Science Education International
Vol. 19, No. 3, September 2008, pp. 323-330

ICASE *International Council of Associations in Science Education*

Using PARSEL Modules to Contextualizing the States-Of-Matter Approach (SOMA) to Introductory Chemistry

GEORGIOS TSAPARLIS (gtseper@cc.uoi.gr),
University of Ioannina, Department of Chemistry, Ioannina, Greece

ABSTRACT: SOMA (States-Of-Matter Approach) is an introductory chemistry program for all students in the tenth or eleventh grade (age 16-17), which introduces chemistry through the separate study of the three states of matter. SOMA is basically a formalistic approach. In this paper, we discuss the use of PARSEL modules in providing a teaching approach to SOMA. This has been realized using two PARSEL modules. One module (which can be covered within the SOMA major unit on Gases) is about carbon dioxide in carbonated beverages and relates to gas solubility in liquids, gas pressure, gas laws, physical and chemical equilibrium, and acid–base chemistry. The second module (which can be covered within the SOMA major unit on Solids) includes salt, salts, crystals and crystal structure, ionic bonding, uses of salt, and its role in human health. It is proposed that a large number of other PARSEL modules can also be coupled with and used in SOMA.

KEYWORDS: PARSEL approach, scientific literacy, States-Of-Matter Approach (SOMA).

Introduction

The *States-Of-Matter Approach* (SOMA) is a curriculum arrangement for the teaching of introductory upper-secondary school chemistry for general education, which introduces chemistry through the separate study of gases, solids, and liquids (Tsaparlis, 2000). It is intended as a one-year upper secondary chemistry course in tenth or eleventh grade (student average age 16-17). The course introduces chemistry in a logical and, at the same time, pedagogically sound way, by means of the three states of matter. As a consequence, the curriculum is divided into three major units, that is: a) Air, gases, and the gaseous state; b) Salt, salts, and the solid state; c) Water, liquids, and the liquid state. A relevant book has been also written in Greek. SOMA takes a basically holistic, formalistic approach to chemistry, although a current trend in science education is the need to re-examine the educational approach to science (including chemistry) education by making school education through the context of science more relevant to the students. PARSEL (***P**opularity **A**nd **R**elevance of **S**cience **E**ducation for scientific **L**iteracy, 2006*) is a recent European

Commission Project that provides relevant teaching modules in English, but also in a number of other European languages. Some aspects of PARSEL aims are:

- Putting forward a responsible citizen view of scientific literacy.
- Promoting relevance of learning in science lessons to the lives of students.
- Utilizing conceptual science learning to undertake socio-scientific decision making.

In this paper, I discuss the connection between PARSEL and SOMA, and the coupling of the two. This connection occurs directly in two modules, one module that incorporates science ideas about carbon dioxide in carbonated beverages, and another module deals with salt.

Rationale for SOMA

The rationale for the SOMA approach derives from the need to move away from the traditional linear approach, which is based on the logic of teaching chemistry topics, such as, atomic structure, periodic table, molecular structure, states of matter, gas laws, chemical reactions, solutions, acids-bases-salts, oxidation and reduction, and organic chemistry. In the linear formal approach, the applications and uses of chemistry (the *context*) are relegated to some 'small-print' information, which is not set in examination questions, and, consequently, not read by the students. It could be said that the linear approach simply constitutes an adaptation to secondary education (*transposition didactique*) of university general chemistry programs and textbooks. Research in science education considers such approaches as being unsatisfactory, and recommends that school science should be an entirely new construction that takes into account educational and cognitive psychology, as well as science-education theory (Johnstone, 2000).

With regard to the formal/logical arrangement of introductory chemistry, I take into account three such subject approaches that, according to Fensham (1994), can be designated as: (a) the substances approach, (b) the atomic structure approach, and (c) the chemical reactions approach. SOMA is an educationally-driven method, that is, a mixture of the previously mentioned three approaches. In SOMA, chemistry is introduced through the separate study of the three states of matter: the *states-of-matter approach* (*SOMA*). It should be pointed out that *SOMA* seems to have some features in common with two other *Science-Technology-Environment-Society (STES) approaches*, an older (Gymer, 1973), and a more recent one (Schwartz, Bunce, Silberman, Stanitski, Stratton, & Zipp, 1997).

In *gases*, the molecules are small, only a few non-metals (O, H, N, C, S, F, Cl, and the inert (noble) gases) are studied, while only covalent bonding is included and no intermolecular interactions exist. The study of hydrocarbons provides for an integrated study of inorganic and organic chemistry. Atomic and molecular structures (but not the periodic table) are easily introduced here. Chemical reactions, stoichiometry, reaction energetics, and gas laws provide the physical-chemistry part of the unit.

In *salts*, ionic bonding and crystal structure are studied. The periodic table and oxidation numbers are also introduced, while covalent solids and metals are also part of this unit. In *liquids*, intermolecular bonds are treated. Organic chemistry is part of this unit, while solution chemistry, and acids and bases (including organic acids) are also studied. The unit concludes with chemical reactions in aqueous solutions.

Each major unit concludes with a corresponding major social and environmental issue. Air pollution, the greenhouse effect, and the depletion of ozone layer are a major theme in air and gases. Waste disposal and recycling of materials (especially of metals) are considered with solids. Water quality, water pollution, and acid rain are themes in water and liquids.

SOMA and PARSEL

The main aim of both SOMA and PARSEL is to contribute to scientific literacy. SOMA, as a chemistry course for general education, conceptualizes scientific literacy from two perspectives (Tsaparlis, 2000): (1) *Chemical literacy* in its narrow sense, that is, the basic chemical knowledge that is useful and essential for living, especially in the modern technological society; (2) *Chemical culture*, that is, a satisfactory knowledge of how nature functions chemically. In addition, SOMA has taken into account the need to cultivate students' higher-order cognitive skills (HOCS) (Zoller & Tsaparlis, 1997; Tsaparlis & Zoller, 2003).

PARSEL can contribute both directly and inderictly to the contextualization of SOMA. This can be done by incorporating the PARSEL philosophy into the SOMA curriculum structure. The module about carbon dioxide is intended to relate to part of the unit on gases in SOMA and provides a social relevance that can stimulate the subsequent learning of the conceptual chemistry ideas. The module on salt can provide a social relevance to one component of the unit on solids in SOMA. A direct introduction to components of the unit of liquids in SOMA is currently lacking, although many modules are connected in one way or another to water, the liquid state, solutions, and acids and bases, as it will be explained later.

'The Gas We Drink: Carbon Dioxide in Carbonated Beverages'

Science Content

Through the familiar bottled or canned carbonated beverages, soft drink chemistry and physics are studied in this module, providing a real-life approach to the study of conceptual science that is important for socio-scientific decision making within society. Gas solubility in liquids, gas pressure, gas laws, physical and chemical equilibrium, and acid–base chemistry can all be introduced. In elaborating the problem-solving component of the module, students work collaboratively in groups and propose, and then apply in the laboratory different methods for measuring the volume of carbon dioxide contained in a beverage, and then to determine the pressure that prevails inside the unopened bottle or can. Additionally, the teacher can perform a carbon-dioxide fountain demonstration, and the explanation of the phenomenon can be discussed to consolidate the conceptual learning, before transferring this to the socio-scientific decision making at hand. The suggested teaching-learning approach, written in the PARSEL format, is outlined in Figure1. This illustrates that stage one is estimated to take one lesson in developing the issue and checking on prior knowledge, whereas stage two is estimated to take 3 to 4 lessons for the inquiry-based experimentation, and stage 3, one additional lesson for discussing the issue raised earlier. A flowchart of the suggested teaching sequence within each of the three stages, again in the PARSEL format, is offered in Figure 2. This indicates the student involvement in the planning, as well as in the carrying out of the experimental components.

STAGE	TEACHING - LEARNING APPROACH	TEACHING - LEARNING OUTLINE
1. Setting the scene	Material presented through a real life title and scenario. Revision of prior knowledge (1 lesson)	1. Becoming familiar with the scenario. 2. Revision of properties of CO_2 especially method of detection, pH and whether soluble in water. 3. Realization that the socio-scientific question to answer is 'are soft drinks cans safe from explosion?'
2. Inquiry-based Problem Solving	Teacher guided, student-centred material includes Problem Solving, Nature of Science and Conceptual Science Learning (and consolidation of the conceptual learning through adequate feedback - assessment). (3-4 lessons plus homework))	1. Tackling the problem. First how do we know there is CO_2 in soft drinks? Is the acidity associated with CO_2 harmful? 2. Teacher guidance. Does temperature affect the amount of CO_2 in solution? Experimental investigation 3. Students realize they need to determine pressure in the can/bottle. Experimental planning and determination 4. Teacher guidance to enable students to calculate CO_2 from the pressure measurements 5. Knowing head space and volume of liquid, determine volume of CO_2. Experimental measurements involved.
3. Socio-Scientific Decision Making	Teacher guided, student centred material includes reasoned socio-scientific decision making (and consolidation of the conceptual learning through adequate feedback – assessment). (1 lesson)	1. Knowing the amount of CO_2, the effects of temperature and the volume the gases would occupy at high temperatures, we can decide whether drinking soft drinks are safe. 2. Students will realize that the thickness of the metal can is important for safety - the thicker the can, the better. But of course the thicker the can, the higher the cost of the can and hence the soft drink.

Figure 1. Suggested Teaching-learning Approach

SOMA Overall Objectives/Competencies

The students are expected to:

1. study the dissolving of gases in liquids, and the dissolution of carbon dioxide in water;
2. realize that carbonated beverages are under high pressure;
3. working in groups, propose and apply a method for determining the amount of carbon dioxide that is contained inside a carbonated beverage;
4. devise methods for estimating the pressure inside a sealed bottled or canned carbonated beverage;
5. apply the ideal-gas equation in the estimation of the above pressure;
6. consider the experimental errors that enter in various procedures for estimating the pressure;
7. observe a demonstration of a "carbon dioxide fountain" and explain it, using the knowledge gained through the previous investigations. Note that acid-base chemistry and the neutralization reaction (which belongs to the unit on liquids) also enters this demonstration.

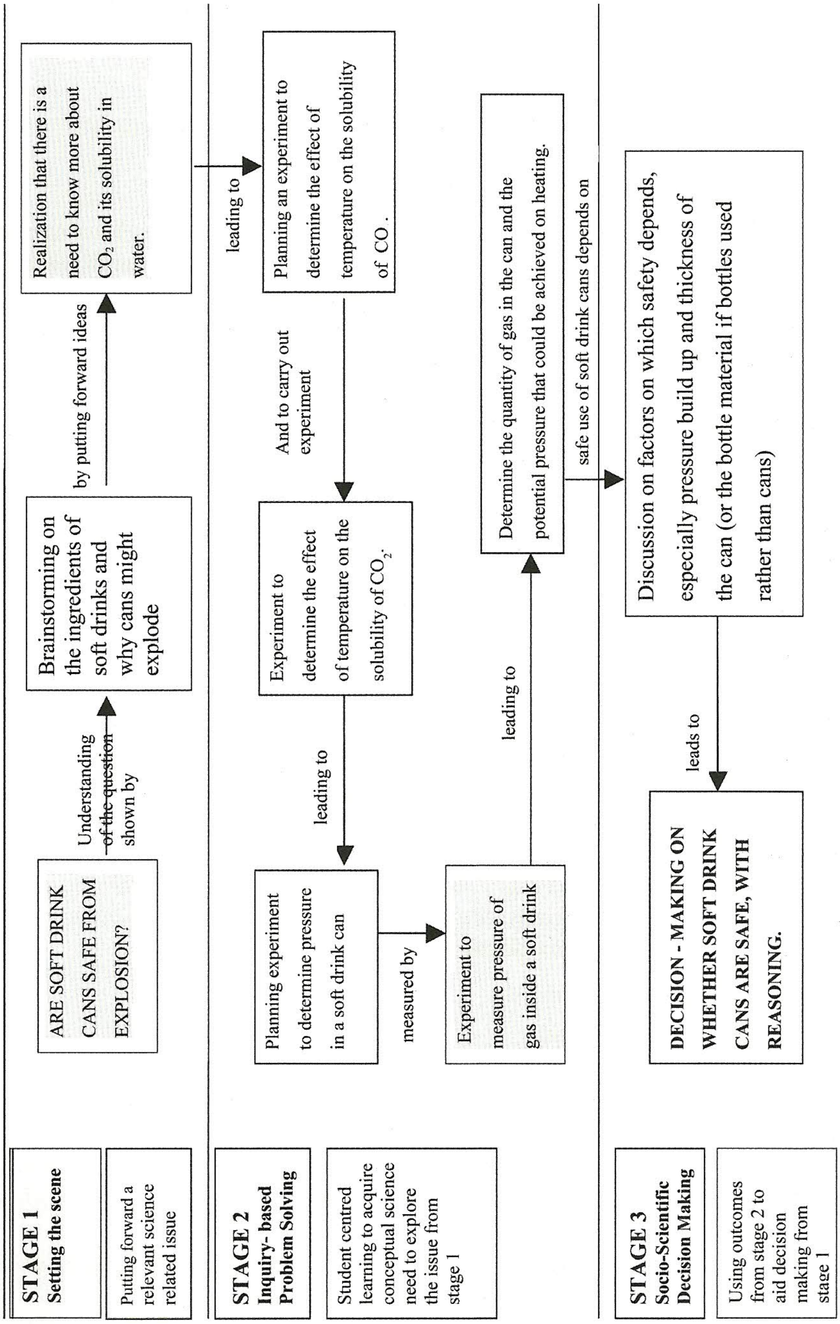

Figure 2. Suggested Teaching Flowchart.

Competences:

Investigative skills, manipulative skills, cooperative-work skills, concept understanding, theory development and application, experimental-error analysis, and communication skills.

Curriculum content: Chemistry and physics

Anticipated time: 5-6 teaching periods at school, plus pre-activity preparation at home.

Prior learning: Properties of gases, gas laws, ideal gas law.

PARSEL competencies go wider as scientific literacy relates to the Nature of the subject (chemistry in this case), personal development, and social learning. Additional competencies included in SOMA materials are:

- transfer of ideas on gases in liquids to enable students to participate in well-justified and socio-scientific decision making on social issues relating to the use of pressurized gases in liquids;
- development of leadership skills in supporting colleagues in group work and in putting forward meaningful plans for undertaking scientific problem-solving;
- showing a willingness and an attitude to safe working towards others in carrying out experimental work.

Introducing the PARSEL Module 'Salt: The Good, the Bad, and the Tasty'

Science Content

Through a consideration of health related to salts in the body, salts in general (and among them sodium chloride, or cooking salt in particular) are recognized as a main class of inorganic compounds. Sodium chloride is found dissolved in seawater, but mainly extracted for household use as mineral salt, which may come under various colours. Salt crystals, other crystals, and crystal structures are studied, and a method for growing large crystals is developed. The concept of electricity-conducting materials and especially of electrolytes, and the concept of ionic bonding are also introduced. Finally, the many uses of salt, and its positive, but also negative role in our health are explored.

SOMA Overall Objectives/Competencies

The students are expected to:

(1) appreciate that salts are a main class of inorganic compounds; (2) study the origin of salt; (3) observe beautiful salt crystals and study crystals, crystal structures, and even grow their own big salt crystals; (4) find out that molten salt or aqueous salt solutions are electricity conducting materials and further be introduced to the concept of ionic bonding; (5) study the many uses of salt, and its positive, but also negative role in our health.

Competences: Investigative skills, manipulative skills, and communication skills.

Curriculum content: Chemistry, geology, and health education.

Anticipated time: Three teaching periods at school, plus at home study and project work, plus experimental activities at home.

Prior learning: Salts, solution chemistry.

PARSEL competencies go wider as scientific literacy relates to the nature of the subject (chemistry in this case), personal development, and social learning. Additional competencies included are:

- transfer of ideas on salts and their importance in the body to enable students to participate in well-justified socio-scientific decision making on social issues relating to healthy living;
- development of leadership skills in supporting colleagues in group work and in putting forward meaningful plans for undertaking scientific problem solving;
- showing a willingness and an attitude to safe working towards others in carrying out experimental work.

Other PARSEL Modules that Can Be Used with SOMA

Modules related to gases: Junior climatologists required! How can we avoid global climate change? – Reflexions on air pollution, tornados, and global climate change" / No smoke without a fire - (un)desirable combustion / What is worse, cigarettes or narghile?

Modules related to solids: Preventing holes in teeth: Are beliefs justified? / Do you need to know chemistry in order to be a good bones surgeon? / Which soil do we choose?

***Modules related to liquids*:** Substances in everyday life "Where do the fizzy bubbles 'in' the fizzy tablets come from?"/ Shampoo: Is there truth behind the advertisement? / KieWi&Co.: Ways into the microscopic world "What happens to the ice cubes in my soft drink?" / Boiling point as a matter of geography / Should we do more to save monuments from corrosion? / How much can you drink and be able to legally drive? / Which cleaning agent do we choose? / Which soil do we choose? / Bathing and bubbling with chemistry / Brushing up on chemistry / Growing plants – does the soil matter? / Can lake water be made safe?

The Follow-up Course to SOMA

It is evident that SOMA constitutes an introduction to chemistry, but not a complete chemistry course for general education. A follow-up, one-year course is necessary for the eleventh or the twelfth grade, which will mainly concentrate on the uses and applications of chemistry.

Following the SOMA approach, it could be proposed that this course consists of the following chapters: (1) Overview of organic chemistry; (2) Polymers and plastics; (3) Drugs; (4) Biomolecules; (5) Food chemistry; (6) Chemistry and agriculture; (7) Energy; (8) Chemistry, Earth, and Space; (9) Chemistry as an ever-growing science. Chapter 7 covers also nuclear chemistry and radiochemistry. Chapter 8 is about the nature of science (NOS).

However a PARSEL approach can also be considered, where the socio-scientific issues are delineated and the conceptual science then identified and studied. This then leads to meaningful socio-scientific decision making to enable students to appreciate the place of science with society and appropriate scientific literacy attributes needed for responsible citizenry.

This approach can centre around: Are we overusing plastics? / Which is the best fuel? / Science in a class of its own: renewable energy sources / My iPod works with energy from bull shit / Chemistry in a class of its own: building blocks of life / To become fit and strong eat eggs all day long / The truth about proteins in my body / I love candy! And they keep telling me not to eat it! / Zero emission cars – is it feasible? / Should vegetable oil be used as a fuel? /Milk - keep refrigerated /A big problem for Magellan: Food preservation / Waist deep in waste – necessity or irresponsibility?

Of course this is not a structured approach in a scientific sense, but then the whole point of the PARSEL approach is that it places emphasis on the needs of society, and hence the importance of viewing science learning from a societal point of view.

Conclusion

We live in a chemical world, where our personal well-being, the standards of living, but also the future of our planet are closely connected to and affected by the chemistry interacting with our lives. It is unfortunate that in our world, mainly because of lack of knowledge, the words 'chemistry' and 'chemical' have become taboo, and that the public has taken a hostile attitude toward chemistry. It is essential that people should know the importance of chemistry in multiple facets of our life, when to take safeguards, but also to realize that important socio-scientific decisions depend on a strong understanding of the underlying chemistry principles. While in general members of society are unlikely to be called upon to determine solutions to pure chemistry problems, they are more certainly expected to participate in making appropriate decisions in the way in which chemistry with all its potential is wisely used within society. It is here that both SOMA and PARSEL can contribute greatly, leading the students to the 'feeling' that chemistry is not only a useful and a necessary science, but also a cognitively affordable, interesting, and aesthetically enjoyable school subject.

References

FENSHAM, P. J. (1994). Beginning to teach chemistry. In P. J. Fensham, R. F. Gunstone, and R. T. White (Eds.). *The content of science: A constructivist approach to its teaching and learning*, Ch. 2. London: The Falmer Press.

GYMER, R. G. (1973). *Chemistry: an ecological approach.* New York: Harper & Row.

JOHSTONE, A. H. (2000). Teaching chemistry – logical or psychological? *Chemistry Education Research and Practice, 1*, 9–15.

PARSEL. Popularity and Relevance in Science Education for Scientific Literacy (2006). PARSEL Project. See: www.parsel.eu

SCHWARTZ, A. T., BUNCE D. M., SILBERMAN R. G., STANITSKI C. L., STRATTON W. J., & ZIPP, A. P. (1997). Chemistry in context (2nd Ed.). Washington D. C.: American Chemical Society.

TSAPARLIS, G. (2000). The States-Of-Matter Approach to introductory chemistry. *Chemistry Education Research and Practice, 1*, 161–168.

TSAPARLIS, G., & ZOLLER, U. (2003). Evaluation of higher *vs.* lower-order cognitive skills-type examinations in chemistry: Implications for university in-class assessment and examinations. *University Chemistry Education*, 7 (2) 50–57.

ZOLLER, U., & TSAPARLIS, G. (1997). Higher and lower-order cognitive skills: The case of chemistry. *Research in Science Education, 27*, 117–130.