9 learners aware of how science forms part of their everyday lives.	Survey item C6f: '*Do science demonstrations and experiments make you aware of how science forms part of your day?*'. GI question 2.

The structured GIs had eight questions related to learners' BAs and AAs after their experience of HoCI. Learners were grouped together according to their frequency of attendance to prevent skewing of results (Figure 2). The survey results were used to validate learners' responses from the GIs and included responses from the quieter individuals. By combining the outcomes of the two instruments', a holistic view of the participating learners could be determined and discussed.

Ethical considerations

The Department of Education (Eastern Cape, South Africa) granted permission to approach and work with the two quintile-1 high schools in this study. Both schools were based in low-socio economic areas and expressed an interest to participate. The principals granted consent for their Grade 9 Natural Sciences learners to be briefed on the study. There were sixty-one learners who volunteered to take part in GIs after obtaining the relevant written learner assent and guardian consent.

Ethical clearance was obtained from Nelson Mandela University, Department of Education and the schools. The Research Ethics Committee extensively reviewed all assent and consent forms for Humans (REC-H) of the university before the researcher was allowed to approach the Department of Education, schools or learners involved.

Participants: Grade 9 learners from two quintile-1 schools

The geographic areas in which these schools are situated have relatively high crime rates. Therefore, at the time of the study, these after-school lessons had to adhere to strict time guidelines to assure the safety of the participants. Natural Sciences classes during normal school hours consisted of 33 or more learners per teacher. The learners were aged between 14 – 16 years at the time of the study. Their respective self-identified racial denominations were 'Black' and 'Coloured'. School A was female dominant (57%) while School B was male dominant (69%), with the most frequent gender responding during group sessions at both schools being male.

In accordance with the ethical considerations, learners' participation was voluntary, anonymous and they could drop out of the study at any point without penalty. Before each session, learners were reminded of their ethical rights. Moreover, no learner participant was denied participation at any point. That is, any consenting learner participant could join in at any point of the study even if they missed previous HoCI session(s). Due to these factors the number of participants in the five GIs varied (Figure 2).

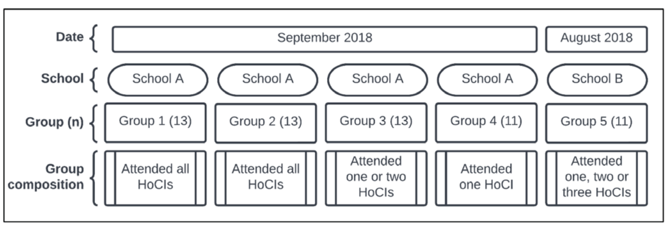

Figure 2. Group interview date, school, and learner composition

School A had four groups and School B one group. Not all sixty-one learners attended all three HoCI sessions (Figure 2). All data received from the learners that were related to their BAs and AAs toward science were regarded valuable and were not discarded based on attendance rate.

Data collection: Group interviews (GIs) and surveys

GIs in combination with surveys were used to allow for data validation. Seven survey items corresponded with the GI questions. Some survey questions mirrored the GI questions (Table 3) to allow learners who were non-verbal by choice to freely write and select opinions best describing their attitudes. The GIs were conducted after school hours at the respective schools (Figure 2). Four different interviewers were

Table 3. Eight-semi-structured questions from group interviews with corresponding attitude(s).

No.	Group interview question	Attitude
1	How is what you have done in 'science club', different from what you normally experience at school?	BA
2	What did you think of the science (chemistry) demonstrations and experiments from the 'science club' and which experiments were your least and most favourite?	BA
3	Would you like to perform more experiments at school, and if so why?	BA
4	Did you find that doing the experiments yourself helped you to understand science (chemistry) topics better or made you more confused?	BA
5	Did you have the opportunity to use feedback from the experiments to improve your learning?	BA
6	Do chemistry experiments and demonstrations encourage you to want to select Physical Science as a subject in Grade 10 and follow a career in science? If yes or no, could you suggest why?	BA & AA
7	If you were able to or wanted to, how would you suggest helping your teacher in the science classroom?	AA
8	Are there any other general points anyone would like to add with regards to science (chemistry) at your school or science (chemistry) in general?	AA

used at School A. All the interviewers received guidance beforehand on the use of the questions, how to explain the questions in simple language and to encourage feedback from learners. None of the learners responded to questions in their mother tongue.

Interviews were conducted simultaneously for each group; this strategy minimised the amount of time learners stayed after school. After their GIs (Table 3) learners completed a survey (supplementary document B) describing their BAs and AAs toward sciences.

Data collection tools

Eight semi-structured questions were posed during the interviews to probe BAs and AAs of the learners (Table 3).

The survey was a three-page document which consisted of sections focusing on gathering demographic information, language, views of science and career aspirations (supplementary document B).

Group interview and survey analysis

The GI responses, positive, negative or neutral, were coded using the set of guidelines illustrated in Table 4.

The GIs were recorded then transcribed verbatim. Interviews were transcribed by two separate researchers and were checked against the recordings. Table 5 shows an extract of a GI transcript. The extract includes the learner's pseudonym, response and coding as positive (+) or negative (-) according to the guidelines in Table 4.

Interviewers' questions and comments were excluded from the coding exercise. Their transcriptions were only included when repeating an inaudible response from a learner. At times, learners gave one-word answers or groups collectively agreed in unison with no further explanation to the question asked. Reluctance to answer may have been due to the learner not feeling comfortable to be heard in their peer group or being recorded.

Once the GI transcripts were coded, they were compared to the codes which emerged from section C3 of the survey, *"Does science interest you?"*. From this exercise, six Behavioural Attitudes (BAs) codes emerged from survey section C3 and eleven from GI questions 1 to 6. Six out of the eleven themes were present in both the survey and BA responses from GIs (Table 6). GI questions 7 and 8 responses were used to probe learners' Affective Attitudes (AAs), and eight themes emerged from this coding exercise (Table 8).

Due to lack of access, it was not possible to use proprietary software packages for data capture and analysis of the survey responses or GI transcripts. The authors of this study made use of free and easily accessible options such as word clouds and Excel to categorise the survey and GI responses. The co-authors co-checked the codes that emerged from the GI transcripts.

Table 4. Guidelines used to group positive, negative, and neutral group interview responses.

Description	Code
Positive response: the learner is complimenting, agreeing to or shows enthusiasm.	+
Negative response: the learner mentions what they do not enjoy, what their classroom lacks, difficulty on topics and disagreement.	–
Neutral responses: such as "I don't know"; "maybe"; "I don't have an opinion" and "whatever goes".	0

Table 5. Extract of group interview transcription with responses coded as positive or negative.

Respond.	Response	Code
N1	I enjoyed, uhm pH. Uhm,	+
	I didn't enjoy mixtures and separation. Mixtures and separation, was [clears throat] boring.	–
Group 1	Laughs.	+
L1	We like acid and base.	+
	So, I didn't like … the mixtures.	–
C1	I enjoyed all of them. But the one I enjoyed the most was the mixtures.	+
B1	I, I enjoyed the mixtures and separation. Because you learn how to separate sand into water and I learned lots of things that are new to me and we didn't have a chance to do here at school.	+
Un1	I didn't enjoy the mixtures, because I struggled a lot to separate water and sand and it became a bit frustrating to me.	–
I2	I like the mixture separation.	+
	And I learnt that when you want to separate different kinds of stuff objects you use different kinds of stuff.	+
	For example, to separate sand from water, you use filter bags, to separate iron from water you can use magnets.	+

respond. = respondent

Table 6. Behavioural attitude themes observed from the group interviews and survey responses.

Codes		Behavioural attitude themes observed from responses	
Code	BA Code	Survey section C3	Group interview (Q1 to Q6)
0	Blank	No response from learner.	No response from learner.
1	Fun	Fun, interesting, like science, interest.	Exciting, enjoy, like, informative.
2	Experiments	Experiments, practicals, Do practicals.	Continue with experiments, visual.
3	Learning new things	Discover new things, learn more things, discover, teaches (NEW), educational, experience/s.	New experiences, new learning style, cooperation, everyone learns.
4	Solve problems	Solutions helps us understand. Solving problems, understand what we don't, knowing.	Helpful, find solution, make understand more.
5	Easy	Easy, simple.	Not difficult.
6	Career choice	Career choice, good for my career choice, it's what I want to study, follow dreams.	Want to be scientist/engineer, world needs scientists.
7	Write only	None observed	Write only, don't understand when writing, not practical, watch videos only, use YouTube, don't understand when writing.
8	Frustrating	None observed	Frustrating, difficult, hard, not easy, confused, more confused.
9	Understand	None observed	Understand better, learn more, teaches more, before science club did not understand.
10	Applied learning	None observed	Visual, hands-on, practically, actual, apply, can't learn from a book, better than writing.
11	No interest	None observed	Scared, no fun, boring no interest, don't like it.

In addition to the checking process for the GI responses, word clouds for each question were generated to qualitatively identify the most frequently occurring terms to code the survey. This was to support and cross check the line-by-line coding exercise. The responses per GI question were also generated as positive and negative word clouds using the guidelines in Table 4.

Using the BA and AA code frequencies from GI questions 1 to 8, the percentage frequency of code occurrences was calculated, as summarised in Table 7 and Table 8. The percentages from Table 7 and Table 8 were then used to plot Figure 3 and Figure 4, respectively.

FINDINGS AND DISCUSSION

The 11 Behavioural Attitudes (BAs) and 8 Affective Attitudes (AAs) which emerged from the GI coding exercise were quantified using a frequency (%) calculation. These are shown as 2-D stacked bar graphs in Figure 3 and Figure 4, respectively. These figures provide a snapshot to the learners' BAs and AAs from the Group Interviews (GIs).

The Affective Attitudes (AAs) had four and five themes emerging from questions 7 and 8 respectively. The most frequent responses on learners' BAs after Hands-on Chemistry Intervention (HoCI) were having fun, learn new things solving problems and to understand. Learners' AAs after HoCI showed that they wanted to teach others, find solutions and help.

The authors recognise that the learners who volunteered may already have had a positive attitude toward science before taking part in this study as their attendance at this study was voluntary.

Table 7. Frequency of behavioural attitude code occurrence from group interview questions 1 to 6, n = 61.

CODE	Group Interview Question (%)					
	Q1	Q2	Q3	Q4	Q5	Q6
No response (0)	0	49	0	0	0	0
Fun (1)	9	12	18	5	0	29
Experiments (2)	30	0	4	0	7	0
Learn new things (3)	22	15	29	0	0	29
Solve problems (4)	0	7	7	5	43	7
Easy (5)	0	0	0	0	7	0
Career choice (6)	0	0	14	0	14	21
Write only (7)	30	0	0	19	0	0
Frustrating (8)	0	2	0	5	14	0
Understand (9)	9	0	11	54	7	14
Applied learning (10)	0	2	18	11	7	0
No interest (11)	0	12	0	0	0	0
Total	100	100	100	100	100	100

Table 8. Frequency of affective attitude code occurrence from group interview questions 7 and 8, n = 61.

Code	AA code	Affective attitude themes observed from responses	Q7%	Q8%
1	New (1)	New lab/equipment.	0	21
2	Experiments (2)	Do experiments.	0	7
3	Teach (3)	Teach others (teacher, friends or family).	27	29
4	Solutions (4)	Experience/find solutions/improvement.	0	29
5	Science (5)	I love science	0	14
6	Help (6)	Helping set out chemicals/cooperate with the task at hand.	33	0
7	Test (7)	Testing practicals.	20	0
8	Suggest (8)	Suggest each lesson's practical.	20	0
Total			100	100

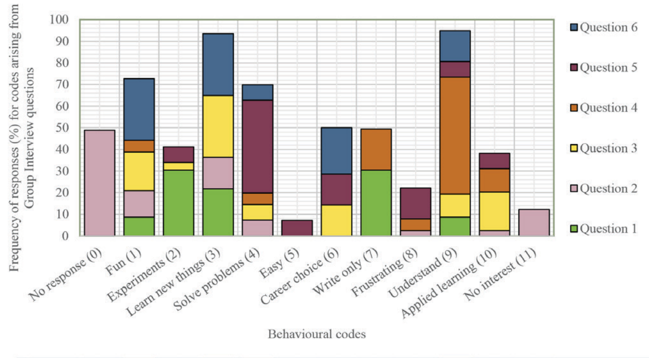

Figure 3. Frequency (%) of behavioural attitude codes emerging from group interview questions 1 to 6.

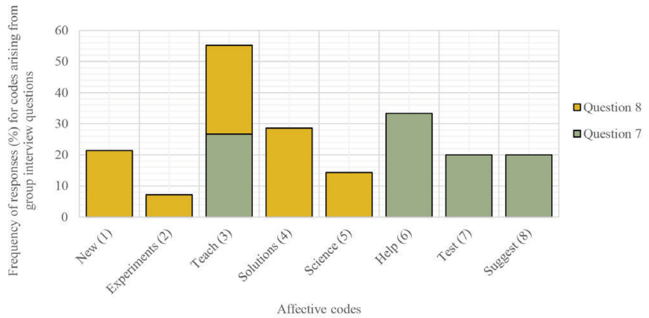

Figure 4. Frequency (%) of affective attitude codes emerging from group interview questions 7 and 8.

Behavioural attitudes (BAs)

Differences experienced between after school science club and classroom science

As shown in Figure 3, The most prevalent positively associated themes from "How is what you have done in 'science club', different from what you normally experience at school?" (question 1, Table 3) were that learners understood the topic under study better when done practically and the experience was new and exciting. Moreover, working in a co-operative environment (as stated by learner X5) strengthens comprehension of a topic.

X5: 'The environment is different because everyone cooperates with what is being said and what is being done'

The way learners respond to school and other educational settings, and the benefits they derive from these experiences are influenced by socio-cultural environments in which they are socialised and schooled.[17] The negative comments were mostly due to learners not being able to conduct their own experiments in their Natural Sciences classroom at school with statements such as:

A2: 'in class [school science] we just write the rules and you listen to the teacher explain the rules'

O4: '… because in school we don't do experiments like physically, we don't see reactions…'

The statements by X5 and A2 were similar to responses received in an after school science club study based at a low socio-economic school in Makhanda (Eastern Cape, South Africa).[24] This may imply that learners in schools of similar socio-economic background, even from a different location, have similar BAs toward hands-on science. Since a school lab is more interactive than a conventional classroom, this may offer "opportunities for productive cooperative interactions" and potential to provide a "positive learning environment".[23]

Thoughts on experimental science and the least and most favourite experiments

The responses below for "What did you think of the science (chemistry) demonstrations and experiments from the 'science club' and which experiments were your least and most favourite?" (question 2, Table 3) highlighted that these learners prefer a more exciting, hands-on approach to learning, that is also directly applicable to their daily lives. In addition to this, they also enjoyed learning new chemistry and science topics when practically demonstrated. Similar sentiments to those expressed by learners in this study have been reported in various studies[11,28], where the enjoyment of the activities encouraged learners to explore and learn more about science.

> *K1: '…those are the things that you learn about that we learn about outside the school'*

> *J2: 'I enjoy the combustion the most because I learnt that, uhm … substances that we see around us every day can be [used] to, to make experiments'*

> *O5: '… my favourite one was where we had to prove but [that] we actually inhaling oxygen and then exhaling carbon dioxide and then we had to examine the mixtures'*

The significance of these responses was that learners relate to science more readily when they can see how it forms part of their daily lives. Willingness to learn also increased when a fun aspect is included in chemistry teaching. However, experiments which required a higher level of cognitive thinking or had lower text cohesion, such as the 'mixtures and separation' session from this study, frustrated the learners. This frustration may have led them to associate difficulty with boredom. Yet learners such as L5 thought that even though one of the experiments was boring, he still regarded practical work as 'good'.

> *U1: '…I struggled a lot to separate water and sand and it became a bit frustrating to me'*

> *N1: 'I didn't enjoy mixtures and separation. Mixtures and separations was boring'*

> *L5: 'separation of mixtures was like the most boring one for me but all of them were good, all of them were good'*

The comments above may give insight to why learners have the pre-conceived notion of science being difficult. The notion may be due to the lack of interactivity within the classroom leading them to directly link boredom with difficulty. Alternatively, they are frustrated due to a real or perceived difficulty and then become bored with the procedure. Learners want the opportunity to prove and explore scientific concepts, not just to be told what the specific outcome of an experiment should be, emphasising the importance of science investigations.

Moreover, in the South African context, the language of instruction may possibly have caused confusion. Since the learners involved at School A mostly spoke isiXhosa (88%) or came from mainly English-speaking households such as School B, English (86%) or English and Afrikaans (14%). The use of code-switching has been discussed in studies carried out in multilingual science classrooms in rural schools. There are possibilities for coherent pedagogic bridging to assist learners who do not use English as their social or home language.[35] Bridging the gap may be done by using a systematic approach of combining languages, where the everyday language (isiXhosa) is used to explain a scientific concept in combination with the language of reporting (English).[35] Learners used code-switching which is considered a common place amongst multilingual individuals.[20] Code-switching may also be used as an empowerment tool to improve learners' academic performance in mathematics and overall understanding of new scientific terminology.[36]

Improved learning experience from well-placed curriculum based practical experimentation

There were no negative responses from any of the learners involved in all five GIs for "Would you like to perform more experiments at school, and if so, why?" (question 3, Table 3). The learners wanted to experience more experiments which allowed better learning in contrast to 'writing it down' during the conventional classroom teaching. They also said that *science club* should be a permanent fixture at their schools, directly implying the willingness to learn new science topics when they are done practically. The HoCI approach also revealed the importance of science related careers to learners as shown by selected statements below:

> *K1: '…in order for us to learn we have to do things practically and our world needs scientist who can identify problem, find a solution and solve it until it leads to results'*

> *U2: '…we would like to share the experience … to teach other kids*

> *E5: '…things you don't see every day, things people tell you but you don't actually believe it but when you see it it's like, it's in front of your face you get to see it …'*

Some studies have emphasised that the science curriculum tends to put too much weight on its academic characteristics.[37] This further removes the relatability of science to everyday life resulting in a divergence between science-in-society and science-in-school. This causes science as a school subject to seem irrelevant and not useful to the learner. K1 and U2's respective statements, which voiced that they saw the relevance of science in connection to their everyday lives, finding solutions and having physical evidence of a scientific outcome are in line with those reported by Chikunda and Ngcoza[37]. E5's statement imply that to a certain extent the growing gap between learners' life-worlds that are changing rapidly and the slow transformation of science practices in the classroom may be a contributing cause to the learners' declining attitudes towards science.[38]

Independent and self-reliant experimentation leads to better understanding

The most dominant codes associated with responses categorised as positive and negative were 'understand' and 'write only', respectively from question 4. "Did you find that doing the experiments yourself helped you to understand science (chemistry) topics better or made you more confused?" (question 4, Table 3). Learners such as O1 and U2 said that they had a better understanding of the science topics when doing the experiments using the HoCIs.

> *O1: 'it helped me, because in the classroom [school setting] we used [to] writing notes. The teacher will explain the notes but we didn't have imagination …'*

> *U2: '…we use the information we are given in class [school setting] and we corroborate it with the information we get from the chemistry class [science club] …'*

Responses from O1 and U2 reveal the importance of connecting the CAPS Natural Sciences theoretical chemistry component taught in class to relevant hands-on experiments. The connection with HoCIs allowed learners to think about the concepts and collaborate with their peers to understand the science.

Some, such as G5, also said that notes and videos (YouTube) used in the classroom confused them.

> *G5: 'it [HoCIs] gave better understanding than the [YouTube] videos that ma'am showed us about that'*

Learner U2 supported G5's observation by describing how HoCI can be used in conjunction with their Natural Sciences lessons. Learners struggled to draw clear connections from classroom videos relating to their CAPS curriculum. The struggle to connect may have been due to the lack of connection between the YouTube videos and the specific socio-economic world view of a learner at a quinitile-1 school, or language barriers since most YouTube videos are normally presented in English.

Learner W5 supported by G5's statement highlighted their dissatisfaction with videos shown in their school classroom when compared to carrying out experiments independently.

> *W5: 'we always saw videos about stuff but never understood what's happening'*

Similar aspects of learners not understanding the topic by making an incorrect inference from a video with the science content have been observed in selected public and private schools in Kocaeli, Turkey.[39] This was contrary to a study done on a flipped classroom setting which encouraged alternative teaching practices using videos from platforms such as YouTube.[40] Some authors recommended that learning can be supported by videos in the classroom.[10] However, they recognised that it may be problematic in lower socio-economic situations due to the availability of resources.[10]

Feedback from after school science club carried over to the classroom

The learners used feedback from the HoCI sessions to improve their chemistry learning experience in their classroom at school (question 5, Table 3). The statements which stood out from the question "Did you have the opportunity to use feedback from the experiments to improve your learning?" were:

> *L5: 'Yes, some work. Some questions may be like in class and then pops up that same stuff you do in class is the same you did in experiments'*

> *K1: 'I didn't understand it [pH scale] when using notes, I did it practically then it was clear to me'*

> *U2: 'Physical Science is not difficult as people say it is difficult'*

The significance of these statements emphasised how learners reported a better understanding of chemistry and science concepts after the intervention. The improved understanding stems from being able to make a connection between their traditionally taught curriculum in class to HoCIs in the *science club*.

Enabling the knowledge gap to be bridged between 'difficult' classroom science with relatable experiments may lead to improved comprehension of the science topic. Similar sentiments were expressed by a learner from a previously disadvantaged school based in Makhanda, South Africa.[41] The learner, after noticing the lack of participation from other quintile-1 schools in science fairs, stressed that it may be due to "fear of trying it" and the fact that science, regardless of schooling background "is meant for everybody".[41]

Experiments influence Physical Science selection and aspirations for a career in science

All responses from learners for question 6 (Table 3) were positive as illustrated by the statements belonging to two learners from different groups.

> *C1: '…when this program was informed, I had doubt about doing science but then after I joined the program I, I found science very fun and it was more understandable to me'*

> *O4: '…I wasn't sure I was into [Physical Science] next year, but when I did science physically, I usually know I can do this, and I can next year'*

These responses demonstrate that interactive HoCIs had a positive effect on learners wanting to select Physical Science in Grade 10. The responses also showed that the subject became more manageable to learners after their experience of HoCIs. B1's sentiment below, however, was related to economic importance of science driven careers within South Africa after HoCI:

> *B1: 'yes, I want to do science next year because in this country you can't do without knowledge and to know how what to use and work with …'*

The response resonated with studies done on enhancing education for sustainable development in chemistry teaching with recognising and linking economic importance to chemistry.[42]

Affective attitudes (AAs)

Assistance and cooperation in natural science class to allow for better learning

All responses to question 7 (Table 3) were positive, with learners confirming how once they have learnt a new scientific skill which they enjoyed, they want to pass it on or help another person which infers that the HoCI encourages learners to share knowledge and scientific ideas with each other:

> *U1: 'I can try to assist the science teacher in my class … they did practicals ages ago and, maybe forgotten how to do it so I am in science club right now, in the present tense, so I can't forget what I did last week or yesterday, so I can assist my teacher'*

This statement also highlights that educators can gain valuable knowledge from motivated learners in the conventional Natural Sciences classroom. Learners mostly want improved learning environments and will assist and cooperate to improve their communities.

Sharing scientific knowledge with the community and others

The five themes which emerged from question 8 (Table 3) included: 'new lab/equipment'; 'do experiments'; 'teach others'; 'improve, experience, and find solutions'; and 'love science'. While only ten learners in total, across three GIs (1, 2 and 4) were vocal in their responses they provided rich data by expressing their point of view. These groups were from School A, the self-identified 'Black' learners. The question, "Are there any other general points anyone would like to add with regards to science (chemistry) at your school or science (chemistry) in general?" elicited learners' sense of community and concern to ensure that everyone could have equal opportunities and experience in learning science, in the way they had. They were also keen to share their knowledge with members in their communities:

> *Un1-1: 'the meaning of knowledge is you can teach younger audiences like our younger brothers, siblings, cousins, can teach them about science and tell them that science is there …'*

> *Un1-2: 'I want to do science because I'll learn to educate people who are saying science is hard to give my knowledge to them showing them science is not hard it's not difficult'*

> *E4: 'In science … find the solution to problems in our daily lives…science makes our lives easy…'*

CONCLUSIONS

This study focused on the South African public-school *Matter and Materials* section of the CAPS curriculum for Natural Sciences. The implementation of this curriculum sometimes neglects to make the chemistry relevant to their Grade 9 audience's socio-economic environments. The approach used in this study was to make chemistry experiments accessible and relatable by using a Hands-on Chemistry Intervention. This subsequently had a positive effect on the learners' Behavioural Attitudes (BAs) and Affective Attitudes (AAs) towards science.

Findings from this research showed that the primary issue of learners' lack of interest in chemistry and science was due to lack of resources, connection to their lives and the pre-conceived notion of the difficulty of science as a subject.

Throughout the study, one of the unexpected secondary trends to emerge were how male learners were more dominant in the HoCI sessions. Their inclination toward a STEM career, as well as being vocal in the GIs, was evident. Studies on high school learners from public high schools in Texas, United Sates of America found similar findings with respect to males being more likely to follow a career in STEM, when compared to females.[26] With regards to the socio-cultural context in Eastern Cape (South Africa), females tend to be the care givers at home and are normally socialised into circumstances where they are encouraged to follow the guidance of a male figure.

The primary contribution of this study is that hands-on and interactive experiments improve chemistry teaching and learning. Secondly, experiments can be aligned with the curriculum in a cost-effective manner by making use of easily accessible items and recycled materials such as plastic 2 litre bottles (combustion HoCI session), magnets (mixtures and separation HoCI session) and jam jars (pH HoCI session). HoCIs should always be constructed using variable levels of cognitive difficulty, so that they may still provide meaningful learning.

Moreover, the informal setting of an after-school science club that was directly linked to the learners' curriculum sparked their interest and awareness of the importance of science. Learners became confident when learning was conducted in small groups (three to four) because they could freely discuss the topic being taught in their own social language(s). In addition, the after school HoCI sessions influenced learners to want to carry over their newfound knowledge to the school setting classroom and assist their educators. Learners did this because they wanted to enhance and share their scientific learning experiences with their peers who did not have the same opportunity. Moreover, HoCI positively influenced learners' confidence. The relevance and practicality of science was revealed to the learners which made them want to continue with Physical Sciences in Grade 10 in the future.

Learners reported that they retained knowledge more effectively when performing HoCIs. The element of enjoyment and novelty from HoCI regardless of the level of difficulty or the schools lack of resources made learners more positive, open to learn about, communicate science, as well as possibly to pursue a university career in science. The findings from this study are in line with Vygotsky's social learning theory as learners found the environment of the science club conducive to their understanding of selected topics. The HoCls allowed learners to participate actively in conducting experiments.

RECOMMENDATIONS

For future research, this study can be repeated in public schools of varying quintiles. This could be done to determine if quintile-5 (advantaged schools) learners have a different outlook to quintile-1 learners. The comparison may be used to draw inferences from the different world views on socio-cultural, socio-economic practices and circumstances.

Additionally, longitudinal studies can be carried out on the present cohort of learners' selection of Physical Science to determine their future career choice. Learners should also be encouraged to keep personal reflection journals for rich description of their views on their behavioural attitudes towards Physical Science.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICAL APPROVAL

The study was conducted in accordance with the Nelson Mandela University ethics, under ethics clearance number H16-SCI-CHE-001.

SUPPLEMENTARY MATERIAL

Supplementary information for this article is provided in the online supplement.

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