ICT-enhanced Chemistry Teachers Development

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Introduction

The ICT-enhanced teacher development (ICTeTD) model is conceptualized “as the process in which ICT enhances the social, personal and professional development of teachers, and as one in which the enhancement of development in one aspect cannot happen unless the other aspects develop as well. ICTeTD is regarded as context-dependent since social, personal and professional development of teachers as well as their use of information and communication technologies (ICTs) are influenced by the context in which the teachers are operating” (Temechegn, 2011: p.8).

The ICTeTD model is described as a tetrahedral framework of technological pedagogical content knowledge (TPCK) (figure 1). It conveys the transformed nature of TPCK from its constituent content knowledge, pedagogical knowledge and technological knowledge. “The tetrahedral framework recognizes and indicates the progressive, transformed and dynamic nature of TPCK. Furthermore, the entire knowledge base for teachers is imbedded within a context” (Temechegn, 2011: p 18).

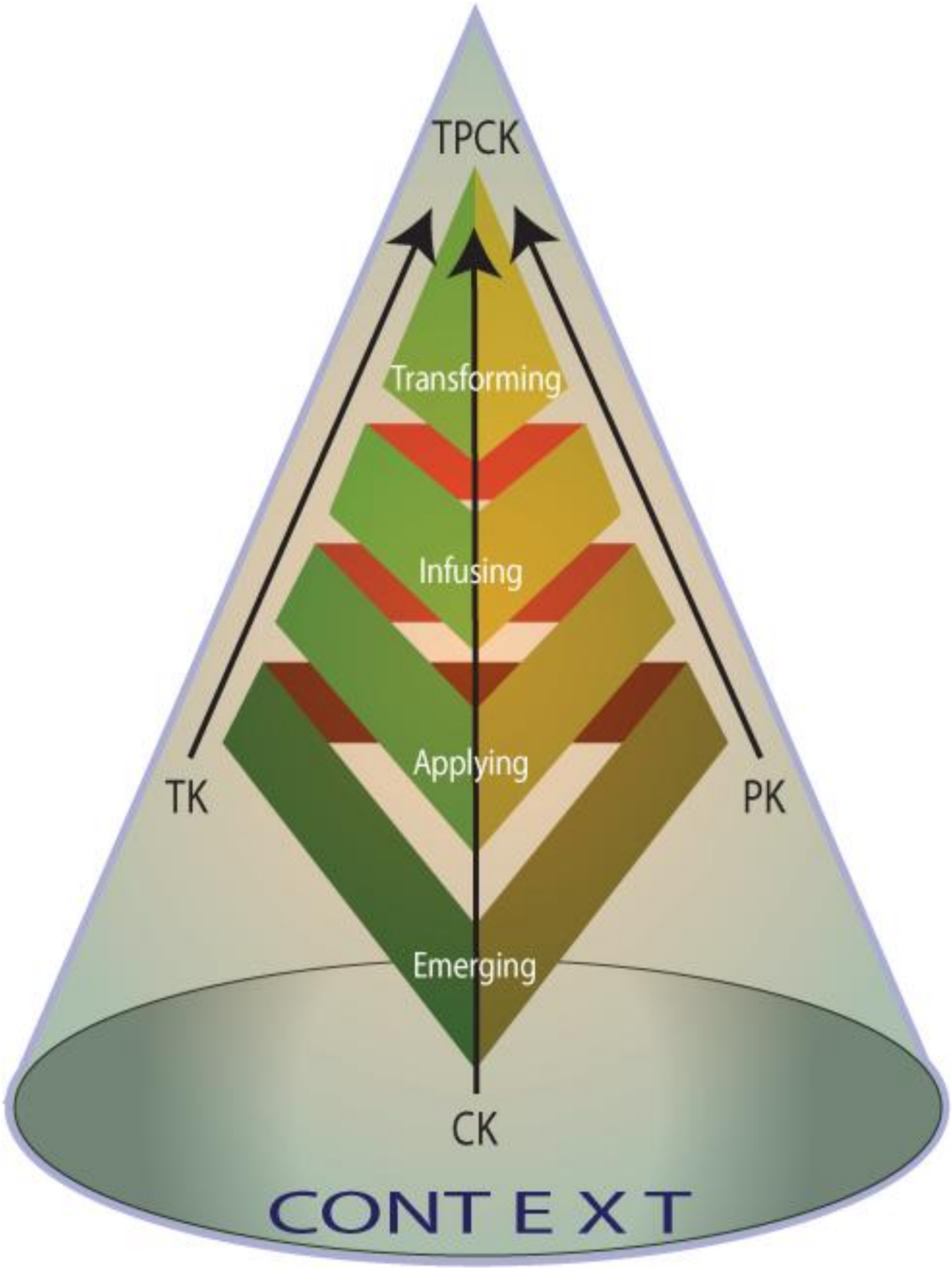


Figure 1. ICTeTD Model (Temechegn, 2011: p. 19)

In the ICTeTD model (figure 1), technological knowledge (TK) and pedagogical knowledge (PK) are in the plane of the page whereas content knowledge (CK) is outward (towards the reader) of this page. All the three knowledge areas are at the same level of (have equal importance) forming the pyramid. The pyramid is made of 'fleshes' of TPCK--a transformed knowledge through proper interactions of CK, PK and TK (Temechegn, 2011).

Temechegn further states that the triangular face on the right side of figure 1 and formed by its base CK and PK represents PCK (pedagogical content knowledge), that on the left side formed by CK and TK represents TCK (technological content knowledge), and the back face formed by TK and PK represents TPK (technological pedagogical knowledge). The triangular face formed by CK, PK and TK is the base of the pyramid and represents the basic level of TPCK. In going towards the top of the pyramid, each triangular plane parallel to the base of the pyramid represents a certain degree of progressively higher continuum of TPCK developed by teachers. Teachers in this tetrahedral model of ICTeTD progress from the initial stage of being aware of TPCK through to being creative and innovative TPCK professionals (that is, from the bottom of the pyramid through to the top of it).

The continuum of transformed knowledge (TPCK) in figure 1 is categorized into four interrelated stages of development, namely *emerging TPCK, applying TPCK, infusing TPCK* and *transforming TPCK.* It should be understood that each stage in the figure represents a continuum of triangular faces/planes of the pyramid parallel to its base, and that the space between successive stages is added merely for visibility of the three dimensional model (Temechegn, 2011).

Emerging TPCK represents an initial stage of TPCK development by teachers. Teachers at this stage are beginning to be aware of the nature and importance of TPCK in their social, personal and professional development.

Applying TPCK is characterized by teachers who started to use TPCK-based programs/lessons developed by others. Teachers at this stage also start engaging themselves in discourses among themselves about what it means to be a teacher of TPCK-based curriculum, about their feelings and students' feelings while experiencing the TPCK-based curriculum, etc.

Infusing TPCK represents a stage of TPCK development by teachers who started to modify, adapt and initiate their own TPCK-based materials/lessons/modules for diverse group of learners. Teachers at this stage have the capability to mentor/advise other teachers about the what and how of TPCK-based educational programs. They can also comfortably adapt themselves to new situations in those programs. They can design and carryout TPCK-based inquiry/research activities to solve personal and institutional problems.

Transforming TPCK is the highest stage of social, personal and professional development of 21st century teachers. Teachers at this stage are creative and innovative in that they not only develop new and appropriate TPCK programs for their institutions but also theorize about the nature and methodologies of TPCK.

All these progressively higher levels of teacher development are imbedded within a given context, represented as a cone surrounding the pyramid. Context is understood here as involving the cultural, political, psychological, and related factors that influence teacher development.

Emerging TPCK in Chemistry

The emerging stage is linked with institutions at the beginning stages of ICT development. Such institutions begin to purchase computer equipment and software or perhaps have had some donated. In this initial phase, administrators and teachers are just starting to explore the possibilities and consequences of adding ICT for school management and the curriculum. The institution is still firmly grounded in traditional, teacher-centered practice. For example, Chemistry teachers in such institutions/schools tend to lecture and provide Chemistry content while students listen, take notes, and are assessed on the prescribed content. The institution/school provides discrete time periods for each subject. Learners' access to technology is through individual teachers. A curriculum that focuses on basic skills and an awareness of the uses of ICT assists movement to the next approach (Temechegn, 2012).

The focus in the emerging stage is on the basic technical functions and uses of ICT. This stage involves teachers' competencies in word processing, spreadsheet, database, presentation software and uses of Internet and e-mail. Besides the kinds of ICT competencies relating to concepts and operations, there are many social, legal and ethical issues associated with the use of ICT about which teachers need to know. The facilities required to access information easily from remote sources, the ability to download it to a personal computer, and the utilization of the information in a classroom assignment, brings with it a host of social, legal, and ethical issues relating to copyright, evaluation of information sources, and appropriate forms of acknowledging electronic information.

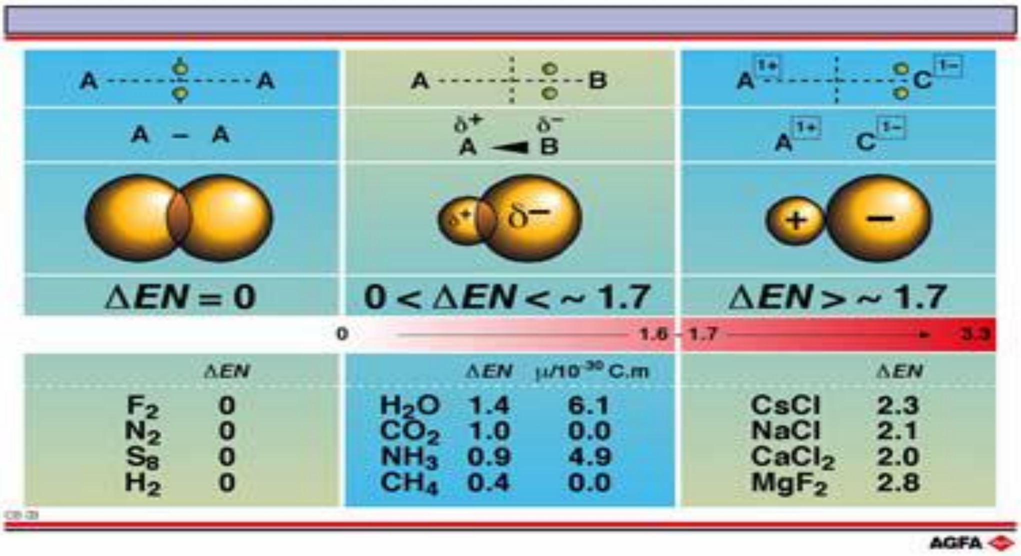
The emerging TPCK stage in Chemistry can be applied using productivity tools like Microsoft word, Excel, PowerPoint, etc. Let's say that a Chemistry teacher has taught the states of matter in the previous sections of his/her period and now it is time to teach (as per the Chemistry curriculum) the structures of simple organic molecules like methane, ethane, propane, etc. The usual way is to present the nomenclature and their structures on the chalk board (which is a two dimensional object—2D). It is, however, learnt through chemistry education research that most students could not understand the three dimensional (3D) nature of the structure of the molecules. Furthermore, it is time consuming for the Chemistry teacher to draw the structures every time he/she wants to teach/review the structures for different sections of a grade level.

At the emerging stage, the teacher is expected to have the skills of preparing a power point presentation (ppt) such as for simple organic molecules. Take a look at [Simple Organic Molecules](#).

The length of contents of the lesson can be increased at any time depending on the particular topic the teacher is teaching. What is important here is that, when using the ppt (technological knowledge) in the classroom, the teacher needs to point out that students usually misunderstand the structures drawn on chalk boards and in some textbooks as being 2D (pedagogical knowledge) rather than 3D (content knowledge).
It is also possible to prepare a ppt for use as an assessment tool. Let's assume that the Chemistry teacher wants to know to what extent his/her students understood the content he/she has taught them regarding the states of matter. One way is to prepare a ppt involving pictures of actual objects and ask them to write down their responses on a sheet of paper when each slide is shown to the whole class. Note that such an approach can accommodate a large number of students in one class as long as the ppt is visible to every student. To illustrate this approach, click here Solid Liquid Gas.

In addition, the Chemistry teacher at the emerging stage can use transparencies prepared by others. One example is the UNESCO chemistry teaching material entitled DIDAC. See the following examples extracted from that material. These slides can be copied and/or printed onto overhead transparencies and be used for teaching in the Chemistry classroom.

Example 1: The link between the differences in electronegativity and the type of bonding

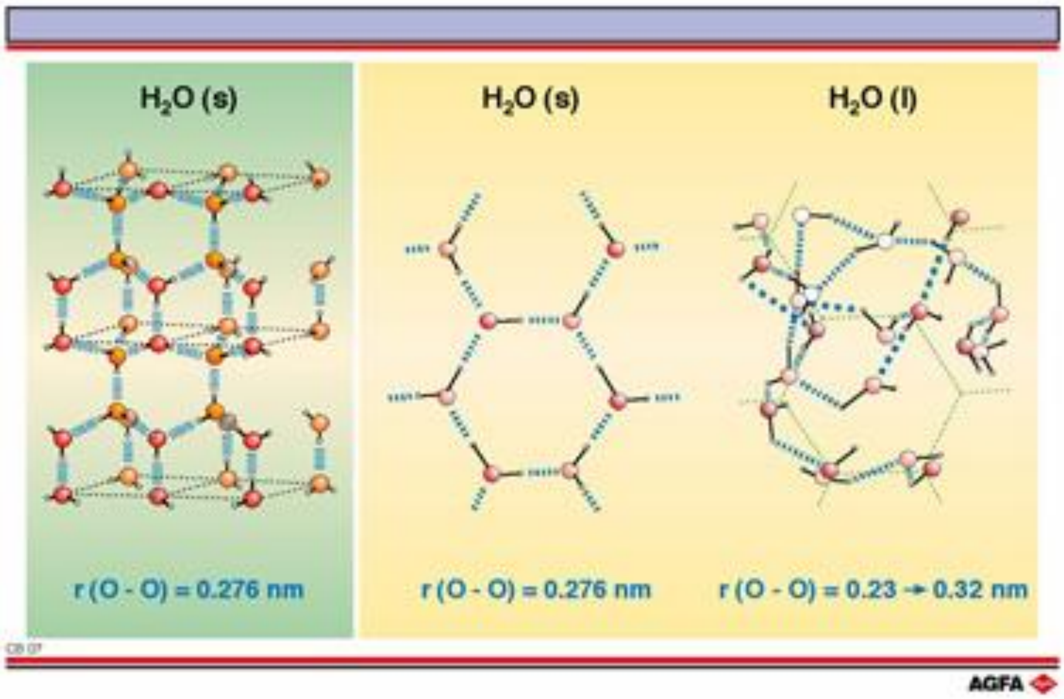


Beware!

- **Substances built up of molecules which have clear polar bonds e.g. H_2O, NH_3, CO_2, CH_4 do not necessarily behave as polar substances.**
- **It is possible that the various polar bonds in a molecule cancel each other out, or as it were, "neutralize" each other.**

- **The direction and charge of the dipole moments generated by the polar bonds has to be taken into consideration, as does the resulting dipole moment for the whole molecule.**
- **CO_2, for example, is an apolar molecule with two polar bonds between the C and O atoms, each having opposite dipole moments. H_2O and NH_3 are polar molecules, CH_4 is apolar.**
- **Nonetheless, all of these compounds contain polar chemical bonds.**

Example 2: Structure of water as an example of hydrogen bonding



Left side, the three-dimensional representation of the structure of ice:

- The lattice contains a hexagonal structure. Each water molecule has four neighbors in a tetrahedral configuration.

⇒ A very open structure that has a very low density.

- When it is warmed (to 4° C) the hydrogen bonds are partially broken resulting in a denser structure. On further warming the thermal agitation of the water molecules increases and the density again decreases.

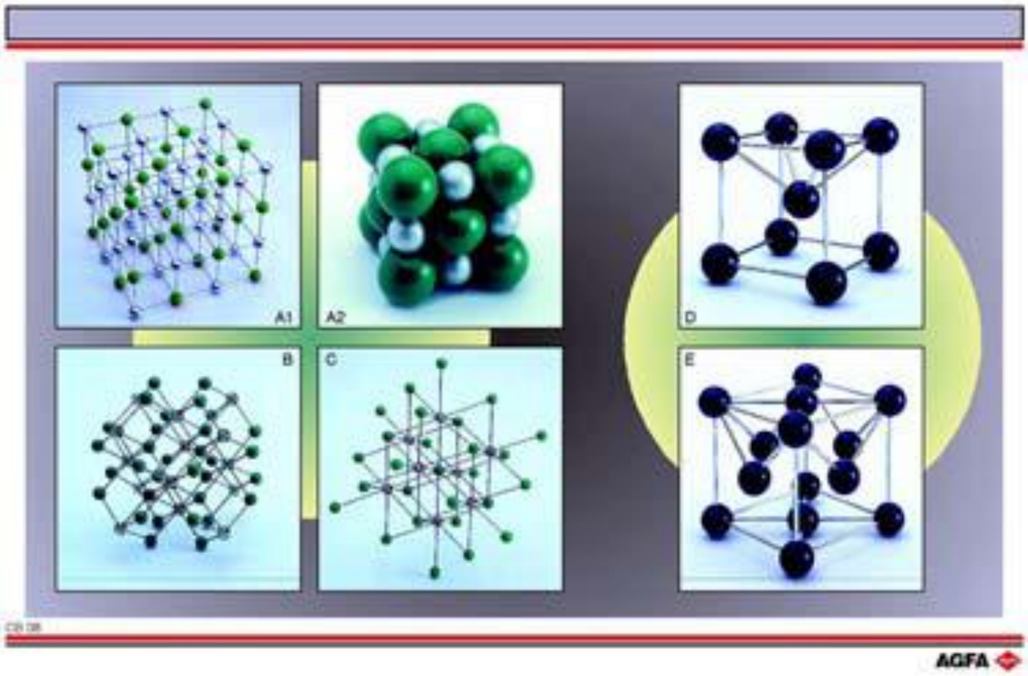
Right side compares the structure of ice with the structure of water at a given instant in time (computer simulation):

- The hexagonal pattern of ice is shown by a light green dotted line
- The blue dotted line represents the hydrogen bonds. The shorter the distance between the dots the shorter the hydrogen bond.
- The color of the oxygen atom indicates to what extent it is out of the plane: white atoms are in the plane whilst dark brown atoms are between 0.7 and 1.0 nm in front of the plane. The light pink and red

atoms are at an intermediate distance; the darker the color the further the atom is in front of the plane.

Hydrogen bonds are essential for the spatial configuration of biologically important molecules such as proteins.

Example 3: Lattice Structures



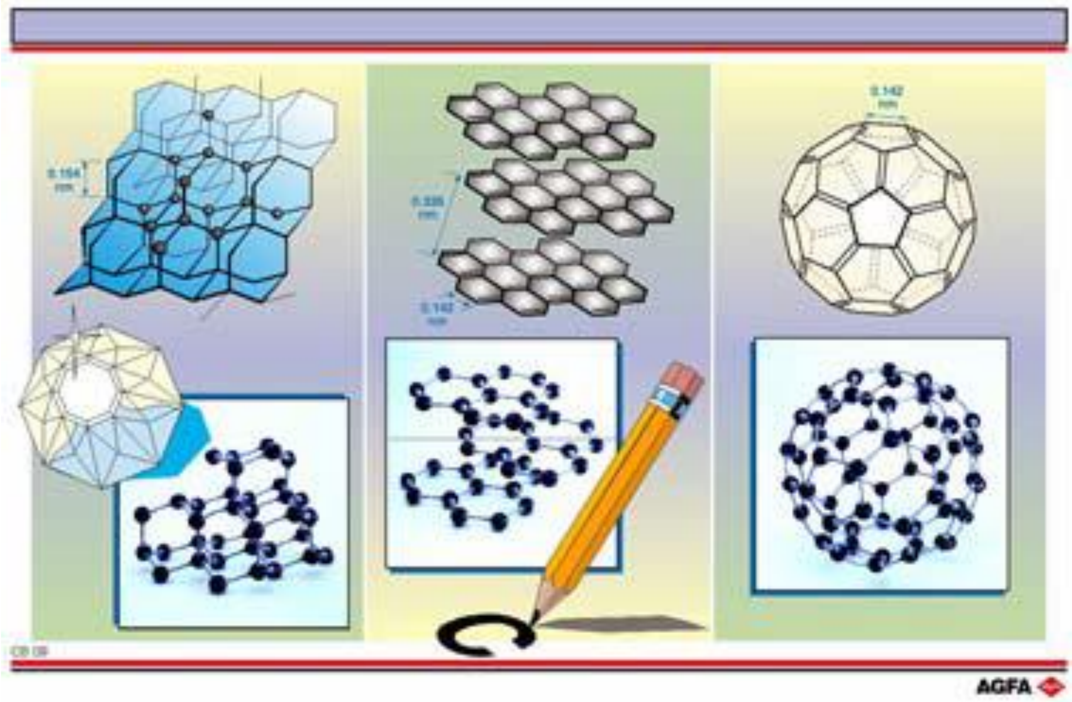
Ionic Lattices

- **A1 = NaCl (open structure)**
- **A2 = NaCl (close-packed structure)**
- **B = CaF_2**
- **C = CsCl**

Metal Lattices

- **D = Fe (bcc unit cell)**
- **E = Cu (fcc unit cell)**

Example 4 : Allotropes of Carbon: Diamond, Graphite and Fullerenes



Diamond (left):

- Each atom is bonded via sp3-hybrid orbital to four atoms in a tetrahedron.
- All four valence electrons are paired in bonding orbitals.

⇒ Diamond is stable, being an insulator with a high melting point and the hardest substance on earth. It is transparent and has a high refractive index.

Graphite (middle):

- Each atom is bonded to another three atoms by sp2-hybrid orbitals.
- Consists of layers of flat, hexagonal rings of carbon atoms. The layers are held together by London force. They slide easily over each other.

⇒ Graphite is a soft, black material and is used as a lubricant.

- Each atom contributes three valence electrons to the three s-bonds. The fourth electron forms a π-bond with a neighboring atom. This is not a localized bond but it moves freely throughout the π-system.

⇒ The electrical conductivity parallel to the layers is high, but is low perpendicular to the layers.

Fullerene, C_{60} (right):

- This molecule consists of 60 carbon atoms divided into 20 six-rings and 12 five-rings, like a football.
- In 1996 Robert F. Curl, Sir Harold W. Kwoto and Richard E. Smalley received the Nobel Prize for chemistry for this discovery.

Applying TPCK in Chemistry

In the applying stage, Chemistry teachers use ICT for professional purposes, focusing on improving the teaching of their subject so as to enrich how to teach with a range of ICT tools. The applying stage is linked with institutions in which a new understanding of the contribution of ICT to learning has developed. In this phase, administrators and teachers use ICT for tasks already carried out in institution management and in the curriculum. Teachers still largely dominate the learning environment.

For example, instruction may be supplemented with ICT such as electronic slide presentations and word-processed handouts. Students receive instruction and add notes to teacher prepared handouts. They use ICT tools to complete required lessons and are assessed on prescribed content. The school/institute provides discrete time periods for each subject with some flexibility to combine subjects and time periods. Learner access to technology is through one or two classroom computers and computer labs. Until now, ICT has been taught as a separate subject area. To move to the next phase, the institute chooses to implement an ICT-based curriculum that increases ICT across various subject areas with the use of specific tools and software (Temechegn, 2012).

Let's assume that the Chemistry teacher wants to teach the topic Elements and Atoms to his/her students. Apart from preparing and using a powerpoint presentation by him/herself, as in the case of the emerging TPCK, the teacher can also download from the Internet lessons that teach the topic and prepared with a screenshot software and he/she can project it to the classroom. Such materials have also audio components that the students can listen to. The teacher can stop the multimedia lesson at any time if he/she wants to emphasize a certain point in the lesson and/or to ask questions that the student could predict/hypothesize before listening and watching the next segment of the recorded lesson. To illustrate this, click here Elements & Atoms.

Infusing TPCK in Chemistry

In the infusing stage, Chemistry teachers infuse ICT in all aspects of professional life to improve student learning and the management of learning processes. ICT enables teachers to become active and creative in stimulating and managing the learning process, by infusing a range of preferred learning styles and uses of ICT in achieving educational goals. Teachers are required to master authoring tools, animation tools and multimedia tools to develop instructional software in Chemistry (Temechegn, 2012).

The infusing stage is linked with institutes/schools that now have a range of computer-based technologies in laboratories, classrooms, and administrative areas. Teachers explore new ways in which ICT changes their personal productivity and professional practice. The curriculum begins to merge subject areas to reflect real-world applications.

For example, Chemical content is provided from multiple sources, including community and global resources through the World Wide Web. Students' access to technology enables them to choose projects and ICT tools that stimulate learning and demonstrate their knowledge across subject areas. The Institute/School provides the flexibility to combine subjects and time periods. Learners have more choices with regard to learning styles and pathways. They take more responsibility for their own learning and assessment. ICT is taught to selected students as a subject area at the professional level. To advance to the next phase, institutions choose an ICT curriculum that allows a project-based, ICT-enhanced approach. These schools begin to involve the community more in the learning environment and as resource providers (Temechegn, 2012).

At the infusing TPCK stage, the Chemistry teacher starts designing his/her own lessons by using free software available for educational purposes. One such software is the Advanced Chemistry Development (ACD/ChemSketch). As stated in the reference manual, ACD/ChemSketch is a chemical drawing software package from ACD/Labs designed to be used alone or integrated with other applications. ChemSketch is used to draw chemical structures, reactions, and schematic diagrams. It can also be used to design chemistry-related reports and presentations.
ACD/ChemSketch has the following major capabilities:

• **Structure mode** for drawing chemical structures and calculating their properties.
• **Draw mode** for text and graphics processing.
• **Molecular Properties** calculations for automatic estimation of:
o Formula weight
o Percentage composition
o Molar refractivity
o Molar volume
o Parachor
o Index of refraction
o Surface tension
o Density
o Dielectric constant
o Polarizability
o Monoisotopic, nominal, and average mass

ACD/ChemSketch can stand alone as a drawing package or act as the “front end” to other ACD/Labs software such as the NMR Predictor engines. Once ACD is installed in the computer, the Chemistry teacher can follow the instructions/user manual for drawing and animating, for instance, the structures of organic molecules.

Transforming TPCK in Chemistry

The transforming stage is linked with institutions that have used ICT creatively to rethink and renew their institute. ICT becomes an integral part of daily personal productivity and professional practice. The focus of the curriculum is now much more learner-centered and integrates Chemistry in real-world applications, both in real and virtual environments.

For example, students may work with community leaders to solve local problems related to water by accessing, analyzing, reporting, and presenting information with ICT tools. Learners' access to technology is broad and unrestricted. They take even more responsibility for their own learning and assessment. ICT is taught as a subject area at an applied level and is incorporated into all vocational areas. The institution has become a centre of learning for the community. Teachers need to master special software, learning management system, simulation and modeling tools, networking and various web tools, in order to innovatively transform the teaching and learning system.

At this stage, the Chemistry teacher is a creative and innovative person. He/she can design, implement and evaluate a range of technological tools in Chemistry teaching and across the curriculum. At this stage the Chemistry teacher should be able to design school chemistry website at least using opensource software like Joomla. He/she should also be able to use the content management software like Moodle for wider and online learning.

Further Reading

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