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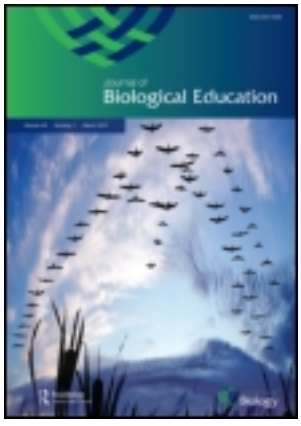

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Educational Research

Revisiting learning difficulties in biology

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When students from Scottish schools were surveyed 15 years ago about their difficulties in learning biology, two main topic areas stood out as high in perceived difficulty: water transport in plants and genetics. In the interim, curricular changes have been made in which cognisance was taken of these findings. The present study was a revisit to ascertain the changes in student perception. The water transport problems are found to have largely disappeared, but the genetics difficulties have remained. This paper tries to locate the root causes of this by interviewing students and teachers, and by consulting examiners' reports. Pointers emerge which are capable of leading to possible solutions.
Key words: Genetics, Learning difficulties, Biology.

Introduction

More than 15 years ago, a study was published about the learning difficulties encountered by secondary school and university students in learning biology (Johnstone and Mahmoud, 1980). Two topic areas proved to be most troublesome; water transport in plants and genetics.

It was decided to revisit this area and to see what changes in student perception, if any, had occurred in the intervening period.

The sample chosen was 207 first-year university students who were studying biology, but not necessarily planning a career in biology. A list of topics was compiled from the published syllabuses of the Scottish Examination Board at Standard Grade (approximately GCSE level) and at Higher Grade (university entrance level). This list was amplified from the most commonly used textbooks.

The total list comprised 36 topic headings. Students were asked to indicate their view of the difficulty of each by using four defined headings:

1. Easy (I understood it without difficulty).
2. Moderate (I had difficulty, but I understand it now).
3. Difficult (I still do not understand it).
4. I did not study this topic.

The percentage of students who had studied the topic recording it as difficult (3) was calculated.

The results are set out in table 1. Only six topics were recorded as difficult by over 10 per cent of the students who had studied them (table 2). Five of the six topics listed in table 2 were from the field of genetics, and four of these came at the top of the list.

It is also interesting to look at the topics which the students declared to be easiest (table 3). Three of these are in the general area of transport; the very area which was, in the past, rated as difficult. In the light of Mahmoud's work in the early 1980s (Johnstone and Mahmoud, 1980), considerable changes were made in the Scottish syllabuses which have resulted in this difficult topic becoming accessible to students.

However, the general area of genetics is still posing problems and this is not just the opinion of students, but is supported by the chief biology examiners of the Scottish Examination Board in their annual reports (1992-1995).

However, when the same topic list which was given to students, was given to five senior biology teachers, all with more than five years' experience, there was some indication that student and teacher views did not correspond. The only topic on the difficulty list on which both students and teachers agreed, was 'Monohybrid and dihybrid crosses and linkage'.

If teachers' perception of what was difficult to learn did not correspond closely with the students' views, a possible source of the problem may be emerging. This does not imply that the topic is not intrinsically difficult, but that the way in which it is presented may be adding to the difficulty.

Student interviews

It was decided that one-to-one interviews with a sub-sample of students might help to throw light on (a) the intrinsic difficulties, and (b) the presentational difficulties in genetics topics. To give structure to the interviews, an outline protocol was devised, but there was a large degree of freedom in the recorded student responses. The protocol provided 'headings' under which later analysis could be done, such as: language and terminology, mathematical content, amount of discussion, points of biological content and time allowance.

From these interviews, a number of pointers emerged which may give clues to underlying difficulties.

Language

Genetics is an area with a complex and large vocabulary.

Table 1 List of biology topics and students' responses (see Introduction for columns 1–4). Column 5 shows index of relative difficulty of each topic. (The index is the number of students reporting difficulty in a topic (total number of students in the sample – a number of students who did not do the topic).)

Topics	1	2	3	4	5
Active transport and secretion of materials	124	74	3	6	1.5
Diffusion and osmosis	172	30	1	4	0.5
ATP and chemistry of respiration	99	94	10	4	4.9
Absorption of light by photosynthetic pigments	94	88	12	13	6.2
Chemistry of photosynthesis	92	91	15	9	7.6
Sexual and asexual reproduction in plants	86	83	16	22	8.6
Developing eggs of fish and mammals	50	53	8	95	7.2
Growth differences between plants and animals	75	67	6	59	4.1
DNA and RNA (structure and function)	135	62	4	6	2.0
Cellular response in defence (Immune system)	103	81	10	13	5.2
Mitosis	102	88	13	4	6.4
Meiosis	78	100	24	4	11.9
Gametes, alleles and genes	77	104	21	4	10.4
Monohybrid and dihybrid crosses and linkages	65	93	45	4	22.2
Genetic engineering	76	86	25	20	13.4
Mutation	106	76	17	8	8.5
Natural selection, specification and adaptive radiation	103	76	11	17	5.8
Enzymes	151	50	3	3	1.5
Aerobic and anaerobic respiration	135	59	8	4	4.0
Genetic control of development and metabolic processes	50	93	22	39	13.3
Hormonal influences in animals and plants	76	89	15	26	8.3
Feeding and digestion	90	58	5	53	3.3
Excretion and the role of the kidney	103	74	10	19	5.3
Skeleton, muscle and movement	90	39	8	68	5.8
Heart, blood and blood circulation in mammals	95	49	5	56	3.4
Mammalian lung and breathing	84	50	4	67	2.9
Central nervous system, sense organs and co-ordination	62	69	16	59	10.8
Physiological homeostasis	89	85	17	14	8.9
Maintaining a water balance in animals and plants	116	67	6	18	3.2
Population dynamics	103	62	9	33	5.2
Food and energy chain in ecosystem and pollution	114	53	4	34	2.3
Obtaining food in animals and plants	128	49	1	28	0.6
Behavioural responses of animals to danger	129	41	6	31	3.4
Defence mechanisms in plants	102	59	3	42	1.8
Antibiotics and biological detergents	51	50	10	96	9.0
Fermentation of yeast and baking and brewing	61	44	9	91	7.9

Students were not confident about the precise meaning of words such as 'allele', 'gene' and 'homologous'. They were confused about the distinctions between look-alike and sound-alike words such as homologue, homologous, homozygous and homozygotye. One student commented:

> 'I think we had to learn a lot of things at the same time. We had to memorize a lot of knowledge *and the meaning of new terms.*'

Mathematical content

Mathematical expressions caused problems and the symbols were not used consistently by teachers and textbook writers:

> 'Mathematical expression is really an important reason why I do not understand genetic crosses. Maybe I am not good at maths and therefore do not understand crosses, but especially in genetic crosses, a lot of symbols are used and sometimes it is confusing.'

> 'I think genetics is much more related to maths than any other topic in biology.'

General attitudes

These were not always or often negative, but the intrinsic interest was clouded by factors of language and representation:

> 'At the beginning I found genetics more difficult than other biology topics and I did not like it... but when I began to understand it, I realized it was interesting and I began to enjoy it.'

> 'I like genetics, but I could not understand it easily and it was disappointing.'

Topics – similar yet different

One of the main problem areas lay in the topics of Meiosis and Mitosis. Because of their similarity, teaching them side by side added to the confusion between them. This is a well recognized source of psychological learning blockage when subtly different topics are taught side by side (Ausubel, Novak, and Hanesian, 1978).

> 'Our teacher taught us the topic of meiosis and mitosis at the same time and he gave comparisons between them. In the lesson I thought that I had learnt these two ideas very well, but after a month, when I asked myself, I could not remember much... they were so similar that I was confused.'

> 'I learnt the phases of meiosis very well. I still remember them, but I must admit that I did not understand the *significance* of meiosis and so I didn't understand linkage.'

Table 2 Topics of highest difficulty

Topic	Difficulty index
Monohybrid and dihybrid crosses and linkages	22.2
Genetic engineering	13.4
Genetic control of development and metabolic processes	13.3
Meiosis	11.9
Central nervous system, sense organs and co-ordination	10.8
Gametes, alleles and genes	10.4

'I could not say that I know the significance of mutation... I did not understand why it is a source of variation, but I just learned the types of mutation.'

One of the teachers who was interviewed had this to say about mutation, 'Many people think that mutations happen in response to problems faced by organisms. They find it difficult to grasp that mutations are random and are then selected by the effects of environmental factors on organisms'.

Time allowance

Both students and teachers were clear that not enough time was available to tackle this difficult area, and that what was needed was discussion and time for digestion and experiment.

Summary and discussion

Although the area of genetics is posing a problem, the proportion of students who are reporting that they are still in difficulty is relatively small (10–20 per cent). However, our sample is made up of university students who have successfully passed university entrance level in biology, and so it is to be expected that the proportion of 'sufferers' would be small. What the situation is like among the many school pupils who studied biology, and were either unsuccessful or chose not to study biology at higher level, can only be conjecture. However, it would be a fair assumption that they found genetics at least as troublesome, or more likely, more troublesome than the students in our sample. Indeed, it can be seen that if we were to combine the responses in column 1 and 2 in table 1, a large number of students found the topics difficult, at least initially.

In other sciences, there are similar areas of difficulty which carry over from one level of education to another. Analysis of the nature of these topics leads to a realization that their complexity lies in the fact that the ideas and concepts inherent in them exist on three different thought levels: the Macro and tangible, the Micro (or even Sub-micro and molecular), and the Representational (Johnstone, 1991).

Table 3 Topics of least difficulty

Topic	Difficulty index
Diffusion and osmosis	0.5
Obtaining food in animals and plants	0.6
Enzymes	1.5
Active transport and secretion of materials	1.5
Defence mechanisms in plants	1.8

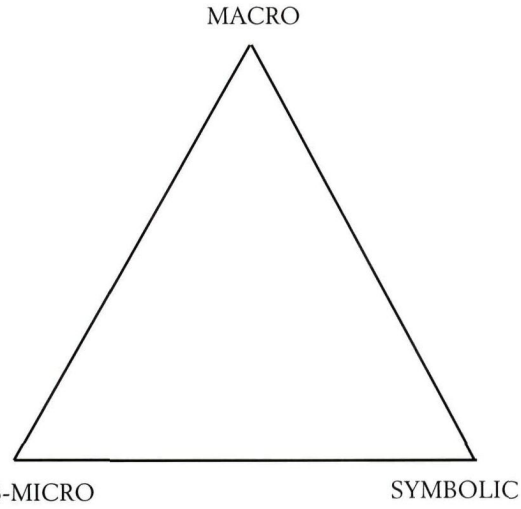

Figure 1 *Three levels of thought.*

The topics in genetics have the same form (figure 1). Observations of morphological characteristics of living things, such as flowers or insects, form the MACRO and are accessible to the senses. The appeal to genes, alleles and so on to explain the MACRO takes students into the SUB-MICRO, which is not directly accessible to the senses. These are then represented and manipulated by mathematical devices which are SYMBOLIC of what is happening at the SUB-MICRO, and giving rise to the MACRO.

Educational implications

The teacher, as an expert, has the facility to flit intellectually from corner to corner of the triangle (figure 1), and even to operate within the triangle where thoughts can comprise all three components simultaneously and in differing proportions. This is not an intellectual facility shared by novices. To begin with, they operate at one level (or corner) at a time and then progress to thinking along one side, combining two corners. It is a long time before they can follow the teacher into the body of the triangle.

It may be that the solution to the learning problems in genetics is to develop this thinking slowly, coming back to it many times and controlling the complexity by operating on the sides of the triangle only. This will need time to develop experimental experience of the MACRO, careful control of vocabulary and concepts in the SUBMICRO and phased introduction of the SYMBOLISM.

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