TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 9, Sayı 4, Aralık 2012

Journal of
TURKISH SCIENCE EDUCATION
Volume 9, Issue 4, December 2012

http://www.tused.org

Giving Thought to Students' Alternative Conceptions in Stereochemistry: One Teacher's Basis for Pedagogical Content Knowledge Improvement

Stephen J.M. MDACHI[1]

[1]Dr., University of Dar es Salaam, College of Natural and Applied Sciences, Dar es Salaam-TANZANIA

Received: 16.11.2011 **Revised:** 14.06.2012 **Accepted:** 01.07.2012

The original language of the article is English (v.9, n.4, December 2012, pp.22-34)

ABSTRACT

This paper is a reflection on the author's own classroom experience. It focuses on the importance of paying attention to students' alternative conceptions and using these conceptions as the basis to improve the teacher's pedagogical content knowledge. Students' alternative conceptions are expressed as "incorrect" responses to questions asked. Instead of ending at discarding the "incorrect" responses, the author, in collaboration with the students, have taken time to analyze the responses so as to unveil the hidden meaning or cognitive implications therein. This reflective practice has proved useful in uncovering students' alternative conceptions and other content learning difficulties. Conversely, the same practice has helped the author to have another look at the content he teaches as well as the methods he employs and polish up both of these and blend them so as to come up with an integrated and contextualized 'subject matter for teaching' or pedagogical content knowledge.

Key Words: Alternative Conceptions; Learning Difficulties; Pedagogical Content Knowledge; Stereochemistry

INTRODUCTION

Chemistry, let alone organic stereochemistry, does not seem like it will be a lot of fun to a beginner. When first approached, chemistry can seem like an incomprehensible compilation of hundreds of chemical symbols, diagrams, millions of chemical formulas, never-ending number of chemical reactions and a host of other things. Therefore, for learners to come to understand and love the world of chemistry, the patience and careful guidance of a chemistry instructor/teacher are of paramount importance.

How though is this patience and careful guidance acquired? It might be tempting to answer this question by simply saying that these qualities are a result of a good grounding in the subject content-(chemistry in this case) and in pedagogy. However, this might at best only be partially true. While content knowledge (the actual subject matter that is to be learned and taught) and pedagogical knowledge (the process and practice or methods of teaching and learning) are essential elements of teacher knowledge, these two are not all the knowledge

---

Corresponding Author email: stephenmdachi@gmail.com

© ISSN:1304-6020

that a teacher should posses in order to be able to offer more effective assistance to learners. Another category of teacher knowledge, which is Pedagogical Content Knowledge (PCK), is vitally important. Pedagogical content knowledge is sometimes called subject matter for teaching and learning and it is distinct from the understanding of a content specialist.

This paper discusses how paying attention to students' alternative conceptions can assist a teacher to improve his/her PCK or subject matter for teaching and learning and thereby making her/him more resourceful to the students. The paper cites specific examples from a chemistry course content, which the author has been teaching for the past one and half decades. Firstly though, this paper briefly reviews the literature on the aforementioned elements of teachers' knowledge. This section aims at providing clarifications on the distinctive features of these components of teacher professional knowledge.

Knowledge Bases for Teaching

Teacher professional knowledge consists of academic Content Knowledge (CK), general Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK). Academic Content Knowledge (CK) refers to one's understanding of the subject matter that is to be learned and taught. In other words, content knowledge refers to knowing about the topic (Bucat, 2005; Mishra & Koehler, 2006). Knowledge of the subject matter includes familiarity with the concepts and their relationships, rules, problem solving skills, connections within and between topics, various forms of accurate information representation, and methods of acquiring and applying knowledge just to mention a few. On the other hand, pedagogical knowledge (PK) refers to one's understanding of teaching and learning processes independent of the subject matter (Bucat, 2005; Mishra & Koehler, 2006). It encompasses knowledge of: how the human brain works, how people learn, how people work in groups, how motivation is related to learning, strategies to elicit students' prior understanding, rational linking of instructional strategies to student learning, etc. (Carlson & Gess-Newsome, 2011; Etkina, 2007).

As pointed out earlier, the third component of teacher professional knowledge is pedagogical content knowledge (PCK). According to van Driel *et al.* (1998) the concept of PCK, which was introduced by Shulman in 1986, refers to teachers' interpretations and transformations of subject-matter knowledge in the context of facilitating student learning. It implies a transformation of subject-matter knowledge so that it can be used effectively and flexibly in the communication process between teachers and learners during classroom practice. Additionally, PCK encompasses understanding of common learning difficulties and alternative conceptions of students. As a consequence, teachers develop PCK from their own teaching practice. Some evidence supporting this claim indicates that unexpected student ideas trigger teachers to re-evaluate their pedagogy (Seymour, 2006). Furthermore, in-service coaching can also lead to PCK development.

The preceding description of PCK, though not thorough, shows that this aspect of teacher professional knowledge exists as the intersection of content and pedagogy. Consequently, PCK goes further than a simple consideration of content and pedagogy in isolation from one another. PCK represents the amalgamation of content and pedagogy into an understanding of how particular aspects of subject matter are ordered, tailored, and represented for teaching. We can diagrammatically symbolize PCK by connecting the two circles; one for content knowledge (CK) and the other for pedagogical knowledge (PK) so that their intersection represents PCK as the interplay between CK and PK (see Figure 1).

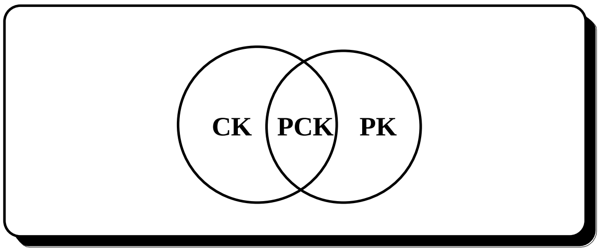

Figure 1: The Two Spheres of CK and PK are Joined by PCK

In today's world of science and technology one cannot ignore the role of technology in the teaching and learning process. Thus, in addition to CK and PK, technological knowledge (TK) is essential for developing good teaching. Moreover, rather than treating CK, PK and TK as separate bodies of knowledge, Mishra and Koehler (2006) argues that we need to look at these three components in pairs: pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and all three taken together as technological pedagogical content knowledge (TPCK). In other words, the interaction between CK, PK and TK give rise to four kinds of interrelated knowledge as depicted in Figure 2.

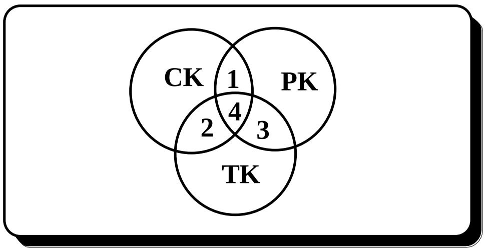

Figure 2: Overlap of CK, PK and TK lead to:
1 = PCK, 2 = TCK, 3 = TPK and 4 = TPCK

As mentioned earlier, this section is a very brief attempt at discussing the key elements of teacher professional knowledge. It is certainly not an exhaustive review of what constitutes teacher professional knowledge. Nevertheless, this short account gives one a glimpse at the complex nature of teacher professional knowledge and puts PCK, which is the focus of this paper, in its context. It was previously stated that PCK encompasses understanding of common learning difficulties and alternative conceptions of students. The section that follows briefly examines the scope and significance of students' alternative conceptions in science.

Students' Alternative Conceptions: The Scope and Significance of the Problem

Before discussing specific examples of students' alternative conceptions in stereochemistry, it would be prudent to briefly consider how prevalent the problem of students' alternative conceptions is in science and, in particular, chemistry. "Alternative conceptions" is deliberately used instead of "misconceptions" because the latter sounds condemnatory given the fact that these conceptions may have previously been useful to the learners. Conversely, the term "preconceptions" attempts to conceal the embarrassing fact that many of these alternative conceptions arise during the course of teaching. Students' alternative conceptions/frameworks refer to non-traditional ideas or notions about the natural world tenaciously held by students and are usually contrary to the ideas generally accepted by conventional scientists. These ideas are said to be persistently difficult to change and thus only carefully directed efforts by teachers will effectively address them (Wenning, 2008). The recognition and characterization of students' beliefs and prior knowledge seems to be crucial to helping them build scientific understandings (Talanquer, 2004).

Research in science education during the last forty years has shown that students enter science classes, including chemistry classes, with many preconceived ideas about the behaviour of the natural world (Talanquer, 2004). Some researchers believe that these beliefs are derived from earlier school and learning experiences as well as their current goals and motives. Other researchers point to misunderstanding, miscommunication, miseducation, and even a misapplication of well-established physical principles as possible reasons for the formation of alternative conceptions (Wenning, 2008). Still others cite common-sense reasoning, everyday analogies, visible effects and changes, and common (non-scientific) word usage as the causes for alternative frameworks in students' minds (Taber, 1998). They predict that some classes of alternative conceptions are culture-specific, a product of the analogies and metaphors common in particular cultures or built into particular languages, rather than being universal.

Regardless of their origin, many researchers agree that notions held by students that are contrary to those traditionally accepted by mainstream scientists are prevalent, persistent and difficult to change. If it is true - and I am convinced it is – that student' alternative conceptions are steadfastly held and stubbornly resistant to change, then this should be a cause for alarm to educators. This is because existing knowledge and understanding form the basis for deeper and lasting learning (Ausubel, 1968; Bilal & Erol, 2009). Thus, students will need to draw on their pre-instructional conceptions (existing 'knowledge') for bits that they can reorganize and reprocess to form new concepts. Consequently, instruction that fails to acknowledge and address these alternative conceptions will prove unable to foster real growth in understanding of the subject.

Ascertaining what the learner already 'knows' (alternative conceptions) contributes to the search for linking concepts and developing effective strategies for teaching. Recognising the concepts the students possess requires concerted effort on the part of the teacher to 'listen' to their students more effectively. In this context, 'listening' entails more than hearing the verbal answers and explanations from students and thereby affirming the efforts of those who "got it right" and ignoring the "wrong" answers; it involves considering how and why some attentive learners could come to the "wrong" verbal or written answer and, in so doing, explore all the possible meaning of the solutions that students can offer. This means implicit trust on the teacher's part that the "wrong" or unexpected answers were arrived at by some purposeful process and thus the "wrong" arguments merit breakdown to make the logical error perceptible (Coppola, 1995). At this point the instructor will have opened a 'window' into the learners' thinking and thus availing opportunities for her/him to erase the "wrong" and bring into focus the correct conceptions.

In the next section of this paper, the author discusses how 'listening' and positively reacting to students' alternative conceptions in his content-filled course module (called Stereochemistry and Reaction Mechanisms) has proved beneficial to his progress in teaching practice. On the other hand, the author believes that this improvement in pedagogical content knowledge (PCK) has benefited the students in return.

Students' Alternative Conceptions in Stereochemistry: Specific Examples and Their Significance in the Improvement of One Teacher's Pedagogical Content Knowledge

Having contextualized PCK and briefly explored the prevalence and significance of students' alternative conceptions in science, the author would like to discuss how paying attention to students' alternative conceptions in his content-laden subject matter course has assisted him to continually re-evaluate his pedagogy and thus improve his PCK. The course in question is called *Organic Chemistry II* and in particular the module dealing with *Stereochemistry and Reaction Mechanisms*. Organic Chemistry is one of the most important branches of the chemical sciences; it is central for the study of Pharmacy, Biochemistry, Molecular Biology, Biotechnology, and Medicine, just to mention a few. In the University of Dar es Salaam, Organic Chemistry is taught to undergraduate students through a number of courses. The two basic and compulsory Organic Chemistry courses for chemistry majors are *CH117: Organic Chemistry I* and *CH243: Organic Chemistry II*, which are taught in the first and second years of study, respectively. Our Organic Chemistry curricula, like any other chemistry curricula, incorporate many abstract concepts, which are essential to further learning in both chemistry and other sciences.

The abstract nature of some chemistry concepts along with other content learning difficulties contributes to the observation that many learners regard Organic Chemistry as a 'difficult' subject. For this reason, it has become my aim, and I believe the aim of other chemistry teachers, to reduce obstacles to learning and make the subject accessible in such a way that maximum meaningful learning can take place. One basic principle to achieve this, as pointed out by Sirhan (2007), is the importance of taking into account concepts already held by students. In the course of my teaching practice for nearly one and half decades, I have recognized a number of alternative frameworks in my students' minds. The sections that follow discusses some examples of these alternative conceptions, whether formed prior to or during the course of my instructions, and my response to fine-tune my pedagogical approaches so as to ease the learning difficulties.

(a) The Use of Solid and Hatched Wedges to Represent *Cis*- and *Trans*-Alkenes

The concept of *cis* and *trans* or geometric isomerism in alkenes is not new to second year chemistry majors. In fact, it is not supposed to be new even to first year students who studied chemistry at secondary school level. In *Organic Chemistry I* geometric isomers of alkenes are usually represented using the same type of bond lines or bonds. For example, the two 2-butenes, that is, *cis*-2-butene and *trans*-2-butene are represented as depicted in Figure 3. The concept emphasised here is that: *cis* isomers have identical atoms or groups of atoms on the same side of the double bond while *trans* isomers have identical atoms or groups of atoms on opposite sides of the double bond. This is quite correct, of course, as long as the three-dimensional (3-D) aspects of molecular structure are not considered.

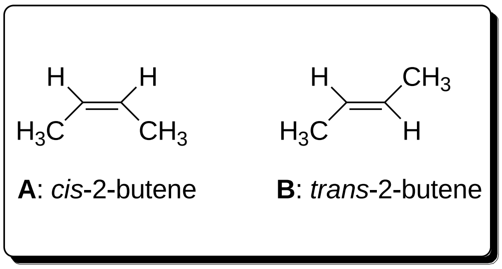

Figure 3: The Use of Plane Lines to Represent *cis* and *trans* Alkenes

In *Organic Chemistry II*, however, a new symbolism is introduced in the representation of geometric isomers of alkenes. This is done so as to capture the 3-D nature of molecular structures, which is the spirit of the *Stereochemistry and Reaction Mechanisms* course module. Here three types of lines are used: solid wedges (thick lines), hatched wedges (dashed lines) and normal or plane lines. Each type of lines has 3-D meaning attached to it. The solid wedges represent bonds projecting towards the observer; the hatched wedges represent bonds projecting away from the observer and the normal lines are bonds on the plane of the paper or any other writing media. Thus, the two isomeric 2-butenes are represented using this 'new' symbolism as shown in Figure 4.

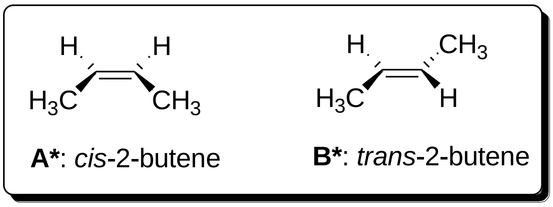
A*: *cis*-2-butene **B***: *trans*-2-butene

Figure 4: Using Three Types of Lines to Represent *cis* and *trans* Alkenes

In the course of my teaching practice, however, I have encountered unexpected responses such as those shown in Figure 5, which are judged as 'wrong' from the standpoint of the standards accepted by mainstream scientists. Unfortunately, the common practice of judging students' responses on a scale of right to wrong ends at this point without further deconstruction of the 'wrong' so as to uncover the *hidden meaning* or *cognitive implications* (*i.e.*, alternative conceptions) in the actual responses. Certainly, this practice distracts teachers' attention from the actual student work and prevents them from exploiting student thinking to inform their practice (Wenning, 2008).

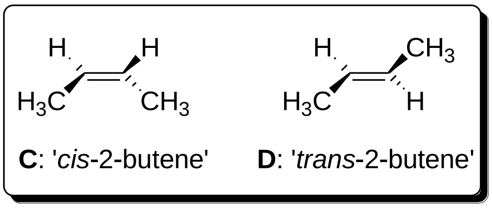
C: '*cis*-2-butene' **D**: '*trans*-2-butene'

Figure 5: '*Cis*-and *trans*-2-butene' as Incorrectly Conceived by Some Students

Reflecting (through student and teacher discussions) on the students' responses/answers in this case reveals that the "wrong" or unexpected answers were arrived at by some purposeful process using an alternative framework based on prior knowledge and, therefore, they deserve adequate analysis to unearth the logical error. According to these students structure **C** is a 'correct' representation for *cis*-2-butene because the identical atoms/groups of atoms (the **H**s and **CH_3**s) are on the 'same side' of the double bond as in structure **A** (Figure 3). In addition, the students feel that they have included the 3-D aspects of molecular structure by using the three kinds of bond lines. To these the students the 'same side' of the double bond in **C** means either towards the upper or lower part of the writing paper just as it was in **A**. Similar reasoning is likely used to arrive at structure **D** as *trans*-2-butene. Certainly, the prior knowledge from *CH 117* or even earlier instructions has influence in the reasoning of these students.

The preceding deconstruction reveals that the 'wrong' was rationally arrived at using a different mind framework. The error here is the failure to attach 3-D meanings to the type of bond lines. Had the students paid attention to this piece of detail they would have realised that the two **H**s as well as the two **CH_3s** in structure **C** are pointing in opposite sides of the double bond, hence, with some refinement, structure **C** could represent *trans*-2-butene. What refinement? Because double bonds are rigid and cannot be twisted or rotated, the refinement required here is removing the ‘twisted double bond’ connotation that **C** portrays. In fact, geometric isomerism in alkenes is a direct consequence of the rigidity or restricted rotation of the double bond.

Finally, the basic structure depicted in Figure 6 is emphasised and the fact that for an alkene geometric isomer to be *cis*, identical atoms/groups of atoms must be on the same type of bonds; *trans* alkenes must have identical atoms/groups of atoms on different type of bonds.

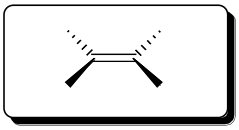

Figure 6: Basic 3-D Structure of a C-C Double Bond

(b) Representation of Molecular Structures as Seen through the Looking Glass: Mirror Images of Molecules

In discussing the concepts of chirality and enantiomerism, instructors cannot avoid mentioning objects and their mirror images as well as molecules and their mirror images. Teachers and textbooks alike assert that molecules, just like other objects, have mirror images. This analogy is, of course, true provided some limits are established. However, some unexpected answers come up when students are asked to represent a molecule and its mirror image using standard stereochemical projections such as Fischer Projections. An example is shown in Figure 7, where a student responds to a question that requires drawing the Fischer projections of (*R*)-2-hydroxypropanal and its mirror image (*i.e.*, its enantiomer, (*S*)-2-hydroxypropanal). The structure on the right hand side of the looking glass (the mirror image or (*S*)-2-hydroxypropanal) is definitely not written in accordance with scientifically agreed precepts. But why did the student come to this mirror image structure? Giving thought to this question during discussion with the students and my own instruction reveals that the student arrived at this structure by taking the object and mirror image analogy too far or beyond its limits of application. In addition, common-sense reason as well as visible effects and changes contributed to the formation of this alternative conception.

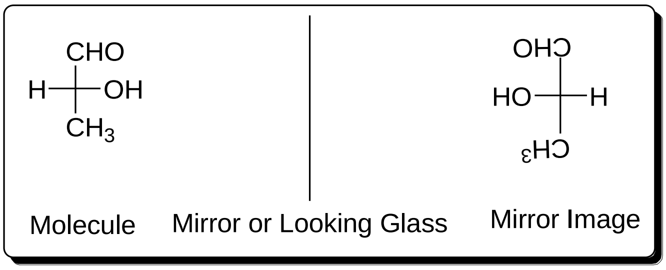

Figure 7: A molecule and its Mirror Image as Conceived by Some Students

Thus, despite the advantages of fitting in analogies into classroom instruction, it is worthwhile noting that an analogy may cause confusion by itself because students may have a different understanding of the point that the instructors wish to convey. Thus, finding the proper descriptions, limits and repetitively specifying the similarities and differences between the concepts and the analogies is necessary (Wu & Foos, 2010). In this case the limit is that the two groups on the horizontal bonds exchange positions – right become left and left become right, just as the mirror image of the right hand is the left hand and *vice versa*. Figure 8 shows the proper representation of (*R*)-2-hydroxypropanal and its mirror image (*i.e.*, its enantiomer, (*S*)-2-hydroxypropanal).

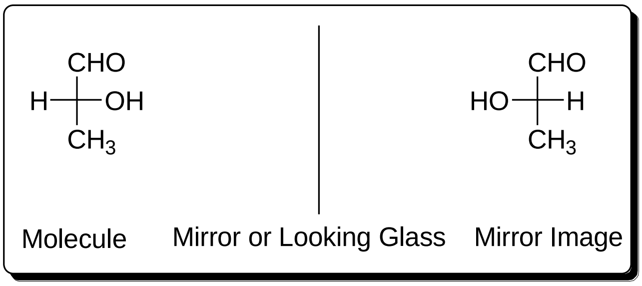

Figure 8: Proper Representation of a Molecule and its Mirror Image

(c) The Inter-conversions of Different Stereochemical Representations

The 3-D aspects of molecular structure are usually attended to by employing a variety of stereochemical projections. The common ones include: sawhorse projections, Fischer projections, Newman projections, perspective drawings (also called Wedge-and-Hatched lines formulas). In Cycloalkanes, particularly cyclohexanes, the planar, boat and chair conformations/projections are used. One objective of the *Stereochemistry and Reaction Mechanisms* course module is to enable learners to interpret the meaning of these projections so as to gauge the 3-D information they possess. One way to test this ability is to ask students compare structures having the same constitution but represented by means of different stereochemical projections. Students also can directly be asked to convert a given stereochemical projection into another type of projection. Quite a lot of 'weird' (from the expert's viewpoint) responses come out from students. For example, students asked to convert the perspective drawing (*R*)-2-butanol (that is, **E**) into a stereochemically correct Fischer projection for this enantiomer come up with **F** as the answer (Figure 9).

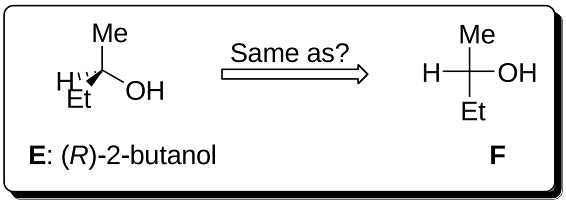

Figure 9:Incorrect Conversion of a Perspective Drawing into a Fischer Projection

What is the hidden meaning in this answer even though it is 'wrong'? As the class ponders on this question one realizes that the students surely are aware of the fact that a standard Fischer projection has to have the longest carbon chain in the vertical line (**Me** to **Et**). Common-sense dictates that in structure **E** the sequence **Me**-to-**Chiral carbon**-to-**Et** is approximately vertical and **H** is on the left while **OH** is on the right hand side leading to structure **F**. Acknowledging the deliberate efforts put forward by the students to reach at their answer makes easier for the instructor to provide the missing bits (bridging concepts) that, if considered, would have led to the correct response. In fact, what the student is missing here is the ultimate test for identity or otherwise of stereoisomers – the ***R/S*** or absolute configuration; if the student had assigned the ***R/S*** or absolute configuration for structure **F**, she/he would have realised that the latter has an ***S***-configuration (it is actually the enantiomer of **E**). To get back to stereoisomer **E** from **F,** in the form of a Fischer projection, one needs to just interchange the positions of **H** and **OH**. These bits plus a few others would help, I believe, to readjust the students' conception on this matter. Without doubt, such analysis as this helps the instructor to be more fluent in future presentations of the same topic to the benefit of the students.

(d) Stereochemical Projections of Disubstituted Cyclohexanes

In *Organic Chemistry II* the 3-D aspects of cyclohexanes are expressed using three types of projections: the planar or two-dimensional (2-D), chair and boat conformations. The first two are more generously used than the latter although for different reasons. The planar form of cyclohexane rings are simple to draw whereas the chair conformations, although complicated, are the most stable and accurate representations of cyclohexanes. Both the chair and boat conformations are 3-D structures. Two areas where students experience some learning difficulties with respect to stereochemical projections of disubstituted cyclohexanes will be discussed in this section, namely: (1) converting the planar (2-D) to chair conformation (3-D) and (2) interpreting some geometric isomers (*cis* and *trans* isomers) in chair conformations.

1. Converting a Planar (2-D) to a Chair (3-D) Structure

Care need to be exercised in converting a 2-D to a 3-D structure of a disubstituted cyclohexane so that the information held in the 2-D structure is faithfully transferred to the 3-D structure. For example, in the 2-D structure of a *trans*-disubstituted cyclohexane derivative the thick wedges represent bonds pointing up and the hatched lines are bonds pointing down. This information has to be accurately conveyed to the equivalent 3-D structure. Given the 2-D structure of *trans*-2-methylcyclohexanol (**G**) and adhering to the rules: wedges (or bold lines) in 2-D are the "UP" positions and dashes (or hatched lines) in 2-D are the "DOWN" positions and that UP is UP and DOWN is DOWN, regardless of being axial or equatorial, a student should arrive at **H** as the matching 3-D structure of the same compound (Figure 10).

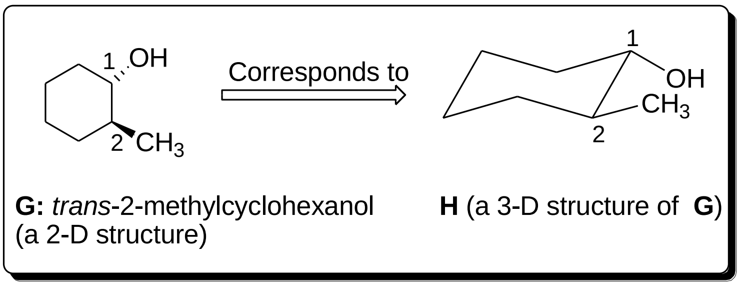

Figure 10: Conversion of a 2-D to a 3-D Structure of Substituted Cyclohane

Some students, however, may draw structure **J** (Figure 11) as the 3-D form of **G**. Indeed, **J** represents *trans*-2-methylcyclohexanol since the **OH** and **CH_3** groups are pointing in opposite sides – one is UP and the other is DOWN. Despite its apparent rationality, yet this condition (UP-DOWN) alone does not prove that the stereochemical information contained in **G** has been dutifully transmitted to its corresponding 3-D. One, but decisive, rule has been violated by the student in this case. In arriving at **J** it would seem like the **ring-to-CH_3** bond was a hatched (a DOWN bond) and, conversely, the **ring-to-OH** bond was a thick wedge (an UP bond). But this is just the opposite of structure **G**; in fact **J** represents the mirror image or enantiomer of **G** and, of course, of **H**. In other words, the 2-D structure, which can accurately be converted to **J**, is **K** and not **G**.

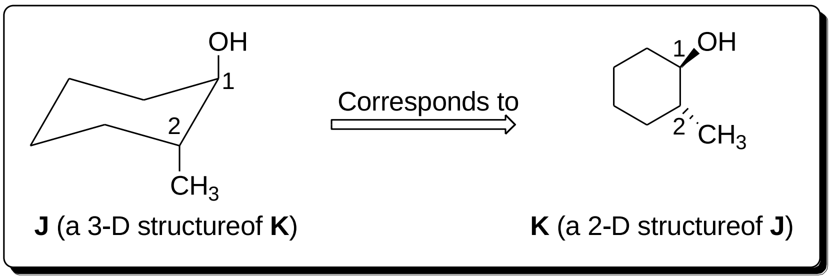

Figure 11: **J** and **H** are Enantiomers just as are **K** and **G**

The caution that the author will give to the students during discussions is: Make sure the "UP" and "DOWN" implications, as portrayed by the bold lines (thick wedges) and the hatched lines (dashes) in the 2-D structure, respectively, unfailingly get across to the 3-D; don't rely on the "UP" and "DOWN" in the 3-D, especially when the compounds are chiral. Additionally, students are advised to confirm if the ***R***/***S*** designations are in conformity with their arguments.

2. Interpreting some Geometric Isomers (cis and trans Isomers) in Chair Conformations

Over the years of teaching practice, the author has noticed some learners expressing doubts in accepting some representations of *cis* and *trans* isomers of disubstituted cyclohexanes. For example, when told that structure **L** (Figure 12) is *trans*-1,2-dimethylcyclohexane, some students do not accept this or they accept with great difficulties. What is in the minds of these students that make it so difficult to see the 'obvious'? The author has come to recognise that these students have developed an alternative framework, which does not allow the fitting in of this 'new' information. The root of this is likely to be the instruction itself (unfortunately!), common-sense reasoning as well as the appearance (visible effects) of the structures. During the instruction the terms "UP" and "DOWN", "opposite sides/directions" and "different sides/directions" are normally used interchangeably and synonymously to describe the relative positions of the substituent groups in *trans* isomers. This might cause some students to disagree because common-sense dictates that the two **CH_3s** are projecting toward the same point **X** (Figure 12); how can they be pointing in "opposite directions"?

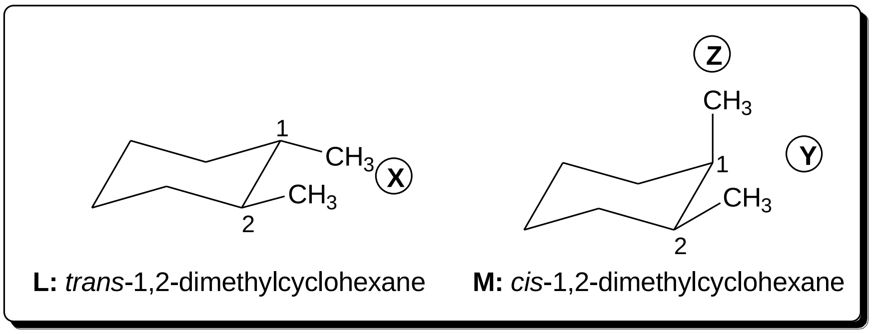

Figure 12: Common-sense may lead to incorrect nomenclature of geometric isomers **L** and **M**

Similarly, some students have difficulties in accepting that **M** (Figure 12) represents *cis*-1,2-dimethylcyclohexane. Why? Because one $\mathbf{CH_3}$ points towards point **Y** and the other $\mathbf{CH_3}$ points towards point **Z** and that **Y** and **Z** are not on the "same side" as *cis* geometry would require. What can be the antidote to the above mentioned problems? In a few words: Avoid using terms that may have ambiguous meanings. For *trans* isomers avoid the use of "opposite/different sides/directions" and stick to "UP" and "DOWN" while for *cis* isomers maintain the use of "UP and UP" or "DOWN and DOWN" and ovoid the use of "same side/direction". One more thing to remember: in both situations, "UP" is "UP" and "DOWN" is "DOWN" regardless of group's axial or equatorial position.

The above account has not exhausted all the learning and, of course, teaching difficulties as well as the students' alternative conceptions that the author has come across over the last fifteen years. These are just a representative few and they serve as examples and reminders for all practicing teachers to be watchful so as to recognize and address similar problems in order to foster students' real growth in understanding of any subject. The described actions that the author takes to rectify the different problems encountered does not represent new understanding in subject content but rather it is the interpretation, transformation and rearrangement of the same content with the aim of facilitating teaching and learning. In other words it is pedagogical content knowledge (PCK) and not content knowledge (CK). Since PCK is subject or topic specific, teachers have to cultivate this important aspect of professional knowledge every time they are allocated a new course to teach. The general implication of this is that teacher professional development does not end at one's graduation from college, it is a lifelong process.

CONCLUDING REMARKS

In this paper, the author has noted the observation that chemistry is regarded by many students as a "difficult" subject hence demanding the patience and careful guidance from dedicated teachers. These teacher qualities develop and are honed as teachers practice over extended time periods. Classroom practice affords teachers the opportunity to integrate content knowledge (CK) and pedagogical knowledge (PK). In so doing, teachers come to acquire a very important aspect of teacher professional knowledge, which is pedagogical content knowledge (PCK). PCK develops as practising teachers encounter problems such as students' alternative conceptions and other learning and teaching difficulties; situations that set off teachers to re-examine the content they teach as well as the methods they use and fine-tune both of these and blend them so as to come up with an integrated and contextualized 'subject matter for teaching' or PCK.

After establishing the fact that the development of one's PCK can be triggered by, among other factors, encounters with students' alternative conceptions as well as other content learning difficulties, the paper briefly explores the scope and significance of these teaching and learning problems. Subsequent to this brief review, the author has sampled specific examples of students' alternative conceptions and other learning difficulties from a course content he has taught over the last fifteen years. The author has attempted to show how paying attention to these difficulties and reacting positively to re-adjust his presentations has helped both the teacher and the learners.

The examples cited are a reminder to all instructors of an age old truth that students possess knowledge even before they come to our classes. This prior knowledge may enhance understanding of the current instruction or it may be a cause of learning difficulties. If instructors endeavour to ascertain this knowledge and reprocess so as to bring it to harmony with what they are teaching, both parties will reap benefits; the instructor would have enriched her/his PCK and, thus, enabled to render fruitful services to her/his clients – the students/learners. Teaching is not a neutral activity, and it is a joint venture. As teachers, we want to change the way our students think about the natural world, and we are concerned with causing change in a fruitful way. We can learn a great deal by listening and watching our students carefully as they learn.

The author is, therefore, convinced that paying attention to students' alternative conceptions and other learning difficulties does merit all the effort and urges teachers to put forth that effort for their professional improvement and students' benefits. The author cannot agree more with Ausubel (1968) who said: 'if I had to reduce all of educational psychology to just one principle I would say this: "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly"'.

Acknowledgements

I would like to thank my colleagues from the Faculty of Education, Mkwawa University College of Education (a Constituent College of the University of Dar es Salaam) for their valuable inputs during the preparation of this paper.

REFERENCES

Ausubel, D.P. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart and Winston.

Bilal, E. & Erol M. (2009). Investigating students' conceptions of some electricity concepts. *Latin-American Journal of Physics Education, 3*(2), 193-201.

Bucat, R. (2005). Implications of chemistry education research for teaching practice: Pedagogical content knowledge as the way forward. *Chemical Education International, 6*(1), 1-2.

Carlson, J. & Gess-Newsome, J. (2011, January). Assessing pedagogical content knowledge among secondary school science teachers. A paper presented at ASTE Conference Minneapolis, Retrieved on 15th July, 2011 from

www.bscs.org/pdf/BSCS _ASTE _PCK_ 2011.pdf

Coppola, B.P. (1995). Progress in practice: Using concepts from motivational and self-regulated learning research to improve chemistry instruction. *New Directions for Teaching and Learning, 63*, 87-96.

Etkina, E. (2007). Pedagogical content knowledge. A paper retrieved on 12th July 2011 from http://gse.rutgers.edu and http://www.islephysics.net.

Mishra, P. & Koehler, M.J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Records, 108*(6), 1017-1054.

Seymour, J. (2006). How does pedagogical content knowledge emerge from classroom teaching? *PME-NA 2006 Proceedings, 2*, 805-808.

Sirhan, G. (2007). Learning difficulties in chemistry: An overview. *Journal of Turkish Science Education, 4*(2), 2-20.

Taber, K. S. (1998a). An alternative conceptual framework from chemistry education. *International Journal of Science Education, 20*(5), 597-608.

Taber, K.S. (1998b). The sharing out of nuclear attraction, or 'I can't think about physics in chemistry'. *International Journal of Science Education, 20*(8), 1001-1014.

Talanquer, V. (2004). Common-sense chemistry: A model for understanding students' alternative conceptions. *Journal of Chemical Education, 15*(1) 1-6.

van Driel, J.H., Verloop, N. & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35*(6), 673-695.

Wenning, C.J. (2008). Dealing more effectively with alternative conceptions in science. *Journal of Physics Teacher Education Online, 5*(1), 11-19.

Wu, C. & Foos, J. (2010). Making chemistry fun to learn. *Literacy Information and Computer Education Journal, 1*(1), 1-5.