CONSTRUCTIVISM IN THE CHEMISTRY CLASSROOM

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Abstract
Constructivism is an epistemological learning theory based on observation and scientific study on how people learn from interaction of experimental ideas. Here, new knowledge is constructed from the individual leaner's pre-existing knowledge and experiences by means of assimilation and accommodation. In the chemistry classroom, the students construct their knowledge by actively participating in such learning processes as discovery, inquiry and experiments to draw inferences and formulate new ideas while the teacher acts as a facilitator. This paper examined the term-constructivism, its different faces and application in the chemistry classroom. The differences between the constructivist teaching approach and the traditional view of teaching and learning chemistry are looked into and its uses to inculcate such qualities as self-confidence, critical thinking and even entrepreneurial skills into the students are also highlighted. The paper posits among others that Nigeria, through her curriculum planners should adopt constructivist approaches in all facets of education especially in the teaching and learning of chemistry though some critics insist that it is not good for novice leaners.

Keywords: Constructivism, Assimilation, Accommodation, Knowledge, Chemistry Classroom

Introduction

Constructivism, according to Bodner, (2006) is viewed as a learning theory which describes how learners acquire knowledge by building on existing or prior knowledge based on their learning experiences. It is based on the principle that knowledge is not "discovered" but "constructed in the mind of the learner. D'Angelo, Touchman and Douglas (2009) posit that constructivism can refer to one of many such different but related concepts as epistemological theory, learning theory, and pedagogy. As an epistemological theory, it focuses on how bodies of knowledge come to be and holds that disciplines are constructed by human interactions and decisions. More commonly, educators see constructivism as a non-behaviourist, learning theory where learners construct knowledge based on what they already understand as they make connections between new information and old information. A cognitive conflict arises when they encounter discrepancies between what they already know and new persuasive information which brings their prior knowledge into question. The resolution of this conflict by constructing new knowledge from pieces of prior knowledge is what they call 'learning'. Constructivist pedagogy

proposes that instructors must take students' prior ideas, experiences and knowledge into account while providing opportunities for them to construct new understanding.
Educational Broadcasting Corporation (2004) defines constructivism as a theory based on observation and scientific study about how people learn. It posits that people construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences. It further explains that when we encounter something new, we reconcile it with our previous ideas and experiences, may be, changing what we believe or discarding the new information as irrelevant. In any case, we are active creators of our own knowledge which we achieve by asking, exploring and assessing what we know.
Dougiamas (1998), in his own words describes constructivism as:

- building on knowledge known by the student.
- education being student centered; students have to construct knowledge themselves.
- a theory, a tool, a lens for examining educational processes.

Furthermore, Bruner (2015) defined it as a theory of knowledge which argues that humans generate knowledge and meaning from an interaction between their experiences and their ideas. According to him, constructivism has influenced a number of disciplines including psychology, sociology, education and the history of science.

At its inception, constructivism, was used to examine the interaction between human experience and its reflexes or behaviour pattern which Piaget (1970) called 'Schemata'. Such philosophers as Socrates, Immanuel Kant, Montessori, Lev Vygotsky and John Dewey focused on helping students construct meanings on their own rather than having teachers transmit information to them, as stimuli from their environment shapes their understanding of the world. Constructivist theory is generally attributed to Piaget who articulated mechanisms by which knowledge is internalized by learners though it is developed from Kelly's (1950) work on personal construct and Ausubel's (1960) on learning based on what the learner knows. He posited that through processes of assimilation and accommodation, individuals construct new knowledge from experience. Assimilation means incorporation of new experience into an already existing framework without changing the framework. This, according to Bruner (2015), may occur when individuals align with their internal representations of the world, misunderstand input from other events or even see such events as unimportant. In contrast, when their experiences contradict their thoughts, their internal perceptions may change. Accommodation is the process of reframing one's mental representation of the external world or learning from one's or others' failure. Here the new information causes cognitive conflict that may result in the reorganization of the learner's knowledge framework.

Constructivism, according to D'Angelo et al, (2009) and Dougiamas (1998), is not a specific teaching method but a learning theory; although Kuliah (2014) sees it as a method whose central challenge is theory development. It is often confused with constructionism which is an educational theory developed by Seymour Papert

(1990), inspired by constructivist and experiential learning ideas of Piaget. Hence constructionism is a branch of constructivism which states that the learner constructs knowledge based on his ideas, explorations, interactions and experiments for others to study, comment on or discuss. This idea is employed in the creation of websites and computer software (Dougiamas, 1998). Some others confuse constructivism which promotes learning through students' active construction as facilitated and guided by adults with maturationism which advocates that the students' naturally occurring development and learning should be allowed to blossom without adult interventions. In this case, the students are allowed to guide themselves. Constructivists according to Kuliah (2008), see learning as an active process in which the learners actively construct knowledge as they try to comprehend their reality world. This is quite different from the traditional view of knowledge which is based on the common-sense belief that a real world exists regardless of whether we take interest in it or even notice it. It sees instructional goals as recalling facts, generalizations, defining concepts and performing procedures, hence, ignoring the difference of pre-existing knowledge of individual while the constructivists view learning as the product of interaction between existing understanding and new knowledge.

Faces or Branches of Constructivism

There are five major faces of constructivism based on points of views and where the construction of knowledge takes place.

These faces are:

1. Trivial/Personal constructivism which is the simplest idea in constructivism and the root of all the other branches. Its principle, according to Piaget (1970) is 'knowledge is actively constructed by the learner, not passively received from the environment'.
2. Radical Constructivism proposes that construction of knowledge takes place solely in the learner's mind and on an individual level. Like Piaget's (1970) assimilation and accommodation principles, learning is viewed here as a cognitive activity through which individuals actively incorporate new information and experiences into those already stored in memory. Here previous knowledge is modified in order to help with current problem solving and more sophisticated knowledge. The implication is that radical constructivism does not deny an objective reality, but simply states that we have no way of knowing what that reality might be (Bruner, 2015). Moreover a person cannot ascertain that what other people have constructed in their minds is exactly the same as what he has constructed. The emphasis therefore is on the individual learner as a constructor but not the extent to which the human environment affects learning.
3. Social Constructivism proposes that learning takes place in the interaction between learners and their social world. Learner's social world includes such people that directly affect him as teachers, friends, students, administrators and participants in all forms of activity. As there is no strict boundary between the

mind and the environment, a person's understanding of the world cannot be removed from the way he uses language to view it, describe it and discuss it with others. Social constructivist teaching methods include teaching the contexts that might be personally meaningful to students, class discussions, small group collaborations and valuing correct answers. An example is the teaching of saponification in an organic chemistry class where the teacher uses questions to lead a class discussion on the preparation of local soap. Here emphasis is on the teacher's use of multiple ideas to maintain a balance between teacher guidance and student initiated exploration, as well as between social learning and individual learning.

4. Cultural constructivism states that such cultural influences as custom, religion, biology, tools and language, and not just the environment of a learning situation affect the students' learning. This, as posited by Dougiamas (1998) involves a new conception of the mind, not as an individual processor, but as a biological developing system that exists within an individual brain and in the tools, artifacts and other symbols used to facilitate social and cultural interaction. These tools affect the way we think - example, a label on a full reagent bottle in the chemistry laboratory can save long explanation. Cultural constructivism is more complex than radical constructivism, as it highlights the need to consider fully the contexts of the student and that of the knowledge to be learned (Dougiamas, 1998).
5. Critical constructivism is that within social and cultural environments in order to improve its success as a referent to cultural reform. It encourages questions through conversation and critical self-reflection and promotes conditions-for establishing dialogue towards achieving mutual understanding.

These conditions include primary concern for maintaining, caring and trusting relationships to achieve goals and interests.

Application of Constructivism in Education

Piaget's theory of constructivist learning has had wide ranging impact on learning theories and teaching methods in education and is an underlying theme of many educational reform movements. Research supporting constructivist techniques has been mixed with others contradicting those results. More so, since its introduction by Piaget, constructivist teaching has found increasingly wide acceptance by researchers and educators though it still remains less widely practiced (Taber,2006; Mayer 2004).

There are five instructional approaches with constructivist designs which D'Angelo et al. (2009) stated as:

1. Case-based learning : This type uses real life examples to build knowledge by resolving questions about a specific case as in medicine, law and education. These questions have no single right answers but are used to generate ideas within small groups and the interactions among participants. Here the teacher facilitates the students' interactions while the students choose analysis

techniques and work toward solutions of the open-ended problem. They benefit from this type of instruction because they are given an opportunity for decision making as part of their learning process and address different viewpoints.

example of a case study: Three primary school pupils were going home from school after a heavy downpour with such thunder and lightning that some electric poles fell with some wires. As soon as the pupils stepped their feet into a water logged path on their way, they got electrocuted.

What could be the cause of their death?

What part did the water play in this death?

Suggest ways this type of death can be avoided in future.

2. Discovery learning: This engages learners in problem solving to make a discovery as in experiments and scientific thinking. Students are provided with a problem and given opportunity to explore and formulate solutions to the problem. The role of the teacher here is to create the conditions for inventions rather than provide ready-made knowledge. So he guides them to develop problem-solving skills and creativity as they are more likely to retain knowledge if they discover it on their own. Students benefit from this type of instruction because it fosters curiosity and creativity.

   An example of this type is providing students with the necessary materials and asking them to distinguish between metals and non metals.

3. Inquiry-based learning: This places the responsibility for learning and understanding concepts on the students as they determine the content, learning process and the assessment of learning. It uses questions to guide instruction rather than predetermined topics while the teacher monitors the students' learning process through interviews, journaling and group discussions.

   Students benefit from this as it helps them develop meta-cognitive learning skills upon which they can build toward future educational experiences.

   An example of this type is guiding students with cookbook type of directives in volumetric analysis.

4. Problem based learning: This teaches students to think critically, analyze problems and use appropriate resources in guided experience to solve complex real life problems. The students identify the nature of the problem and determine what resources they need to utilize to solve it while the teacher offers scaffolding by providing examples of how to approach that problem. This helps the students to develop problem solving and self-directed learning skills to construct flexible knowledge and become effective collaborators. Students benefit as they integrate analytical skills with content knowledge as members of a team.

   An example of this type is engaging students in qualitative analysis.

5. Project-based learning: This type uses the process of investigation to encourage understanding. It involves collaborative learning where the teacher provides guidelines (like checklists) for the students as they progress toward the completion of their projects. By providing students with authentic problem,

project based learning offers them a meaningful experience that promotes the development of research skills as they organize their work.

An example of this type is finding out the influence of availability and usage of laboratory apparatus on effective learning of chemistry.

Different constructivist approaches appear however, to vary in their levels of efficacy: Research findings proved that students engaging in guided discovery learning activities perform better than those in pure discovery curricular, because, according to Mayer (2004) in pure discovery method, learners receive little or no guidance while in guided discovery, they receive substantial guidance.

Although constructivist instruction can take any of these forms and more based on the instructor's theoretical commitments, it focuses on students' active role in their own learning as they build and organize their knowledge (Bruner, 2015).

In addition, the goals of constructivist teaching often include promoting democratic learning environment and student-centered instruction. Hence teachers feel comfortable in this role as they view uncertainty and conflict as natural and potential learning producers.

Constructivism in the Chemistry Classroom

In the chemistry classroom. The constructivist view of learning can point towards a number of different teaching practices. In general, it means encouraging students to use such active techniques as experiments, problem-solving and discovery approaches to create more knowledge and to reflect on and talk about what they are doing and how their understanding is changing. The teacher makes sure he understands the students' pre-existing conceptions and guides the activity to address them and to build on them. The constructivist chemistry teacher encourages students to constantly assess how the activity helps them gain understanding. By questioning themselves and their strategies, the students in the constructivist chemistry classroom ideally become 'expert learners' which gives them broadening tools to keep learning. So with a well - planned classroom environment, the students learn "how to learn' (Taba, 2006). Just Like a spiral, when students continuously reflect on their experiences, they find their ideas gaining in complexity and power, and they develop strong abilities to interpret new information. One of the teacher's main roles becomes to encourage this learning and reflection process; e.g. in a chemistry lesson on "Introduction to Electro-Chemistry, after the definition of cell, the constructivist teacher asks them to bring out the overripe oranges and torchlight bulbs they were earlier asked to bring along to school for the lesson. He then distributes short electric wires tied to two Yods' (electrodes) respectively and asks them to connect the free ends of the wires to the bulb. After piercing two sides of the orange with the free ends of the two rods and letting the rods stay in there, the students begin to 'explore the world' of electro-chemical cells while the teacher watches with keen interest, guiding them and as a facilitator asking them questions. After this, the students and teacher talk about what they have learned and how their observations and experiments helped (or did not help) them to understand the concept better. The goal here is to

make the learners active thinkers as they work together to ask and answer questions (reciprocal questioning). They become 'experts' on a part of a group project; teach it to others (Jigsaw classroom) and work together to research a particular controversy, (structured controversy). Contrary to criticisms by some conservative or traditional educators, Bruner (2015) insists that constructivism does not dismiss the active role of the teacher for the value of expert knowledge; rather, it modifies that role, so that teachers help students to construct knowledge rather than to reproduce a service of facts. He provides such tools as problem-solving and inquiry-based learning activities for students to formulate and test their ideas, draw conclusions and inferences, and convey their knowledge in a collaborative learning environment. The teacher therefore acts as a facilitator, helping the students to understand the content instead of giving a didactic lecture that covers the subject matter. This makes the students play an active role in the learning process by constructing knowledge actively rather than just mechanically ingesting it from the teacher or textbook. Emphasis therefore turns from the teacher and the content to the learner. Brunner (2015) further asserted that a facilitator and not a teacher is needed in the constructivist method of learning in the chemistry classroom/laboratory. This is because while a teacher tells, a facilitator asks, while a teacher lectures from the front, a facilitator supports from the back, while a teacher gives answers according to a set curriculum, a facilitator provides guidelines and creates the environment for the learner to arrive at his own conclusions, and while a teacher gives a monologue, a facilitator is in a dialogue with the learners.

Application of Constructivism in the Chemistry Classroom

TOPIC:	ACIDS, BASES AND SALTS.
DURATION;	Three lesson periods of 45 minutes each
CLASS:	SS 1students
FIRST LESSON PERIOD:	Introduction - Acids
Length of instruction:	45 minutes
Specific objective:	At the end of the lesson, the students should be able to:

√ define an acid, a base and a salt.
√ demonstrate the physical properties of an acid.
√ explain the chemical properties of an acid.
√ state the uses of an acid.

INSTRUCTIONAL MATERIALS: Unripe fruits (pineapple, orange, like/lemon), ash of burnt plantain peel or palm bunch and table salt which the students were asked to bring along to school. Other materials include red and blue litmus paper, dilute and concentrated acids, powdered metals, like zinc and magnesium, distilled water and beakers.

ENTRY BEHAVIOUR; The students have learnt Metals and Non Metals in their JSS3Basic Science.

INSTRUCTIONAL PROCEDURE:

Step I: **Invitation/Engagement**

The students are asked to bring out the materials they were asked to come with. They tend to physically classify the materials they brought into acids, bases and salts.

Step 2: **Exploration Stage**

The teacher writes a cookbook form of directives on the chalkboard, divides the students into groups of twos to make sure every student participates fully and asks them to distinguish acids from bases and salts, experimenting with those materials they brought and the ones provided for them.

Step 3: **Explanation**

- ❖ Students come together
- ❖ Teacher discusses ideas of students - students communicate their ideas/findings in groups and as members of a class. Their findings should also include the properties and uses of acids. Students ask questions based on their findings.
- ❖ Teacher clarifies their views and explains the concepts formed on a) acid, b) base, c) salt, d) physical properties of acids, e) chemical properties of acids, f) uses of acids.

Step 4: **Evaluation**

Teacher evaluates students who may also evaluate themselves

Step 5: **Taking Action/ Follow-up**

Teacher gives out projects to students to browse the Internet for the other various uses of palm bunch/ plantain peels and the chemical contents of plantain peels.

The teacher also asks each student to grind a handful of chippings to powder and bring to class for the next lesson.

Importance and Criticisms of Constructivism in the Chemistry Classroom

Bruner (2015) found out from his studies that using constructivist teaching methods resulted in better student achievement than traditional teaching methods. His study also revealed that students preferred constructivist methods over traditional ones, though he did not find any difference in student self-concept or learning strategies.

Moreover constructivism has influenced the course of programming and computer science. Some programming languages e.g. 'Togo' have been created, wholly or in part for educational use to support the constructionist theory of Papert (1980). It also makes for easy learning hence teachers can use the information of the students' pre-existing knowledge to create the instruction which helps to avoid misunderstanding of concepts. Teachers, according to Kuliah (2008), can use varied strategies which explore students' experiences and stimulate them to reflect and think critically

relating to their experiences and the new knowledge. Such strategies can be orientation, elicitation of ideas, reconstruction of ideas, application of ideas and review.

In chemistry education, constructivism plays an important role to improve teaching and learning in chemistry and to develop research areas. The teaching strategies here help to create meaningful learning process in chemistry. It makes the chemistry student an active participant rather than a passive recipient of knowledge hence giving him increased retention of any information learnt or discovered in the process.

Constructivist method of learning gives intrinsic motivation and enthusiasm to (earn further, making them acquire skills which they can also use for new learning, entrepreneurship and problematic situations. Furthermore Dogru and Kaiender (2007) as cited by Bruner (2015), compared science classrooms using traditional teacher- centered approach to those using constructivist student-centered methods. Their findings revealed that immediately after the lessons, no significant difference was noticed, but in follow-up assessments fifteen days later, students taught with constructivist learning method showed better retention of knowledge than those taught with traditional methods.

On the other hand, some philosophers posit that constructivist theories are misleading and contradict known findings. Mayer (2004) for instance, argued that the notion that 'Learning by doing' enhances learning has little or no empirical evidence of proof given novice learners, but instead, that guided discovery is better. He also asserted that not all teaching techniques based on constructivism are efficient or effective for all learners as some educators misapply it. He rather proposed 'cognitive active learning' for learners and 'guided practice' for instructors. Kirschne, Swellwer and Clark (2006) described constructivist teaching method as unguided method of instruction' and an example of fashionable but thoroughly problematic doctrines with little benefit for practical pedagogy or teacher education. They suggest more structured learning activities for learners with little or no prior knowledge.

D'Angelo et al. (2009) opined that constructivist approaches are under - implemented and under-utilized as they are still foreign to both students and teachers.

According to Taber (2006), students who are constructing new knowledge on poor foundations or incorrect knowledge (misconceptions) will run into difficulties as they try to integrate -their new and existing knowledge. It is now the work of the constructivist chemistry teacher to understand his students' misconceptions so as to challenge and help them reconstruct the knowledge.

In summary therefore findings have shown that constructivist approaches have great potential but require authentic implementation in order to achieve that potential.

Conclusion

In conclusion therefore, constructivism, which is a way of thinking about knowing and building models of teaching and learning, has been and still remains the best method of teaching and learning chemistry. This is because it is a method which, not only instils entrepreneurship skills and self confidence into the students, but also prepares and equips the chemistry student to transform from a mere 'learner' to the 'Chemist' the Nigerian society needs for her scientific and technological advancement in this 21st century. No wonder the current National Educational Curriculum Model - the NERDC model is based on constructivism.

Recommendations

Based on these therefore, the following recommendations are made.

1. The Federal Government, through her curriculum planners should ensure the implementation of this approach they have recommended especially in teaching and learning chemistry.
2. States, through their education ministries should liaise with entrepreneurs to organize trainings for chemistry teachers to be able to use this approach for their students to meet up with societal demands on graduation.
3. More research work should be carried out by educators on constructivist approaches in other subjects also, to find out how best to implement them.

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