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| Title | A Piagetian-based programme for learning “Elements and Symbols” |
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| Source | *Singapore Journal of Education, 5*(1), 20-24 |
| Published by | National Institute of Education (Singapore) |

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# *A Piagetian-Based Programme for Learning "Elements and Symbols"*

## Introduction

Piaget's learning theory on cognitive development has had considerable impact on science education (Piaget, 1964; Inhelder and Piaget, 1958; Craig, 1972). The theory classifies cognitive learning into four successive stages: (a) sensory-motor, (b) pre-operational, (c) operational, and (d) formal. Various programmes and instructional strategies have been developed based on the theory (Batt, 1980; Karplus, 1977; Renner and Stafford, 1979; Ryan, et al., 1980; Herron, 1978; Good et al; 1978). An application of this theory for teaching and learning scientific concepts is the Piagetian learning cycle (Karplus, 1977) which is of growing interest among science educators. This article intends to introduce briefly the learning cycle in general and suggest a learning cycle for teaching a topic in chemistry: "Elements and Symbols".

## Piagetian Learning Cycle

According to Piaget (1964), there are four factors explaining cognitive development from one stage to another. They are (1) maturation, (2) experience with physical environment, (3) social transmission, and (4) self-regulation. Among the four factors, Piaget considers "self-regulation" the fundamental one for the learning process. The learning process involves three steps: (a) assimilation, (b) disequilibrium, and (c) accommodation. "Assimilation" is the process of incorporating data into existing structures. Initially, a person assimilates a new experience into his reasoning pattern (operation) through interaction with the environment and/or objects with his senses. He will react to it with his understanding. At this stage, the reasoning pattern is disturbed because of inappropriate or ill-fitting responses. So "disequilibrium" occurs. The mental structures need to be adjusted in order to compensate for this "disturbance" and consequently equilibrium will be restored. This means "accommodation" has taken place. The new experiences are now combined with the previous reasoning pattern to generate a new logical reasoning pattern. Reasoning that makes use of direct experience, concrete objects and familiar actions is considered to be a concrete reasoning pattern, whereas that based on abstractions, for instance concepts, theories, mathematical relationship, is considered to be a formal reasoning pattern.

The Piagetian learning process (assimilation, disequilibrium and accommodation) closely adheres to the structure of the discipline of science (Renner and Stafford, 1979). Piaget's theory was adopted by Karplus (1977) who has developed a strategy for incorporating it into a pragmatic method for use in the classroom situation. (Karplus, 1977; Karplus and Lawson, 1974). This strategy is called the learning cycle. It consists of three instructional phases that combine experience with social transmission and self-regulation. They are (1) exploration, (2) invention and (3) application.

The exploration phase allows students to participate in activities to develop new experiences based on his past experiences. It involves minimal guidance and allows for observation with answers which are not necessarily correct. (Fowler, 1980). This is an important step for chemistry learning, especially for those who are beginners, as most of the basic concepts in chemistry require formal thinking, which most students have difficulty comprehending (Ingle and Shayer, 1971; Hudson, 1976). The new experience should raise questions that the students are unable to explain by their present reasoning pattern. As a result, mental disequilibrium will occur and they will be ready for self-regulation. This step is also known as "gathering data".

The invention phase provides social transmission – interactions between teacher and students, students and students, students and media (e.g. textbooks, films, computers). The concepts and principles are introduced and related to their own findings in the exploration activities. The teacher or the printed handout plays an important role here. Moreover, reinforcement activities should be given to help students familiarize themselves with the new concepts learned so that the retention of knowledge grasped will be increased and the learning will be more significant. This step is also called "getting the idea" or "concept introduction".

The last phase, i.e. the application phase or "expanding the idea", provides students with additional experiences by making them apply the skills or concepts learned during the invention phase. The students become problem-solvers. Individual guidance in identifying difficulties and resolving them is essential in this phase.

The learning cycle emphasizes activity-centred teaching which provides many concrete experiences and examples as the foundation for concepts. This is supported by Chiappetta (1976) and Smith (1978). According to Renner (1971, 1979), the enquiry-oriented method leads to better performance in the learning of formal concepts as well as concrete concepts. Goodstein and Howe (1978) also reported that the real beneficiaries of the use of concrete experiences were the students at the highest cognitive level rather than those at the lowest level.

As an example of application of the learning cycle in chemistry, a programme for learning "Elements and Symbols" for 12–14 year old students is described below.

*Teaching of "Elements and Symbols"*

The science of chemistry starts with the identification and appreciation of the nature and properties of the non-living matter which surrounds us. The basic knowledge in chemistry is about the elements – the names of elements and their common characteristics, the classification of elements into metals and non-metals and into three physical states, the symbols for elements and how they are derived from their English and Latin names. Thereare patterns and generalizations in the names, characteristics and symbols of elements. The realization and appreciation of these aspects are essential to make learning interesting. Moreover, such realization and appreciation is one of the important aims to be achieved in learning chemistry (De Rose, 1970, 1971). But many teachers tend to ignore the importance of this basic knowledge and to teach this "topic" simply by listing down the names and symbols in corresponding order and asking students to learn them by heart. If the students see and touch the elements, their learning will definitely be more meaningful. The improvement of this type of learning situation could be made by incorporating the learning cycle into the teaching process.

The concepts involved in the topic "Elements and Symbols" are classified as concrete because they are based on observable criteria and require concrete reasoning pattern for understanding. Renner and other researchers (Renner and stafford, 1979; Chiappetta, 1976; Smith, 1978; McKinnon and Renner, 1971) find that most of the students reach the formal stage only between the ages of 15 to 20. This means that the majority of children at 12–14 years are still functioning at the pre-formal (concrete) stage. The learning of the concrete topic "Elements and Symbols" by students at the concrete stage would not be a big problem, if (a) real objects of elements are shown to allow students to touch and feel with their different senses, and (b) activities in generalization, identification, familiarization and application are provided. The approach employed here for instruction and guidance is the enquiry method which stimulates students to explore and to think about the subject matter. The teacher asks questions and these questions guide the students in carrying out activities in the use of the materials to get the needed information. The concepts are then assimilated and accommodated.

The aims of the programme described below are:

(a) to help beginning students to understand better the relationship between elements and symbols through some aspects of the properties of elements, and

(b) to keep students' interest alive, and help them to widen the scope of their understanding of chemistry.

1. **Exploration Phase**
Students are given a list of English names of common elements (arranged alphabetically), together with their Latin names and their corresponding symbols in three columns in the form of a handout or big chartboard. E.g.

| English Name | Latin Name | Symbol |
|---|---|---|
| aluminium | aluminium | Al |
| carbon | carbonum | C |
| chlorine | chlorinum | Cl |
| copper | cuprum | Cu |
| gold | aurum | Au |
| iodine | iodinum | I |
| iron | ferrum | Fe |
| lead | plumbum | Pb |
| silver | argentum | Ag |
| etc. | etc. | etc. |

They then explore the real samples of the elements, which are either sealed separately in small test tubes (for gases or liquids) or in small plastic or glass containers (for solids). Special attention should be paid to safety precautions. The students are allowed to interact with these concrete materials by observation and feeling so as to acquire information about elements with a minimum of guidance. The required information here is confined to (a) the physical state (solid, liquid or gas) under ordinary conditions, (b) metal or non-metal, and (c) colour.

If the real objects (elements) are not available owing to certain constraints, substitutes for these will be flash-cards (Lipson, 1972) or slides which depict the elements together with the appropriate names and symbols. If possible, opportunity should be given for students to widen their experience by viewing video cassettes, films, film-loops, and film-strips which provide further information on these elements.

Finally, students are asked to complete the following table for all the elements they have thus explored:

| Element | | Symbol | Physical state under ordinary conditions | Metal or Non-metal | Colour |
|---|---|---|---|---|---|
| English Name | Latin Name | | | | |
| | | | | | |

2. **Invention Phase**
Students' answers in the completed table in the exploration phase will be discussed among teacher and students. In the discussion, the scientific terms such as "physical state", "metal" and "non-metal" which describe the concrete experiences students have encountered, can be clarified.

After the completion of the table, students working in groups will be encouraged to look for patterns existing in the table with some guidelines e.g. relationships between "name and symbol", "name and state", "name and metal/non-metal and colour". Students are also required to point out the exceptional cases in the patterns they have observed.

Once students have finished their group work, the teacher can then highlight and clarify the correct trends and generalizations which they are expected to have observed. After that, the following reinforcement activities can be brought into the teaching strategy.

(a) Card Games
    (i) Simple Type – It only involves names and symbols of elements. This type of card games is very common and can be found in most of the literature (Gang, 1971).

    (ii) Complex Type – This involves names, symbols, physical states, and metal/non-metal. The design of the cards is similar to that of the simple type, except for two additional series of cards, (physical state and metal/non-metal) which are provided as well. Assuming that N elements are used and that there are four cards for each element, now with two additional (joker) cards added, the pack will then have altogether (4N + 2) cards. The way of playing can be the same as in Gin Rummy or in Element cards (Lipson, Ploutz, 1970). Players can win this game only when they know the elements well so that they are able to match the set for different elements.

(b) Computer-Assisted Instruction (CAI) Programmes
In this phase, the CAI programmes could consist of simple objective questions such as multiple-choice, true-false, and fill-in-

the-blank items. The content of the questions should relate closely to the table discussed above. Some of such CAI programmes are commercially available (Shaw et al., 1978). The appropriate format recommended for this programme is the matching type.

3. **Application Phase**
In this final phase, students are expected to extend their concepts from invention to prediction as well as to solve some of the related problems. Activities which can be organised are:

(a) Predicting something from a set of given data
Some of the known elements, their names and symbols, will be put in a special table (e.g. in the form of a periodic table). Students will be required to look for the patterns of the arrangement, together with some other information provided (e.g. physical state and metal/non-metal) and deduce some facts related to the topics covered. Such questions can provide students with ideas to be developed later e.g. (i) elements can be grouped, and (ii) there is a periodic change in such a grouping. This activity will definitely heighten students' interest in the further learning of chemistry.

(b) Crossword Puzzles
Students can be asked to solve simple crossword puzzles. The clues in these crossword puzzles should be mainly confined to those rules and generalizations which students have studied previously.

More difficult crossword puzzles can also be designed. In this case, students will need more exploration by themselves under the guidance of the teacher. Samples of crossword puzzles can be obtained from some of the literature listed in the references (Hudson and Hind, 1977; Barr, 1980).

(c) Computer-Assisted Instruction (CAI) Programmes
The CAI programmes for this phase could be in the form of objective questions at the higher cognitive level. One simple example is to ask students to identify an element and its symbol from a set of information (e.g. some of the physical properties) provided. The programme should be designed in such a way that communication between students and computer is not confined to just "right" or "wrong" answers, but is capable of providing explanations and guidance.

Conclusion

In this article we have introduced briefly the Piagetian learning cycle, and suggested a Piagetian-based programme for learning a chemistry topic entitled "Elements and Symbols". In this programme we stress first-hand experience with real objects. We believe that based on such interaction, the effectiveness of teaching in terms of retention and significance of the knowledge gained will be far greater. The approach described here is of primary importance in learning science, especially chemistry. We hope that this article will contribute to the continuing discussion among the community of science teachers of more stimulating and effective approaches in teaching science.

**References**


Barr, I. (1980). Crossword puzzle of the elements. *Journal of Chemical Education,* 57, 7, 495.

Batt, R. H. (1980). A Piagetian learning cycle for introductory chemical kinetics. *Journal of Chemical Education,* 57, 9, 634 – 635.

Chiappetta, E. (1976). A review of Piagetian studies relevant to science instruction at the secondary and college level. *Science Education,* 60, 253 – 261.

Craig, B. S. (1972). The philosophy of Jean Piaget and its usefulness to teachers of chemistry. *Journal of Chemical Education,* 49, 12, 807 – 809.

De Rose, J.V. (1970). Independent study in high school chemistry – A progress report. *Journal of Chemical Education,* 47, 8, 553 – 560.

De Rose, J. V. (1971). A basis for improving and evaluating chemistry courses. *Journal of Chemical Education,* 48, 10, 676 – 678.

Fowler, L.S. (1980). An application of Piaget's theory of cognitive development in teaching chemistry : The learning cycle. *Journal of Chemical Education,* 57, 2, 135 – 136.

Gang, R. L. (1971). *Chem Bingo* Utah : Teaching Aids Co.

Good R., Mellon, E.K. and Kromhout, R.A. (1978). The work of Jean Piaget. *Journal of Chemical Education,* 55, 11, 688 – 693.

Goodstein, M.P. and Howe, A. C. (1978). Application of Piagetian theory to introductory chemistry instruction. *Journal of Chemical Education,* 55, 3, 171 – 173.

Herron, J. D. (1978). Piaget in the classroom – guidelines for applications. *Journal of Chemical Education,* 55, 3, 165 – 170.

Hudson, A. G. and Hind, S. (1977). *Chemical Grosswords.* Wolverhampton: Sigma Technical Press.

Hudson, M. J. (1976). Introducing the mole. *Education in Chemistry,* 13, 4, 110 – 114.

Ingle, R. B. and Shayer, M. (1971). Conceptual demands in Nuffield O - level chemistry. *Education in Chemistry,* 8, 5, 182 – 183.

Inhelder, B. and Piaget, J. (1958). *The Growth of Logical Thinking from Childhood to Adolescence.* New York : Basic Books Inc.

Karplus, R. (1977). Science teaching and the development of reasoning. *Journal of Research in Science Teaching,* 14, 2, 169 – 175.

Karplus, R. and Lawson, C. A. (1974). *SCIS Teacher's Handbook.* Berkeley : The Regents of the University of California.

Lipson, J. I. (1972). *Element Cards.* London: Heyden and Son Ltd.

Mckinnon, J. and Renner, J. (1971). Are colleges concerned with intellectual development? *American Journal of Physics,* 39, 9, 1047 – 1052.

Novick, S. and Menis, J. (1976). A study of student perceptions of the mole concept. *Journal of Chemical Education,* 53, 11, 720 – 722.

Piaget, J. (1964). Cognitive development in children : Piaget – development and learning. *Journal of Research in Science Teaching,* 2, 176 – 186.

Ploutz, P. (1970). *Elements.* Ohio : Union Printing Co.

Renner, J. W. and Stafford, D. G. (1979). *Teaching Science in the Elementary School.* New York : Harper and Row, (3rd ed).

Ryan, M. A., Robinson, D. and Carmichael, J. W. Jr. (1980). A Piagetian - based general chemistry laboratory program for science majors. *Journal of Chemical Education,* 57, 9, 642 – 645.

Shaw, K., Hepburn, P. and Want, D. (1978). *Chemical Element Games.* London : Schools Council.

Smith, P. J. (1978). Piaget in high school instruction. *Journal of Chemical Education,* 55, 2, 115 – 118.