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PRE-SERVICE CHEMISTRY TEACHERS' DEPICTION OF NOMENCLATURE RELATED ALIPHATIC HYDROCARBON CONCEPTS

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Abstract
The main purpose of the study was to determine pre-service chemistry teachers' (PCTs) understanding of nomenclature related concepts of aliphatic hydrocarbons (AHCs). The study investigated PCTs understanding on nomenclature related concepts of AHCs. A qualitative case study approach, through in-depth interview, was employed to look into PCTs understanding. Twelve PCTs, from two intact classes of 87 students, were selected randomly for the interview. The participants were second year PCTs registered in Introductory Organic Chemistry I course in Arbaminch College of Teachers Education, Ethiopia in the year 2017 G.C. A semi-structured interview was used for assessing understanding of PCTs in relation to nomenclature of AHCs. A framework analysis approach was applied to analyze interview data. The results of analysis revealed that the PCTs in the Intervention Group (IG) had better acquisition of nomenclature related concepts than those in the Comparison Group (CG) after conceptual change instructional approach through the use of Conceptual Change Texts (CCTs). The PCTs' responses showed several conceptions which are at variance with chemist's outlook.
Keywords: Pre-service chemistry teachers, hydrocarbons, conceptual change, nomenclature, IUPAC system

INTRODUCTION

Education in general and chemistry education in particular are fused with things to be addressed properly. Several seemingly different problems converged to push the education even deeper in to uncharted territories. Researchers, teachers and teacher educators are expected to go deep into these uncharted territories. These problems could be piecemeal, may not be all at once. These problems in chemistry could be area specific too. Different Literatures confirmed the existence of difficulties in college level organic chemistry courses (Johnstone, 2006; Johnstone, 2010; O'Dwyer and Childs, 2017). For instance, O'Dwyer and Childs (2017), in their recent study, confirmed that learners face difficulty almost in all concepts of introductory level organic chemistry. The difficulty is related to the fact that proper understanding of chemistry requires understanding ideas at macroscopic, sub-micro level and symbolic level (Johnstone, 1991, 2000). Macro level shows the sensory experience of substances (substances at this level can be seen, touched or smelled), the sub-micro level focuses on particulate aspects like atoms, ions, molecules and chemical structures, while the symbolic/representational level focuses on symbols, formulae, equations, calculations, tables and graphs (Johnstone, 2000). Naming requires proper understanding of formulae at symbolic level. There are different formulae in relation to organic compounds. The problem is that instructors shift directly from macro level to symbolic level without giving attention to sub-micro or particulate level to illuminate ideas in chemistry (Mirzaie, Shahmohammadi, & Kouhi, 2010), which are abstract to comprehend. Nomenclature is part of introductory organic chemistry. Students provide names to different organic compounds including aliphatic hydrocarbons. Nomenclature is a system by which names are formed through a range of nomenclatural operations in harmony with a set of principles, rules and conventions (Faver, Powell & IUPAC, 2014). The International Union of Pure and Applied Chemistry (henceforward, IUPAC) is in charge of setting up nomenclature rules compounds (Panico, Powell, Richer & IUPAC, 1993). Naming of organic compounds is based on certain IUPAC rules, though there are two naming systems-systematic and non-systematic (trivial). To establish an international standard of naming compounds, the IUPAC system (systematic naming) of naming is employed. However, common (non-systematic) naming is also in use. Using IUPAC rules, when students are offered the structural formulae, they can write names of corresponding compounds. Similarly, when learners are familiar with IUPAC names, they can write structural formulae. Nomenclature is a drill-and-practice exercise (Shaw & Yindra, 2003:1223). Learners should be allowed in this drill-and-practice exercise with follow-up of their instructors. Simple lecturing with few examples may not bring change (Adu-Gyamfi, Ampiah & Appiah, 2017) as traditional instruction plays inactive role in learning (OECD, 2018). Due to this students have inadequate understanding in relation to nomenclature of hydrocarbons (Adu-Gyamfi et al., 2017; Akkuzu & Uyulgana, 2016; Duis, 2011, O'Dwyer, 2012). Adu-Gyamfi and colleagues (2017), for example, confirmed that chemistry students' difficulties in IUPAC naming of organic compounds, such as aliphatic hydrocarbons, included their failure to identify correct number of carbon atoms, and inability to identify substituents and functional groups.

However, there is limited study that focuses on determining the effect of Conceptual Change Text (henceforward, CCT)-based instruction in understanding basic concepts in organic chemistry (Sendur, 2012; Sendur & Toprak, 2013). Thus, this qualitative study is required to spot the effectiveness of conceptual change approach using CCT on nomenclature of aliphatic hydrocarbon concepts.

Objective and Research Questions

The paramount aim of the study was to look in to pre-service chemistry teachers' (henceforward, PCTs) understanding of nomenclature related concepts of Aliphatic Hydrocarbons (AHCs). To achieve this major objective the following research questions guided the study.

1. In what ways do PCTs explain nomenclature related concepts of AHCs before running conceptual change approach through the use of CCTs and conventional instructional approach?
2. How do PCTs explain nomenclature related concepts of AHCs after running conceptual change approach through the use of CCTs and conventional instructional approach?
3. Is there change in understanding nomenclature related Aliphatic Hydrocarbon (AH) concepts after running conceptual change approach through the use of CCTs and conventional instructional approach?

METHODOLOGY

Case Study

A case study of the outcome of conceptual change instructional practice on chemistry pre-service teachers' group members gave an opportunity to understand how these participants brought change in introductory organic chemistry course related nomenclature concepts. This study focused on developing insights into PCTs understanding of nomenclature related concepts. Due to this major concern randomized sampling was not employed. To get thorough portrayal of PCTs understanding on nomenclature related concepts of aliphatic hydrocarbons, case study was employed. Case study has been used as a valuable qualitative research approach in different studies (Harrison & Treagust, 2000; Lyons, Freitag & Hewson, 1997; Solomon, 2008; Sweeney, Bula and Cornett, 2001).

Research site, Population and Participants

This study was conducted in Arbaminch College of Teachers Education, Ethiopia. The participants were from a convenience sample of eighty-seven PCTs, in two classes, registered in Introductory Organic Chemistry I in the same college in regular Program. The two intact classes were assigned as comparison and intervention groups. Interviews were conducted with six students from each group before and after the treatment. That is, a total of twelve randomly selected chemistry PCTs participated in the qualitative interview. The composition was from students of both categories (high achievers, medium achievers and low achievers). Based on previous semester GPA, from the six-comparison group chemistry PCTs two were high achievers, two were medium achievers and the remaining two were low achievers. Two of the comparison group participants were females. Again, from the six intervention group PCTs two were high achievers, two were medium achievers and the remaining two were low achievers. Here also the selection was based on previous semester GPA. Two of the intervention group participants were females too.

Treatment

In this study all concepts of AHCs treated. The classroom lecturer completed the intervention in three fifty-minute sessions in a week. These class-hours were accompanied with a three-hour lab session in a week. The same lecturer taught these groups during the intervention period. The lecturer received trainings on the execution of conceptual change approach through the use of CCTs (Appendix-C) before the intervention. The nomenclature related concepts were covered in regular class hours as part of concepts of AHCs. No special class hour arrangement was made for the intervention. Two text versions (traditional text and CCT) were used during the intervention in relation to nomenclature related AH concepts. Nomenclature related AH concepts comprised naming of alkanes, alkenes and alkynes. CCTs were used in the intervention group in relation to naming of alkanes, alkenes and alkynes whereas traditional module-based texts (which address students' alternative conceptions implicitly) were used in the comparison group. CCT infused instruction was employed in the intervention group. CCTs deal with students' alternative conceptions unambiguously.

Instrument

To solicit information, semi-structured interview questions related to nomenclature were prepared to conduct one-on-one interviews with individual participants. A semi-structured interview protocol (Appendix-A) was designed by the researcher and used for assessing understanding PCTs in relation to nomenclature related concepts. Semi-structured interviews are tools to get lots of qualitative data (Solomon, 2008).

Trustworthiness and Validity of the Instrument

Trustworthiness was ensured based on literature search (Shenton, 2004). Also, validity (face and content) of the tool was checked by three senior lecturers in the research site.

Pilot Study

The semi-structured interview instrument had been pilot tested before it was administered to the respondents during the main study. Piloting was conducted on small sample respondents in a different college. The semi-structured interview prepared as well as the conceptual approach were piloted.

Procedures of Data Collection

To satisfy the objective of the study, twelve pre-service chemistry teachers from intervention (six participants) and comparison group (six participants) were randomly chosen for the interview. Participants were selected from students of both categories (low, medium and high achievers) based on registrar office data of the study site. Then, the researcher gave orientation to participants selected on individual basis about the nature of interview guide, confidentiality during and after completion of the study, and importance of recording during the research work. Participants consented to participate. Participants consented to participate in the study. Participants were probed to give more ideas while interviewing. Data were stored in audio appliance (based on the consent obtained) before manual transcription.

Data Analysis

Analysis was done after manual transcription. After manual transcription, alternative conceptions categorization, identification of correct conceptions, frequencies and extensiveness of concepts generation was carried out (Skelly, 1993; Osman, 2017; Sobal, 200l). Ideas gathered from participants helped for the analysis process.

RESULTS

Initial Understanding of Nomenclature Related Aliphatic Hydrocarbon Concepts

Q1. In what ways do PCTs explain nomenclature related concepts of AHCs before running conceptual change approach through the use of CCTs and conventional instructional approach?

Table-1 below depicts alternative conceptions (henceforward, ACs) of aliphatic hydrocarbons in relation to nomenclature of AHCs. ACs were reflected by both Comparison Group (henceforward, CG) and Intervention Group (henceforward, IG) participants.

In the two groups, there were 17 ACs. Ten ACs were in the CG and 7 were in the IG. Six ACs from 10 in the CG were AC-Lang type, 2 were ACs-prior K type and 2 were OCog-Asp-ACs. Six of the seven ACs in the IG were AC-Lang type, 1 was ACs-prior K type and no OCog-Asp-ACs was acquired by participants in this group. ACs-Lang types were comparable as well as dominant in both groups.

From ten ACs reported from the CG participants, seven were reported only once, one AC was reported twice another one AC was reported four times, and also another one AC was reported five times by participants. Again, from seven ACs reported from IG participants, four were reported only once, two ACs were reported five times, and one was reported six times. From the reported ACs some are explicated by majority of the participants in both groups. For example, bond line formula confuses students in naming alkynes (students consider the linear four carbon system as two carbon system). Four (67%) of the participants from the CG and six (100%) of the participants from the IG were with this AC before intervention. Also, the presence of double bond in bond line formula of alkene molecules with substituent confuses students (33% CG; 83 IG). Another significant AC among participants from both groups was related to branching or presence of substituents on alkane molecules. Branching confuses students during naming of alkane molecules. Five (83%) of the participants from the CG and five (83%) of the participants from the IG were with this AC before intervention.

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Table 1. ACs experienced by CG and IG participants before intervention on nomenclature of AHCs

ACs of CG				ACs of IG			
Alternative conceptions involving Language (ACs-Lang)							
1)Alkyl groups are considered as large and small alkane members appearing as substituents (naming alkanes with substituents confuses students).	5	4)Alkyl group substituents in the alkane molecules are confused with alcohol functional group appearing in long chain alkane molecules.	1	1)The presence of double bond in bond line formula of alkene molecules with substituent confuses students	5	4)The general formula of alkynes confuses students in naming (students associated naming with incorrect general formula)	**1**
2)The presence of double bond in bond line formula of alkene molecules with substituent confuses students	2	5)IUPAC naming system is confused with common naming system	1	2)Bond line formula confuses students in alkyne molecules (students consider the linear four carbon system as two carbon system)	6	5)IUPAC naming system is confused with common naming system	1
3)Bond line formula confuses students in alkynes (students consider the linear four carbon system as two carbon system)	4	6)Naming alkane molecules with substituents using alphabetical orders confuses students	1	3)Naming substituted alkane molecules confuses students	5	6)Naming alkane molecules with substituents using alphabetical orders confuses students	1
Alternative Conceptions involving Prior Knowledge (ACs-Prior K)							
7)Confusing total number of carbon atoms in alkane molecules with the number of carbon atoms in the longest chain.	1	8)Alkane molecules can have double and triple bonds in their structures.	1	7)Confusing total number of carbon atoms in alkane molecules with the number of carbon atoms in the longest chain.	1		
Other Cognitive aspect Alternative conceptions (OCog-asp-ACs)							
9)Naming system of alkane molecules has formula to be used	1	10)Naming of alkane molecules is related to electronic configuration	1				
Extensiveness of ACs			18	Extensiveness of ACs			20

Table 2. CoCs experienced by CG and IG participants before intervention on nomenclature of AHCs

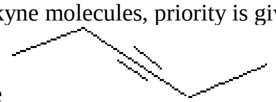
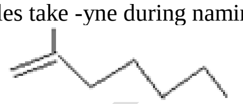
	Concept	CG pre	IG pre
		Frequencies	
1.	In naming alkane molecules, the first step is identification of parent chain/longest chain selection	5	5
2.	CH3CH(CH3)CH(CH2CH3)CH2CH2CH3 is 3-ethyl-2-methylhexane	1	
3.	An alkane molecule with three carbon atoms is propane		1
4.	An alkane molecule with four carbon atoms is butane		1
5.	Alkane molecules can be named by using IUPAC rule		4
6.	Alkane molecules can be named by using common naming system		1
7.	The molecule CH3CH(CH3)CH2CH3 is 2-methylbutane	2	3
8.	The molecule CH3CH(CH3)CH(CH2CH3)CH2CH2CH3 is 3-ethyl-2-methylhexane		2
9.	In naming alkene molecules, priority is given to the C-C double bond.	1	2
10.	In naming alkyne molecules, priority is given to the C-C triple bond.		1
11.	The molecule  is 3-hexyne	1	
12.	In naming alkane molecules, after identification of parent chain/longest chain substituents should be given attention	1	1
13.	In naming alkane molecules with different substituents, alphabetical order of substituents should be considered.	2	2
14.	In naming alkane molecules with different substituents, numbers are separated from numbers by commas.	1	
15.	In naming alkane molecules with different substituents, numbers are separated from letters by hyphen.	2	
16.	Alkane molecules take -ane during naming	1	
17.	Alkene molecules take -ene during naming	2	
18.	Alkyne molecules take -yne during naming	1	
19.	The molecule  is 2-methyl-1-heptene	4	
	Number of correct conceptions	13	11
	Extensiveness	24	23

Table 2 shows PCTs correct conceptions (henceforward, CoCs) in nomenclature related aliphatic hydrocarbon concepts. From thirteen CoCs reported from the CG participants, seven were reported only once, four were reported twice, no CoCs was reported three times, one CoC was reported four times and another one CoC was reported five times by participants. Again, from eleven CoCs reported from IG participants, five were reported only once, three were reported twice, one CoC was reported three times, one CoC was reported four times and another one CoC was reported five times by participants. From the reported CoCs some are explicated by majority of the participants in both groups.

For example, in naming alkane molecules, the first step is identification of parent chain/longest chain (83%CG:83%IG); the molecule CH3CH(CH3)CH2CH3 is 2-methylbutane (33%CG:50%IG); in naming alkane molecules with different substituents, alphabetical order of substituents should be considered (50%CG:50%IG) and in naming alkene molecules, priority is given to the C-C double bond (17%CG:33%IG). This showed that before intervention the PCTs showed low (most CoCs occurred once in CG and IG) but comparable CoCs. The interview responses of participants (both in terms of ACs and CoCs) from CG and IG before intervention, showed that during the pre-test the PCTs had difficulties in nomenclature related aliphatic hydrocarbon concepts with poor CoCs.

Later Understanding of Nomenclature Related Aliphatic Hydrocarbon Concepts

Q2. How do PCTs explain nomenclature related concepts of AHCs after running conceptual change approach through the use of CCTs and conventional instructional approach?

Table-3 below depicts ACs in relation to nomenclature of AHCs. In the two groups, there were 16 ACs. Eleven ACs were in the CG and 5 were in the IG group. Seven ACs from 11 in the CG were ACs-Lang type, 2 were ACs-prior K type and 2 ACs were reported on OCog-Asp-ACs type. All Five ACs were reported in relation to ACs-Lang type. ACs-prior K type and OCog-Asp-ACs were not reported in the IG. ACs-Lang type is dominant in groups.

Table 3. ACs experienced by CG and IG participants after intervention on nomenclature of AHCs

AC of CG	Freq.	AC of IG	Freq.
Alternative conceptions involving Language (ACs-Lang)			
1. Bond line formulas of alkene molecules confuse students	3	1. Bond line formulas of alkene molecules confuse students	2
2. Bond line formulas of alkyne molecules confuse students (four carbon system in bond line formula is treated as two carbon system)	6	2. Bond line formulas of alkynes confuse students (four carbon system in bond line formula is treated as two carbon system)	6
3. Naming alkane molecules with substituents confuses students	4	3. Alkyl groups are confused with alkynes in naming alkanes when coming as a substituent	2
4. Alkynes are confused with alkyl groups	1	4. Alphabetical order of substituents confuses students in naming alkane molecules	2
5. IUPAC naming system is confused with common naming system	1	5. IUPAC naming system is confused with common naming system	1
6. Alphabetical order of substituents confuses students in naming alkane molecules (methyl comes first than ethyl)	1		
7. Students confuse -ene of alkene molecules with -yne of alkyne molecules during naming	1		
Alternative Conceptions involving Prior Knowledge (ACs-Prior K)			
8. Confusing total number of carbon atoms in alkanes with the number of carbon atoms in the longest chain.	1		
9. Alkane molecules have double in their structure	1		
Other Cognitive aspect Alternative conceptions (OCog-asp-ACs)			
10. Naming system of alkane molecules has formula to be used	1		
11. Electronic configuration helps in naming alkanes	1		
Extensiveness of ACs	20	Extensiveness of ACs	13

From eleven ACs reported from the CG participants, eight were reported only once, one AC was reported three times, another one AC was reported four times and also another one AC was reported six times. Again, from five ACs reported from IG participants, one AC was reported only once, three ACs were reported two times and another one AC was reported six times. From the reported ACs, some are explained by significant number of participants in both groups. For example, bond-line formulas of alkyne molecules confuse participants (four-carbon system in bond-line formula is treated as two carbon system). Six (100%) of the participants from the CG and six (100%) of the participants from the IG were with this AC after intervention. Another considerable AC among participants from CG was related to bond-line formula of alkene molecules. Bond-line formula of alkene molecules confuses students during naming of alkenes. Three (50%) of the participants from the CG and two (33%) of the IG members were with this AC after intervention.

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Also, two (33%) of IG participants confuse alkyl groups with alkynes in naming alkanes with substituents and two (33%) of the same group members have difficulty in putting substituents alphabetically during naming.

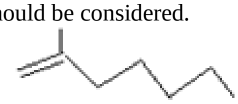
Table 4 below shows PCTs CoCs in nomenclature related AHCs after intervention. From seventeen CoCs reported from the CG PCTs, seven were reported only once, five were reported twice, two were reported three times, no CoC was reported four times, two were reported five times and another one CoC was reported six times by participants. Again, from twenty-one CoCs reported from IG PCTs, nine were reported only once, five were reported twice, one CoC was reported four times, five were reported five times and another one CoC was reported six times by participants. From the reported CoCs some are explicated by majority of the participants in both groups.

For example, in naming alkane molecules, the first step is identification of parent chain/longest chain (100%CG:67%IG); the molecule $CH_3CH(CH_3)CH_2CH_3$ is 2-methylbutane (83%CG :100%IG); the molecule $CH_3CH(CH_3)CH(CH_2CH_3)CH_2CH_2CH_3$ is 3-ethyl-2-methylhexane (83%CG:83%IG); in naming alkene molecules, priority is given to the C-C double bond (33%CG:83%IG); and in naming alkane molecules with different substituents, alphabetical order of substituents should be considered (33%CG:83%IG). Other CoCs include the molecule CH2=C(CH3)CH2CH2CH2CH2CH3 (bond-line formula) is 2-methyl-1-heptene (50%CG:83%IG) and in naming alkyne molecules, priority is given to the C-C triple bond of the alkynes (17%CG:83%IG). This showed that after intervention the PCTs in the IG showed more CoCs than the PCTs in the CG.

The interview responses of participants (both in terms of ACs and CoCs) from CG and IG after intervention showed that during the posttest the PCTs in the Conceptual Change Instructional Approach (henceforward, CCIA) group had reduced ACs with understanding in nomenclature related AHCs than those in Conventional Instructional Approach (henceforward, CIA) group.

Table 4. CoCs experienced by CG and IG participants after intervention on nomenclature of AHCs

	Concept	CG post	IG post
		Frequencies	
1.	In naming alkane molecules, the first step is identification of parent chain/longest chain selection	6	4
2.	For the same substituent occurring more than once in an alkane molecule we use terms like di-, tri-, tetra-, and so on.	1	
3.	In naming alkene molecules, the first step is identification of parent chain/longest chain selection		1
4.	In naming alkyne molecules, the first step is identification of parent chain/longest chain		1
5.	In naming alkane molecules, the nature of the bond and substituents are given attention		1
6.	Methane is an alkane		1
7.	Alkane molecules can be named using IUPAC rule		2
8.	The molecule CH3CH(CH3)CH2CH3 is 2-methylbutane	5	6
9.	The molecule CH3CH(CH3)CH(CH2CH3)CH2CH2CH3 is 3-ethyl-2-methylhexane	5	5
10.	In naming alkene molecules, priority is given to the C-C double bond.	2	5
11.	In naming alkene molecules, substituents get attention after the C-C double bond	1	
12.	In naming alkyne molecules, priority is given to the C-C triple bond.	1	5
13.	In naming alkyne molecules, substituents get attention after the C-C triple bond of the alkynes.	1	
14.	The molecule  is 3-hexyne	1	
15.	In naming alkane molecules, after identification of parent chain/longest chain substituents should be given attention	2	1

16.	Pentane is five carbon containing alkane		1
17.	Hexane contains six carbon atoms		1
18.	In branched/substituted alkane molecules numbering should be on the direction where substituents take the lowest possible numbers		1
19.	In naming alkane molecules with different substituents, alphabetical order of substituents should be considered.	2	5
20.	In naming alkane molecules with different substituents, numbers are separated from numbers by commas.	1	
21.	In naming alkane molecules with different substituents, numbers are separated from letters by hyphen.	1	
22.	Alkane molecules take -ane during naming	2	2
23.	Alkene molecules take -ene during naming	3	2
24.	Alkyne molecules take -yne during naming	2	1
25.	In naming alkene molecules with different substituents, alphabetical order of substituents should be considered.		2
26.	In naming alkyne molecules with different substituents, alphabetical order of substituents should be considered.		2
27.	The molecule  is 2-methyl-1-heptene	3	5
	Number of correct conceptions	17	21
	Extensiveness	39	54

Changes in Understanding Nomenclature Related Aliphatic Hydrocarbon Concepts

Q3. Is there change in understanding nomenclature related AH concepts after running conceptual change approach through the use of CCTs and conventional instructional approach?

Interviews were run with selected PCTs using questions related to nomenclature of AHCs before and after intervention. Prompts were used as appropriate when students have ideas to forward on the concept of nomenclature of AHCs. The interview response showed that during the pretest PCTs had complexity in describing and understanding nomenclature of aliphatic hydrocarbons. Sometimes conflicting ideas were reflected by participants. During the posttest the same students exhibited improved understanding. This section presents changes in nomenclature related AHCs understanding of PCTs. The section is divided into four thematized sub-sections: features related to rules for naming hydrocarbons; features related to naming of alkanes; features related to naming of alkenes and features related to naming of alkynes.

Features Related to Rules for Naming Hydrocarbons

Appendix-B1 gives summary of changes in understanding of PCTs in relation to features related to rules for naming AHCs. It incorporates several ideas. In relation to this first theme different CoCs and ACs were reflected from participants. For example, before CIA five participants (C-01, C-02, C-03, C-04 and C-05) in the CG reflected the CoCs “in naming alkane molecules, the first step is identification of parent chain/longest chain selection”. Also, before CCIA six participants (IP-01, IP-02, IP-03, IP-04, IP-05 and IP-06) in the IG reflected the same CoC. After intervention, six participants (C-01, C-02, C-03, C-04, C-05 and C-06) from CIA group and four participants (IP-01, IP-02, IP-05 and IP-06) from CCIA group echoed the CoC “in naming alkane molecules, the first step is identification of parent chain/longest chain selection”. The change is better in the CIA group. One Participant (C-01) from CIA group and two participants (IP-01 and IP-02) from CCIA group reflected the CoC “in naming alkene molecules, priority is given to the C-C double bond” before intervention. After intervention, two Participants (C-01 and C-02) from CIA group and five participants (IP-01, IP-02, IP-03, IP-04 and IP-05) from CCIA group reflected the same CoC. There is better change in the CCIA in terms of this CoC. In addition, the CoC “in naming alkane molecules, after identification of parent chain/longest chain substituents should be given attention” was reflected by one participant (C-01) before CIA. The same CoC was reflected by one IG participant (IP-01) before CCIA. After intervention, the same CoC was reflected by two participants (C-01 and C-02) and one Participant (IP-01) from the CIA and CCIA groups respectively. The CIA group participants' response is better in terms of this particular CoC after intervention. Besides, the CoC "in naming alkane molecules with different substituents, alphabetical order of substituents should be considered" was reflected by two participants (C-04 and C-05) before CIA. The same CoC was reflected by one IG participant (IP-06) before CCIA. After intervention, the same CoC was reflected by two participants (C-04 and C-06) and five Participants (IP-01, IP-02, IP-03, IP-05 and IP-06) from the CIA and CCIA groups respectively. The CCIA group participants' response is better in terms of this particular CoC after intervention. Moreover, the CoC "in naming alkyne molecules, priority is given to the C-C triple bond" was reflected by one participant (C-01) before CIA. The same CoC was reflected by one IG participant (IP-01) after CCIA. After intervention, the same CoC was reflected by no participant and five Participants (IP-01, IP-02, IP-03, IP-04 and IP-06) from the CIA and CCIA groups respectively. The change in the CCIA group is much better as can be deduced from CoCs reflected from participants.

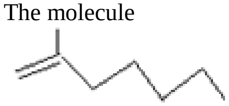
In relation to the same theme the number of participants with ACs in CG and IG remained the same–one both before and after intervention (appendix-B1). IUPAC naming system is confused with common naming system by the participants. But the full account of interview data from each PCT participant in the groups (CG and IG) indicated better change in the IG in terms of "features related to rules for naming hydrocarbons".

Features Related to Naming of Alkanes

Appendix-B2 gives summary of changes in understanding of PCTs in relation to features related to nomenclature of alkanes. It includes numerous ideas. In relation to this second theme different CoCs and ACs were reflected from participants. For example, before CIA two participants (C-03 and C-04) in the CG reflected the CoC "the molecule CH3CH(CH3)CH2CH3 is 2-methylbutane". Also, before CCIA three participants (IP-01, IP-02 and IP-03) in the IG reflected the same CoC. After intervention, five participants (C-01, C-02, C-03, C-04 and C-05) from CIA group and six participants (IP-01, IP-02, IP-03, IP-04, IP-05 and IP-06) from CCIA group echoed the CoC "the molecule CH3CH(CH3)CH2CH3 is 2-methylbutane". The change is comparable in the groups. One Participant (C-02) from CIA group and no participant from CCIA group reflected the COC "the molecule CH3CH(CH3)CH(CH2CH3)CH2CH2CH3 is 3-ethyl-2-methylhexane" before intervention. After intervention, five Participants (C-01, C-02, C-03, C-05 and C-06) from CIA group and five participants (IP-01, IP-02, IP-03, IP-04 and IP-06) from CCIA group reflected the same COC. There is better change in the CCIA in terms of this COC. In addition, the COC "an alkane molecule with three carbon atoms is propane" and "an alkane molecule with four carbon atoms is butane" were reflected by one participant (IP-02) before CIA. The same COCs were not reflected by any one of the CG participants both before and after CIA. After intervention, COCs "methane is an alkane", "pentane is five-carbon containing alkane" and "hexane contains six carbon atoms" were reflected by participants: IP-04, IP-02 and IP-02 (again) respectively.

In relation to the same theme six ACs were reflected by CG participants both before and after intervention with no conceptual change. But in the IG three and two ACs were reported before and after intervention respectively (appendix-B2). This shows there is conceptual change or gain in the IG though the ideas reflected from participants are few. The full account of interview data from each PCT participant in the groups (CG and IG) indicated better change in the IG in terms of "features related to alkane nomenclature".

Table 5. Features related to naming of alkenes and alkynes

Theme	Idea manifested	CG Participants				IG Participants			
		CC		AC		CC		AC	
		Pre	post	Pre	post	Pr	post	Pre	post
Features related to alkene nomenclature	The molecule  is 2-methyl-1-heptene	C-03, C-04, C-05, C-06	C-01, C-04, C-05				IP-01, IP-02, IP-03, IP-04, IP-05		
	The presence of double bond in bond line formula of alkene molecules with substituent confuses students			C-02, C-03				IP-02, IP-03, IP-04, IP-05, IP-06	
	Bond line formulas of alkene molecules confuse students				C-02, C-03, C-04				IP-05, IP-06
	Students confuse -ene of alkene molecules with -yne of alkyne molecules during naming				C-05				
Features related to alkyne nomenclature	The molecule  is 3-hexyne	C-05	C-02						
	Bond line formula confuses students in alkynes (students consider the linear four carbon system as two carbon system)			C-01, C-02, C-03, C-04	C-01, C-02, C-03, C-04, C-05, C-06			IP-01, IP-02, IP-03, IP-04, IP-05, IP-06	IP-01, IP-02, IP-03, IP-04, IP-05, IP-06
	The general formula of alkynes confuses students in naming (students associated naming with incorrect general formula)							IP-01	
	Alkynes are confused with alkyl groups				C-03				

Features Related to Naming of Alkenes

Table 5 above gives summary of changes in understanding of PCTs in relation to nomenclature of Alkenes. It includes a number of ideas. In relation to this third theme one COC and three ACs were reflected from participants. The COC was related to naming of the alkene: 2-methyl-1-heptene given in bond-line structural form in the interview protocol (Appendix-A). Before CIA four participants (C-03, C-04, C-05 and C-06) in the CG reflected the COC 'the compound is 2-methyl-1-heptene. After CIA, the participants who correctly responded were three: C-01, C-04 and C-05.

In the IG before CCIA, no participant predicted the name but after CCIA five participants (IP-01, IP-02, IP-03, IP-04 and IP-05) correctly named the compound as 2-methyl-1-heptene, which is much better change. In relation to the same theme one and two ACs were reflected by CG participants both before and after intervention with no conceptual change. But in the IG one AC was reflected before CCIA. Also, another one AC was reported after CCIA in the same group. Though there is difference in terms of the number of ACs, the IG had better change as the ACs change from one AC to two ACs in participants of CIA group (Table-5 above). The full account of interview data from each PCT participant in the groups (CG and IG) indicated better change in the IG in terms of "features related to alkene nomenclature".

Features Related to Naming of Alkynes

Table 5 above gives summary of changes in understanding of PCTs in relation to nomenclature of Alkynes. It includes different ideas. In relation to this fourth theme one COC and three ACs were reflected from participants. The CoC was related to naming of the alkyne: 3-hexyne, given in bond-line structural form in the interview protocol (Appendix-A). Before CIA one participant (C-05) in the CG reflected the CoC 'the compound is 3-hexyne'. After CIA, a different participant (C-02) reflected the CoC 'the compound is 3-hexyne' but with a big confusion. No participant from IG reflected the same CoC both before and after intervention. In relation to the same theme one and two ACs were reflected by CG participants both before and after intervention respective with no conceptual change. But in the IG two and one ACs were reflected but with much larger magnitude in relation to bond-line formula of the given structure. Students consider the linear four-carbon system as two carbon system. This AC was manifested by four CG participants (C-01, C-02, C-03 and C-04) before CIA and six participants (C-01, C-02, C-03, C-04, C-05 and C-06) after CIA. The same AC was manifested by both six CG participants (IP-01, IP-02, IP-03, IP-04, IP-05 and IP-06) before CCIA and after CCIA. One IG participant (IP-01) associated naming with incorrect general formula. One CG participant (C-01) had confused naming Alkynes with alkyl groups. The change in the groups is inconclusive in terms of Alkyne nomenclature.

Overall, the interview responses obtained from the PCTs indicate that these respondents had COCs and ACs about the nomenclature of aliphatic hydrocarbons. In three nomenclature related themes (aspects related to rules for naming AHC, aspects related to naming of alkanes and aspects related to naming of Alkenes) CCIA group made meaningful change. However, the change is inconclusive in terms of naming of Alkynes. When considered holistically, the IG participants made better changes. This may lead us to the conclusion that the PCTs in treatment/IG had much better understanding than those in the CG in nomenclature related concepts of aliphatic hydrocarbons.

Table 6 below shows that prior to intervention the CG participants experienced 10 ACs but after intervention/CIA they experienced 11 which shows, there is no improvement in understanding nomenclature related AHCs. Also, the same table depicts that the extensiveness of the same group participants.

Table 6. Summary of ACs and extensiveness in relation to nomenclature related concepts of aliphatic hydrocarbons

Area of Focus	Group	AC-pre	AC-post	AC-Gain or CC*	Ext-pre	Ext-post	Ext-Gain or CC*
Nomenclature of AHCs	CG	10	11	-1	18	20	-2
	IG	7	5	+2	20	13	+7

CC=conceptual change-*
indicated using plus sign (+) when there is decrease in AC frequency and extensiveness.
It is indicated using minus sign (-) when there is increase in AC freq. and ext.

Extensiveness of ACs shows no improvement as the participants extensiveness was 18 before intervention and 20 after intervention. Prior to intervention, the IG participants experienced 7 ACs but after intervention/CCIA they experienced 5, which shows there is improvement in understanding nomenclature related AHCs. Besides, the same table depicts that the extensiveness of the IG participants was with improvement. Extensiveness of ACs was 20 before intervention and 13 after CCIA. There is improvement in the IG both in terms of number of ACs and extensiveness proving the superiority of CCIA in relation to nomenclature of AHCs.

Table 7. Summary of CoCs of groups in Nomenclature of aliphatic hydrocarbons

Area of Focus	Group	COC-pre	COC-post	COC-Gain	Ext-COC pre	Ext-COC post	Ext- Gain
Nomenclature of aliphatic hydrocarbons	CG	13	17	+4	24	39	+15
	IG	11	21	+10	23	54	+31

Table 7 shows that prior to intervention the CG participants experienced 13 CoCs in total but after intervention/CIA they experienced 17 which shows, there is improvement in understanding nomenclature of AHCs. Also, the same table depicts that the extensiveness of the same group participants-24 before CIA and 39 after CIA. Extensiveness of CoCs showed improvement of 15 in the group.

Prior to intervention, the IG participants experienced 11 CoCs but after intervention/CCIA they experienced 21 CoCs, which shows there is improvement in understanding nomenclature of AHCs. Also, the same table depicts that the extensiveness of the IG participants with much improvement: 23 before CCIA and 54 after CCIA. Extensiveness of COCs showed improvement of 31, which is much higher than the CIA group value. There is much better improvement in the IG both in terms of number of ACs and CoCs proving the superiority of CCIA in relation to nomenclature.

DISCUSSION

Alternative conceptions and correct conceptions of aliphatic hydrocarbons in relation to nomenclature were reported in the findings of this study. The groups differ in terms of nomenclature related concepts after intervention. For instance, after intervention the CG participants experienced more ACs than the number of ACs before CIA but the IG experienced less ACs after intervention/CCIA. After the treatment the ACs decreased on the side of CCIA participant indicating improved level of understanding. After intervention the CG participants experienced more COCs than the number of COCs before CIA but the COCs of IG are much larger with much better improvement after intervention/CCIA. In terms of extensiveness much improvement was observed in the IG in relation to nomenclature of aliphatic hydrocarbons. The interview responses obtained from the pre-service chemistry teachers indicate that these respondents had ACs on nomenclature of aliphatic hydrocarbons. Scientifically acceptable ideas were reflected during the interview by this participant. The findings of this study concord with the findings of other study (Adu-Gyamfi et al., 2012, 2013, 2017; Omwirhiren & Ubanwa, 2016; Sarkodie & Adu-Gyamfi, 2015). For instance, Adu-Gyamfi et al. (2017), in their study, found that students had difficulties in naming structural formulae of branched- and substituted-chains of alkanes and alkenes, geometrical isomers, dienes, unbranched alkynes, primary and tertiary alkanols, diols, alkanoic acids, and alkyl alkanoates.

Conclusion

This study provided qualitative data to examine the effects of CCT-based instruction on understanding nomenclature related concepts of aliphatic hydrocarbons. The prime purpose was to look in to PCTs' understanding of nomenclature related concepts of AHCs. Particularly, three research questions were investigated in relation to this major objective. These research questions were what kind of explanations do PCTs have on nomenclature related concepts of AHCs before running conceptual change approach through the use of CCTs and conventional instructional approach?; what kind of explanations do PCTs have on nomenclature related concepts of AHCs after running conceptual change approach through the use of CCTs and conventional instructional approach?, and is there change in understanding nomenclature related AH concepts after running conceptual change approach through the use of CCTs and conventional instructional approach? This part of the study brings the findings together. Before CCT-based instruction, using semi-structured interview protocol participants were asked about nomenclature related concepts of AHCs. This was simply to know initial understanding of the PCTs. At the outset, the participants had poor understanding with ACs. After CCT-based instruction, the same protocol was used to gather qualitative data. Analyses of the data revealed that PCTs in the CCIA group had better understanding than those in the CIA group. That is, the PCTs who participated in the CCIA group showed enhanced understanding in nomenclature concepts than the PCTs in CIA group. The PCTs in the CCIA group explained nomenclature related concepts of AHCs at a more refined level than those in CIA group. The intervention enabled PCTs in the CCIA group explain their ideas better. The CG/CIA group harbored more ACs. There is reduced ACs with increased CoCs in the IG/CCIA group. The study confirmed supremacy of CCIA over CIA in nomenclature related concepts of AHCs.

Recommendations

Even though, there is no bold attempt to solve all the problems we have in science education in general and chemistry education in particular for good, this study has some recommendations on the basis of the literature review made, findings, discussions, and conclusions reached. The most important recommendation is to instructors of organic chemistry. While teaching organic chemistry in general and nomenclature related concepts in particular instructors should consider the prior knowledge of their students. Substantial ingenuity is required from instructors in this regard. This may necessitate instructors to depart from their comfort zone. Instructors should use or create materials that are based on conceptual change approaches (such as including students' prior knowledge in textual part) before presenting canonical views. This will serve as a stepping stone to all other nomenclature related exercises in chemistry. Also, instructors should show all the formulae (expanded structural formula, condensed structural formula and bond-line or line-angle formula) before taking learners to naming compounds related practice. As nomenclature is a drill-and-practice exercise in naming compounds (Shaw & Yindra, 2003), instructors should create an environment in which learners are involved in individual and group activities. Instructors/lecturers role should shift from unvarying instruction providers to facilitators involving students in different activities. In relation to alkyne molecules, learners assume four-carbon system as two-carbon system in naming. This problem was widespread among the PCT participants in this study. More exercises should be given to learners on bond-line formula related nomenclature as the learners face grave difficulty in naming triple-bond containing hydrocarbons with four-carbon systems in linear geometry. As far as the researcher's knowledge is concerned, this in-depth nomenclature related college level study could be said the first of its kind in Ethiopian as well as in international context. Thus, similar studies with large samples are warranted.

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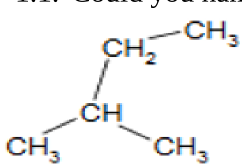
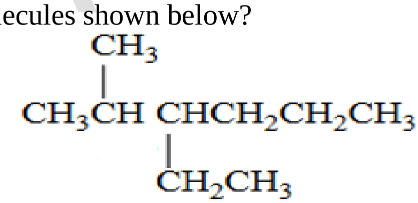
APPENDICES

Appendix-A

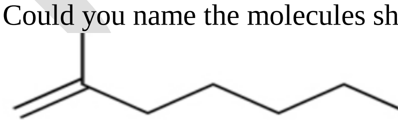
Interview Items

1. How do we name Alkanes? Explain.
    1.1. Could you name the molecules shown below?

A) 

B) 

2. How do we name Alkenes and Alkynes? Explain
    2.1. Could you name the molecules shown below?

A) 

B) 

Appendix-B1: Changes in Understanding of Nomenclature/Features Related to Rules for Naming HCs

Theme	Idea manifested	CG Participants				IG Participants			
		CC		AC		CC		AC	
		Pre	post	Pre	post	Pre	post	Pre	post
Features related to rules for naming hydrocarbons	In naming alkane molecules, the first step is identification of parent chain/longest chain selection	C-02, C-01, C-05, C-04, C-03	C-01, C-02, C-03, C-04, C-05, C-06	-	-	IP-01, IP-02, IP-03, IP-05, IP-06	IP-01, IP-02, IP-05, IP-06	-	-
	In naming alkene molecules, priority is given to the C-C double bond	C-01	C-01, C-02	-	-	IP-01, IP-02	IP-01, IP-02, IP-03, IP-04, IP-06	-	-
	In naming alkane molecules, after identification of parent chain/longest chain substituents should be given attention	C-01	C-01, C-02	-	-	IP-01	IP-01	-	-
	In naming alkane molecules with different substituents, alphabetical order of substituents should be considered	C-04, C-05	C-04, C-06	-	-	IP-06	IP-01, IP-02, IP-03, IP-05, IP-06	-	-
	In naming alkane molecules with different substituents, numbers are separated from numbers by commas	C-05	C-05	-	-	-	-	-	-
	In naming alkane molecules with different substituents, numbers are separated from letters by hyphen-2	C-04, C-05	C-05	-	-	-	-	-	-
	Alkane molecules take -ane during naming	C-05	C-03, C-05	-	-	-	IP-03, IP-04	-	-
	Alkene molecules take -ene during naming	C-04, C-05	C-0-3, C-04, C-05	-	-	-	IP-03, IP-04	-	-
	Alkyne molecules take -yne during naming	C-05	C-04, C-05	-	-	-	IP-04	-	-
	Alkane molecules can be named by using IUPAC rule	-	-	-	-	IP-01, IP-02, IP-03, IP-05	IP-02, IP-06	-	-
	Alkane molecules can be named by using common naming system	-	-	-	-	IP-01		-	-

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Appendix-B1: (Continued)

Theme	Idea manifested	CG Participants				IG Participants			
		CC		AC		CC		AC	
		Pre	post	Pre	post	Pre	post	Pre	post
Features related to rules for naming hydrocarbons (cont.)	In naming alkyne molecules, priority is given to the C-C triple bond	-	C-01	-	-	IP-01	IP-01, IP-02, IP-03, IP-04, IP-06	-	-
	For the same substituent occurring more than once in an alkane molecule we use terms like di-, tri-, tetra-, and so on	-	C-04	-	-	-	-	-	-
	In naming alkene molecules, substituents get attention after the C-C double bond	-	C-01	-	-	-	-	-	-
	In naming alkyne molecules, substituents get attention after the C-C triple bond of the alkynes	-	C-01	-	-	-	-	-	-
	In naming alkane molecules, the nature of the bond and substituents are given attention	-	-	-	-	-	IP-05	-	-
	In naming alkene molecules, the first step is identification of parent chain/longest chain selection	-	-	-	-	-	IP-05	-	-
	In naming alkyne molecules, the first step is identification of parent chain/longest chain	-	-	-	-	-	IP-05	-	-
	In branched/substituted alkane molecules numbering should be on the direction where substituents take the lowest possible numbers	-	-	-	-	-	IP-02	-	-
	In naming alkene molecules with different substituents, alphabetical order of substituents should be considered	-	-	-	-	-	IP-02, IP-03	-	-
	In naming alkyne molecules with different substituents, alphabetical order of substituents should be considered	-	-	-	-	-	IP-02, IP-03	-	-
	IUPAC naming system is confused with common naming system	-	-	C-03	C-03	-	-	IP-01	IP-04

Appendix-B2: Changes in Understanding of Nomenclature/Features Related to Alkane Nomenclature

Themes	Idea manifested	CG Participants				IG Participants			
		CC		AC		CC		AC	
		Pre	post	Pre	post	Pre	post	Pre	post
Features related to alkane nomenclature	The molecule CH3CH(CH3)CH2CH3 is 2-methylbutane	C-03, C-04	C-01, C-02, C-03, C-04, C-05	-	-	IP-01, IP-02, IP-03	IP-01, IP-02, IP-03, IP-04, IP-05, IP-06	-	-
	The molecule CH3CH(CH3)CH(CH2CH3)CH2CH2CH3 is 3-ethyl-2-methylhexane	C-02	C-01, C-02, C-03, C-05, C-06	-	-	-	IP-01, IP-02, IP-03, IP-04, IP-06	-	-
	An alkane molecule with three carbon atoms is propane	-	-	-	-	IP-02	-	-	-
	An alkane molecule with four carbon atoms is butane	-	-	-	-	IP-02	-	-	-
	Methane is an alkane	-	-	-	-	-	IP-04	-	-
	Pentane is five carbon containing alkane	-	-	-	-	-	IP-02	-	-
	Hexane contains six carbon atoms	-	-	-	-	-	IP-02	-	-
	Alkyl groups are considered as large and small alkane members appearing as substituents (naming alkanes with substituents confuses students)	-	-	C-01, C-02, C-03, C-04, C-06	-	-	-	-	-
	Alkyl group substituents in the alkane molecules are confused with alcohol functional group appearing in long chain alkane molecules	-	-	C-01	-	-	-	-	-
	Naming alkane molecules with substituents using alphabetical orders confuses students	-	-	C-03	C-04	-	-	IP-02	IP-03, IP-05
	Confusing total number of carbon atoms in alkane molecules with the number of carbon atoms in the longest chain	-	-	C-02	C-04	-	-	IP-01	-
	Alkane molecules can have double and triple bonds in their structures	-	-	C-01	-	-	-	-	-
	Naming system of alkane molecules has formula to be use	-	-	C-05	-	-	-	-	-

Appendix-B2: (Continued)

Theme	Idea manifested	CG Participants				IG Participants			
		CC		AC		CC		AC	
		Pre	post	Pre	post	Pre	post	Pre	post
Features related to alkane nomenclature (cont.)	Naming of alkane molecules is related to electronic configuration	-	-	C-01	C-01	-	-	-	-
	Naming substituted alkane molecules confuses students	-	-	-	C-03, C-04, C-05, C-06	-	-	IP-01, IP-03, IP-04, IP-05, IP-06	-
	Alkane molecules have double in their structure	-	-	-	C-06	-	-	-	-
	Naming system of alkane molecules has formula to be used	-	-	-	C-05	-	-	-	-
	Alkyl groups are confused with alkynes in naming alkanes when coming as a substituent	-	-	-	-	-	-	-	IP-05, IP-06

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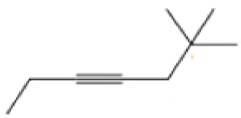
Appendix-C

Sample conceptual change text: Naming Alkynes

What is the IUPAC name of the following Alkyne? Explain.



(I) 4,4-dimethyl-2-pentyne
(II) 2,2-dimethyl-3-pentyne

Some students accept option I, because when alkynes are represented using bond-line formula they assume the place where the bonds curve or bend are the only place where we have carbon atoms of the alkyne. This is not accepted by scientific community, it is called a misconception.

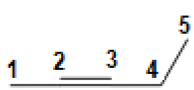
Some students accept option II, because when alkynes are represented using bond-line formula they assume numbering should start in the direction where we have more substituents to take the lowest possible numbers. This is not accepted by scientific community, it is called a misconception.

Naming alkynes with bond-line formula

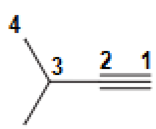
Alkanes are named using the same IUPAc rule which is applied in naming condensed structural formulas. For larger molecules, number the longest carbon chain that contains the triple bond from the end that gives the triply bonded carbons the lower numbers. Show the location of the triple bond by the number of its first carbon. Since Alkynes have linear geometry or shape, we draw them with four carbon atoms in a straight line while using bond-line representations.

Thus, the above molecule is 6,6-dimethyl-3-heptyne

Examples:

1) 

2-Pentyne

2) 

3-Methyl-1-butyne