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Research on the Scientific Thinking Skills of Students at Various Levels

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The research, made possible by grant RP11/95BHK from the Nanyang Technological University, examined the ability of students at various educational levels to think scientifically when presented with a range of chemical phenomena. The sample of 105 students was composed of 25 students at junior college year 1 (JC1) level, 45 at JC2 level, 12 fourth year undergraduate university students and 23 post-graduate students. The main data collection instrument was the clinical interview. Each subject was interviewed in-depth for about one hour on a one-to-one basis. Each interview was taped, transcribed verbatim and then analysed. Five familiar chemical reactions were used as foci for discussion in the interviews. For each reaction, the interviewee was asked, among other things, to make predictions about the overall energy change involved, and to give explanations as to why the change took place (i.e. the driving force for the change).

Scientific thinking was defined as the ability to "offer explanations in terms of formal concepts that meet communal norms". It was also defined as conceptually dominated thinking as opposed to perceptually dominated thinking, which is thinking based on observable features in a problem situation.

The results show that significant proportions of the interviewees across the various levels were using perceptually dominated thinking rather than conceptually dominated thinking. At the same time, they were unable to use science concepts consistently across the five reactions. It was inferred that these students were unable to think scientifically. Reasons for the lack of scientific thinking ability were explored in post-interview discussions with interviewees. The outcome reveals that students' inability to think scientifically may be broadly classified into three inter-related categories, viz. those that relate to (1) the learner, (2) the instructor/teacher and (3) the curriculum.

Reasons associated with the learner

With respect to the learner, many reasons may be offered. One reason could be the tendency of students to reduce theoretical knowledge and principles to a factual level and to apply this in a rote manner. In a situation where learners view the syllabus content as heavily loaded, this rote learning could be more prevalent (see curriculum-related reasons). In addition, rote learning might be further encouraged if the learner views science as predominantly a collection of facts.

Another reason relates to preconceptions or pre-existing misconceptions that learners might have with respect to certain concepts which impede the acquisition and use of scientific concepts in their thinking.

Reasons associated with the instructor/teacher

There are research studies, as well as anecdotal evidence, which show that the instructors/teachers themselves may be lacking in scientific thinking ability or may be harbouring misconceptions about science concepts; and these could contribute to the learner's acquisition of misconceptions and lack of scientific thinking ability.

Another reason relates to the pedagogical method. If the instructor/teacher fails to help learners appreciate the nature of science as both a product and a process (i.e. as the construction of predictive conceptual models) and, instead, presents science as nothing more

than a collection of facts, rules, algorithms and procedures to be memorised, then it would not be surprising if the learner tends to apply these by rote and hence cannot think scientifically.

Reasons associated with the curriculum

Among the reasons related to curriculum is the heavily loaded syllabus or loaded timetable. This could then mean that there might not be adequate opportunities to allow students to internalise concepts gradually, which could result in poor long-term memory retention. In order to handle a high volume of information, some students tend to adopt surface learning strategies (i.e. rote memorisation), rather than seeking meaningful linkages. Another reason relates to the inadequate description of the nature of science in the curricular materials; also the presentation of the content in the form of independent, disjointed topics, which tends to encourage students to compartmentalise topics, hindering the understanding of generic concepts, principles and models across topics. It has concluded that no single factor operates alone. Instead, a variety of these factors operate in concert to result in students' lack of scientific thinking ability.

Research published in:

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