Improving Chemistry Laboratory Work

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The Problem

Laboratory work has long been recognised as an integral part of the science curriculum. Research studies show that students' attitude towards chemistry is most strongly correlated with positive attitude towards Chemistry laboratory, followed by students' participation in laboratory activities (Okebukola, 1986). Hence doing laboratory work may lead to improved process skills, and the acquired skills may promote a more desirable attitude towards the subject. The 'what' and 'how' of laboratory work are likely to be the contributing factors to the success of the improvement of the skills. But what is the actual practice in our schools?

Usually Chemistry practicals require students to follow a set of detailed instructions and to write a formal report on it. A verification of something already know is often emphasized rather than the process skills. 'Drill and practice' is applied to train students to pass the practical examination. Teachers and students place great emphasis on obtaining the correctness of the answers and the mastery of process skills is normally left to chance.

Under such circumstances, is the practice compatible with the spirit of science? If not, are we able to improve upon it? Can we fulfil the objectives of the practical work set in the GCE 'O' Level Chemistry syllabus (UCLES 1988)?

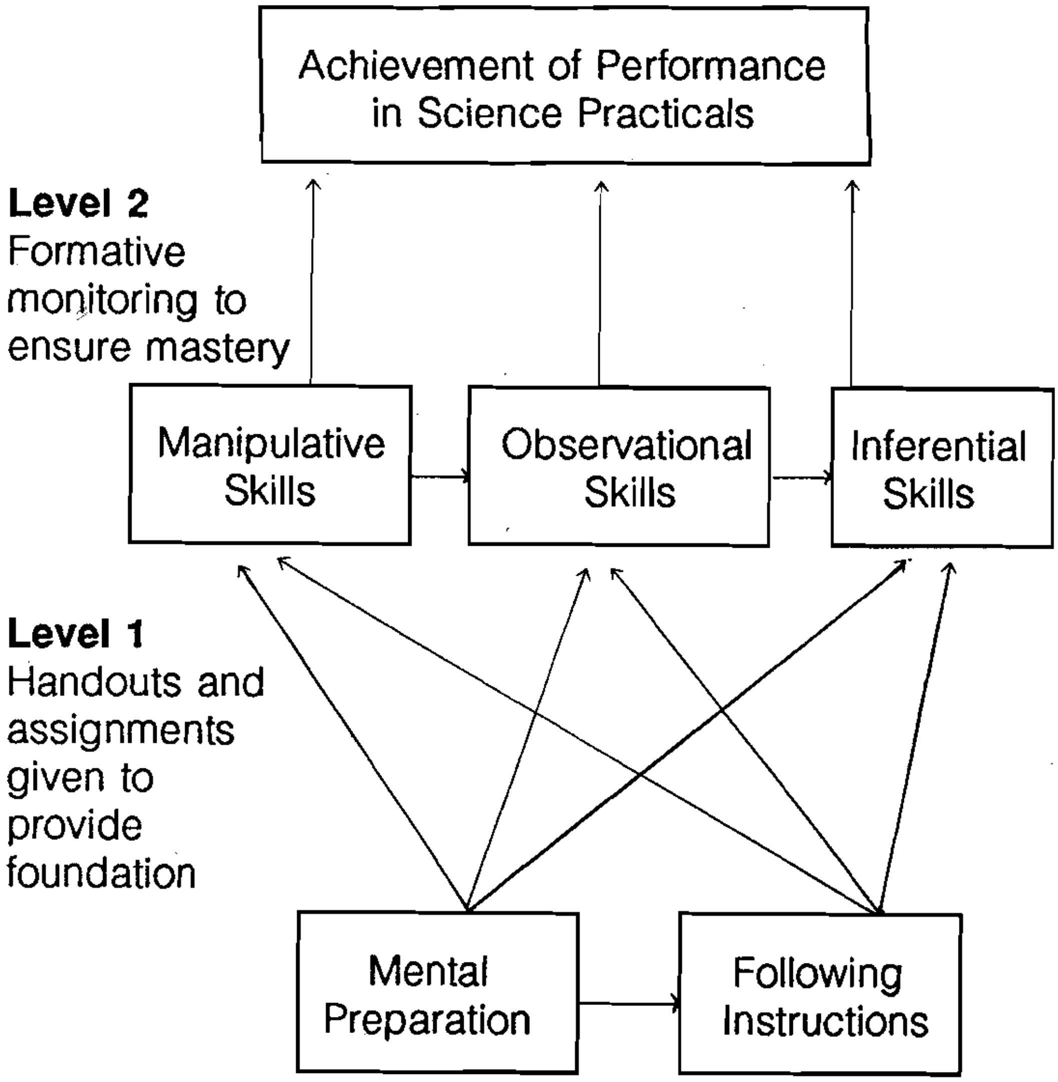
How Can We Improve Upon It?

Here we would like to share our experience of conceptualizing the Modified Laboratory Instruction (MLI) for qualitative analysis in Chemistry (Goh et al., 1987). The following are the reasons for the development of the MLI:

1. We believe that for any experiment, process skills involved can be presented systematically to the students. The learners as well as the teachers should be aware that the mastery of one process skill will affect the development of another process skill. In the case of qualitative analysis, the relationship among some skills is shown in Fig. 1.

Fig. 1

Conceptual Framework of MLI



It is obvious that only the correct manipulative skills and observational skills can possibly lead to the correct inference. Therefore we should first emphasize the manipulative and observational skills. For a series of experiments, the order of the experiments to be conducted should be according to the complexity of the process skills to be introduced. In qualitative analysis, we can start with the physical appearance of chemicals which involves only simple observations and simple inference. Then the solubility of chemicals in water can be introduced. Simple manipulative, observational and inferential skills are required in this case. Subsequently, we can introduce 'the addition of reagents, such as precipitants/acids' and 'the heating of chemicals' etc., which require more complicated skills.

2. The strategies used for the instruction in each experiment should be carefully planned. The basic principles to follow are: from known to unknown, from simple to complex and from concrete to abstract. But the way we select the materials and organise the content will have an effect on the success of the learning. For the selection of the materials, we would suggest the use of chemicals which provide precise results, especially for the first few experiments. Our rationale for doing so is:

   (a) For the beginner, we would like to focus on:

      - the ability to understand and follow instructions

      - the ability to distinguish observation from inference

      - the way students present their observation and inference

   (b) We have to avoid confusion in order to reduce the effect of overloading of information (Johnstone, 1986).

For the organization of content, the Piagetian learning cycle has been proved to be practical. The cycle takes place in three phases in the following sequence: exploration, invention and application (Karplus, 1977) which corresponds to the enquiry of science.

3. The proper selection of materials and the well designed worksheet do not automatically guarantee the success of laboratory work. The pertinent question we have to ask is, how do we ensure the mastery of process skills in the laboratory. The following are suggestions which can be used:

(a) **Providing handouts to students**

Handouts on the 'what', 'how' and 'why' of the practical skills as well as theoretical aspects of qualitative analysis could serve as some form of pre-lab activities to prepare the students. These handouts also include the training of the skill of following instructions.

(b) **Demonstrating the skills**

As we introduce each new manipulative skill to students, the correct way of doing it should be demonstrated and the reasons(s) for doing so should be explained clearly. These will make them more confident and more convinced in using the new skill.

(c) **Exercising mental practice**

Mental practice is the practice of certain manipulative skills mentally (Beasley, 1985). This can be usually carried out outside the laboratory as students go through the handout or after they have learnt the respective skill. This process will have the effect of reinforcement.

(d) **Continuous monitoring and coaching**

During the laboratory session, as students are practising their skills, it would be the best time for us to get feedback about their degree of mastery level for the skills involved. If we keep monitoring closely, with the aid of a checklist, it is not difficult to see the mistakes students make. If on the spot we make them aware of their mistakes and provide them opportunities to correct such mistakes, then the chances of them repeating the same mistakes can be reduced.

(e) **Providing feedback on what is wrong**

The performance of certain skills such as observational and inferential skills cannot be easily monitored during the laboratory session, but can be detected from what students present in the worksheets. Giving 'right' or 'wrong' answers with no reasons or explanations provided is inadequate feedback. The same mistake may be repeated. 'The reason or explanation for each error' provides the insight of the source of mistakes. Students are hence more convinced in correcting their mistakes.

4. Our present mode of laboratory work is confined mainly to experiments which have a well-defined set of instructions. As a result, students tend to follow the instructions blindly. To overcome such a shortcoming, opportunities should be provided for students to design the experimental procedures themselves. During the feedback sessions in the laboratory, we should explain to students how the experimental sequence is being designed. This requires a logical combination of the knowledge of theory and process skills. Such a training provides students a chance to link theory and practice. Hence, the design of the procedure for an experiment can further reinforce such link. In addition, the skill of following instructions can be improved.

5. Several problems arise if the assessment of laboratory work is confined only to a practical test as in Singapore now. The most serious problem is that only a few skills are being tested, e.g. observational and inferential skills. The manipulative skills are not assessed because of the assumption that there is a direct correlation between the practical skills and observational skills which is not supported by research evidence (Toh et al, 1985). In fact, the mastery of practical skills can only be justifiably assessed by a checklist. To assess such skills within one practical examination is nearly impossible, because of the large number of manipulative skills involved in the practical and the large number of students. Alternatively more teachers are needed if the assessment is to succeed.

   In order to solve this problem, it is necessary to have a system which involves a wider coverage of process skills to be assessed and, at the same time, is still applicable within the present constraint. It is likely that the combination of a practical examination and an alternative-to-practical test, which consists of simulated data and questions on theory and practice related to practical work in general, can best fulfil the objectives of the assessment and also would be fair to all students. The format of the alternative-to-practical test can follow closely that of Paper 6 set by the University of Cambridge Local Examinations Syndicate.

Conclusion

In fact, the above suggestion has been put into practice and tested (Goh et al., 1987). The results obtained show that it is viable. The difference between the Modified Laboratory Instruction and the present setting in the school lies mainly on the processes of feedback and assessment.

Getting feedback about 'what', 'how' and 'why' on the techniques as well as the procedure used will make students more confident in applying the required process skills. Including more process skills in the assessment will encourage students to be more aware and to exercise these skills. As we can see, the success of the laboratory work depends mainly on us. Hence, improving Chemistry laboratory work is really a challenge for all the Chemistry teachers.

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