



Teaching Pre-service Teachers who Perceive Fear and Ignorance of Chemicals: Why Should this be a Concern to Chemistry Teachers?

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Abstract

One of the aims of chemistry teaching is to provide students with the optimum condition for understanding concepts needed to interpret and predict natural phenomena. But the fulfilment of such hope cannot occur unless what is presented to the students is relevant and meaningful to them. The central concern of this study is to examine pre-service science teachers (henceforth, 'subjects') whose fear and ignorance of chemicals impinges on their learning of chemistry. Two cohorts of third-year subjects in a semester chemistry course participated in the study. The study was motivated by the outcry regarding the general decline in student performance since their first year registration in the four-year science education degree programme. Data were derived from the subjects' responses to "My View and Knowledge of Chemistry" (MVKC) questionnaire and field notes. The findings of the study revealed that the subjects' interest and areas of concern varied: two-thirds indicated that they were most afraid of demonstrations and experiments about the properties of chemical substances and their reactions, while a quarter of them said the latter stimulated their interest in learning. The implications of the findings for chemistry education and instructional practice are highlighted in the paper.

Keyword: Chemistry, Chemicals, Pre-service Teachers, Argumentation Skills.

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INTRODUCTION

Student understanding of chemistry consists of information that they learn in the classroom and information that they bring into the classroom. In the environment in which students grow up and have their first childhood experiences, they interact with chemicals or products derived from the

study of chemistry. Through the many valuable experiments with chemicals that chemistry provides, they not only investigate and master the chemicals surrounding them, but they also use and enjoy the products derived from chemicals. Despite the usefulness of chemical products, which is at the very heart of chemistry, many students still perceive fear and ignorance of chemicals. The fear now being expressed is that if the present trend continues, a time might come in which the bulk of science students would be chemically illiterate.

Purpose of the Study

This study is concerned with investigating the reasons for pre-service teachers' perception of fear and ignorance of chemicals pertaining to their learning of chemistry. In view of the already existing poor performance since their first-year registration in the four-year science education degree programme, part of this investigation included their learning experience, views and knowledge of, and about chemical (or chemistry in general). To ascertain other possible reasons for variations in their fear and ignorance of chemicals, their perceptions of the impact of chemicals (or chemistry) on society was also explored. Therefore, the problem to address is defined as 'My View and Knowledge of Chemistry' (MVKC). MVKC is threefold: a) 'My View of Chemistry' (MVOC), b) Learning Experience in Chemistry (LEIC), and c) View about Chemistry and Society (ACAS). More will be said about these categories later.

Insights into the work done by colleagues in the field of chemistry education research from 2004–2013 have contributed to the knowledge of conceptions and conceptual change among students (Teo, Goh, & Yeo, 2014), problem solving in chemistry (Bodner & Herron, 2002), improving students' understanding and expanding real life problems on concepts of reaction (Kurt & Ayas, 2012). Other reform efforts have acknowledged the importance of chemistry education and practice by emphasizing the need to review research on the teaching and learning of chemistry topics such as chemical kinetics (Bain & Town, 2016).

Recently, Spierenburg et al. (2017) have shown how misconceptions in the exploding flask could be resolved through students' critical thinking. All these have been done to develop and integrate knowledge of the natural world into students' understanding of chemistry. However, despite the efforts of chemistry education reformers to publicize the importance of chemistry, many high school students receive little or no exposure to the most important concepts in chemistry, such as, 'chemical', a concept essential to understanding key aspects of living things. This matter is even more pronounced in many chemistry classrooms in African countries.

From the foregoing, in South Africa it is clear that science students graduating from secondary school have at least done chemistry. However, many of these students leave secondary school with little useful knowledge of chemistry and some with the impression that it is an extremely difficult subject with little relevance to their lives. This, to a large extent has contributed to a lack of interest towards learning chemistry, among the subjects of the current study. For example, the subjects do not seem to be interested in chemical information within many modes, including the classroom chemistry lecture, demonstrations, and laboratory activities. In addition to this, whenever the term 'chemical' is used in the science classroom the subjects would hastily enter into debate in which they would argue and express their fear of chemicals or what some call "chemophobia" (i.e. the fear concerning chemicals and chemistry).

Furthermore, the current debate in South Africa about the government's decision to use nuclear energy to support power production and other amenities has equally stirred up fear and reactions in many members of South African society. This stance is further exacerbated by the media, who are always seeking to make a sensational front-page story out of any chemical spill or any environmental issue that involves chemicals. This culture is, however, mostly shrouded in a veil of secrecy, fear, misinformation and mistrust (Lazic & Kaigo, 2013). As a result, information on chemicals has been distorted and frequently misrepresented, resulting in a shift in students' perception, opinion, attitude and acceptance towards chemistry as a subject.

Although it is accepted that students may be influenced by some major chemical accidents which they have heard about or seen, this may unduly influence their opinions and perceptions about the word 'chemical'. All the same, many students have little understanding that their bodies are made of chemicals, and that water and common salt (NaCl) are chemicals. One problem with the word 'chemical' is that it is not possible to give it a satisfactory definition. Oxford dictionary defines chemical as 'a substance obtained by or used in a chemical process'. But almost any substance can be obtained by or used in a chemical process, so chemical is essentially synonymous with substance.

The literature dealing with students' view of chemistry seems to suggest that an unmonitored students' view of the subject-matter can hinder their learning (e.g., Autida, 2012; Festus & Ekpete, 2012; Mahdi, 2014; Spierenburg et al., 2017). It is well known that students' understanding of chemicals and their reactions is fundamental to the teaching of chemistry. On this point, the subjects of the current study take every chance to foster fear over chemical reactions and anything to do with hands-on chemical activity. Little is known as to why this has persisted in the last three years of their chemistry education studies. Also of concern is the issue of insufficient information in the area this study is canvassing, especially in South Africa, as well as on the need for improvement where inadequacies are identified. This being the case, why does it matter if many students (in this case, the pre-service teachers) are afraid and ignorant about chemical science and about chemistry in particular? It matters because science teachers are mediators of critical knowledge, skills and the essence of our science culture.

Whatever the case, teachers are in position of influence in the lives of the future generations of scientists, engineers, technologists, and so on, thanks to the conscientious teachers who invest in the leaders of tomorrow. Therefore, the conundrum 'like teacher like learner' is relevant, stemming from the fact that a poorly-trained teacher will likely produce a poor chemical engineer, doctor, technologist, fellow teacher and the like. If this be the case, how can we ensure that teachers we produce are prepared to teach chemistry without fear and ignorance about the subject-matter? The extent of such a paradigm shift is investigated in this research study, through the following research question:

- Why should students who perceive fear and ignorance of chemicals be a concern to chemistry education?

REVIEW OF LITERATURE

Previous studies on students' conceptions of chemistry have consistently shown that a cognitive chasm exists between students' knowledge and their understanding of chemistry (e.g., Kurt & Ayas, 2012; Potgieter, Davidowitz & Venter, 2008; Price & Hill, 2004; Walker & Sampson, 2013). Another consequence of chemistry image is that fewer students are expressing an interest in becoming professional chemistry teachers or chemists. Ogunniyi (1995) has said that studying a demanding school subject, particularly science in South Africa, no longer appeals to the students' intellectual interests. This is taken to mean that a shortage of qualified chemistry (or science) teachers will only exacerbate the problem of educating this generation of students about chemistry. And this will come at a time when an increased number of chemists will be needed just to cope with the environmental problems caused by increasing populations and ever-increasing expectations of higher living standards.

Teaching chemistry is very demanding and it is not just classroom instructional discourse. It includes among other things, helping students to develop skills that can be used in their daily lives. Mahdi (2014) investigated what makes students choose or not choose chemistry and what the main factors are, that contribute to an understanding of chemistry as a subject. The study adopted four aspects to appraise students' attitudes towards chemical education, including students' perceptions toward chemistry, the concept of chemical knowledge and its understanding, and an application of chemical knowledge as an understanding and as a career. The results showed that students were positive about most statements which supported their education, despite the perception that chemistry is a difficult subject.

The work of Price and Hill (2004) revealed that one of the reasons for the decline of chemistry in Australia is due to a lack of relevance of chemistry in the eyes of the general public and a late realization of the importance of chemistry education among students. There is no doubt that several obstacles have bedevilled chemistry as a subject. Results from the study done by Autida (2012) showed that a majority of the 354 students surveyed have positive perceptions towards chemistry and it had been shown that some of these views were affected by the gender and ethnicity of the students. Autida further suggested that knowing the perception of students about chemistry is useful in designing teaching strategies to uplift or maintain positive attitudes (p.231).

Talking about teaching strategies, Mumba, White, and Rollnick (2002) investigated the overall gap between high school and first-year university chemistry at one of the universities in South Africa. In their investigation of teaching strategies, four first-year university chemistry lecturers and four secondary school physical science teachers were observed and interviewed. One of their main findings revealed that there was a major difference in the teaching styles employed by the subjects. The same lag is probably true of the topic beginning with the efforts made by Bradley, Brand, and Langley (1985) towards an understanding of the school-university gap in chemistry.

Other researchers have looked at the assessment of preparedness of first-year chemistry students. For example, Potgieter et al. (2008) carried out a study with mainstream students (N = 771) at two universities to determine the minimum level of content knowledge and conceptual understanding of chemistry required for success at these institutions, which can be used to

benchmark a general criterion for measuring preparedness for tertiary chemistry. One of their main findings revealed gaps in the assumed pre-knowledge of students who had qualified for admission to study chemistry at their respective institutions.

Some adjustment problems of first-year chemistry students in terms of language and culture were also studied by Rollnick and Manyatsi (1997), in addition to which Rollnick (1998) studied the influence of language on the second language teaching and learning of science. One of the major findings revealed that incompetence in the medium of instruction is a potential transition problem, especially for students from secondary schools where teaching is punctuated with code switching (i.e. using local language interchangeably with English language during teaching). It can be assumed therefore that methods for imparting pertinent knowledge of chemistry to students who are chemophobia should aim at helping them to surmount the pedagogical inadequacies their education has left them in chemistry. The remedy does not lie in a greater dissemination of chemical/chemistry information to students using a tradition-led approach. The method should promote a way of thinking and not as a body of knowledge and fixed facts (Zohar & Nemet, 2002). Kuhn (1991) agrees with this view when she pointed to the need for actively engaging students in thinking in order to promote scientific knowledge building. In fact, there is enough research evidence to show that providing students with activities that require discussion and debate gives teachers the opportunity to engage students in the construction of arguments and belief revision (Erduran, Osborne, & Simon, 2004; Kuhn, 2010; Ogunniyi, 2007a; Walker & Sampson, 2013).

A more recent study that took place in South Africa examined the opportunities that university science educators gave their student teachers to develop and practice argumentation skills and also concluded that curricular activities be designed in such a way that help students to learn science in an atmosphere where they can express their worldviews freely, clear doubts, modify or even change their viewpoints in light of a more convincing evidence (Iwuanyanwu & Ogunniyi, 2019). According to this recommendation, engaging students in argumentation sets the scene for building new knowledge and for changes in their views (Leitao, 2000).

Many salient studies have explored the potential of argumentation as an instructional tool to provide students with the needed discursive communal learning environment where they communicate their viewpoints with their peers as well as reflect on their own assumptions (Evagorou & Osborne, 2013; Von Aufschnaiter, Erduran, Osborne, & Simon, 2008; Walker & Sampson, 2013). Kuhn (2010) feels that the argumentation process must be seen by the students to have a clear goal, a purpose that goes beyond mere simple mechanistic motion through the process. They must be able to reflect on and learn from what they are doing. For this reason, the current study is premised on the belief that exposing the subjects to dialogical argumentation could be useful in mediating the status quo of their learning chemistry.

As mentioned above, the choice of argumentation instruction is largely because it has been found to be effective for knowledge building and belief revision, especially when dealing with controversial issues such as the current study is canvassing (e.g. Berland & McNeill, 2010; Ghebru & Ogunniyi, 2017; Walker & Sampson, 2013). The researches of Driver, Newton, and Osborne, (2000), Erduran et al. (2004), and Zohar and Nemet (2002) showed the use of argumentation instruction provides to query both students' ideas and their friends' ideas. These

researches based on Toulmin (1958) model marked an epoch in the use of argumentation instruction in science learning and teaching. However, it is known that one of the limitations of Toulmin Argument Pattern (TAP) model among other things is that it only deals with syllogistic forms of reasoning. From this point of view, in order to improve inquisition and discussion among the subjects of the current study, the study has also adopted Ogunniyi's (2007a) Contiguity Argumentation Theory (CAT). CAT deals with both logical and non-logical arguments, especially those commonly encountered by the subjects when discussing socio-scientific issues.

The modified levels of TAP by Erduran et al. (2004) include:

Level 1: non-oppositional arguments or arguments with simple claims versus counter-claims.

Level 2: arguments with claims supported with grounds (data, warrants and backings) but with no rebuttals.

Level 3: arguments with claims supported with grounds and only occasional weak rebuttals.

Level 4: arguments with claims supported with grounds and at least one strong rebuttal.

Level 5: arguments with claims supported with grounds and with more than one strong rebuttal.

In this study, the five levels of argumentation listed above were used to examine the subjects' responses to the research instruments. Thus, argumentation is addressed in the study on three levels, namely: self-conversation (intra-argumentation); critical thinking processes; dialogues between two or more people within a small group (inter-argumentation) and across groups (trans-argumentation) Ogunniyi (2007a). The study, therefore, considers using arguments consisting of claims, data, warrants, backings, and rebuttals in the juxtaposition of the cognitive stages of CAT.

The five categories of CAT to be used side-by-side with the levels of TAP are:

Stage 1. Dominant: The prevailing idea or worldview considered to be the most appropriate for a given context.

Stage 2. Suppressed: The worldview that is subordinated to the dominant one for the same reason.

Stage 3. Assimilated: The worldview that is subsumed by the more dominant one.

Stage 4. Emergent: The worldview that evolves from a new experience, e.g. the acquisition of a new concept in a science class.

Stage 5. Equipollent: Two powerful worldviews exerting equal cognitive force on a person's worldview.

It is worthwhile, however, to note that in South Africa a cursory review of literature shows some studies that have been done in which CAT and TAP were used to mediate science instruction in an interactive learning environment guided by a dialogical argumentation instructional model (DAIM) (e.g., Ghebru & Ogunniyi, 2017; Ogunniyi, 2007a; Ogunniyi & Hewson, 2008; Ramogoro & Ogunniyi, 2010). Results from these studies showed that DAIM provided ample opportunities for teachers and students to co-construct knowledge through arguments, discussion and dialogue. In particular it allowed students to express their views and reach possible consensus where feasible (Diwu & Ogunniyi, 2012). Given these beneficial effects of

argumentation instruction, this study uses DAIM as a platform to mediate the three categories: MVOC, LEIC and ACAS, the central concern of the study.

METHODOLOGY

Subjects in this case study were two cohorts of 28 pre-service teachers taking a semester chemistry course in a four-year science education programme. The sample was purposely targeted, given the purpose of the study. Using a one-group time series design, two-stage sample formulation was performed. First, a selection of the subjects was stratified by a comparability of the two groups of subjects in terms of their performance in chemistry since their first-year registration. A second criterion considered was based on the willingness of the subjects to participate in the study. In line with the semester course guideline, subjects were exposed to bi-weekly chemistry lectures lasting for one-and-half (1.5) hours per session.

Research instrument development began with the author reviewing questionnaires that were used in a research report titled 'The Future of Chemistry Study', which was published by the Royal Australian Chemical Institute (p. 55-56). From these questionnaires, the author derived a questionnaire, 'My View and Knowledge of Chemistry' (henceforth, MVKC). The MVKC incorporated a set of 43 items on students' views, knowledge and attitudes towards chemicals (or chemistry in general). As mentioned earlier, MVKC has three categories: MVOC, LEIC and ACAS, which the researcher believed would generate adequate data to address the concerns raised in the study. In addition, open-ended questions that could engender debates on a number of controversial issues prevalent at the time of this study in South Africa were included in the research instrument.

Preliminary drafts of the research instruments were vetted for face, content and construct validity by two independent experts who have commendable knowledge and experience in teaching chemistry to secondary school and university students. Each item was rated in terms of clarity on a four-point scale (1 = irrelevant, 2 = relevant, but not so clear, 3 = relevant and clear, and 4 = excellent). In this regard, items with scores of 1 were eliminated, items with scores of 2 were revised based on feedback from the three reviewers, while items with scores of 3 or 4 were retained. This process further reduced the items from 43 to 30.

After a series of revisions the MVOC, LEIC and ACAS interactors had inter-rater reliability values of 83%, 78% and 87% respectively. This process helped ensure that individual items were clear and unambiguous and that the study as a whole would provide new information about non-Western chemistry students who perceive fear and ignorance of chemistry and its reactions. It was also hoped that the data from the research instruments would provide the necessary platform on which to base a remedial chemistry teaching program in the form of dialogical argumentation and instructional-based lectures. Finally, the research instruments were deployed to gather baseline data in the first week of the semester course. Each subject was asked to read each of the 30 items carefully and to express an opinion: strongly agree (SA), strongly disagree (SD) or not sure (NS) as an option with respect to the response choices listed under each of the three categories (i.e. MVOC, LEIC and ACAS).

Following the baseline data collection, the subjects were exposed to a series of chemistry lectures during which various tasks, guided by DAIM, were completed. Subjects were divided into small groups: A – F, with each group consisting of 4 – 6 members. An example of such a task, #X1 for testing subjects' view and knowledge of chemistry, is provided in the paper. Through the application of DAIM as espoused by Ogunniyi (2009), the completion of tasks was undertaken as follow:

- Individual tasks (intra-argumentation), where subjects are expected to respond to assigned tasks and then educe valid reasons for their choices. Categories of their arguments to support their stances are identified using levels of TAP and stages of CAT.
- Small group tasks (inter-argumentation) where subjects who share their individual tasks propose solutions and get opportunities to defend their own views and to convince one another of possible viable solutions to the problem statements. Each group, including the group leader, consisted of 5 – 6 members.
- Small group presentations to other groups within the classroom led to whole class argumentation. The roles played by group leaders and members were rotated among members to ensure that all participants had the opportunity to perform different functions from the ones they performed at the individual task level. The group leader also ensured that tasks assigned to his/her group were conducted in a respectful manner, such that tacit understanding and co-constructed knowledge were shared to achieve communal consensus.
- Lesson consolidation by the researcher through a process called trans-argumentation mediation, a process in which an attempt is made to reflect a common practice among scientists. The researcher (mediator) moved from group to group, playing devil's advocate by asking thought-provoking questions as well as sorting out incipient problems (Erduran et al., 2004).

Through this approach, subjects were guided to present their views as a claim and then also provide reasons as evidence to support their claims. At the end of each task they had to identify the source of their view, experience or knowledge claims about, and of chemical (or chemistry in general). The latter generated the post-intervention data. The researcher was responsible for determining the levels of TAP or the types of CAT mobilized in the classroom discourses.

The initial process of data analysis was to identify key concepts and emerging themes that form the categories of issues canvassed in the study. For example, a tally system was used to find out the frequency counts of each of the categories. The frequency counts were turned into percentages and used to gauge discussion with the excerpts, reflecting levels of TAP and cognitive states of CAT. For ease of reference, the subjects' responses that have reference to the categories of CAT are presented in the [first bracket] while excerpts that have references to TAP are presented in the [second bracket].

RESULTS

Figure 1, a diverging stacked bar chart shows the percentages by frequency of subjects' categories of response on 10 of the 30 question-items. Under 'my view of chemistry' (MVOC), the percentages of 'strongly agree' categories are shown to the right of the zero line. The opposite is shown to the left. The 'not sure' view is split down the middle. The primary interest is not to synthesize the stance of the subjects per se but to capture their feelings, actions and pragmatic opinion based on the categories. To ascertain this, the total percent to the right or left of the zero line was considered; the breakdown into 'strongly' or 'not' is of less interest, so that the primary comparisons do have a common baseline of zero.

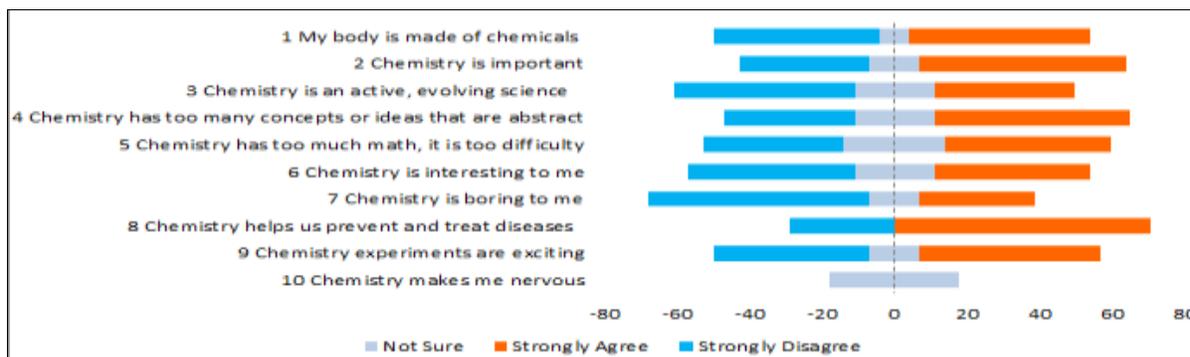


Figure 1: Diverging Stacked bar charts depicting the subjects' view of chemistry

An examination of the response options reflected in Figure 1 shows that the subjects expressed the highest agreement (71%), indicating that chemistry helps us prevent and treat diseases [CAT stage 1], followed by chemistry is important (57%), but it has too many concepts or ideas that are abstract (54%). Relative to the subjects' chemophobia, agreement in the descending order was that the study of chemistry or dealing with chemicals makes me: nervous (46%), afraid that I might get injured (39%) or bored (32%), [CAT stage 2].

It is evident from the subjects' responses that there is some level of dissatisfaction with their learning of chemistry. This is true in the negative, with the subjects' learning experience in chemistry (LEIC) (Table 1). The agreement in the descending order was a lack of confidence in their ability to do chemistry, with the statement 'chemistry is too difficult' (46%). Subjects were relatively evenly split in their responses to the statement, 'I could not do chemistry' (43%) and 'I do not have enough maths and science background' (43%). In this regard, only 36% indicated that they were comfortable working in a chemistry lab and with chemicals. In terms of the disagreement, the order was that 61% of the subjects indicated they could do chemistry because they had enough science and maths backgrounds (54% and 46%), and because they like chemistry (43%), [CAT stage 1].

Table 1: Percentage response choices of subjects to items on LEIC

Key Concept and Categories	SA	SD	NS
11 I could not do chemistry	43	57	0
12 I don't have enough science background to do well in chemistry	36	54	11
13 I don't have enough mathematics background to do well in chemistry	43	46	11
14 I don't like chemistry	54	43	4
15 I get anxiety just thinking or hearing about chemistry or chemicals	64	36	0
16 I am afraid that chemistry might expose me to dangerous chemicals	61	29	11
17 I am afraid that I could get injured in a chemistry laboratory	39	61	0
18 I feel comfortable around chemicals, working in a chemistry lab excites me	36	57	7
19 I have always liked chemistry, it is my favourite	43	43	14
20 I began to like chemistry because of my chemistry teachers	46	43	11

SA = Strongly Agree; SD = Strongly Disagree, NS = Not Sure

Another area that concurs with the results arising from this study is the subjects' views about chemistry and society (ACAS) (Table 2). The highest agreement (68%) was observed in the item stating that stories about chemical accidents reported in the media have contributed to their tendency towards chemophobia [CAT stage 2]. This may indicate that the subjects' views are being consumed by a more powerful one i.e. media in terms of persuasiveness and dominance. Likewise, 54% agreed that only chemists need to know chemistry, not everyone (43%), because it has done more harm than good (50%), even though it is useful for solving the problems of everyday life (43%). Despite its relevance to the well-being of the society (43%), we don't need chemicals in our society, so they should be banned (39%), [CAT stages 1 & 3]. Certainly, a situation in which over two-fifths of the subjects express misgivings is worthy of closer attention.

Table 2: Percentage response choices of subjects to items on ACAS

Key Concept and Categories	SA	SD	NS
21 Chemistry positively impacts society	44	48	7
22 Everyone should know some chemistry	46	43	11
23 Chemistry is useful for solving the problems of everyday life	43	54	4
24 Chemistry has made the world a better place	36	50	14
25 Chemistry has done more harm than good	50	46	4
26 Only chemists need to know chemistry	54	43	4
27 Stories about chemical accidents reported in the media led me to be chemophobic	68	32	0
28 We don't need chemicals in our society, so they should be banned	39	46	14
29 Everything you hear, see, smell, taste, and touch involves chemistry and chemicals	32	39	29
30 Chemistry is relevant to the well-being of society	43	46	11

N = 28; SA = Strongly Agree; SD = Strongly Disagree, NS = Not Sure

It is also important to highlight that 50% of the subjects know that their bodies are made of chemicals [CAT stage 1], despite which 39% disagree that everything they hear, see, smell, taste, and touch does not necessarily involve chemistry and chemicals [CAT stage 2]. Also, the highest percentages of uncertainty or 'Not Sure' among the subjects in responding to the three categories tested were: 'MVOC' (18%), 'LEIC' (14%) and 'ACAS' (29%). With this evidence there seems to be a need to expose subjects to general pedagogy and related responsibilities during their preparation in order to make chemistry more effective and relevant to them, their future learners, and in turn the society.

As part of the effort to mediate the subjects' status quo about chemical and chemistry in general, the following extracts showed how the subjects responded to an open-ended question (#X1) structured to initiate dialogical argumentation. In this task the subjects were urged to use alternative arguments i.e. arguments that contradict one's original opinion. The criterion for argument formulation was whether the written responses produced by the subjects included a conclusion with at least one relevant justification. Arguments generated by the subjects were classified according to the levels of TAP and CAT respectively. The problem statement reads:

In olden times the fertility of soil was achieved by allowing the land to lie fallow (unused). Alternatively, natural fertilisers such as manure and ground animal bones, which were ground, were used. Scientific research later established that fertilisers contained large quantities of nitrogen (N), phosphorus (P) and potassium (K). While it was easy to obtain the minerals, the sources of nitrogen were very limited. As the world population grew, so did the demand for nitrogen-rich fertilisers. At the same time the sources of nitrogen were being depleted. Fritz Haber designed a process which used nitrogen from the air and hydrogen from natural gas to manufacture ammonia. The process was also used to make ammonium nitrate which was used to manufacture explosives during World War I. Today the ammonia produced is used in the plastic industry and in many other products.

Group Task:

By identifying positive and negative viewpoints with reference to the above narrative, use justifiable arguments to convince your classmates on the impacts of the Haber process on human and social development.

Subjects from group A at the forefront of the critical audience gave reasons why chemicals such as ammonium nitrate should be banned, the most being the use of ammonium nitrate in making explosives or bombs. However, their one-sided presentation was further consolidated by group B, who underscored the assumption put forward by group A. Data generated showed that this idea was commonly held by the majority of the subjects.

Group A: First...three members of our group said that it is their first time to hear about the story of Ammonia.

Group A: Since ammonium nitrate...is used in making explosives, people's lives are at risk...

Group B: *We think the Haber process of making ammonia is useful in many ways...it helps to promote life, at the same time it is use for destroying lives.*

Group A: *Yes, the same chemical is also use to grow food...to feed people, and then kill them (laughing)...can we say it is like a knife...use for cutting vegetables and other stuffs in the kitchen but when it is in the wrong hands at the wrong time...people kill each other with it...so is ammonium nitrate .*

Group B: *We think ammonium nitrate (NH₄NO₃) is dangerous to be allowed around us...it can get into the wrong hands...even terrorists can destroy lives if they have common access to chemicals...also making this chemical causes different kinds of pollutions.*

Group A: *We think ammonium nitrate is good and bad...but its badness is bigger than good...so government should ban it.*

Group B: *Yes we agree our government should ban it...and make it difficult for people to access it...we must find other ways of making fertilizer.*

*[Prevailing ideas-CAT stage 1] (TAP level 2 Argumentation)

Subjects appraised different sides of the issue, conjectured grounds (data, warrants and backing), and offered counterclaims, but no rebuttals. In all they considered the view that they deem possible. This possibility they think is worthy of consideration, hence their conclusion. [Prevailing ideas- CAT stage 1] (TAP level 2 Argumentation). While groups A and B tried to justify their views, it was difficult for group C to ignore the issue of banning chemicals on the basis that they are used for making explosives. Countering their opponents' arguments, groups C and D presented the alternative usefulness of chemicals for societal well-being, in particular chemical relevance to food production.

Group C: *We disagree with groups A and B, the scientist Haber did a brilliant work...just because the same chemical can be used to make explosives cannot take away the good it brings...think about how many people that would be starving today...we are already starting to starve...watch TV and see people dying of hunger...*

Group A: *Can that be a justification to allow ammonium nitrate and other chemicals around us?*

Group B: *Yes, we acknowledged the benefits, it seems group C is missing the point...the task says ammonium nitrate is use in making explosives...like bombs. So we are not for it.*

Group D: *Lindiwe (pseudonym)...is right...we agree with group C. Maybe groups A and B don't know that the same chemical is used in making explosives in mining industry.*

Group B: *And so...?*

Group D: *Our country's economy is largely depended on minerals...mining of gold, platinum, etc...so if ammonium nitrate is banned there will be more troubles in our already troubled country.*

Group A: *Yes, that's just one side of the coin...but may I ask another question... can't we find alternative ways of mining, like old ways of mining?*

Group C: I suppose, but that one may not be assured...*how sure are you the old ways of mining can generate enough jobs and minerals? It is not as easy as said that we must find alternatives... but taking away or banning the chemical can lead to job losses, and low food production from farmers.*

Group B: Yes, that is very true...you are making some points, and nearly got me convinced, for if not, the dangers of chemicals I would have rested our case...is there no alternative?

Group D: What do you consider to be the “alternative”? Hope, you don’t say old ways of mining...because by little or no means will the old ways be efficient to meet the needs of mining companies and our economy.

Group B: Quite the reverse, I am very far from thinking so...give me time to think through it...but surely not in the use of old ways of mining...

Subjects offered various components of arguments, in which justifications are supported with counterclaims, grounds, and multiple rebuttals challenging the claims or counterclaims and respective grounds (TAP level 6 Argumentation). Groups C and D fostered the prevailing idea or worldview considered to be the most appropriate for the given context, while groups A and B’s views were transformed [CAT stage 3] into a more powerful one in terms of the persuasiveness of the dominant idea generated by groups C and D. In light of reviewing their own understanding as stronger and more convincing arguments emerge, they became more aware of their own ideas and ideas of others. Working together in a group, the subjects seem to have benefited greatly from sharing their views. The group placed emphasis on the serious impacts of the Haber process in the industrial sector, such as mining.

An emphasis on safety is important, but the correct approach is not to ban chemicals or stop doing interesting and instructive experiments with chemicals, but to do them safely. This corroborates the view of the following subject as her group was interacting during their presentation.

Group D: *No doubt our society benefits from the discovery made by Haber...oh yes...my colleague is saying something...go ahead Elna (pseudonym).*

Elna: *...uhm...from what my cousin brother who works as a paramedics told me...I think NH_4NO_3 is used in medicines to improve our health, not only that it can be used in making plastics used to make other containers...including those we buy from the grocery stores...(Conjecturing grounds).*

Elna continued...look group F are nodding to what I am saying...“verras”... I take that for yes...“lekker”...so you guys are also saying...chemistry and chemicals are important in our lives...*goeie*...“dankie”...

Group F: *Yes, initially we had only considered the negative impacts of NH_4NO_3 , but as you and other groups are saying...I think all we just need is to practice safety when we handle or work with chemicals.*

Translation: The italicised words used by Elna are Afrikaans, one of the South African official languages. In Afrikaans the meanings of these words are: “Verras” (surprise), “lekker” (nice) “goeie” (good) and “dankie” (thanks). Translation varies.

Subjects from group E highlighted various concerns stemming from misuse of chemicals, common negligence by industry when handling chemical wastes, in addition to which they challenged the theses of groups C, D and F. But, it seems they capitalised on the negative impacts of chemicals on society than on the positive impacts on human development, and yet interestingly they appeal to their peers to synchronize their point of view.

Group E: *...we have heard what other groups are saying...all we can say is to add to what have already been said....but on the negative side, generally chemicals cause air pollution...water pollution...land pollution...too much nitrates in water can cause problems to babies...*

Group B: *Yes, you are correct. We agree.*

Group F: *But the process of ammonium nitrate production can be controlled. Or are you saying regardless of safety mechanism in place?*

Group E: *No, no...how can you manage it when chemical industries dump wastes around our surroundings? Or have you not heard of negligence from manufacturing companies in the Eastern Cape, dumping waste chemicals in the open areas?*

Group A: *...especially in our province, nearby my auntie's place there are chemical industries that throw their rubbishes around and when it rains, the water carry the chemical stuffs into the dams where the locals fish....*

Group D: *How come I never heard about it? I live in the same province since my childhood.*

Group A: *It was all over the media. First it was broadcasted on TV and radio. Later on it went viral on the social media after the affected community took to the street, protesting for the closure of the company. It happened about two years ago, as to why you didn't hear about it. I can't tell.*

Group E: *So there are problems...dead zones...like last time we heard on the news that chemicals from companies are killing fishes...that's why the price of fish went high (laughing)...you know we like fish, it is my favourite...we should all agree that chemicals are dangerous, monstrous.*

Group D: *We are not for such belief.*

Group C: *Agree, we just think the negative impact of chemicals can be managed. With safety precautions, we can co-exist with the monster as group F puts it.*

The general views and knowledge among subjects from groups A, B and E were that chemicals pose a danger to humans, and that it should be banned or that public access to chemicals be restricted by the government. They provided justifications for their arguments with claims and counterclaims, with grounds, but only a single rebuttal challenging the claim made by group F (TAP level 3 Argumentation) and [CAT stage 2]. Although, as stated by groups C and D, they acknowledged the negative impacts of chemicals or the danger misuse of chemicals can pose. They attempted to provide arguments with multiple rebuttals and at least one rebuttal challenging the grounds of opposing views (group A), in which they explain why their views should be accepted by their opposition (TAP level 5 argumentation). Thus, the view on the negative impacts of chemicals held by groups C and D was subsumed by the more dominant one i.e. the positive impacts of ammonium nitrate [CAT stage 3].

Lack of space would not permit other subjects' stances similar to those above to be presented here. All the same, unless students have some knowledge and understanding of the properties and reactions to important and common inorganic and organic substances and of the roles that they play in industry, in nature and the environment, and in living matter, we may not claim that they will be the chemically literate citizens that we need now and in the future. For example, in order to be able to understand and intelligently discuss problems of atmospheric pollution, one needs to know something about the structure, properties and reactions of ozone, sulphur dioxide, carbon dioxide and the oxides of nitrogen.

DISCUSSION

Results arising from this study have presented us with an array of insights regarding the status of pre-service teachers' views, knowledge and experience in learning chemistry and chemical reactions, which are, after all, the very heart of chemistry. The overview of the subjects' responses attributed positive attributes to items 2, 8 and 17 under MVOC and LEIC. Again, their responses to items 7, 14-17, 23 and 27 under the three categories were generally negative, indicating that what is taught in chemistry and how it is taught to students in secondary school science in South Africa as preparation for further university studies needs closer attention. Why should this be a concern to chemistry educators? Other studies have sought answers to this question. Potgieter et al. (2008) found that inadequate pre-knowledge of chemical reactions and electrochemistry was most noticeable among 771 first year chemistry students in their study. If we want good chemistry students, we have to reflect on our teaching and analyse what we are teaching in order to imbue every student with the maximum understanding of chemistry, so that he/she benefits most from the teaching and practice of chemistry provided by universities.

From a close examination of the subjects' responses to the group task mediated via DAIM, it seems reasonable to suggest that chemistry teachers should be made aware of the importance of learner-based lessons, so that they do not develop negative attitudes towards the subject. Studies have shown that when the teaching of science becomes relevant to students and advocates student methods of thinking, learning, and solving problems, it encourages active participation, and intellectual debate, increasing cognitive or perceptive shifts among students (e.g., Berland & McNeill, 2010; Festus & Ekpete, 2012; Mahdi, 2014; Price & Hill, 2004). Also, an examination of results from the category of ACAS, with the exception of a few subjects who disagree, shows that the subjects' perceived fear and ignorance of chemicals stem robustly from media reports that chemicals are something harmful or dangerous to a person's health and the environment [CAT stage 2]. Thus, ideas projected by the majority of the subjects are dominant in the commonsensical worldview of chemistry. This might be just one of the variables sufficient to indicate a causal relationship between the subjects' chemophobia and their poor realisation of the importance of chemistry or chemicals in their everyday lives.

Despite the concerns raised above, some subjects were aware of the positive impacts of chemistry and chemicals on human and social development [CAT stage 3]. But over two

fifths of the subjects tended towards the negative in their responses to the three categories tested (MVOC, LEIC and ACAS), [CAT stage 1]. However, when the subjects were exposed to group tasks, 24% of those whose responses had tended towards negativity became dissatisfied with their initial stance, believing rather that “chemistry and chemicals are important in our lives - we just need to practice safety when we handle or work with chemicals”. This indicates that the subjects’ worldview exerted equal cognitive force on the positive and negative impacts of chemistry [CAT stage 5]. It seems, therefore, that knowing the perceptions of students in chemistry is useful in designing teaching strategies to uplift and maintain positive attitudes towards this subject (Autida, 2012).

Furthermore, the subjects in the study who do well in the course are often those who have learned how to put numbers into a memorised formula and get the right answer, but this is not necessarily the type of teachers who will teach their future students chemistry conscientiously. In their responses to items that sought to harmonise the significance of chemistry and chemicals in everyday life, the subjects felt that chemistry or the chemical per se is not useful for solving the problems of everyday life (54%) when the use of which is endangering people’s lives (50%), [CAT stage 2]. Perhaps the main reason for this is the way the subject has been taught or presented to school learners in South Africa. Having been involved in training teachers and working with teachers across various fields of science learning at the secondary and tertiary levels of education, the teaching and learning of chemistry are more influenced by examinations and, as a consequence, various components of the subject-matter that could inspire the students are severely restricted for convenience and for the sake of managing the curriculum. If that is the case, it is difficult, if not impossible, to expect students to demonstrate anything other than rote learning.

Surely, therefore, to give students a real feel for chemistry there should be much more emphasis on how one uses chemical reactions to make new substances. For example, a thorough treatment of quantum mechanics and its application to chemical bonding is an essential part of every chemistry major program. Importantly, synthesis is the heart of chemistry. It is challenging and creative, and will appeal to many students who are not inspired by endless problems on balancing equations, on equilibrium and on thermochemistry, for example. One way is to leave out a considerable amount of the material that is presently in many chemistry courses, some of which are tied to curricula that have not changed for twenty years or more. This does not produce the chemically literate university graduate whom we need so badly, nor does it attract bright innovative minds to further studies in chemistry. The ultimate goal is that chemistry students should be positively disposed to the emergence of new knowledge, compatible with new demands. However, for this new knowledge to be worth learning, it has to appeal to the student, be meaningful, reliable, consistent and applicable not only in the classroom situation, but in everyday life as well (Soudani, Sivade, Cros, & Medimangh, 2000).

The results of this study suggest that there is a need for both teachers and educators to consider using a combination of instructional strategies (including dialogical argumentation) in their teaching. This is taken to suggest that traditional expository

methods are not as effective as the alternative method, in which dialogue among the subjects plays a significant role in helping them achieve cognitive or perceptive shifts, as well as reaching possible consensus where feasible. It is then apposite to suggest that the instructional approach adopted in the study (DAIM) could serve as a useful means to motivate students in developing a positive attitude towards the subject matter.

CONCLUSION

Looking at the results arising from the study, one could see that subjects seemed to have made a significant attempt to express their stances regarding the issues canvassed in this study. Chemistry is an experimental science and we need a more rational evaluation of the real risks involved, taking into account the extremely small number of exposures that are usually involved. We teach students how to drive safely and they should also be taught how to handle potentially dangerous substances safely. An emphasis on safety should be highly prioritised.

Findings from this study have implications for teacher- professional development programmes and instructional practices, as well as curriculum planners, to keep in mind that chemistry cannot flourish if what is taught and how it is presented do not attract the very best students into chemistry, do not provide a useful background in chemistry for other science and non-science majors who will take up a substantial and important segment of the general public. But in the long term, especially in South Africa, early education is more important in science, including chemistry, which should start in elementary school and continue through secondary school to university, where at least all science students should take a general chemistry course. It should give a considerably greater emphasis to chemical change – reactions and synthesis, what has been called ‘descriptive chemistry’, although this should be understood to mean organic as well as inorganic chemistry.

Conflicts of interest

I declare there are no conflicts of interest exist in this study.

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