Developing a Better Understanding of the Relationship Between Transpiration and Water Uptake in Plants

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Performance on a multiple-choice item in a public examination indicates that most students do not understand the principle of the bubble potometer and its limitations in measuring transpiration rate. Teaching strategies are suggested to overcome these problems by helping students to compare the bubble potometer with the weighing method, develop the concept of assumptions, and resolve cognitive conflicts. To rectify the alternative conception on the role of transpiration, an interactive activity is designed to guide students to expose their preconceptions, design investigations to test them and evaluate the validity of the original ideas.

KEY WORDS: potometer; transpiration; water relations; alternative conceptions.

INTRODUCTION

Transpiration is a topic essential for understanding the water relations of land plants. For the Certificate-level (Grade 11) biology examination in Hong Kong, students are required to master the concept of transpiration, and study various factors that affect this process, such as light, temperature, relative humidity, and air movement (HKEA, 1999). Similar requirements are also stipulated in the syllabuses of other examination boards (e.g. Board of Studies, New South Wales [NSW], 1994; Midland Examining Group, 1998; NISEAC, 1995). In relation to this, students have to conduct investigations on transpiration using the bubble potometer, and develop an appreciation of the limitations of the experimental methods used. Another key concept required for understanding the water relations of land plants is the interaction between water uptake through the roots and water loss through transpiration. This paper reviews some of the conceptual problems experienced by students when studying these areas, as based on students' performance on a multiple-choice item and an analysis of curriculum materials. Instructional strategies are suggested to help students to overcome these problems and develop a more comprehensive picture of the water relations of land plants.

ASSESSING UNDERSTANDING OF THE LIMITATIONS OF THE BUBBLE POTOMETER

A multiple-choice item in the Biology paper of the 1999 Hong Kong Certificate of Education Examination (HKCEE) assesses students' understanding of the limitations of the bubble potometer (Fig. 1). This question demands the recall of the idea that the rate of movement of the bubble in a bubble potometer measures directly the rate of water absorption of a plant rather than its rate of transpiration. This idea is basic to understanding the limitations of potometry as a method for measuring transpiration rate. It was anticipated that only the weakest students would have any difficulty in acquiring this concept.

ANALYSIS OF STUDENTS' PERFORMANCE

The performance of 37,254 candidates on this item is analyzed in Fig. 2 According to the overall performance in this multiple-choice paper, the candidates were divided into 10 ability groups of equal number. The first 10% ability group included candidates with the lowest scores, while the top 10% ability group consisted of those with the highest scores.
Fig. 1. Multiple-choice item on the bubble potometer.

The number of candidates in the 10 ability groups choosing each option is presented as a graph. This gives a pattern of performance that illustrates how well an option, whether it be the key or a distracter, may discriminate the high-ranking and low-ranking candidates. Inside the legend box, the value within each bracket indicates the percentage of candidates choosing a particular option, and the correct option is marked with an asterisk.

The responses across ability groups, as summarized in Fig. 2, show an obvious positive correlation between the candidates’ scores (percentage choosing the key, option D) and the merit order of the ability groups. The discrimination power for this question is also acceptable \( (D = 0.304) \). However, less than half of the candidates (45.25%) were successful in this item. This reveals that majority of the candidates did not know that the bubble potometer measures the rate of water absorption, a prerequisite concept for appreciating the limitations of potometry.

While Options A and C were chosen by only a small number of low-scored candidates, Option B appeared to be a very powerful distracter, attracting most of the unsuccessful candidates (47.05%). These students erroneously considered that movement of the bubble measured the rate of transpiration. As 76% of the total candidature gained a pass grade or above in the 1999 HKCEE Biology examination, it means that this error was committed by a substantial proportion of candidates who had passed the Certificate-level Biology. For those candidates lying between 24 and 75 percentiles, as indicated in Fig. 2, more of them chose Option B than the key. This reveals a serious lack of understanding of the basic principle of potometry in the students.

Fig. 2. Performance of certificate candidates on the “bubble potometer” item.