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LEARNING AND UNDERSTANDING THE CONCEPT OF IONS AND IONIC BONDING IN SENIOR SECONDARY SCHOOL CHEMISTRY CURRICULUM WITH THE AID OF COURSEWARE

[1]Hassan Aliyu & [2]Abdulrashid Abubakar Garba

[1]Department of Science Education, Faculty of Education,
Sokoto State University (SSU), Sokoto, Nigeria
nagoronyo@gmail.com/aliyu.hassan@ssu.edu.ng
https://orcid.org/0000-0003-4929-3126

[2]Department of Chemistry, Faculty of Science,
Sokoto State University (SSU), Sokoto, Nigeria

Abstract

The maturity of digital technologies has given way to new design methods that now allow institutions to more effectively address the unique set of specific learner needs in order to sustain their academic journey. Today, instructional software like courseware is designed to address specific challenges in learning and understanding a concept. Courseware is a collection of teaching materials in digital format delivered through software, multimedia, and data transmission systems. It is software containing educational content, instruction, and instructional strategies. Hence, courseware was used to compare the performance of students who received direct instruction to those who received instruction through courseware to see how well students understood ions and ionic bonding. It adopted a quasi-experimental research design where 32 students participated in the activities. The performance of these students was evaluated before and after receiving interventions. The results reveal that those students who received instruction through courseware understood the concept of ions and ionic bonding better than those who received direct instruction. Chemistry learning is heavily reliant on students' abilities to comprehend microscopic descriptions of how substances are formed and what functions they serve. Other difficult areas of chemistry, such as solubility, equilibrium, covalent bonds, hydrogen bonds, molecule geometry, the element activity concept, chemical equilibrium, dissolution, electrolyse, and batteries, necessitate courseware testing.

Keywords: Ions, Ionic bonding, Courseware, Chemistry, Learning

Introduction

The learning and understanding of the basic concepts in chemistry relies on the conceptualization, comprehension, and understanding of chemical bonding, including how, why, where, and when it will occur. Unfortunately, both teachers and students perceived the teaching and learning of the concept of chemical bonding as challenging or difficult due to its abstract nature, leading to misconceptions. The task of learning chemistry at the macroscopic, microscopic, and symbolic levels by the chemistry triplet requires the student to make use of subject-specific as well as highly abstract verbal and nonverbal thinking skills. Thus, in a "regular" classroom setup, teachers try to transform abstract chemical content into a teachable form, mainly through verbal explanations accompanied by parallel symbolic representations of content on the board. Students must simultaneously pay attention to both the verbal expressions and visual input and, through their integration, make sense of them (Marchak et al., 2021). This reveals that chemistry constitutes the core of the metacognitive processes needed to understand a concept and apply it to any form of problem solving. As it affects the learning and teaching of both theoretical and experimental concepts of the subject, visual understanding is a conceptual competence based on verbally mediated sense-making processes. These representational competences are essential for assigning the correct meaning to abstract chemical content through visualization and generating correct mental models, and they cannot be overlooked.

The concepts of chemical bonding that involve the teaching, learning, and understanding of ionic bonds, molecules, ions, and giant lattices are highly abstract, and in order to fully understand these concepts, students must be familiar with the mathematical and physical concepts and laws that are associated with the bonding concept, such as orbitals, electro-negativity, electron repulsions, polarity, and Coulomb's law. Therefore, many of these misconceptions, according to Nahum et al. (2010), are caused by the oversimplified models used in textbooks, the use of traditional pedagogy that paints a rather constrained and occasionally inaccurate picture of the problems related to chemical bonding, and the assessment of students' achievement that affects the way the topic is taught. Essentially, the notions of chemical bonding must be given in a way that is both true to scientific principles and understandably simple for the learners. This is due to the fact that knowing about chemical bonding enables the learner to predict and explain the physical and chemical characteristics of substances.

Particles at the submacroscopic level—atoms, ions, electrons, and molecules—are not like more familiar particles such as salt or sugar grains. Most chemistry teachers, according to Nahum et al. (2010), use a set of models that are now known to be incomplete representations of the structure of matter; they refer to this well-liked but incorrect conceptual toolkit as "folk molecular theory" (FMT). Some of these theories include:

i. Because of its metallic interaction with delocalized electrons, copper conducts electricity.
ii. Because covalent interactions between its atoms are so tightly intertwined in a lattice, diamonds have a high melting point.
iii. Due to the crystal's strong ionic bonds, which also allow the ions to form bonds with water molecules when hydrated, sodium chloride is soluble in water but insoluble in benzene.
iv. Because it contains tiny covalent molecules, water evaporates quickly.
v. Water forms a lattice of hydrogen-bonded molecules, which causes it to expand as it freezes.
vi. A charged rod can divert a stream of water because the molecules' polar bonds create a dipole moment.

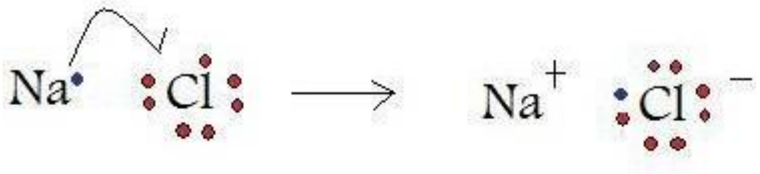

Figure 1: Formation of anion and cation of Chlorine and Sodium

Concept of Ions and Ionic Bonding in Secondary School Curriculum

There are two different kinds of ions. Positive ions called cations are created when electrons are lost. To become a sodium cation, Na+, an electron is removed from a sodium atom, for example. Anions are the negative ions created by electron gain. Anions are termed with the suffix "-ide"; for instance, chloride is the name of the anion of chlorine (Cl-). Electron transfer is the process whereby one atom loses an electron and another atom gets that electron. Figure 2 shows a clear illustration of electron transfer between sodium and chlorine atoms.

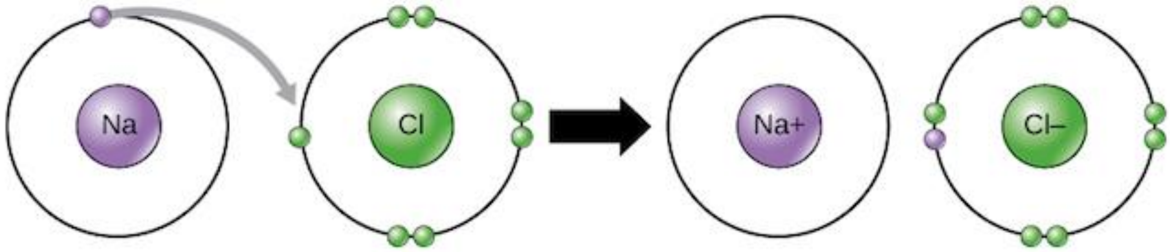

Figure 2: Transfer of electron between atom of Chlorine and Sodium

Ionic bonds are bonds formed between ions with opposite charges. For instance, positively charged sodium ions and negatively charged chloride ions attract each other to make sodium chloride, or table salt. Table salt, like many ionic compounds, doesn't consist of just one sodium and one chloride ion; instead, it contains many ions arranged in a repeating, predictable 3D pattern (a crystal), as indicated in Figure 3.

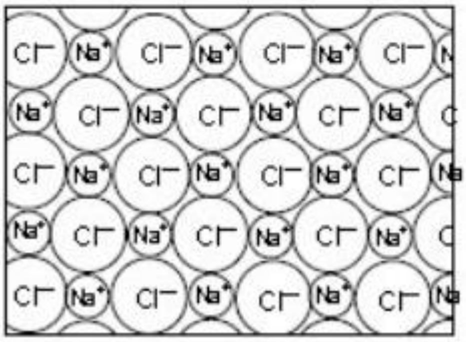

Figure 3: Crystal arrangement of ionic bonding formed between Sodium and Chlorine

Cations and anions are arranged in a regular, ordered array in the crystal of ionic substances. Ionic bonding holds the structure together by attracting electrostatic forces between each ion and all of its oppositely charged neighbors. In this way, ionic bonding is the net cooperative effect acting over the entire crystal (Vladušić et al., 2016). Chemical species in a substance are held together by bonds, which are attractive forces. These forces come into play when species with opposing electrical charges, such as ions, atomic nuclei, and electrons, are attracted to one another (Vladušić et al., 2016). Ionic bonding is an idealised form of bonding that relies on the attraction of diamagnetic ions that form when electrons are transferred between atoms with very different tendencies to lose or gain electrons (Luxford & Bretz, 2013).

In a chemical molecule, the electrostatic attraction between ions with opposing charges results in a interaction known as an ionic bond, also known as an electrovalent bond. When the valence (outermost) electrons of one atom are permanently transferred to another atom, a bond of this kind is created. If an atom receives electrons, it becomes a negatively charged ion (cation), but if it loses them, it becomes a positively charged ion (cation) (anion). Ionic or electrovalent compounds are produced via ionic bonding, and the compounds generated between nonmetals and alkali and alkaline-earth metals serve as the best examples of this type of compound. The electrostatic forces of attraction between opposite charges and repulsion between comparable charges orient the ions in these types of ionic crystalline solids so that every positive ion is surrounded by a negative ion, and the opposite is true. In other words, because of the way the ions are structured, the positive and negative charges alternate and balance one another, leaving the substance overall with no charge. In ionic crystals, electrostatic forces have a considerable magnitude. These substances thus tend to be solid and nonvolatile.

Application of Courseware in teaching chemistry

Courseware is instructional content that is typically packaged for use with a computer and is designed as tools for teachers or trainers or as tutorials for students. It is a piece of digital educational content created to aid in teaching. However, it might be an online tool that enables the "packaging" of several course components, such as content, communication, and grading. In other words, "courseware" is a software package that students use to supplement or replace traditional course activities. It is also a collection of teaching materials in digital format that are delivered through software, multimedia, and data transmission systems. Courseware is a web-based software programme that includes educational materials, instructions, and teaching techniques.

As observed from various interpretations of courseware, scholars consider it as a software (Centre & Park, 1996; Gettys et al., 2000 and Pavlinic et al., 2000), web-based tool (Brusilovsky et al., 1998; Getty et al., 2000; Vassileva & Deters, 1998), multimedia (Talib et al., 2019; Tsoi et al., 1999) used in training understanding of difficult concepts. These justify the diversity of technological tools authors called courseware.

Many academics have previously created interactive courseware to aid in chemistry instruction. For example, Gettys et al. (2000) created courseware to teach crystallographic concepts to undergraduate chemistry students; Wang et al (1998) develops a courseware for teaching organic chemistry laboratory; Shao et al (1996) develops courseware for teaching introductory analytical chemistry; To help students grasp organic chemistry and experimental methods in terms of its three levels of representation, Tsoi et al. (1999) developed courseware.; Johnson & Morris (1997) created courseware for general chemistry to emphasise the connection between macroscopic observations and microscopic representations of chemistry concepts as these concepts are taught in the lecture and the laboratory.

Theoretical Framework

Given that it is complicated and abstract in nature, chemistry is a challenging topic for both students and teachers to master and teach. For instance, the creation of the majority of chemical concepts and explanations of chemical processes, or an understanding of the microscopic world—which is connected to the phenomenological world and is necessarily transferred through the use of symbols. The capacity to describe and interpret chemical problems utilising macroscopic (observable), molecular (particulate), and symbolic forms of representation thus forms part of the conceptual understanding of chemistry (Stawoska, 2012). Johnstone (1991, 1993, 1997, 2000, 2006) presented a model of thinking in chemistry that consists of three modes, referred to as "levels of thought": the macro, the sub-micro, and the symbolic. This is because chemistry is such a complex subject. This multi-level way of thinking can be symbolised by the edges of a triangle, shown in Figure 1, with the sub-micro and symbolic modes at the base and the macro mode at the tip.

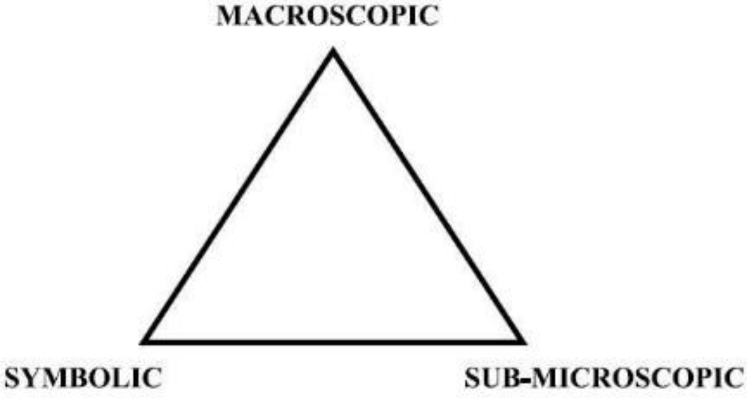

Figure 1: The three representational levels in chemistry (Johnstone, 1991)

The macroscopic, submicroscopic, and symbolic domains of Johnstone's Multiple Levels of Representation (Johnstone, 1991, 2010), with an emphasis on the latter two the macroscopic domain consists of observable characteristics, such as the solid in a salt shaker's white, crystalline form or laboratory studies of physical or chemical characteristics. The white crystals would best be described in the sub-microscopic domain (also known as the particulate domain) as an ordered lattice of alternating sodium ions and chloride ions and the nature of the interactions between these ions. Lastly, knowledge of this same substance in the symbolic domain would consist of the formula NaCl and attractions between Na+ and Cl^- ions known as ionic bonds.

Chemical phenomena, which are studied at the macroscopic level, can also be studied at the sub-microscopic level but are generally described at this level in order to solve some complicated problems. The same occurs at the symbolic level. However, students are apparently able to understand complex ideas when asked to express the relationships between all the representational levels. According to Campos dos Santos & Arroio (2012), the utilization of visual tools (pictures, concrete models, photos, graphics, diagrams, computational programs, and other kinds of visualization tools) in teaching chemistry is required to promote visualization capacities and understanding of the representations.

Justification

As it relates to visualising the atom, molecule, ions, and the interaction of these particles, chemistry is complicated and challenging for learners to learn because it incorporates concepts involving invisible and intangible particulate matter (Demissie et al., 2013). The process of studying chemistry presents a number of difficulties for learners, despite the fact that teachers expect their learners to understand and remember the various names, definitions, and classification schemes they met (Mamlok-Naaman et al., 2010 and Luxford & Bretz, 2013). Thus, the complexity of chemistry has implications for the teaching of chemistry today.

The fundamental premise behind traditional teaching methods is that the information that mankind has amassed in the past must be transmitted to students in its current state. Therefore, lecturing has long been the primary method of achieving this goal, and as a result, pupils have developed a passive attitude, both physically and cognitively.

Chemistry students are expected to understand the scientific ideas at the particulate level of matter in a manner that can be used to explain the properties of matter and different types of changes that take place in a vast array of chemical phenomena. Thus, it is crucial for teachers to maximise the impact of their instructional strategy in order to promote deep, high-quality student learning and engaged learning of the subject matter. A chemist can see a chemical bonding at the macroscopic level, what the reaction will appear like to the student's eye, and at the particulate level, what changes are occurring among the particles, with the aid of Technology Driven Pedagogy (TDP), which uses animation, simulation, and video integrated with student-centered learning to visualise complex and abstract concepts of chemistry (Demissie et al., 2013).

Chemical bonding occupies a crucial aspect of chemistry, in which understanding the concepts leads to understanding other more complex chemical processes like chemical reactions in both organic and inorganic chemistry. Many scholars investigate the concept of chemical bonding (Luxford & Bretz, 2013; Mamlok-Naaman et al., 2010; Nahum et al., 2010 and Vladušić et al., 2016).

In order to look into Croatian students' understandings of bonding in ionic substances, Vladui et al. (2016) undertook a study titled "Understanding Ionic Bonding: A Scan across the Croatian Education System." The participants adopted a questionnaire called "The Truth About Ionic Bonding (TTAIB)," created by Taber (2002). This instrument is a set of 20 assertions that describe mental models that are compatible with either the molecular or electrostatic frameworks of ionic bonding. The findings indicate that a significant percentage of students—and even teachers—appear to have alternative conceptions. The majority of high school and college students and teachers think that the formation of a bond in sodium chloride is caused by the transfer of electrons from a sodium atom to a chlorine atom. It is not understood that oppositely charged ions throughout the crystal exhibit reciprocal and multidirectional electrostatic attractions. The writers came to the conclusion that a significant portion of students, as well as a substantial number of teachers, do not fully comprehend the secondary school curriculum. The teachers and the textbooks are the most evident sources of learners' understandings, whether they are good or bad. The biggest misconception about ionic bonding in sodium chloride is that it happens as a result of an electron transfer and creates a bond between the donor and the acceptor.

Moving Beyond Definitions: What Student-Generated Models Reveal about Their Understanding of Covalent Bonding and Ionic Bonding was the title of a study done by Luxford & Bretz (2013) to explore students' descriptions of ionic and covalent bonding beyond definitions in order to explore students' knowledge about chemical bonding. Students are asked to use art tools to make models that illustrate and explain covalent and ionic bonding during the interview. Despite the fact that students were able to recall definitions, analysis of the student-created models and the explanations that accompanied them revealed numerous errors concerning covalent and ionic bonding.

All challenges generating misconceptions about chemical bonding were associated with the way teachers teach (pedagogy, contents, and text-books) and the way students learn, which led to students’ misconceptions. Mamlok-Naaman et al., (2010) stressed that for the chemistry students to improve their understanding of chemical bonding, it is essential to revise the scientific content, the pedagogical approach, and the assessment methods.

Objectives of the Study

Chemistry learning largely depends on students’ ability to understand the microscopic descriptions: how substances are formed and what are the functions of the substances. These microscopic worlds are usually not related to the students` everyday experiences. Therefore, external representations are the only way to overcome these barriers and enable students to visualise and understand ionic bonding from a particular point of view, to see why and how the change takes place. Such a visualisation would include not only the nature of the substances involved but also other aspects of the mechanism by which the reaction takes place. Thus, the study intends to evaluate students' understanding of ions and ionic bonding by comparing their performance between those taught with direct instruction and those taught with the aid of courseware.

Methodology

The research was quantitative and used a quasi-experimental design. Ions and ionic bonding are a subtopic of a concept called "chemical bonding" in the chemistry curriculum. Chemical bonding is the fifth topic in Senior Secondary School 1 (SS1) or Form 4 under the theme "the chemical world." Thus, SS1 students are appropriate respondents for the study. About 32 SS1 students of Government Day Secondary School Arkilla participated in the study. These students belong to the same class, making it the only science class in SS1 block. This whole class of 32 students was split into two groups using random sampling to enable fair distribution and representation of the strengths of all students in both groups. While the first group was tagged "the experimental group," the second group is "the control group," both consisting of 16 students each. The control group learned about ions and ionic bonding through a traditional instructional approach, while the experimental group learned the concept with the aid of courseware. Each group was evaluated before and after the intervention using a similar assessment tool.

Initially, function analysis and engineering product design were deployed to design and develop courseware for facilitating the learning of ionic bonding. Later, a flexible guideline for building an effective instruction and performance support tool called the ADDIE model was used to design the instruction conveyed by the courseware. The acronyms stand for analysis, design, development, implementation, and analysis, representing steps taken during the design and development of instruction. Each step has an outcome that feeds into the subsequent step.

Table 1: Plan of the Experiment

Group	Pre-evaluation	Intervention	Post-evaluation
Experimental	Pre-test	Courseware	Post-test
Control	Pre-test	Traditional instruction	Post-test

"The truth about ionic bonding" (TTAIB) developed by Taber (2002) was used for this study. It consisted of 20 statements that identify ways of thinking that are consistent with either of Taber's molecular or electrostatic frameworks of ionic bonding. Respondents were asked to decide whether each statement was true or false.

Results

Student scores were computed in Microsoft Excel, which was later imported into Statistical Package for Social Sciences version 25 for the analysis. The analysed data is represented in the table below.

Table 2: Paired-group t-test for the pre-and-post tests of the control and experimental groups

Group	Pre-test Mean scores	Post-test Mean scores	T-test
Control	1.4	13.6	0.00
Experiment	1.9	22.6	0.00

It can be observed from Table 2 that there is a difference between the mean scores of the pre- and post-test of both the control and experimental groups. This can be further confirmed by the significance value of 0.00, which indicates that there is a significant difference between the pre- and post-tests of both the control and experimental groups. Although both approaches had an effect on the participants' performance, the result revealed that students in both groups performed better after the intervention. To confirm this finding, further correlation testing was conducted by the researchers.

Table 3: Spearman's rho correlation between post-tests of control and experimental groups

			Mean_Experimental	Mean_Control
Spearman's rho	Mean_Experimental	Spearman Correlation	1	.212**
		Sig, (2-tailed)		.000
		N	32	32
	Mean_Control	Spearman Correlation	.212**	1
		Sig, (2-tailed)	.000	
		N	32	32

** Correlation is significant at the 0.01 level (2-tailed)

It can be observed from Table 3 that the result indicated that although both groups had their students' performance increase after the invention, the correlation coefficient was 0.00, which indicated that there was no significant relationship between the scores of the experimental and control groups. Thus, the result indicated in Table 2 is confirmed by this test for correlation. The students taught with the aid of the courseware performed better than those taught with a traditional approach (without the courseware).

Discussion

The result goes in favour of the experimental groups for performing better than the control group. Courseware is software that provides students with visual aids when learning abstract concepts such as ions and ionic bonding, allowing them to gain a better understanding of the concept. This finding is not surprising because this is not the first time courseware has been reported to be effective in facilitating the learning of chemistry. A similar finding was made by Talib et al. (2018), who used courseware to determine the concise and effective usability of interactive courseware in overcoming misconceptions in learning acid-base chemistry. Their result indicated that interactive courseware can be concise and effective in overcoming misconceptions in learning chemistry.

Pavlinic et al. (2000), investigated students' experiences on chemical concepts using four courseware conveying varying topics within the chemistry curriculum. The finding reveals that courseware, as an instructional designed software; it's flexibly matches the diverse needs of student in learning chemical concepts. Centre & Park (1996) usable and intuitive interface of the courseware help students understand spatial chemistry. Gettys et al. (2000), created a courseware to teach crystallographic concepts to undergraduate chemistry students.

Ions and ionic bonding are among the chemical concepts Üce & Ceyhan (2019) consider to be abstract, complex, and hard to understand for students in the field of chemistry education. Thus, Luxford & Bretz (2013) emphasised that students need to understand ionic bonding beyond definitions. A significant number of teachers have demonstrated inadequate understanding of the accepted model of ionic substances. Consequently, understanding chemical bonding is fundamental and essential for the understanding of almost every topic in chemistry. Vladušić et al. (2016) reported that the most obvious sources of students' understandings, whether good or poor, are the teachers and the textbooks. As a result, teachers must create courseware to help students understand ions and ionic bonding.

Conclusion

The study compared the performance of students who received direct instruction to those who received instruction through courseware to see how well students understood ions and ionic bonding. It adopted a quasi-experimental research design where 32 students participated in the activities. The performance of these students was evaluated before and after receiving interventions. The results reveal that those students who received instruction through courseware understood the concept of ions and ionic bonding better than those who received direct instruction. Chemistry learning is heavily reliant on students' ability to comprehend microscopic descriptions of how substances are formed and what functions they serve.

We cannot keep teaching those microscopic chemical processes with imagination and assumptions, just as we can't teach the way we were taught due to changes in the brain structures of children born in this millennium. Teachers of chemistry must take advantage of technological advancements by creating instructional activities that provide visual aids for abstract microscopic chemical processes. Through this, one can guarantee the production of secondary school graduates that understand chemical processes to the fullest, like real scientists. Courseware has been once again proven to be effective in facilitating the learning of chemical concepts, especially microscopic. It is now left for teachers to develop their intellectual abilities and computer skills toward instruction design in the system of chemistry education.

Recommendations

The following recommendations were generated from the finding:

1. Science teachers should be encouraged to teach chemistry students with the aid of the courseware so that students can perform better. It has been empirically established that those taught with a traditional approach do not perform very well.
2. Government and school authority must make sure that up to date courseware for teaching chemistry in schools are adequate available and utilized.

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