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Chemistry for Today and the Future: Sustainability Through Virile Problem-based Chemistry Curriculum

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Abstract: This study examines how chemistry as a subject could be made more relevant to real life world of the learners. The reason for this study is that most of the present strategies of lesson delivery in classroom make the students to be disenchanted from science. Additionally, the society is willing to see the products of science delivery beyond scores and grades in the daily life of students. The only way this can best be done is to teach students in such a way that they can transfer science knowledge, skills and attitudes acquired into daily life practice. . The authors proposed a problem-based chemistry curriculum that will make the subject of immense benefits not only for today but for the future. Theoretical framework, the application and actual classroom illustrations of problem-based learning were discussed in the paper.

Key words: Chemistry discipline, problem-based chemistry curriculum, real life application, science and society

INTRODUCTION

Teachers, parents and administrators are being faced with many changes in education. Many people are concerned that the high school graduates are not capable of making real-life decisions. One reason is the claim by Anderson et al (1992), Ezike (1985) and Gallagher, Sher, Stephen & Workman (1998) Zoller (1993) that eighty five percents of teachers' questions and methods do not provoke high-order thinking but recall or simple comprehension of materials of learning. As a result students see chemistry teaching as unpopular (Kracjik et al, 2001; Osborne and Collins, 2001, Sjoberg, 2001; WCS, 1999, Holbrook, 2009), because there is a gap between their wishes and teachers' teaching (Hofstein et al, 2001; Yager and Weld, 2000; Holbrook and Rannikmae, 2002). The situation is not changing because teachers are afraid of change themselves and need guidance (Alkenhead, 1997; Bell, 1998; Rannikmae, 2001a). Chemistry discipline should equip learners with knowledge needed to solve everyday real world problem. Fahmy (2000) states that this is the most interesting thing about the discipline. It applies to human daily lives. This is one clear argument for problem-based approach to pedagogy. A problem-based chemistry curriculum and an approach to teaching will lessen the difficulty most students have in applying chemistry to real world life outside the classroom. Such proven approach will help to bridge the gap that Venkatachemy et all (2005) refers to exist between 'know what' and 'know how' in learning. It is also argued that the activity in which knowledge is developed and deployed is not separable from learning and cognition on one hand and problem solving on the other (Gagne, 1976 & Oloruntegbe 2003). Situations might co-produced knowledge through activity (Venkatachemy et all 2005), hence it is assumed that learning and problem-solving are fundamentally situated. Without the necessary capability for problem solving it appears science teaching and learning will be of little or no use for the students and the society.

Cognitive scientists posit that learning results from the exploration of the environment (Bruner, 1966; Gagne, 1976; Inhelder & Piaget, 1958; Piaget, 2000) and that the learning so acquired will in turn help the learner solve his own problem as he/she interacts with the environment (Kim, Bonk & Teng, 2007). The need for problem-based chemistry at higher level of learning is also to accommodate such aims as evidenced in constructive learning (Fosnot, 2005), open-ended inquiry and learning environment (National Research Council, 1995), goal-based scenario (The Higher Education Academy, 2009) self reflection and creative problem-solving, researching "market, pitching and selling.

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There is not much a sure way to sustainable development other than to expose students not only to how to solve immediate problems, but to acquire a novel way of solving daily problems of living. There is no other time than now that the whole world is facing economic down turn that we need to evolve a problem-based curriculum as well as creating employable and sellable skills in students. There is no any other subject other than chemistry that the dream of sustainable development can be achieved. Apart from the fact that chemistry touches all aspects of human life, proficiency and capability in other science and science-based careers anchor on the subject. To make chemistry teaching and learning able to fulfill the roles of generating useful education or functionality in our lives, it must be made relevant to the home, the environment, future employment and most definitely for future changes and developments within the society. The essence of this paper is to raise the need for problem-based chemistry curriculum and to generate practical application of emergent approach at classroom level.

Theoretical Framework:

The cognitive scientists like Gagne and Suchman and pragmatist like Dewey can be said to pioneer studies in problem-based learning. In Gagne's view, problem solving involves combining previously learned rules into a new, never-before-used higher-order rule (Gagne & Driscoll, 1988). This was a follow-up of his (Gagne's) theory of learning hierarchy and learning prerequisite (Gagne, 1976). Gagne identifies five major categories of learning, which are verbal information, intellectual skills, cognitive strategies, motor skills and attitudes (Gagne, Briggs & Wager, 1992). Gagne further suggests that different internal and external conditions are necessary for each type of learning. For example, for cognitive strategy to be learned there must be a chance for practice to develop new solutions to problems. To learn attitudes, the learners must be exposed to credible role models and persuasive arguments. He suggests further that learning tasks for intellectual skills can be organized in a hierarchy according to complexity: stimulus recognition, response generation, procedure following, use of terminology, discrimination, concept formation, rule application, and problem solving (Allens, 2009; http://tip.psychology.org/gagne.htmi). It can be seen that problem solving is one of the prerequisite for the overall development of the child in Gagne's perspectives of education. The overall development of the child is the inclusive function of education. Very often we hear phrases like balanced curriculum (Massachusetts Department of Education, 2000; The Baltimore Sun, 2008), child-centered teaching (Katsuko, 1995, Swanson, 2008; Yeung, 2009), humanistic approach to teaching (Schrrmacher, 2006) and the development of the total child (Chisholm, 1985) as scholars lend support for education that meets the need of the child in and out of the classroom.

Problem-based learning cannot be discussed without recourse to John Dewey's philosophical perspectives on education also. Dewey (1933) stressed the importance of learning through experience. Dewey believed teachers need to appeal to students' experiences. This is the basis of motivation in students. He also believed that students learn best by doing, by discovery and by thinking through problems which are at the root of problem-based learning. Suchman in Hassard (2004) gave a graphic illustration of problem solving session. This is given in a separate section below.

Other studies like those of Seifer & Simmons (1997), Lacek (2001) and Orimogunje (2004) gave different views of the concept. Seifer & Simmons (1997), for example, sees problem –based learning as an appeal that enhances communication skills, encourages active participation and helps students become more self reliant learners. Being self reliant learners, the students determine what materials should be researched and how they will go about finding information from sources like the internet, interviews, reviewing recent publications and so on.

The Lamphier Curriculum Center (2000) provided excellent overview of the problem-based learning process. An ill-structured problem is initially presented to the students. Gallagher, Sher, Stephen and Workman (1995) define an ill-structured problem as a real life problem that can be solved in more than one way. It is presented without all the necessary information to solve the problem and the realization that the scope of the problem may change as new information arises. The introduction of an ill-structured problem occurs before any pertinent information is given to the students.

The relative effectiveness of the approach has also been written about. Birch (1986), Gallagher, Stephen & Rosenthal (1992), Stephen, Gallagher & Workman (1993) and others describe the approach as being capable of developing in students better problem solving skills; resulting in better understanding and retention of biochemistry content; and that the application shows better promise for pedagogy.

Steps to Problem- based Learning:

Several steps of what constitute the problem-based learning process were also given by some authors like Birth (1986 and Greenald (2000). For instance, while some identify five steps, others talk about six, seven and so on. Birch (1986) model consists; recognition of a problem, initial formulation of the problem, description of the problem, identification of key relationship, identification of solution for analysis and testing and evaluation of solutions. These steps parallel the steps involved in scientific method. Greenald (2000) listed ten steps which are; encountering an ill-defined problem , having the students ask questions, pursuing problem finding, mapping problem finding and prioritizing, investigating the problem, analyzing the results, reiterating learning, generating solutions and recommendations, communicating the results, and conducting self-assessments.. The major components identified by Seifert and Simmons are; problem formulation, data collection, brainstorming solutions, evaluating and selecting solutions and implementing the solutions. Whatever the number and the complexity of steps, one thing is common, almost all of the steps involve the active participation on the part of the students with the teachers acting as coaches or facilitators.

What exactly characterize problem-based learning? Hill (2000) and Lacek (2001) identify the followings:

- The formulation of problems must come from key curricular issues;
- The problem should be ill-structured;
- Teachers become coaches or facilitators letting the students make their own decisions;
- Students are not told how to solve the problems, they are only given guidelines for approaching the problems and must search for needed information;
- Performance assessment completes the problems. For example assessment can be through keeping of journals throughout the project.

The requirement for problem-based learning is, however enormous but realizable. Training of teachers is central to the development (Barrows, 1994). There must be consultants or resource faculty. Problem simulation is also a key curricular requirement. Learning resources should be available to students. There must also be flexible timetable scheduling. Barrows (1994) even suggests that there should be no curricular schedules except for initial orientation, weekly meetings, and examinations. Whatever the involvement, the justification for such, according to chemistry educators, is that of meaningfulness and a worth while endeavor.

Applications for Sustainability:

It is thought that a properly conceived problem-based chemistry curriculum will look beyond mere teaching the curriculum content and address topical and problem centers of the society. For instance, atomic structure as a topic would be extended to recycling of chemical wastes (Oloruntegbe & Ayeni, 2009) The heaps of wastes on the landscapes in some countries, that are not only eyesores, but are posing serious harmful effects on man /woman and his/her environment could be turned to useful materials through recycling – waste to wealth. It is held that matter never wears out or matter cannot be destroyed or created (Kelter, Carr & Scott,1999; John Dalton 1766-1844). Theoretically all materials are recyclable. The theory behind recycling is that of John Dalton (1766-1844). Dalton affirmed that matter cannot be created nor destroyed. Then law of conservation of mass was used to verify this theory. Kelter, Carr & Scott (1999) stated that behind this theory and law there is a simpler concept that atoms never wear out. Take a process that converts ethene, formed from carbon and hydrogen, to polythene materials (plastics), many of these materials are thrown away after use as wastes. They litter the landscapes in some towns and cities and create problems of landfills in others. These wastes can be converted to a less, yet still useful materials like candle. Recycling or reuse is in line with this principle that nothing should be left as wastes.

Employing problem-based learning will make teachers and students see every topic in the curriculum or syllabus as a way of solving societal problems not just acquiring science knowledge and skills. No doubt, acquisition of science knowledge and skills are needed. Their applications in achieving and fostering socioeconomic development and sustainability are much more needed. Provided on the table below is a kind of paradigm shift and transfer expected of curriculum content to problem-based orientation.

Topic	Look beyond	Look towards
Atomic structure	Postulate, theories and principles of modern atomic structure	Recycling of chemical wastes
Chemical bonding	Formation of compounds or molecules	Green chemistry, producing something not only useful but supporting the environment
Stochiochemistry	Studying the composition of matter	Study how much sugar is consumed daily by citizen in the food they eat and the effects
Chemical reactivity	Activity series and its discovery	Recovering silver and goal coins from ocean wreck
Representative elements	Properties, production and uses	As means of producing fine chemicals for domestic and industrial use
Electrolysis, electrochemistry	Cathodes, anodes, simple electrolytic and electrochemical cells	How to prolong the life span of industrial and house hold materials easily spoiled by rusting and corrosion

Similar pattern can be followed in translating chemistry contents or topics in problem-solving exercises.

Two centuries ago Curie (1881) studies crystal compression and deformation under electric field. Almost all digital electronic circuits today rely on this phenomenon in the form of crystal oscillators. We might be able to have more Curies if we focus more on problem-based learning and let it affects the events in our science classroom. A typical classroom session employing the approach is illustrated by Suchman as presented below.

Suchman's Approach:

Suchman illustrated an approach that involves a group of students in finding explanation to a puzzling problem (Suchman). The illustrated typical problem-solving session goes thus. The teacher presented the problem such as this one: *"In the mountains of the Southwest a number of years ago, dears were quite numerous, although the population would fluctuate slightly. There were also wolves in the mountains. Some people from a small town witness a wolf pack pull down two of the smaller deer in the herds and were horrified. As a result, the people launched a campaign to eliminate the wolves. To the dismay of the people, the years following the elimination of the wolves showed a marked decrease in the population of the deer. Why, when the wolf is the deer's natural predator, should this occur?"* The students began by formulating hypotheses. To test the hypotheses they gathered data by asking the teachers questions. At the middle of questions and answers session, the following can be heard

" Jim and I have another idea", Sam suggested.

" Excellent", Mr. Smith praised. "Go ahead".

" After the dears' predators were eliminated, the population expanded so their habitat couldn't support them, and they became susceptible to starvation, and the population went down", Sam said.

" OK." Mr Smith said. "Can we gather some information to support your idea?"

" Were more bobcats (rodents) seen in the dears' habitat after the wolves were eliminated?" Ronke queried.

" No." Mr. Smith said.

" How about coytoes (young of wolves)?" Ronke continued.

" No again", replied Mr. Smith.

" Were numerous bark less dead trees found in the region after the wolves were eliminated?" Bello continued.

" Yes", Mr. Smith said.

After series of questions and hypotheses testing, evaluating, rejecting and revising, the students eventually got the solution to the problem. They reasoned this way. If there were no rodents or other animals in the deer habitat, the dears must have fed on them. After killing and feeding on the animals and there were no more, they have to be eating the bark of the trees. When this could not do, they were dying probably killing and feeding on their young ones. Suchman's illustration reveals a great deal of brainstorming through hypotheses formulation and testing, as well as collaborative activities between teachers and students. Students tend to be more active while the teacher plays the role of facilitation and initiation of ideas.

A Typical 45 Minutes Problem-based Lesson on Stochiometry:

There are twelve 45-minutes lesson in Lacek's (2001) module. A modification of one of them is presented here to illustrate problem-based lessons.

Course: Chemistry Unit: Stochiometry

Unit goal	*Students should understand the concept of stochiometry using the problem-based learning. Students also would appreciate how stochiometry is used in everyday life*
Lesson objectives	*Students will describe the process of problem-based learning* *Students will describe the roles of the teacher and students in the process* *Students will compare problem-based to the scientific method*
Instructional strategy	*.I Introduction (have students form a circle with their desks for a group discussion* *A. Teacher* *B. Students take turns going round the circle* *II. Climate setting* *Review scientific method (group discussion)* *Teacher introduces problem-based learning* *III. Review unit evaluation* *Final unit assessment : Journal (50% - to be checked daily) Participation – 20% (expected) Final product 30% (group presentation)*
Instructional materials	*Handout, internet facility (getting ready for lab work)*
Evaluation	*Students are given a notebook to use as a journal for the entire unit. They are to keep a log of the daily events in the class, their homework each night is to express their ideas, thoughts and feelings about their work and the days events*

It must be understood this is a beginning of 12 lessons on stochiometry. The appreciation of the real problem-based sessions will follow this initial beginning lesson. In the second lesson, for example, learning objectives include: Students will list the following related problem-based learning problem: hypotheses, problem formation/facts, learning issues, and action plan. Instructional strategies deal with: I. Assigning roles to the four objectives listed above. It is among the students that one will be chosen as a scribe, another interpreter, yet another time keeper. II. Presenting the problem. III. Students are to discuss the problem. Teachers could ask lead questions:

"What do you know?"

"What facts are evident in the problem?"

Anticipated responses are:

"Claim is 1.5 million, 16 oz cans of product formulated in your lab" "Consumer report flat taste".

Students go to generate hypotheses. Teacher may ask further questions such as:

"Why do you think this is so?"

"What ideas do you have about this problem?"

Anticipated responses include:

"Wrong ingredients were used in production"

"Wrong amount of ingredients were mixed"

"Shelf-life/expiration date of ingredients had passed".

Teacher prompts further.

"Can you explain that?"

"If you cannot, would you like to make that a learning issue – problem to be solved?"

Such goes on and on with questions and answers until solutions are arrived at like in Suchman's illustration given earlier. The teacher keeps in mind the curriculum requirements, which are mole ratio, molar mass, percentage yield, theoretical yield and actual yield, calculation involving mass of a reactant and product in a balanced equation given the mass or mole of a different reactant or product.

A curriculum like this one will draft students into finding solutions into real life problems. As mentioned earlier, problems of recycling, producing environmentally friendly materials, and turning gas flaring into domestic and industrial fuel supply can be posed. It is one of the means of preparing students for future endeavor and careers. The society will be better for it

Implications for Pedagogy:

Problem-based chemistry learning like it's allied, laboratory-based involves substantial investments in fund, time, resources and instructional efforts. Investments that are beyond those require in conventional approaches. Historically, chemistry educators have often justified these investments by two related arguments (Institute of Chemical Education, 1990). One, that "doing chemistry" is an integral part of learning chemistry. Two that the acquisition of appropriate chemical skills and attitudes somehow emerges from asking and solving chemistry-related problems. This type of activity is not limited to chemistry, biology or science alone. Problem-solving abilities are needed in all areas of life, as many areas as there are problems to be solved.

Apart from issues of funding, resources and efforts, there are other hindrances or inhibitors which may have to be overcome. Overcoming these will make our scientific endeavor a sure enterprise for sustainable development and a panacea for overcoming the ills of the society. These hindrances are borne in the type of curriculum reforms that are being implemented in many nations. Most science reforms are still discipline-specific, content-oriented and examination-driven. This kind of curriculum reform is capable of truncating properly planned problem-based efforts in schools. While the points here are made for problem-based chemistry curriculum, the approach does not exclude solving social studies, language or mathematics-related problems. Why? This is because life and societal problems are the issues at hand. Solving such problems may involve the quantitative and qualitative abilities of the mathematics, the language of expression and the knowledge of the social system of the environment. These areas can be woven together with teachers' collaboration and team playing. For example a team approach can be taken for teachers to collaborate across disciplines while the division can be intact still. Individualism in learning, teacher dragging students along content and examination line, and rigid time table scheduling may pose obstacles to properly planned and conceived problem-based learning.

Conclusions and Recommendations:

Problem-based learning is a paradigm shift in pedagogical practice, while problem-based chemistry curriculum is a radical departure form traditional ones. Its practice tasks both teachers and students intellectually as it provokes high-order scientific and social thinking and communication abilities. It also challenges both teachers and students in the use of analytical thinking and technological recourses in sourcing information, gathering and analyzing data to arrive at solutions to problems. Problems across disciplines and contents are woven together, presented and tackled in an integrated and interdisciplinary manner. Workings like this one help to reduce compartmentalization and fragmentation which is not noticed any where in the universe where human beings are located. Separations as in separate science offerings are simply human creation and convenience that have for a long time robbed man of the ability to better study, understand, control and benefit maximally from the environment they are living in. Problem-based learning can be a fun and an excitement in the hands of the trained teachers and committed students. Rather than hold on to the traditional ways of teaching and learning that makes the classroom a bore place it is recommended that the approached be employed for real-life science practice.

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