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<td>Author(s)</td>
<td>Chia Lian Sai, Goh Ngoh Khang and Lee Kam Wah</td>
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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 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 retention of knowledge and the learning "step is also called "introduction".

The last phase is called "expanding the experiences and conceptualization. This is similar to Smith (1978) and Howe (1980), the curriculum better performance of students concepts as well as concepts and procedures. (Renner and Smith, 1978) also suggests that the students at this phase require more than those at the pre-operational stage.

As an example of the learning cycle in chemistry, "Elements and Symbols" students is described in this section.

Teaching of "Element and Symbols"

The science of chemistry includes identification and application of the properties of the new substances. The basic knowledge of the elements — their common characteristics, elements into three physical states and how they are named in Latin names. The students at this phase need more questions of the names and the properties of elements. They need to learn these aspects are interesting. Moreover, the invention is one of the basic learning techniques in the classroom. But many teaching methods are not essential of this basic knowledge and simply by listing the corresponding concepts of the students at heart. Like the names of elements, their properties of elements, their physical states, these are all meaningful. The understanding of the learning situation is important in the learning cycle.
selves 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. There are 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.

<table>
<thead>
<tr>
<th>English Name</th>
<th>Latin Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminium</td>
<td>aluminium</td>
<td>Al</td>
</tr>
<tr>
<td>carbon</td>
<td>carbonum</td>
<td>C</td>
</tr>
<tr>
<td>chlorine</td>
<td>chlorinum</td>
<td>Cl</td>
</tr>
<tr>
<td>copper</td>
<td>cuprum</td>
<td>Cu</td>
</tr>
<tr>
<td>gold</td>
<td>aurum</td>
<td>Au</td>
</tr>
<tr>
<td>iodine</td>
<td>iodinum</td>
<td>I</td>
</tr>
<tr>
<td>iron</td>
<td>ferrum</td>
<td>Fe</td>
</tr>
<tr>
<td>lead</td>
<td>plumbum</td>
<td>Pb</td>
</tr>
<tr>
<td>silver</td>
<td>argentum</td>
<td>Ag</td>
</tr>
<tr>
<td>etc.</td>
<td>etc.</td>
<td>etc.</td>
</tr>
</tbody>
</table>

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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:

<table>
<thead>
<tr>
<th>Element</th>
<th>Physical state under ordinary conditions</th>
<th>Metal or Non-metal</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>English Name</td>
<td>Latin Symbol</td>
<td>Solid</td>
<td>Liquid</td>
</tr>
</tbody>
</table>

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 ex-
pected 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 pro-
vide students with ideas to be
developed later e.g. (i) elements
can be grouped, and (ii) there is a
periodic change in such a group-
ing. 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 ex-
ample is to ask students to iden-
tify 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 ex-
planations 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.
I would like to express my gratitude to the author of this problem for making it possible for me to present my ideas. This is an interesting and challenging problem that I have been working on for some time. I hope you will find it equally stimulating and enjoyable.

**Children's crosswords**

1. Matching

Let us start from the fact that the curriculum is divided into different levels. We then need to find a way to produce tests that can be used to assess student understanding. It is important to ensure that the tests are designed to evaluate specific aspects of the curriculum. In this way, we can ensure that students are being taught the material that they need to know.

1. Material (objective) is drafted.
2. It is used with the students.
3. Tests are set that can be used to evaluate the level attained.

If test results are not as expected, the process is repeated.

If the process is repeated once or twice, we find that there isn't a more suitable material to learn. Was there not some theory that led me, and other teachers, to believe that there was likely to be too much emphasis on tests of pupils?

There are, of course, rules of procedure that are fundamental to the problem of learning.

* Talk given by Dr. Smith at the conference.