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EDITORIAL

MISCONCEPTIONS IN CHEMISTRY

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Misconceptions, also referred to as students’ naïve ideas, children’s ideas, alternative conceptions, have been considered as challenges primarily because many of them are highly resistant to change or alteration at least by traditional teaching methods. The research studies of alternative conceptions about chemical phenomena and concepts have been done with students of all ages and grade levels, including graduate chemistry teachers.

The findings support that the conceptions are held by significant proportions of the respondents and are not a function of a particular age group. Traditional teaching, testing and examining in chemistry often does not challenge these conceptions and students can hold them and still be quite successful in the usual tests and examinations.

The three articles in this issue of the AJCE specifically deal with misconceptions and the corresponding instructional strategies in different contexts.

Enjoy reading them!
ACID-BASE AND REDOX REACTIONS ON SUBMICRO LEVEL: MISCONCEPTIONS AND CHALLENGE

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ABSTRACT
From experiences all over the world we know that formulae and chemical equations are memorized very often or are equalized by counting the number of “atoms on the left and right side of the equation”. Looking to our Chemical triangle lecturers, students are jumping from the Macro level just to the Symbolic level. If we would go first from the Macro level to the Submicro level and explain chemical reactions with involved atoms, ions and molecules, then learners would understand chemistry more successfully. With a special questionnaire we are investigating the ability of university students and chemistry teachers in Indonesia, Tanzania and Germany to interpret given chemical equations with involved particles. We could find that a lot of misconceptions are present and should be challenged. [African Journal of Chemical Education—AJCE 9(1), January 2019]
INTRODUCTION

There is a true story of the year 2003 at one of the Secondary schools at Kilimanjaro area in Tanzania. The teacher of a Form-VI class (highest level in schools) did a titration of hydrochloric acid, asked the students to interpret the change of indicator color – and soon the well-known equation was developed at the blackboard: $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$. Author Barke interrupted the lesson with the question: “Please let us know which particles are reacting”. The teacher looked irritated and pointed out that „HCl and NaOH“ are involved. So Barke went to the blackboard, drafted a beaker model and wrote inside “H$^+$ (aq) and Cl$^-$ (aq)” separated from each other. Suddenly a young girl came up with a beaker-model of NaOH solution: “Na$^+$ (aq) and OH$^-$ (aq)”. After some discussion about the function of sodium and chloride ions the students recognized that H$^+$ (aq) ions and OH$^-$ (aq) ions react to form H$_2$O molecules – other ions remain without reacting. The 50-years-old teacher came to Barke and noticed: “Thanks for opening my eyes to neutralization. Why did you not come 30 years earlier – I would have explained neutralization every time like you have done it today”.

This story shows that the Submicro level of the Chemical triangle (see Figure in [1]) seems so important to understand neutralization in the scientific way. Also many other acid-base and redox reactions are confusing if one ignores the ions, that especially the reacting ions explain chemistry in a modern way. BROENSTED proposed since 1928 his idea to look to the particles which react ([1], [7]): for example, H$_3$O$^+$ (aq) ions are proton donors which transfer protons to other base particles. We will investigate this context with students of our universities.
Ions as Important Particles

In chemistry teaching atoms and molecules as smallest particles of matter are well-known – but ions have been ignored in many curricula around the world: Misconceptions can be stated if particles in salt solutions, in ocean water or in mineral water are asked [2]. One example: If a precipitation of barium sulfate from barium chloride and magnesium sulfate solution should be described, one is mostly writing: “BaCl$_2$ + MgSO$_4$ → BaSO$_4$ + MgCl$_2$”.

But there are misconceptions of „partner change” and some curricula explain the precipitation as “double replacement reaction” [3]: “Barium and magnesium are changing partners”. Taking ions into account it is easy to write: Ba$^{2+}$ (aq) + SO$_4^{2-}$ (aq) → BaSO$_4$(s). One should point out that those ions produce crystals with the Ba$^{2+}$SO$_4^{2-}$ ionic lattice, that other ions are “spectator ions” [3] in the sense of not reacting particles: Mg$^{2+}$ (aq) and Cl$^-$(aq) ions remain.

The best way is to draw a concrete model of a precipitation (see Fig. 1) and discuss this beaker model with the aim to develop a scientific mental model on the Submicro level.

Fig. 1: Beaker model; example iron(II)-hydroxide precipitation [2]
EMPIRICAL RESEARCH ACCORDING TO THE SUBMICRO LEVEL

Author Wisudawati developed a questionnaire to give university students the usual chemical equation of acid-base and redox reactions and asked questions according to the involved atoms, ions or molecules, according to particles which do not react, according to the decision if there is an acid-base or redox reaction, and the connected transfer of protons or electrons (see questionnaire in the appendix of this article). Barke gave the same questionnaire to chemistry teachers during a teacher-training seminar in Tanzania, and Hassan created a questionnaire in German language to test students at University of Muenster in Germany.

Asih Wisudawati. At universities of Yogjakarta and Bandung she used the questionnaire (see appendix). During a 60-minutes period students should solve 10 tasks, and about 75 answer sheets have been returned. She got the following results:

- Most of the tasks 2, 5 and 6 are answered in a right way and interpreted as redox reactions. But not in all cases students could mark those particles which are giving electrons, and particles which are taking electrons.
- Reactions 1, 3, 4 and 7 are interpreted in a right way as acid-base reactions – but nearly no student can mark particles which give protons or take protons. In task 3 “weak acid HAc molecule”, it is mostly interpreted as completely protolized into ions without explaining weak acids by equilibria between molecules and ions. Task 8 gives problems: the acid-base reaction of oxide ions with water molecules is interpreted as redox reaction without explaining.
Solid salts are often described without ions: “Molecular symbols like Na$_2$CO$_3$, CaCO$_3$ and MgO” are taken for interpretation. By this misunderstanding metal ions couldn’t be mentioned according to the question which ions are not involved in the reaction.

**Question 9** asks about the most difficult alternative out of (a) – (d). Students are deciding mostly (d) according to the transfer of protons or electrons with following comments: „Proton or electron transfer confuses me; I need basic concepts of chemistry; we need to understand (a) – (c) for an answer; we need a lot of theory and more time to answer”. Also (c) about “spectator ions” is confusing a lot of students.

**Question 10** concerns students’ wishes to go deep into the Submicro level. Many students answer: „Yes – because it is important to learn what particles are doing; to differentiate acid-base and redox reactions better; it helps to understand chemistry; it can support to be a better teacher; I can improve my understanding of chemistry”.

Just the last answers may give an impression how much students will appreciate to get more information about atoms, ions and molecules which are involved in chemical reactions. As soon as he or she will interpret reactions on the Submicro level he or she understands the chemistry behind reactions; and chemical equations should not be memorized – they may be used as short information connected to mental models of those reacting atoms, ions and molecules. Especially the decision whether an acid-base or a redox reaction occur and which particle donates or takes a proton or an electron, can be completely understood.
Barke. He gave in September 2018 same questionnaire to 20 experienced teachers during a one-week-teacher-training seminar in Moshi, Tanzania. The results are very different: some teachers answered nearly perfect, the majority has big problems:

- Teachers cannot avoid the mixture of particles and substances: “H+ ions and OH− ions form water; H+ ions and CO32− ions form water and carbon dioxide gas”. But we have this problem around the world: particles and substances are mixed (see later “Laboratory jargon”).

- They also interpret reactions with „salt molecules”. And if they want to show the chemical structure of compounds they cut into not existing ions: “2H+O2−, Na+O2−H+, 2H+SO4+O2” are some examples. Especially with combined ions like sulfate, nitrate or carbonate ions there are difficulties with indices and exponents in formulae.

- Redox reactions and the equivalence of electrical charges on both sides of equations are other difficulties. Concerning reactions of iron and copper chloride solution Fe and Cu atoms don’t exist: “Fe2+ + Cu2+Cl− → Fe2+2Cl− + Cu2+”. Charges are also misunderstood and wrongly calculated: “Cu2+ - 2e → Cu or 2Ag+ → Ag + 2e or Zn + 2e → Zn2+” are examples.

- Acid-base reactions have been explained by “electron transfer” because teachers don’t know proton transfers (this idea was given through the seminar): “2 H+ + 2 OH− → 2 H2O + 2e or 2 H+ gain 2 e, OH− loses 2e or H+ is reduced, and OH− is oxidized” are misconceptions.

Later after the seminar another Posttest has been performed – and the teachers could show their new knowledge concerning acid-base reaction and proton transfer, and redox reaction and
electron transfer. So we have to admit that teacher education in science and especially in chemistry is so poor in Tanzania because lecturers at teacher colleges mostly hold only the Bachelor degree and have not studied those reactions on the Submicro level.

- Asking task 9 about the difficulties according to (a) – (d) all four alternatives have been irritating the teachers because they have never answered those questions – and have not really understood differences in acid-base and redox reactions. At the end of the seminar they were very thankful to get new insights in understanding chemistry and are now more sure how to explain those reactions scientifically, how to move successfully on the Submicro level.

- According to task 10 they want to go deep into the Submicro level: “Indeed – there is much knowledge in this topic which is very important for teaching; on this way we want to understand more chemistry”, have been some comments.

**Mercedeh Hassan [5].** She created a questionnaire with some other problems as before, but with the same task to write down ionic symbols after offering common chemical equations. She gave her questionnaire to about 30 chemistry students in advanced semesters at Muenster University – and got the result that about 50 % of the answers are correct. But all the other answers show mistakes or even misconceptions:

- Instead of pointing out the involved ions students show molecular symbols for diluted solutions of acids and bases: “HCl(aq), H$_2$SO$_4$(aq), HNO$_3$(aq)”. For ionic solid salts they chose molecular symbols: NaCl, KI, NaHSO$_4$, K$_2$SO$_4$, FeO, CuO, CaO, Ca(OH)$_2$, CaSO$_4$, Mg(OH)$_2$, Mg$_3$N$_2$, MgCl$_2$, and others. So students are thinking like Arrhenius in 1887: Solutions contain the ions, but solid salts not. Are students really thinking of “molecules”
in salt crystals? – or is the writing NaCl only an “abbreviation” for the name sodium chloride? Interviews should decide this in a following investigation.

- If ions have been written compositions and charges are in many cases not correct: “instead of NH₄⁺ it is written N³⁻ + 4 H⁺; instead of 2 OH⁻ there is (OH₂)⁻ or (OH)₂⁻; instead of 2 Cl⁻ there is Cl₂⁻; an H₂O molecule is written as 2 H⁺ + O²⁻ or H⁺ + OH⁻; sulfuric acid solution is described by H₂⁺ + SO₄²⁻ etc. So even in their higher semesters many students are not sure how to formulate scientifically ions for solutions of acids, bases and salts. In some cases, pure sulfuric acid is asked and offered as “H₂SO₄(l)” – but many students are taking ions and not realizing that this time the molecular model is asked as the right one.

- In redox equations the atoms and ions are not differentiated. For the famous reaction of iron with copper sulfate solution students are taking the ions instead of atoms: “Fe²⁺ ion gives two electrons and forms an Fe²⁺ ion”; „Fe²⁺ → Fe²⁺ + 2e⁻ or Fe + CuO²⁺ → Cu + FeO²⁺⁺ etc. Students have the idea to balance „atoms left and right of an equation“ – but not the charges.

- By identification of redox reactions there are in average only 10 % mistakes, by acid-base reactions around 20 % of mistakes – redox reactions are more known than acid-base reactions. Some students even mark both redox and acid-base without a decision for one type. Mercedeh’s analysis: Students may be confronted with two or three different mental models which are competing in their mind, i.e. mixing Arrhenius’ and Broensteds terminology concerning acid-base reactions. Also Lavoisier’s oxidation theory and todays electron-transfer definition are competing mental models in students’ mind.

- At the end of her thesis Mercedeh points out [5]: Misconceptions which are developed during childhood or during school time are taken into lectures of universities – and students
may realize conceptual changes to the scientific way by their studies. In case that they do not change their mental models those students as chemistry teachers will bring misconceptions into school and may transfer them to their pupils. Therefore, every chemistry teacher should integrate the idea of ions as smallest particles of acid, base and salt solutions as soon as those solutions are discussed. To avoid misconceptions regarding solid salts some crystal structures should be shown, and ionic lattices, for example calcium hydroxide, should be symbolized in formulae: Ca$^{2+}$ (Cl')$_2$. Especially crystal structures may be reflected to transfer the idea of giant structures into the mind of students – and differentiate from molecules.

LABORATORY JARGON AND MISCONCEPTIONS OF STUDENTS

According to the Submicro level we have in chemistry a special problem. Lecturers mostly use a “Laboratory jargon” in their lectures and the question comes up whether teacher students take this jargon for their own terminology, or develop “school-made misconceptions” [2] – or even transfer them later as teachers to their students. One example: „2 hydrogen react with 1 oxygen to form 2 water“ is often stated by experts (and the experts know that the involved molecules are meant). If one points out that 2H$_2$ molecules and 1O$_2$ molecule are forming 2H$_2$O molecules (not water!), the explanation is totally clear and good to understand.

Joline Buechter [6]. A German empirical pilot study has shown first results: About half of the investigated participants at Muenster University could reflect and correct given jargon statements – but even after three years of studying chemistry the other students are staying with that jargon or other alternative conceptions. One example of the questionnaire [6]:


“2) Lab. Jargon: "Hydrochloric acid gives off a proton"

a) Hydrochloric acid can be deprotonated.

b) Hydrochloric acid can also absorb protons.

c) \( \text{H}_3\text{O}^+(aq) \) ions are present in hydrochloric acid, they can emit protons.

d) HCl molecules are present in hydrochloric acid, they release protons” [6].

The right answer is of course (c): “\( \text{H}_3\text{O}^+(aq) \) ions are present in hydrochloric acid, they can emit protons”. We took famous misconception (d) and were waiting of “HCl molecules in solution”. Because of the well-known idea of “deprotonation” we offered alternative (a), answer (b) is a fake [6]. The right answer (c) is chosen by 40 % of participants, the real misconception about “HCl molecules in hydrochloric acid” is fortunately taken by only 5 %. But answer (a) has reached the majority of 55 %: Many students are thinking of scientifically good sound of “deprotonation”. Other examples may be studied by Barke and Buechter [1].

Yuli Rahmawati [8]. She created the English version of Joline’s questionnaire and took it to students of UNJ University in Jakarta/Indonesia. Similar results have been obtained (see Table 1). In question 2 “Proton donor HCl” Indonesian students show lower results because they have not chosen \( \text{H}_3\text{O}^+ \) ions but mostly the alternative “HCl molecules release protons”. In question 7 “Neutralization” many students decided “salt formation” as right answer – and not the reaction of \( \text{H}^+(aq) \) ions and \( \text{OH}^-(aq) \) ions. Related to question 10 “Amphoteric \( \text{H}_2\text{O} \) molecule” most students

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don’t look to the H₂O molecule as proton donor and acceptor, but chose the substance “water can be an acid or a base”. In Indonesia most explanations are given related to substances – curricula must change to instruct also on the Submicro level for understanding chemistry.

CHALLENGING MISCONCEPTIONS

What shell we do to avoid those mentioned misconceptions with ions as important particles? As soon as atoms and molecules are well-known and metal atoms in metal structures are visualized by densest sphere packings, molecules by ball-stick models and their molecular structural symbols, also the third group of smallest particles should be introduced: the ions.

Fig. 2: PSE-depiction of a selection of atoms and ions and their spherical models [2]
Fig. 3: 2-D models of ionic lattices in the ion ratio 1:1 (NaCl) and 1:2 (MgCl₂) [2]

Usually, during the introduction of atoms the Periodic table is shown with all atomic symbols, numbers and atomic masses. If one takes spheres to visualize that every atom has a specific diameter, it is easy to symbolize also the corresponding ions with their specific diameter (see Fig. 2): Charge numbers are given without comparing any protons in nucleus and electrons in shells – the ions can be introduced without the differentiated atomic model! Later during higher classes students may work with the nucleus-shell model of atoms and ions and the number of electrons can be discussed for explaining ion charges.

Analogically to the composition of a water molecule by two H atoms and one O atom, one may state that sodium chloride is composed of Na⁺ ions and Cl⁻ ions in an ionic giant structure (see Fig. 3): the ionic symbol for sodium chloride should be shown as (Na⁺)₁(Cl⁻)₁ or for magnesium chloride as (Mg²⁺)₁(Cl⁻)₂ (see Fig. 3). On this way students have chances to know that ions are composing those salts – and may avoid misconceptions of “salt molecules” [2]. After discussing those ionic symbols can be shorten to NaCl and MgCl₂ – but the involved ions should be in the mind of learners, in their mental model of the composition of salt crystals!

The composition of salt crystals can be visualized by 2D-drawings of layers of ionic lattices (see Fig. 3). If afterwards salt solutions will be introduced, (aq)-symbols should be added: Na⁺(aq)
ions and Cl\(^{-}\) ions for sodium chloride solution, Mg\(^{2+}\)(aq) and Cl\(^{-}\)(aq) ions in the ratio 1:2 for magnesium chloride solution. Even the neutralization of acid and base solutions should be visualized by beaker models (see Fig. 4). The \((aq)\)-symbol is important because the learner knows that different charged ions are attracting and would go together. The \((aq)\)-symbols show hydrated ions: 4, 5 or 6 surrounding water molecules are avoiding the strong attraction of ions.

![Beaker model for neutralization of hydrochloric acid by sodium hydroxide solution](image)

**Fig. 4:** Beaker model for neutralization of hydrochloric acid by sodium hydroxide solution [2]

**Neutralization.** Students know the common equation for neutralization, in case of hydrochloric acid and sodium hydroxide solution: HCl + NaOH \(\rightarrow\) NaCl + H\(_2\)O. Asking about the particles which are reacting often HCl and NaOH molecules are mentioned. So it is important to point out that H\(_3\)O\(^{+}\)(aq) ions and OH\(^{-}\)(aq) ions are reacting in the sense of Broensted’s theory [6]:

\[
\text{H}_3\text{O}^{+}(\text{aq}) \text{ ion} + \text{OH}^{-}(\text{aq}) \text{ ion} \rightarrow 2 \text{H}_2\text{O} \text{ molecules}
\]

With the help of the beaker model (see Fig. 4) one can understand that other ions are not reacting: Na\(^{+}\)(aq) ions and Cl\(^{-}\)(aq) ions remain as “spectator ions”, they are not reacting partners. No “solid salt” or “NaCl molecules” are produced – but sodium chloride solution remains. It is
also good to visualize that the number of ions is the same before and after neutralization (four ions in the beaker model of Fig. 4): H$_3$O$^+(aq)$ ions are replaced by Na$^+(aq)$ ions.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{neutralization_diagram.png}
\caption{Concept cartoon concerning the neutralization [4]}
\end{figure}

**CONCLUSION**

In older times, teachers liked to perceive students as “blank pages” and thought that they only have “to fill blank pages” with contents of science. Today we know that at early stages, boys and girls develop their own preconcepts [2]. Empirical studies show that we have more success in teaching and learning when we integrate those alternative models into instruction and after discussing those preconcepts to come up to consolidate the scientific explanation.

Also school-made misconceptions [2] should be mentioned for a special topic to show the right answer between some alternatives. Especially Concept cartoons [4] are suitable to analyze
misconceptions of students and discuss those ideas with the goal of scientific explanation (see Fig. 5). By this way teachers may challenge those misconceptions and may convict students additionally by experiments, concrete models and problem-solving teaching.

Other challenges are working with acids and bases, and with related ions. Following Broensted’s theory acids and bases are molecules or ions – not substances [7]. For working with related ions the special Periodic system of atoms and ions (see Fig. 2) may help. Understanding compositions of salt crystals is easier if involved ions are taken from the Periodic table and combined to models of ionic lattices (see Fig. 3), or even visualized by sphere packings [2]. For visualizing acidic, alkaline or salt solutions one should create and discuss beaker models (see Fig. 4). Students should develop accurate mental models – and misconceptions may be challenged!

REFERENCES

Questionnaire “Redox or Acid-base reaction?”

For understanding Chemistry, we need three levels of reflection:
1. **Macro level** of observations according to substances and chemical reactions,
2. **Submicro level** with interpretation of all observations with mental models by particles of matter like atoms, ions, molecules and by chemical structures,
3. **Symbolic level** with shortenings of mental models by chemical symbols like atomic, ionic, molecular symbols, and chemical equations. In following problems the macro and symbolic level is presented in this questionnaire, the submicro level is asked by participants. One example for the wanted answers in the following eight problems:

**Macro level:** Magnesium reacts with hydrochloric acid, gaseous hydrogen is observed.
**Symbolic level:** \( \text{Mg(s) + 2 HCl(aq) \rightarrow MgCl}_2\text{(aq) + H}_2\text{(g)} \)
**Submicro level:**

**a)** Which particles (atoms or ions or molecules) are involved?
Answer: Mg atoms / H\(^+\) ions, Cl\(^-\) ions / Mg\(^{2+}\) ions Cl\(^-\) ions (1:2) / H\(_2\) molecules

**b)** Write down equation of those atoms, ions or molecules which react!
Mg atom + 2 H\(^+\) ions \rightarrow Mg\(^{2+}\) ion + H\(_2\) molecule

**c)** Which atoms, ions or molecules are NOT involved in the reaction?
Cl\(^-\) ions are „spectator ions“

**d)** Redox or acid-base reaction? Explain transfer of electrons or protons.
Redox: Mg atom gives two electrons: Mg atom \rightarrow Mg\(^{2+}\) ion + 2 e\(^-\) (oxidation)
2 H\(^+\) ions take two electrons: 2 H\(^+\) ions + 2 e\(^-\) \rightarrow H\(_2\) molecule (reduction)

Try to solve the next eight problems in this way!

**Take a blank white paper and write down your answers according to (a) – (d).**

1. Solid sodium carbonate reacts with hydrochloric acid, gaseous carbon dioxide is observed: \( \text{Na}_2\text{CO}_3\text{(s) + 2 HCl(aq) \rightarrow NaCl(aq) + H}_2\text{CO}_3\text{(aq)} \) (H\(_2\)CO\(_3\) \rightarrow H\(_2\)O + CO\(_2\))
2. Zinc reacts with diluted sulfuric acid, gaseous hydrogen is observed: \( \text{Zn(s) + H}_2\text{SO}_4\text{(aq)} \rightarrow \text{ZnSO}_4\text{(aq) + H}_2\text{(g)} \)
3. Acetic acid solution reacts with sodium hydroxide solution, small heat is observed: \( \text{HAc(aq) + NaOH(aq) \rightarrow NaAc(aq) + H}_2\text{O} \) \((\text{HAc} = \text{HOOCCH}_3\))
4. Hydrochloric acid reacts with sodium hydroxide solution, big heat is observed: \( \text{HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H}_2\text{O} \)
5. Iron reacts with blue copper chloride solution, brown copper develops on iron: \( \text{Fe(s) + CuCl}_2\text{(aq) \rightarrow FeCl}_2\text{(aq) + Cu} \)
6. Copper reacts with silver nitrate solution, silver crystals are growing on copper: \( \text{Cu(s) + 2 AgNO}_3\text{(aq) \rightarrow Cu(NO}_3\text{)}_2\text{(aq) + 2 Ag} \)
7. Solid calcium carbonate reacts with acetic acid, gaseous carbon dioxide is observed: \( \text{CaCO}_3\text{(s) + 2 HAc(aq) \rightarrow CaAc}_2\text{(aq) + H}_2\text{CO}_3\text{(aq)} \) (H\(_2\)CO\(_3\) \rightarrow H\(_2\)O + CO\(_2\))
8. Solid magnesium oxide reacts with hydrochloric acid, magnesium oxide dissolves: \( \text{MgO(s) + 2 HCl(aq) \rightarrow MgCl}_2\text{(aq) + H}_2\text{O} \)
9. Let us know which of alternatives (a) – (d) was the most difficult for you. Explain.
10. Do you like to go with (a) – (d) so deep into the Submicro level? Explain.
STUDENTS’ MISCONCEPTIONS OF ACID-BASE TITRATION ASSESSMENTS USING A TWO - TIER MULTIPLE-CHOICE DIAGNOSTIC TEST

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ABSTRACT

The paper portrays students’ misconceptions of acid-base titrations using two a tier diagnostic test. The analysis will inform chemistry teaching and learning, especially about acid-base concepts. The data were collected through a two-tier diagnostic test with 10 stratified multiple choice questions that have been analysed for item validity (rphi = 0.415) and construct validity (V = 0.98) which show that it a valid instrument. Open questions were administered to explore students’ misconceptions. The results showed that 33.50% of students held misconceptions of acid-base titrations in the curriculum. The highest percentage of misconceptions were on acid-base titration indicators, with 40.42% students being more familiar with phenolphthalein for NaOH and HCl titrations than with bromothymol blue. This misconception is sourced from chemistry teaching due to limited understanding of acid-base concepts and the lack of titration practicum in the laboratory with various indicators and types of titration. The lowest percentage of students’ misconceptions at the endpoint of the titration was 11.25% of the students having a good understanding of the endpoint of the titration although some students still have difficulty in distinguishing between the endpoints of a titration and the equivalent point. The results show that the students should have deep understanding of acid-base reactions before learning acid-base titrations. [African Journal of Chemical Education—AJCE 9(1), January 2019]
INTRODUCTION

Students have difficulty in understanding about chemistry because of chemistry concepts [31]. The difficulty is also caused by the complexity chemistry calculations, the language that is rarely used in everyday life and the different levels of representation used by experts in explaining chemical phenomena [30]. The students’ prior knowledge also influences students understanding of chemistry concepts [9]. Students’ prior knowledge was developed through their interaction with the environment before classroom learning with usually faulty concepts or narrow understanding of complex concepts called misconceptions [15].

A misconception is defined as a phenomenon that students’ have different concepts from true concepts [2] [13] [20]. The students’ misconception are caused by teachers, textbooks, context and learning methods [2]. This pre-conception is developed because students misinterpret the symptoms or events that occur in everyday life [16]. The misconceptions come from teachers who are less directional in teaching and learning process so that students are wrong in interpreting a particular concept [4]. Misconceptions can also come from teachers who have misconceptions on certain chemical concepts. This was stated in a study that found a misconception equation between students of 8th grade and prospective teachers, this indicates that the misconceptions possessed by students are derived from the misconceptions of their teachers [5]. In addition, students try to interpret or create their own concepts that sometimes do not fit with the actual concept, thus raising the wrong concept in the minds of the students [9]. The existence of these misconceptions can be fatal because chemical concepts are taught in a hierarchical way from easy to difficult concepts, from simple to complex concepts so that if simple concepts are wrongly interpreted, more students will experience mistakes in understanding the complex concepts of chemistry [20].
Misconceptions can be the result of the students showing decreasing levels of understanding, so that misconceptions needs to be improved. Before the misconceptions be improved, what needs to be done is to identify the misconceptions. One technique for diagnosing student misconceptions is by administering a diagnostic test. For that reason, there is a needs for an instrument that can identify misconceptions [1].

The techniques used to identify misconceptions included observations, descriptions, fact-and-event interviews, conceptual interviews, word associations, and diagnostic tests. The most commonly used techniques are diagnostic tests [17] [29] [36]. One of diagnostic test is the Two-Tier Multiple Choice (TTMC) test. The TTMC is a two-tiered double-choice diagnostic test first described by Davis F Treagust in 1998. The Two-tier diagnostic test is a multiple-choice test consisting of two-tier selections. The first tier contains a number of answer choices, whereas the second tier contains a number of choice reasons for the selected answer on the previous tier [6]. The reasons given consisted of one correct answer and the distractor. Students should choose the reason on the second tier to provide reinforcement of the multiple-choice answers provided. This makes the two tier diagnostic test effective in measuring students’ 'level of understanding and to identify students' thinking and reasoning [3]. One of the advantages of two-tier dual choice versus conventional dual choice tests is to reduce errors in measurement. The use of conventional multiple-choice tests provides a true answer by guessing by 20%, whereas if using a two-tier multiple choice test the chance to answer correctly by guessing is reduced by 4% [33]. This two-tier diagnostic test can be used to help teachers evaluate the misconceptions caused by previous teaching and plan follow-up learning based on the test results [24]. The limited use of two-tier diagnostic tests has been due to the lack of time and lack of knowledge in the development of multiple-choice test development [32].
Titration of acid-base is one of the materials in class XI IPA during the even semester which according to students is difficult, because the material demands students' understanding of acid-base material, salt hydrolysis and buffer. The acid-base material is a relatively difficult material [8] [11] [21] [27]. The concepts contained in solid acid base materials are conceptually and require an understanding that is integrated into many chemical introductory concepts such as particle characteristics in matter, the properties and composition of solutions, atomic structures, ionic and covalent bonds, symbols, formulas and equations of reactions, ionization and equilibrium [30]. While salt hydrolysis material is an abstract material and buffer material (buffer) is a material that is conceptual. Both materials require students' understanding in macroscopic, microscopic and symbolic forms [10] [22]. Characteristics of acid-base material, salt hydrolysis and the buffer solution causes students to have difficulty in understanding it. Difficulties in studying these three materials must have an impact on students' difficulties in studying acid-base titration material, because the three materials underlie acid-base titration material. The difficulties of students in studying acid-base titration material are seen from the number of students who obtained daily test scores below the minimal mastery criteria at the school where the study took place.

There has been a study of misconceptions in students using diagnostic tests. The result of the analysis of acid-base material misconceptions with two-tier tests found that students have difficulty in understanding acid-base material [3] and most students have difficulty in understanding the pH concept as well as a small number of students who have difficulty in pH calculations [26]. Two-tier diagnostic test instruments have been developed on acid-base material by the Plomp's methods with the stages of preliminary investigation; design; realization; test, evaluation and revision [34]. The misconception analysis on salt hydrolysis material found that in general the students were able to infer the properties of the salt solution but it was difficult to write
the equation of their hydrolysis reaction with the source of the school learning, misconceptions of previous learning in chemical equilibrium, acid base and material structure and lack of practice in the laboratory [23]. Analysis of misconceptions of buffer solutions also found that students have difficulty in understanding buffer solutions conceptually because students were unable to visualize buffers on the submicroscopic scale [22]. In the misconception analysis of the thermochemical material, misconceptions that occur in students in the form of theoretical, correlational, and classical concepts. The causes of misconceptions are less learning motivation and improper preconception of students, lack of interaction between teacher and student, less handbook complete and difficult to understand and learning methods that do not lead to the formation of concepts [35].

The use of a two-tier acid diagnostic test instrument is expected to identify students’ misconceptions on acid-base titration materials, since acid-base titration material is a complex material requiring students’ understanding of acid-base matter, salt hydrolysis and buffers and the importance of a teacher’s ability to identify misconceptions in students then conducted research on "Students Misconceptions of Acid Base Titration Assessment Using a Two Tier Multiple Choice Diagnostic Test".

**METHODOLOGY**

This study was conducted on the even semester of the academic year 2017/2018 in April - May in one of the private high schools in North Jakarta. Subjects in this study were students of class XI IPA consisting of 80 students. The study was conducted by giving a written test using a two-tier diagnostic test instrument given to students to analyze student misconceptions on acid-base titration materials. Response answers of students using the two-tier diagnostic test were analyzed showing the students' answers on the first level and reason on the second level [18].
Students got a score of 1 if the answer was correct on both levels of the question, and got a score of 0 if the answer was wrong on one or both levels. In addition to the scores, misconceptions of students are presented in percentages [25] [18], according to the level of students' understanding based on the following categories:

Table 1: Criteria level of student understanding [28]

<table>
<thead>
<tr>
<th>Score</th>
<th>Pattern of student answers</th>
<th>Category level of understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>The answer on first and second level is correct</td>
<td>Understand the concept</td>
</tr>
<tr>
<td>0</td>
<td>The answer on first level is correct, but on the second level is wrong.</td>
<td>Misconception</td>
</tr>
<tr>
<td>0</td>
<td>The answer on first level is wrong, but on the second level is correct</td>
<td>Misconception</td>
</tr>
<tr>
<td>0</td>
<td>The answer on first and second level is wrong</td>
<td>Do not understand the concept</td>
</tr>
</tbody>
</table>

Results of student understanding is then followed up with in-depth interviews of 16 students taken at random with the purposive sampling technique.

The two-tier diagnostic test instrument used in this research consisted of 10 items consisting of 4 concepts of acid-base titrations. Distribution of indicator problem on each concept can be seen in table 2 below.

Table 2: Distribution of indicator questions on each concept

<table>
<thead>
<tr>
<th>Concepts</th>
<th>Indicator of question</th>
<th>Number of question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator acid base</td>
<td>Students can determine indicators used in strong acid base titrations</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Students can mention the influencing factors in determining the indicator used in acid-base titrations</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Students can determine indicators used in weak acid and strong base titration</td>
<td>8</td>
</tr>
<tr>
<td>Calculation of pH</td>
<td>Students can calculate the pH of the solution formed on the addition of 10 ml of sodium hydroxide in a titration experiment of 25 ml of 0.1 M vinegar by 0.1 M sodium hydroxide</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Students can calculate the pH of the solution formed at the addition of 25 ml of sodium hydroxide in an experimental titration of 25 ml of vinegar by 0.1 M sodium hydroxide 0.1 M</td>
<td>4</td>
</tr>
<tr>
<td>Curve titration</td>
<td>Students can show the equivalence point on the presented titration curve</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Students can determine the type of titration of the titration curve presented</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Students can show the buffer zone on the titration curve presented</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Students can determine the type of titration on the two titration curves presented</td>
<td>10</td>
</tr>
<tr>
<td>End-point of titration</td>
<td>Students can define the end-point of the titration</td>
<td>6</td>
</tr>
</tbody>
</table>
At the first stage of the research a review of questions was done by colleagues and by supervisors and followed by the development of research test instruments which are then verified through the validity test, which is done in two ways: the validity of the subject matter and the validity of the construct (construct validity) is done by six teachers who have experience in teaching.

The validity of the item is calculated using the biserial point correlation technique and the obtained value of \( r_{\text{phi}} = 0.415 \) with \( r_{\text{table}} = 0.220 \). This shows \( r_{\text{phi}} > r_{\text{table}} \) then that the problem is valid. While the construct validation is calculated by the Aiken formula, the average validity index of Aiken (\( V_{\text{count}} \)) of the six validators is 0.98 with \( V_{\text{table}} = 0.78 \). From the validation result of the construct then the matter is declared valid because \( V_{\text{count}} > V_{\text{table}} \).

**RESULT AND DISCUSSION**

The percentage of students' level of understanding on the acid-base titration material can be seen in the following table:

<table>
<thead>
<tr>
<th>Level of student understanding</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand the concept</td>
<td>49,88</td>
</tr>
<tr>
<td>Misconception</td>
<td>33,50</td>
</tr>
<tr>
<td>Do not understand the concept</td>
<td>16,62</td>
</tr>
</tbody>
</table>

The table above shows that student misconceptions on acid base titration material is 33,50%. The misconceptions are scattered on the various concepts of acid-base titration material that is on the concept of indicator, pH calculation, titration curve. The distribution of misconceptions in each of these concepts can be seen in the following table.
The distribution of misconceptions in each of the concepts of acid-base titration can be described as follows:

1. **Indicator**

   The concept of the indicator consists of three of questions each of which aims to determine the students' understanding of the principle of the use of indicators in acid-base titrations. The indicator of the problem is 1) Students can determine the indicator used in strong acid and strong bases titrations, 2) the students can mention the influencing of factors in determining the indicator used in the acid base titration, 3) The students can determine the indicator used in weak acid and strong base titrations.

   The percentage of students' level of understanding of this concept is: 45.83% students understand concept; 40.42% of students have misconceptions and 13.75% of students do not understand the concept. The percentage of student misconceptions is spread on three indicators of problem according to figure 1 below.

   ![Figure 1](image)

   **Figure 1** Percentage of misconceptions on the concept of acid-base titration indicator
About 1 percentage of students who understand the concept is 53.75%. It shows that most of the students have understood the concept well. This is indicated from the result of the student's answer during the interview:

Maria Josephine: “the indicators used for strong acid titrations with strong bases are methyl red, bromthymol blue, and phenolphthalein due to the pH trajectory around the equivalence point. In general practicum used phenolphthalein to facilitate in seeing the color and change (colorless - pink)”

While 23.75% of students experience misconceptions, most students with misconceptions expressed phenolphthalein as a strong acid indicator with a strong base and a small proportion of students declared blue bromothymol as an indicator of strong acid and strong base. Here are the results of student interviews that state it.

Nathaniel Richard: “The indicator used for strong acid and strong bases titrations is phenolphthalein (pp) because the color change can be easily observed”

Kelly: “the indicator used for strong acids and strong bases titrations is blue bromthymol (pH range 6.3 - 7.2) because strong acid titration and strong base will touch the equivalence point of about 6 – 7 “

Most students mentioned phenolphthalein as a strong acid and a strong base indicator because students are familiar with phenolphthalein. At the time of practicing strong acid titration with a strong base in the laboratory, students used only the phenolphthalein indicator and rarely use other indicators so that students are only familiar with the indicator of phenolphthalein as an indicator of strong acid and a strong base titration. The understanding of the students is certainly not in accordance with Chang [7] that in the titration of strong acid with a strong base methyl red indicator, blue chlorophenol, bromtimol blue, red cresol and phenolphthalein could also be used
because the indicator trajectory is around the equivalence point. In this case the teacher has a role in the occurrence of misconceptions in students because it only uses phenolphthalein indicator in strong acid and strong bases titrations and rarely uses other indicators. This misconception [2] can be derived from a less precise school-made misconceptions of less directional in teaching and learning process so that students are wrong in interpreting a particular concept [4].

In the indicator of problem 2 there is misconception of 21.25%. The misconception on this indicator is smaller than indicator 1. Most of students have been able to understand the consideration in using indicators in acid-base titrations. This is shown in the students’ answer in the interview:

Winsen : “The pH range should be around the equivalence point because the indicator should work (change color) at the equivalence point for the titration to succeed. The color changes that occur should be easy to observe as valid as the data, such as the color change from colorless to pink then red”

Students have understood that consideration in choosing the indicator used in acid-base titrations is the pH indicator route around the equivalence point [7]. But some students have not understood this well, it is shown from the results of interviews that state:

Arya: “consideration of the use of indicators because it is more flexible, easy to obtain in the laboratory “

The student’s statement indicates the student has the assumption that the indicator used in the titration is an indicator available in the laboratory. The student’s presumption is because the teacher only performs strong acid and strong base titrations by using phenolphthalein indicator. This is what causes the students' knowledge about the limited indicator. So this is a case of school-made misconception [2].
The highest percentage of misconceptions is found in 3rd indicator that is 76.25%. This shows that most students have not been able to understand the indicators used in weak acid and strong bases titrations. This is shown from the student's answer during the interview:

Rio: “the indicator used in weak acid and a strong base titration is phenolphthalein because the color change is easily observed “

The student's reply shows that students have assumed that phenolphthalein is used as an indicator on weak acid and a strong base titration because of its easily observable color change. In this case students have a false interpretation of the use of the phenolphthalein indicator. Students are less familiar with weak acids with strong bases titrations because in practicum learning they rarely does weak acids with strong bases titrations.. For reasons of limited time the teacher introduces only strong acid and strong base titrations with phenolphthalein indicator. Lack of learning with a weak acid acid with a strong base titration is one of the sources of misconceptions in this regard [23]. In addition, students also do not understand well the route (range pH) and the color changes, so students do not understand the reasons for the use of phenolphthalein indicator as a weak acid and strong base indicator. This is in accordance with Barke [2] which states that misconceptions may be caused by previous preconceptions that students misinterpret the use of phenolphthalein indicator is an easily observable color change.

2. Calculation of pH

This concept consists of two indicator questions which each aiming to find out the students' conceptual understanding of the pH of the solution formed during acid-base titrations. The indicator of the problem is 1) The student can calculate the pH of the solution formed on the addition of 10 ml of sodium hydroxide in a titration experiments of 25 ml of 0.1 M vinegar by 0.1 M sodium hydroxide; 2) the student can calculate the pH of the solution formed by adding 25 ml
of sodium hydroxide in a titration experiment of 25 ml of vinegar by 0.1 M to 0.1 M sodium hydroxide.

On the concept of this pH calculation as much as 43.13% students understood the concept; 33.15% held misconceptions and 23.75% did not understand the concept. The percentage of misconceptions is spread across the two question indicators as shown in Figure 2 below.

![Figure 2 Percentage of misconceptions on pH calculation](image)

Indicator 1 requires students 'understanding of the concept of buffer solution and indicator 2 requires students' understanding of the concept of hydrolysis of a salt. Figure 2 shows the misconception of indicator 2 higher than the misconception of indicator 1. It shows that students understanding of salt hydrolysis is very weak compared to students' understanding of buffer solutions. This is evident from the student’s answer during an interview with a student named Bryan Jonathan Yahya:

![Figure 3. student answers about questions related to salt hydrolysis](image)
The student’s answers above show that the students have not understood the concept of salt hydrolysis well. The student has ability to react an acid with a base and have understanding of the concept of mole but the student is wrong in calculating salt pH. Students assume that salt always has pH of 7, This is in accordance with research conducted by Sheppard [30] which finds that students consider the product of neutralization reaction always has pH = 7. Besides students also have no understanding in the use of buffer and salt formulas. This can be seen from the answer of Aldo as follows:

Figure 4. student answers about the use of hydrolysis formula

The answer above shows that students have not understood the salt hydrolysis formula so that students use the buffer formula in solving the problem in indicator 2. This is due to the understanding of the concept of buffer and hydrolysis of a salt is weak. This is in accordance with the research conducted by Indrayani [14] which states that to determine the pH of the solution in the acid-base titration process requires a good understanding of the concept of strong strong base acids, weak basic acids, buffer solutions and salt hydrolysis. The lack of understanding of hydrolysis and buffer salts has an impact on the lack of understanding of acid-base titrations. This is consistent with Beyza [3] who states that a lack of understanding of basic concepts will result in subsequent learning. Students cannot connect between the concepts of hydrolysis of salts, buffers
and titrations. Students consider each concept to be independent so it cannot connect with other related concepts [19].

3. Titration curve

The acid-base titration curve consists of 4 indicators of problems that each aims to know the students' concepts of understanding of acid-base titration curve reading. These indicators are 1) The student can show the equivalence point on the titration curve presented, 2) The student can determine the titration type of the titration curve presented, 3) The student can show the buffer region on the titration curve presented and 4) The student can determine the type titration on the two titration curves presented.

In this concept as much as 46.88% of students understand the concept; 34.08% of misconceptions and 19.08% did not understand the concept. The percentage of misconceptions is scattered on the four question indicators as shown in Figure 5 below.

Figure 5 Percentage of misconceptions on the concept of acid base titration curve identification

The percentage of misconception in indicator 1 is highest compared to other indicators. This indicates that the student has not been able to understand the equivalence point well. Most students were able to show the equivalence point on the titration curve but could not understand the reason well. This can be seen from the percentage of students who answered correctly at level 1 of 71% and the percentage of students who answered correctly on the second level with only
15%. Students have the assumption that the equivalence point occurs when pH = 7 or under neutral conditions. This can be seen from the students' answers during the following interview.

Michelle CB: “Equivalent point because at that time the solution is neutral“

Students This is in accordance with the research conducted by Indrayani [14] which states that the student has not understood the relationship between the indicator color change with the nature of the solution and the student determines the nature of the solution not based on the indicator color but based on the number of moles of each reactant. Consequently, the student considers the nature of the solution at the equivalence point is neutral.

Some students also have the assumption that the equivalence point is related to the number of moles of reactants and moles of the product, this is indicated in the answer during the student interview:

Winsen: “point A is the equivalence point because at this pH the number of moles of reactants is equal to the number of moles of the product“

This is inconsistent with the actual concept that the equivalent point occurs when the number of moles of OH⁻ ions added to the solution is equal to the amount of H⁺ ions originally present [7], which means the H⁺ ions and the OH⁻ ions both are reactants with moles at the same one. Students do not understand the neutralization reaction that occurs in the titration process so that students are wrong in interpreting the equivalence point. This is because the concept of neutralization reaction is loaded with symbolic understanding so that students have difficulty in writing the neutralization reaction of acid-base titrations [14]

In the indicator 3 students as many as 28.8% experience a misconception. The student is able to show the buffer area on the curve but is wrong in interpreting the reason. This can be seen from the student's answer at the interview:
Aldo: “Point Q is a buffer zone because of the gentle curve shape “

The student's reply shows the student’s assumptions about the buffer region of the gentle curve. Students do not understand the meaning of the sloping area that is associated with the reaction between a weak acid and strong base in the case of the image of the curve. This is consistent with a study conducted by Schmidt in Sheppard [30] who found that students had the assumption that the titration curve before the equivalence point, at the equivalence point and after the equivalence point is time-dependent.

4. The end point of the titration

The concept of titration end point aims to find out the students understanding of the acid-base titration endpoint. As many as 87.50% of students have understood about the concept, 11.25% of students have misconception and 1.25% of students do not understand the concept. It shows that most students have understood this concept correctly and there are still a few students who do not understand this concept well.

The student's understanding is seen from most students mentioning that:

Vincent Hadinata: “the titration process will be discontinued at the end point of the titration marked by the change of color “

However, there are a small number of students giving the following answers:

Michelle CB: “titration is stopped when the equivalence point is marked by a change of color “

Students with misconceptions cannot distinguish between the equivalence point and the end of point of the titration. Students have the assumption that is the same. According to Chang [7], the equivalence point occurs when the number of moles of \( \text{OH}^- \) ion added to the solution is equal to the number of moles of \( \text{H}^+ \) ion originally present, whereas the end point of the titration
occurs when the indicator changes color. So the equivalence point and end point of titration are two different things.

CONCLUSION

Based on this research, it can be concluded that the achievement of level students’ conceptions on acid acid titration material was 49.88%. As many ss 33.50% of students have misconceptions and 16.62% students do not understand that concept. Student misconceptions on the acid-base titration material are spread over all concepts. Percentage of indicator of misconception on concept, pH calculation, titration curve and end point of titration obtained were 40.42%; 33.15%; 34.08% and 11.25% respectively. Interviews with students indicate student misconceptions: 1) students were more familiar with the phenolphthalein indicator compared to other indicators, the consideration of the use of indicators in the titration process because it was available in the laboratory and the use of the phenolphthalein indicator in the titration is associated with the easily observable color change without considering the range of pH. The misconceptions were related to the lack of learning in the laboratory in the form of a practicum involving varied indicators and types of titration; 2) Students observe salt has a pH = 7 and students have not understood salt and buffer hydrolysis concept in solving pH calculation problems. This is related to students' inability to connect the concept of salt, buffer and acid-base titration; 3) Students considered the equivalence point to occur at pH = 7 (neutral). This was related to a false interpretation of the equivalence point defined as the number of moles of OH⁻ ions equal to the number of moles of H⁺ ions so as to be equivalent in neutral condition, 4) Students experienced difficulties in distinguishing between equivalence point and end point of titration.
REFERENCES


CONCEPTUAL CHANGE INSTRUCTIONAL APPROACH THROUGH THE USE OF CONCEPTUAL CHANGE TEXTS AND PRE-SERVICE CHEMISTRY TEACHERS’ MOTIVATION

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ABSTRACT
This study explored College level pre-service chemistry teachers motivation in organic chemistry, especially in concepts of aliphatic hydrocarbons. Motivation as an affective domain is an important area of attention in chemistry education in general and organic chemistry education in particular. To capture students learning processes and behavior the investigation on students’ motivation has been done while using Conceptual Change Texts (CCTs) during the instructional process. Participants were 87 pre-service chemistry teachers in Arbaminch College of Teachers Education, Southern, Nations, Nationalities and Peoples regional state (SNNPRS), Ethiopia. Two intact classes, taking Introductory Organic Chemistry I, were randomly assigned as experimental group and comparison group. The data collection instrument was the Chemistry Motivation Rating Scale (CMRS) items. A non-equivalent pre-test-posttest control group design was used to investigate pre-service chemistry teachers’ motivation. Data were collected from pre-service teachers and analyzed using independent samples t-test, Wilcoxon-Ranked test and Mann-Whitney U test. A pre-CMRS established that Conceptual Change Instructional Approach (CCIA) group and Conventional Instructional Approach (CIA) group were comparable at the start. Analysis of students’ responses indicated that students in the CCIA group rated themselves higher than those in the CIA group in Post-CMRS after intervention. Based on the findings and discussions, conclusions were made. [African Journal of Chemical Education—AJCE 9(1), January 2019]
INTRODUCTION

Academic success is contingent on various determinants. Some are cognitive aspects and some others are non-cognitive. Motivation belongs to the non-cognitive strands. This psychological construct has immense pedagogical importance in science education in general and chemistry education in particular. However, it is often an overlooked variable. Increasing the motivation of students to learn science subjects is core to major reforms in science education [1]. Motivation is associated with enhanced student learning [2] provided that students devote time and energy to their studies [3].

Non-cognitive components like motivation should be viewed with the same eye glass as cognitive components [4] but this is not the case in most circumstances in science education. Because of the focus given to cognitive aspects and not for recognizing affective factors like motivation conceptual change theory of Posner and co-researchers [5] was called cold conceptual change [6]. These authors suggest including motivation aspects in conceptual change approach, which recently is evolved as hot conceptual change model [7]. In addition, different studies suggest multidimensional nature of conceptual changes [8] [9] supporting the argument above. Researchers like Dole and Sinatra [10] have given attention to information processing in conceptual change and have also portrayed the impact of motivation on conceptual change in their Cognitive Reconstruction of Knowledge Model. These authors explained how the affective and cognitive characteristics work together.

Approaches to learning have a strategy and a motive component [11]. For instance, intrinsic motivation is the motive component of a deep approach (a strategy aspect) and extrinsic motivation corresponds to a surface approach [12]. By its very nature, chemistry is highly conceptual [13] requiring students to get intrinsically motivated. Even though much can be gained by rote learning,
real understanding in chemistry requires bringing together conceptual understandings of students. When students are not motivated to seek for understanding, teachers face problems. Students will be engaged more easily on problems that are challenging and real-world context related [14]. Which means, students tend to be intrinsically motivated if the problems are interesting, meaningful, challenging, and engaging [13]. This makes motivation as an important factor in the construction of knowledge and the process of conceptual change [15]. Classroom strategies (such as conceptual change instructional approach) optimize student motivation [15].

There is limited research work focusing on motivation in organic chemistry domain. Thus, this research work was intended to study students’ motivation in aliphatic hydrocarbon concepts of organic chemistry education through the use of CCIA-conceptual change texts (CCTs).

THE PROBLEM, PURPOSE OF THE STUDY AND RESEARCH QUESTIONS

College level pre-service chemistry teachers, in the Ethiopian context, take two organic chemistry courses in which aliphatic hydrocarbon concepts are treated in the introductory organic chemistry I course. It has been reported that aliphatic hydrocarbon concepts are among key areas of concern for students [16] [17]. The determination of structural formulae, International Union of Pure and Applied Chemistry (IUPAC) nomenclature, identification and description of functional groups, characteristics of organic compounds, reaction types and reaction mechanisms are among problem areas [17] for college students. These concepts connote barrier for a great majority of students everywhere [18]. Based on the experience and observation of the researcher at the study site, the teaching approach used by lecturers is not in a way to assure meaningful learning. Though it is possible to provide different reasons for performance related problems of students, evidence shows that the reason behind students’ poor performance can be related to instructional approach
employed [19] [20] and motivation [21]. The principal investigator’s experience as a lecturer offering the courses and evidence from registrar office of the study site showed students’ motivation in the two organic chemistry courses is poor. Thus, this study focuses on the effects of Conceptual change instructional approach (using CCTs) on pre-service chemistry teachers’ motivation in relation to aliphatic hydrocarbon concepts.

The primary purpose of this study was to investigate effects of conceptual change instructional approach through the use of conceptual change texts (CCTs) on motivation of pre-service teachers’ in relation to aliphatic hydrocarbon concepts.

To attain the above major purpose of the study the following research questions were articulated:

1. Is there statistically significant difference between experimental and comparison group in reference to Pre-CMRS mean scores?
2. Is there statistically significant difference within experimental and comparison group in reference to Pre-and post- CMRS mean scores?
3. Is there statistically significant difference between experimental and comparison group in reference to Post-CMRS mean scores when CCIA is used in aliphatic hydrocarbon concepts?

METHODOLOGY

Design Type

In order to study the effect of conceptual change instructional approach using conceptual change text on motivation in aliphatic hydrocarbon concepts, the Pretest-Posttest Nonequivalent-
Groups quasi-experimental Design was used. The quantitative quasi-experimental approach with nonequivalent control group design with pretest and posttest was selected in this study.

**Research site, Population and Participants**

This research was conducted in Arbaminch College of Teachers Education, SNNPRS, Ethiopia. The college is a public institution with an enrollment capacity of 3,500 regular Diploma pre-service teachers. The participants in this study were from a convenience sample of 87 pre-service chemistry teachers aged 18 to 24 years (\(M_{\text{age}}=20.01, \ SD=1.28\)) registered in Introductory Organic Chemistry I in the same college in regular Program.

**Instrument**

The instrument used in this study was Chemistry motivation rating Scale (CMRS). The students’ ratings on CMRS served as the basis for judging students’ motivation in this study. It was designed to assess pre-service teachers’ motivation while learning aliphatic hydrocarbon concepts through the use of CCTs. The CMRS (Appendix) used in this study was adapted from appropriate literature [22, 23].

**Reliability and Validity**

Although the authors [22, 23] of the CMRS validated the tool with large sample, to ensure validity in the Ethiopian/study site context CMRS was checked by three senior lecturers of the college/study area. The internal consistency reliability was checked through piloting based on appropriate literature [24, 25].

**Pilot study**

The CMRS was piloted with thirty-three students in a different college in the region. After piloting, the tools’ appropriateness for the main study was ensured through reliability check. The reliability Cronbach’s alpha (using SPSS 20 version) was found to be 0.89 which is good [24-25].
Procedures of data collection

The CMRS was anticipated to show/indicate motivation related data of participants. The experimental Group and comparison group were given pre-CMRS before the intervention. After the intervention (this took seven weeks), post-CMRS was administered to the two groups. Then, scoring the responses from pre-service teachers and generating quantitative data was carried out.

Data Analysis

Quantitative data was made available using CMRS score. Pre-CMRS was normally distributed based on skewness and Kurtosis values [26]. Independent samples t-test was used for analyzing pre-CMRS. Post-CMRS was not normally distributed. For Post-CMRS data, Wilcoxon Signed Ranks Test and Mann-Whitney U test were used to compare groups. For the statistical analysis SPSS 20 version was used.

RESULTS, DISCUSSION AND CONCLUSION

Results

Comparison of Mean Scores of PRE-CMRS

Prior to examining the effect of conceptual change approach on pre-service chemistry teachers’ motivation in aliphatic hydrocarbon concepts in this study, an attempt was made to ensure equivalence of Experimental Group (EG) and Comparison Group (CG). For this purpose, an independent sample t test was performed on the pre-CMRS.

Table-2: Independent-samples t-test results for PRE-CMRS with respect to groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Variable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>SE</th>
<th>df</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-CMRS</td>
<td>.069</td>
<td>85</td>
<td>1.885</td>
<td>.063</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EG</td>
<td></td>
<td>44</td>
<td>3.62</td>
<td>.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG</td>
<td></td>
<td>43</td>
<td>3.48</td>
<td>.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Independent samples t-test analysis (table-2) shows the differences between the Pre-CMRS mean scores of the groups (MExP = 3.62, SDexp = 0.30, Nexp = 44 and MCom = 3.48, SDcom = 0.35, Ncom = 43; t(85) = 1.885, p > 0.05). The Pre-CMRS scores of the groups were not significant (p = 0.05), implying that prior to the intervention the groups were similar.

Comparison of Groups in terms of Pre-and Post-CMRS

To compare Pre-CMRS scores with post-CMRS scores of groups Wilcoxon Signed Ranks Test Analysis was employed.

Table-3: Descriptive Statistics of Comparison Group for Pre-and post-CMRS

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-CMRS</td>
<td>43</td>
<td>3.48</td>
<td>.35</td>
<td>2.48</td>
<td>4.00</td>
</tr>
<tr>
<td>POST-CMRS</td>
<td>43</td>
<td>3.38</td>
<td>.48</td>
<td>1.72</td>
<td>3.96</td>
</tr>
</tbody>
</table>

Table-4: Comparison Group Ranks for Chemistry motivation Rating Scale (Pre-post)

<table>
<thead>
<tr>
<th>POST-CMRS - PRE-CMRS</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative Ranks</td>
<td>26a</td>
<td>21.10</td>
<td>548.50</td>
</tr>
<tr>
<td>Positive Ranks</td>
<td>14b</td>
<td>19.39</td>
<td>271.50</td>
</tr>
<tr>
<td>Ties</td>
<td>3c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. POST-CMRS < PRE-CMRS
b. POST-CMRS > PRE-CMRS
c. POST-CMRS = PRE-CMRS

Table-5: Comparison Group Wilcoxon Signed Ranks test results

<table>
<thead>
<tr>
<th>POST-CMRS - PRE-CMRS</th>
<th>Z</th>
<th>Asymp. Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1.867a</td>
<td>.062</td>
</tr>
</tbody>
</table>

a. Based on positive ranks.
Table-3, Table-4 and Table-5 show descriptive statistics, group ranks and Wilcoxon Signed Ranks test of comparison group respectively. In Table-5, a Wilcoxon Signed Ranks test was performed to check if there was a change in the scores due to CIA. Compared to the pretest scores the comparison group post test scores for CMRS was not significant at p=0.05 level. Wilcoxon Signed Ranks test value was, $Z = -1.867$, $p = .062$.

Table-6: Descriptive Statistics of Experimental Group for Pre-and post-CMRS

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-CMRS</td>
<td>44</td>
<td>3.61</td>
<td>.30</td>
<td>2.64</td>
<td>4.00</td>
</tr>
<tr>
<td>POST-CMRS</td>
<td>44</td>
<td>3.59</td>
<td>.36</td>
<td>1.80</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Table-7: Experimental Group Ranks for Chemistry motivation Rating Scale (Pre-post)

<table>
<thead>
<tr>
<th>POST-CMRS - PRE-CMRS</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative Ranks</td>
<td>21$^a$</td>
<td>19.98</td>
<td>419.50</td>
</tr>
<tr>
<td>Positive Ranks</td>
<td>17$^b$</td>
<td>18.91</td>
<td>321.50</td>
</tr>
<tr>
<td>Ties</td>
<td>6$^c$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. POST-CMRS < PRE-CMRS  
b. POST-CMRS > PRE-CMRS  
c. POST-CMRS = PRE-CMRS

Table-8: Experimental Group Wilcoxon Signed Ranks test results

<table>
<thead>
<tr>
<th>POST-CMRS - PRE-CMRS</th>
<th>$Z$</th>
<th>Asymp. Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-.712$^a$</td>
<td>.477</td>
</tr>
</tbody>
</table>

a. Based on positive ranks.
Similarly, table-6, table-7 and table-8 show descriptive statistics, group ranks and Wilcoxon Signed Ranks test of Experimental group respectively. In Table-8, a Wilcoxon Signed Ranks test was performed to check if there was a change in the scores due to CCIA. Compared to the pretest scores the Experimental group post test scores for CMRS was not significant at p=0.05 level. Wilcoxon Signed Ranks test value was, $Z = -.712, p =.477$. However, this does not confirm that the CCIA is better than CIA in terms of CMRS since the two treatments show non-significant difference using Wilcoxon Signed Ranks test. To check if there is a significant difference exists in scores of CMRS (which was not normally distributed) Mann-Whitney U test was employed.

Comparison of Post-Chemistry Motivation Rating Scale Scores of Groups

As the Post-CMRS data was not normally distributed for the groups, the most appropriate statistical test for POST-CMRS was Mann-Whitney U test.

Table-9: Chemistry motivation Rating Scale (Post-test) means, standard deviations and medians of the study groups

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>25th</th>
<th>50th</th>
<th>75th</th>
</tr>
</thead>
<tbody>
<tr>
<td>POST-CMRS</td>
<td>87</td>
<td>3.48</td>
<td>.43</td>
<td>1.72</td>
<td>4.00</td>
<td>3.32</td>
<td>3.56</td>
<td>3.84</td>
</tr>
<tr>
<td>TREATMENT</td>
<td>87</td>
<td>1.49</td>
<td>.50</td>
<td>1.00</td>
<td>2.00</td>
<td>1.00</td>
<td>1.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Table-10: Mann-Whitney U test results of groups for Chemistry motivation Rating Scale (Post-test)

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Mean Rank</th>
<th>U</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental Group</td>
<td>44</td>
<td>49.89</td>
<td>687.00</td>
<td>.028</td>
</tr>
<tr>
<td>Comparison Group</td>
<td>43</td>
<td>37.98</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Statistics (Table-9) showed that Experimental group chemistry pre-service teachers (median = 3.84; mean rank = 49.89) scored higher on POST-CMRS scales than comparison group chemistry pre-service teachers (median = 3.32; mean rank = 37.98). Mann-Whitney U value (Table-10) was found to be statistically significant U = 687.00, p < 0.05, and the difference between the Experimental group chemistry pre-service teachers and comparison group chemistry pre-service teachers was of size small effect (Eta = 0.24) according to Cohen [27].

**Comparison of Post-Chemistry Motivation Rating Sub-Scale Scores of Groups**

Mann-Whitney U test was used to determine the effect of conceptual change instructional approach on each motivation subscales.

Table-11 (below) shows Chemistry Motivation Rating Subscale (Post-test) means, standard deviations and medians of the study groups. The medians of the two groups in the motivation subscales look somewhat different. This might be due to chance. Therefore, it is necessary to check using Mann-Whitney U test.

Table-12 (below) offers Mann-Whitney U test results for Chemistry Motivation Rating Subscales. For motivation subscales IPOST-CMRS, SDPOST-CMRS, and GPOST-CMRS, Mann-Whitney U values were found to be statistically significant (P= 0.05 level).

Descriptive statistics showed that Experimental group chemistry pre-service teachers (median = 3.80; mean rank = 49.52) scored higher on IPOST-CMRS scales than comparison group chemistry pre-service teachers (median = 3.20; mean rank = 38.35). Mann-Whitney U value was found to be statistically significant U = 703.00, p <0.05, and the difference between the Experimental group chemistry pre-service teachers and comparison group chemistry pre-service teachers was of size small effect (Eta = 0.22) according to Cohen [27].
Table 11: Chemistry motivation Rating Subscales (Post-test) means, standard deviations and medians of the study groups

<table>
<thead>
<tr>
<th>Subscale</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Percentiles (Median)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25th</td>
</tr>
<tr>
<td>IPOST-CMRS</td>
<td>87</td>
<td>3.54</td>
<td>.44</td>
<td>2.20</td>
<td>4.00</td>
<td>3.20</td>
</tr>
<tr>
<td>CPOST-CMRS</td>
<td>87</td>
<td>3.60</td>
<td>.46</td>
<td>2.20</td>
<td>4.00</td>
<td>3.40</td>
</tr>
<tr>
<td>SDPOST-CMRS</td>
<td>87</td>
<td>3.46</td>
<td>.53</td>
<td>1.00</td>
<td>4.00</td>
<td>3.20</td>
</tr>
<tr>
<td>SPOST-CMRS</td>
<td>87</td>
<td>3.22</td>
<td>.64</td>
<td>.60</td>
<td>4.00</td>
<td>3.00</td>
</tr>
<tr>
<td>GPOST-CMRS</td>
<td>87</td>
<td>3.61</td>
<td>.44</td>
<td>1.60</td>
<td>4.00</td>
<td>3.40</td>
</tr>
<tr>
<td>TREATMENT</td>
<td>87</td>
<td>1.49</td>
<td>.50</td>
<td>1.00</td>
<td>2.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

IPOST-CMRS = intrinsic motivation posttest, CPOST-CMRS = Career motivation posttest, SDPOST-CMRS = self-determination posttest, SPOST-CMRS = self-efficacy posttest, GPOST-CMRS = grade motivation posttest

Descriptive statistics showed that Experimental group chemistry pre-service teachers (median = 3.80; mean rank = 49.51) scored higher on SDPOST-CMRS scales than comparison group chemistry pre-service teachers (median = 3.20; mean rank = 38.36). Mann-Whitney U value was found to be statistically significant U = 705.50, p < 0.05, and the difference between the Experimental group chemistry pre-service teachers and comparison group chemistry pre-service teachers was of size small effect (Eta = 0.22) according to Cohen [27].
Table-12: Mann-Whitney U test results for Chemistry Motivation Rating Subscales (Post-test)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Subscale</th>
<th>N</th>
<th>Mean Rank</th>
<th>U</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IPOST-CMRS</td>
<td></td>
<td></td>
<td>703.00</td>
<td>.036</td>
</tr>
<tr>
<td>Experimental</td>
<td>44</td>
<td>49.52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison</td>
<td>43</td>
<td>38.35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CPOST-CMRS</td>
<td></td>
<td></td>
<td>747.50</td>
<td>.084</td>
</tr>
<tr>
<td>Experimental</td>
<td>44</td>
<td>48.51</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison</td>
<td>43</td>
<td>39.38</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SDPOST-CMRS</td>
<td></td>
<td></td>
<td>703.50</td>
<td>.037</td>
</tr>
<tr>
<td>Experimental</td>
<td>44</td>
<td>49.51</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison</td>
<td>43</td>
<td>38.36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPOST-CMRS</td>
<td></td>
<td></td>
<td>751.00</td>
<td>.095</td>
</tr>
<tr>
<td>Experimental</td>
<td>44</td>
<td>48.43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison</td>
<td>43</td>
<td>39.47</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GPOST-CMRS</td>
<td></td>
<td></td>
<td>671.00</td>
<td>.017</td>
</tr>
<tr>
<td>Experimental</td>
<td>44</td>
<td>50.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison</td>
<td>43</td>
<td>37.60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Descriptive statistics showed that Experimental group chemistry pre-service teachers (median = 4.00; mean rank = 50.25) scored higher on GPOST-CMRS subscales than comparison group chemistry pre-service teachers (median = 3.40; mean rank = 37.60). Mann-Whitney U value was found to be statistically significant $U = 671.00$, $p < 0.05$, and the difference between the Experimental group chemistry pre-service teachers and comparison group chemistry pre-service teachers was of size small effect ($\eta = 0.26$) according to Cohen [27].
DISCUSSION

In this study, groups were not significantly different based on the CMRS pretest mean scores. Independent-samples t-test confirmed this. A Wilcoxon Signed Ranks test was performed on CMRS scores to check if there was a change in the scores due to CIA and CCIA. Compared to the pretest scores (in the Comparison and Experimental group) post test scores for CMRS were not significant at p=0.05 level. This means, Wilcoxon Signed Ranks test values were not statistically significant for both groups. To check if there is a significant difference between groups in scores of Post-CMRS, the pre-service chemistry teachers’ motivation was assessed through the use of Mann-Whitney U test as post test data was not normally distributed. The Mann-Whitney U test result indicated that the Experimental group chemistry pre-service teachers scored higher on POST-CMRS than comparison group chemistry pre-service teachers. This finding corroborates with the findings of other similar studies [28] [29] when conceptual change instructional approach is employed.

Moreover, the pre-service chemistry teachers’ motivation sub-scales were assessed through the use of Mann-Whitney U test as post test data was not normally distributed. The Mann-Whitney U test result indicated that the Experimental group chemistry pre-service teachers scored higher on IPOST-CMRS, SDPOST-CMRS and GPOST-CMRS scales than comparison group chemistry pre-service teachers. This finding confirms, in part, the fact that students compare their ability to others by obtaining good grades [15]. Also, this is consistent with the findings in other constructivist-informed instructional methods [30] [31] where students are active like CCIA. For instance, Tosun and Taskesengil [30] obtained similar results by employing problem-based learning. These researchers found positive effects on subscales of motivation when problem-based approach was used. Besides, in Tuan et al. [31] study conducted in Taiwan findings indicated that
after inquiry instruction motivation of students in the experimental group increased significantly than the students in the control group. In this research undertaking, the significance difference between experimental and comparison group in terms of motivation attests the effectiveness of CCIA which was employed in the experimental group. This is perhaps associated with the fact that CCIA has the potential to boost understanding of concepts which are highly linked with practical aspects as this has been confirmed in other studies [32] [33]. The study proved that students taught using CCIA rated high in motivation scales than those in the CIA setting.

CONCLUSION

The main purpose of this study was to investigate effects of conceptual change instructional approach through the use of conceptual change texts on motivation of pre-service teachers’. In this quantitative study, the experimental group participants rated themselves more motivated than the comparison group with small effect size magnitude. At the sub-scales level, the experimental group participants rated high in intrinsic motivation, self-determination and grade motivation sub-scales. Thus, a significant result (though with small effect size magnitude) was obtained in the experimental group confirming the superiority of CCIA over CIA.

REFERENCES


**APPENDIX**

Chemistry Motivation Rating Scales Questionnaire adapted from [22] [23]

**Part-I: General information**

1. Sex(Put √ mark): Male_____ Female _____
2. Age(Put √ mark): 16-18:____ 19-21:____ 22 and above:____
3. Year: (write here)________________
4. Department (write here)_________

**Part-II: Motivation towards chemistry (Put ☐ mark on each item response)**

In order to better understand what you think and how you feel about your chemistry courses, please respond to each of the following statements from the perspective of “When I am in a chemistry course…”

01. The chemistry I learn is relevant to my life
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
02. I like to do better than other students on chemistry tests
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
03. Learning chemistry is interesting
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
04. Getting a good chemistry grade is important to me
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
05. I put enough effort into learning chemistry
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
06. I use strategies to learn chemistry well
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
07. Learning chemistry will help me get a good job
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
08. It is important that I get an “A” in chemistry
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
09. I am confident I will do well on chemistry tests
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
10. Knowing chemistry will give me a career advantage
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
11. I spend a lot of time learning chemistry
O Never
O Rarely
O Sometimes
O Usually
O Always
12. Learning chemistry makes my life more meaningful
O Never
O Rarely
O Sometimes
O Usually
O Always
13. Understanding chemistry will benefit me in my career
O Never
O Rarely
O Sometimes
O Usually
O Always
14. I am confident I will do well on chemistry labs and projects
O Never
O Rarely
O Sometimes
O Usually
O Always
15. I believe I can master chemistry knowledge and skills
O Never
O Rarely
O Sometimes
O Usually
O Always
16. I prepare well for chemistry tests and labs
O Never
O Rarely
O Sometimes
O Usually
O Always
17. I am curious about discoveries in chemistry
O Never
O Rarely
O Sometimes
O Usually
O Always
18. I believe I can earn a grade of ‘‘A’’ in chemistry
O Never
O Rarely
O Sometimes
O Usually
O Always
19. I enjoy learning chemistry
O Never
O Rarely
O Sometimes
O Usually
O Always
20. I think about the grade I will get in chemistry
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
21. I am sure I can understand chemistry
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
22. I study hard to learn chemistry
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
23. My career will involve chemistry
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
24. Scoring high on chemistry tests and labs matters to me
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
25. I will use chemistry problem-solving skills in my career
   O Never
   O Rarely
   O Sometimes
   O Usually
   O Always
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SJIF IMPACT FACTOR EVALUATION [SJIF 2012 = 3.963]

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**RESEARCH PAPERS** reporting the results of original research. It is a peer-reviewed submission that deals with chemistry education at any level (primary, secondary, undergraduate, and postgraduate) and can address a specific content area, describe a new pedagogy or teaching method, or provide results from an innovation or from a formal research project.

**SHORT NOTES** containing the results of a limited investigation or a shorter submission, generally containing updates or extensions of a topic that has already been published.

**REVIEWS** presenting a thorough documentation of subjects of current interest in chemical education.

**LABORATORY EXPERIMENTS AND DEMONSTRATIONS** describing a novel experiment/demonstration, including instructions for students and the instructor and information about safety and hazards.

**SCIENTIFIC THEORIES** describing the scientific, historical and philosophical foundations of theories and their implications to chemical education.

**ACTIVITIES** describing a hands-on activity that can be done in the classroom or laboratory and/or as a take home project.

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