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Finding Out What Students Are Thinking Concerning Light and Sight

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Summary

This paper reports on the results of a study on how 238 ninth and tenth grade students from 6 schools interpret everyday phenomenon involving light and sight. The study uses the Structure of the Observed Learning Outcomes (SOLO) Taxonomy (Collis and Biggs, 1991) to lay the foundation for a Students' Seeing Framework (Jones, Collis, Watson, Sprod and Fraser, 1995a) based on notions of light, eye and object.

The instrument used for the study probed students' understanding of the topic with respect to the mechanism by which they see. A one-to-one interview was also carried out with 14 randomly selected students after the administration of the questionnaire, principally to validate their responses. The results indicate that more than 50% of the students did not demonstrate complete understanding of the concepts of light and vision, even after formal instruction on the topic. Grade level was a factor influencing the development of concepts of light and vision.

Introduction

There is a plethora of studies (see, for example, Stead and Osborne, 1980; Andersson and Karrqvist, 1983; Fetherstonhaugh, Happs and Treagust, 1987; Boyes and Stanisstreet, 1991; Langley, Ronen and Eylon, 1997) to indicate that students are unable to explain everyday events about light and sight, despite having gone through formal science education. This shortcoming is a cause for some concern and there is a need for research to pin down exactly what it is that students are finding difficulty in.

This study examines the topic of light and sight with the intent to better understand the complexities associated with students' concept development. It also aims to find out whether grade level is, in any way, a determinant of how students understand events concerning light and sight. It uses the Structure of the Observed Learning Outcomes (SOLO) Taxonomy (Collis and Biggs, 1991) as the theoretical framework for postulating a Students' Seeing Framework (Jones, Collis, Watson, Sprod and Fraser, 1995a). This framework identifies 3 distinct components (light, eye and object), upon which all explanations involving light and sight are expected to revolve around. A student giving an explanation would need to build connections between these components. From the quality of students' explanations involving the components of light and object (L/O), eye and object (E/O), and light and eye (L/E), it is then possible to construct a hierarchy of understanding. It is postulated that there is a unique order of acquisition in this hierarchy of understanding. For example, L/O 1 precedes L/O 2, and L/O 2 precedes L/O 3. L/O 3 thus represents the highest order of understanding between light and object.

Design

238 ninth and tenth grade students from 6 high schools in Singapore took part in the study. The students were from intact classes because the school set-up did not facilitate a random pick of students without disrupting their curricula programs. These students had been taught the topic of light during their seventh and ninth grades, as a result of the spiral curriculum. They would thus have been exposed to sufficient basic knowledge concerning light propagation, properties of reflection, and concept of darkness--this being the content covered by the instrument administered. A profile of the study sample is shown in Table 1.

Table 1. Profile of study sample

School	Grade Level	No. of Boys	No. of Girls
A	10	11	17
B	10	41	0
C	10	14	14
A	9	16	21
D	9	32	0
E	9	19	19
F	9	17	17

The instrument administered was adapted from Jones, Collis, Watson, Sprod and Fraser (1995b). Rigorous validation procedures were employed to ensure that the instrument and the scoring schedule were reliable and valid. The instrument went through trial testing. It was reviewed by a 9-member team of science educators. Changes were made to eliminate cultural bias. Three judges took part in categorizing the responses from a sample of students' responses, and their outcomes subjected to a Test of Concordance. The Coefficient of Concordance was 0.94, showing good agreement across all three judges in their outcomes. Thus we can analyze the results confident of the reliability of the scoring schedule. Table 2 shows how the students' responses were scored.

Table 2. How students' responses were scored

Score	Interpretation of Scores
0	*No Understanding* (NU) demonstrated.
1 - 4	*Little Understanding* (LU) demonstrated. Students in this category could only elaborate one aspect of a particular relationship among the 3 distinct components (light, eye and object). Their responses, at best, revealed superficial understanding of light and sight.
5 - 8	*Partial Understanding* (PU) demonstrated. Students in this category were better than those in the LU category, as they could point out more than one aspect of a particular relationship among the 3 distinct components of light, eye and object. In addition to this, they could explain some details that were related to light and sight.
9	*Full Understanding* (FU) demonstrated. Students provided full details and showed they could explain the inter-relationships among the 3 distinct components.

To forestall the possibility of misinterpretation of what students had written down when the instrument was administered, 14 students were randomly sampled for a one-to-one interview subsequent to the administration of the instrument, principally to validate their written responses. This provided a rich source of detailed information about what the students were thinking when they answered the questions involving light and sight. To increase the trustworthiness of the research data, informal discussions with the respective science teachers were had, to provide for some means of triangulation of the research findings.

Results and Discussion

An analysis of the distribution of scores for ninth and tenth grade levels (see Table 3) provided a useful insight into the extent to which students were showing understanding of concepts in light and sight. At the ninth grade level 4.9% showed no understanding of concepts in light and sight, while 46.3% were in the LU category. This means a total of 51.2% (= 4.9% + 46.3%) showed little or no understanding of the concepts at all. There were 45.0% and 3.8% belonging to the PU and FU categories, respectively.

Table 3. Distribution of scores for each grade level

Level of Understanding Classification	Score	Percentage in 9th Grade	Percentage in 10th Grade
NU	0	4.9	15.3
	1	8.6	9.5
	2	12.8	9.5
LU			
	3	13.6	13.4
	4	11.3	6.3
	5	9.5	6.5
	6	14.3	8.5
PU			
	7	12.1	9.7
	8	9.1	11.1
FU	9	3.8	10.2

The tenth grade level also demonstrated a very similar trend. The percentages for each of the categories, NU, LU, PU and FU, were 15.3%, 38.7%, 35.8% and 10.2%, respectively. The combined figure for little or no understanding of concepts in light and sight stood at 54.0% (= 15.3% + 38.7%). This figure is rather depressing, both on its own and in relation to those in ninth grade. When one considers that the ninth and tenth graders have had formal instruction *a priori* on the topic, this is a cause for concern. The instruction did not have much impact on the students' understanding of the topic. These findings seem to corroborate the research work of Andersson and Karrqvist (1983) using 12 to 15-year old students in Sweden. They found that 60% of the students did not understand the concepts of light. These numbers are less than satisfactory, to say the least, and it is therefore important to find out what it is that students are finding difficulty in.

The quality of students' explanations can be gleaned from the way they build connections between the 3 components of light, eye and object. Table 4 depicts how good students are at explaining concepts in terms of pairs from the 3 components, viz. light and object (L/O), eye and object (E/O), and light and eye (L/E). Of the 3 component pairs, obviously students found the greatest difficulty in the E/O pair. This is true for both the ninth grade, as well as the tenth grade students.

Table 4. Performance in each of the component pairs

(Maximum possible score is 81)

Component	Ninth Grade		Tenth Grade	
Pairs	Mean	SD	Mean	SD
L/E	59.2	17.7	50.6	21.7
E/O	36.4	13.5	33.0	22.5
L/O	59.7	17.4	54.7	19.3

Students' responses for the E/O pair can be analyzed by classifying the different qualities of possible responses in terms of a hierarchy of understanding. Our basic understanding of E/O in any situation involving explanation of light and sight tells us that acceptable answers must include "*light reaching an object before they reach our eyes.*" In the hierarchy of understanding therefore we operationalized:

Responses such as:	By classifying them as:
"I can look at the object" "I can see the image on the glass"	E/O 1: Lowest level of understanding. Those at this level are *"merely looking at the object"* without exhibiting much understanding at all.
"The light rays are reflected onto an object which enables us to see it"	E/O 2: Partial understanding that eye, object and light must be present to facilitate seeing. Direction of light travelling from object to eye not made explicit.
"Light is reflected from the object and projected into our eyes"	E/O 3: Full understanding demonstrated for the eye-object-light relationship, with the *"passage of light rays from light source to object before they reach the eye"* made explicit.

The range of responses from E/O 1 to E/O 3 represents progressively higher levels of understanding and it is postulated that there is a unique order of acquisition in this hierarchy of understanding. Evidence adduced from responses of the 238 students in the study sample showed that many fall short of E/O 3 in their level of understanding. They did not completely grasp the fact that light rays must fall on an object before they are reflected into their eyes. The importance of light rays falling on an object in order to see the object (classified as E/O 2) represents a partial understanding, and seems to be well appreciated by a large majority in the study sample. However having light rays from the object reaching the eye (E/O 3) was the most difficult to achieve. Table 5 shows the percentage of students who attained each level for the E/O pair for each of the items tested.

Table 5. Percentage of students attaining each hierarchical level for the E/O component pair

Item Tested	E/O 1	E/O 2	E/O 3
1	44.5	27.7	13.9
2	42.4	27.7	7.1
3	58.0	13.0	2.5
4	39.5	31.9	10.5
5	32.8	24.4	6.7
6	37.0	19.7	3.8
7	36.1	13.9	4.6
8	33.2	19.7	7.1
9	24.8	20.2	4.6

Consistent across all the items is the declining percentages recorded from E/O 1 to E/O 2 to E/O 3. This consistency across all the items upholds the validity of the hierarchy of understanding, with E/O 3 as the highest level of classification, and so the most difficult aspect of the E/O pair to achieve.

The topic of light and sight is certainly not an unfamiliar topic to students at the ninth and tenth grade level. Under the spiral curriculum, initial ideas of light and shadows were introduced as early as third grade. These ideas were developed further in their seventh grade and then in ninth grade. At the tenth grade students are geared for an examination conducted by an external agency, the Cambridge University in the U.K. This is an important benchmark examination and the outcomes will decide who gets into junior college and who does not. Competition is very keen for places in these junior colleges. Under such a scenario it is important that students need to be familiar with the work to be tested. As such students often resort to private tutors to help them in their work in an effort to perform better at this tenth grade examination. In situations when content familiarity is achieved, performance seems to improve considerably. This is very much akin to girls' preference for familiarity rather than uncertainty reported by Toh (1993) in students' performance of practical tasks in this journal.

Conclusions and Implications

The study of students' understanding of light and sight discussed in the preceding section has important implications for curriculum implementation, particularly with regards to the way science concepts are being taught in high schools. This study shows that a considerable number of students do not understand the concepts of light even though they have continuous exposure to the phenomena of light and sight. Their inability to link the 3 distinct components of light, eye and object in a cohesive manner and to explain how light rays can be reflected off from an object before reaching the eye of an observer provide evidence attesting to the poor understanding of concepts of light.

Grade level comes out as an important determinant influencing students' understanding of light and sight. Although there is a sizeable number of students who exhibited little to no understanding of the concepts of light and sight in tenth grade, their greater preparedness and maturity as compared to ninth graders is reflected in the higher percentage attaining full understanding.

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