The Eight Percent of Design and Technology Students in Our Class

RESEARCH

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Abstract

Today, approximately 8 percent of all men and 0.05 percent of all women have colour vision deficiency (totally or partially incapable of discriminating colours). In Hong Kong, this percentage of students may lose their opportunity to study design courses as they need to face colour vision deficiency (some call it colour vision disability, or colour vision abnormality) testing when they want to enrol in some of the design courses at some institutions. But is this actually necessary?

A case study of the performance of design and technology students with colour vision deficiency was conducted in Hong Kong. The results indicated that there was no significant difference in the performance of design and technology students with colour vision deficiency and those without. By using the results, this paper tries to illustrate some positive ways of facing this deficiency.

Does colour vision deficiency significantly affect the performance of students?

In Hong Kong, colour vision deficiency testing is one of the entrance requirements for design studies at some institutions. These tests seldom consider the degrees and types of colour vision deficiency. Most of the time, under the current testing (e.g. Ishibara Colour Vision Test) the students with a mild degree of colour blindness would be treated the same as a person with total blindness (approximately only 1 in 30,000 individuals has total colour blindness) and their application would be declined. Thus, students with a slight degree of colour deficiency can be identified and they would lose their opportunity to study design. Or for instance, the students with different degrees of colour deficiency would be totally forbidden to study some design courses in some institutes. But is this actually necessary, and does colour vision deficiency really significantly affect the performance of design and technology students?

As mentioned clearly in the National Curriculum (National Curriculum Council, 1989, 1990; School Curriculum and Assessment Authority, 1994), every student should have an equal opportunity to study design and technology, as well as other subjects. Thus, the performance of design and technology students with or without colour vision deficiency is worthwhile investigating. Therefore, the aims of the study were not used to distinguish the students with colour vision deficiency, but to see the 'truth' behind the deficiency, and to seek a positive way to see and assist this group of 8.05 percent of students.

Methods

All of the six classes of 14–16 year-old design and technology students (n=122) in the same level (Secondary 3) in a school were selected for a study of the design performance of students with colour vision deficiency. Two design and technology teachers from the same school were invited to assess the students' projects. The students and teachers were participating voluntarily. Moreover, all of the records and personal data were kept strictly confidential, as some of the students may not want others to know about their disability.

The study was divided into seven stages:

1) A project brief (to design a bookend) was given to students. They needed to finish the project within six weeks. The project consisted of the use of colour, such as design the graphic on the surfaces of a bookend, and the graphical illustration of the drawings.

2) The two design and technology teachers were invited to assess the students' projects. Before the assessment, the teachers were invited to take the *Ishihara Colour Vision Test* (see Note 1). Although there is no evidence to prove that teachers with or without colour vision deficiency would assess students' performance differently, this study preferred to select teachers without colour vision deficiency to assess the students in order to eliminate the possible correlated cause.

3) The students were also invited to take the *Ishihara Colour Vision Test*. As was the case for teachers, the test did not aim to find out the different varieties of colour vision deficiency, e.g. monochromats, dichromats, protanopia or deuteranopia (Hart, 1992; Sharpe & Nordby, 1989). It only tried to distinguish whether the students had a deficiency or not, in order to compare their design performance with that of other students.

   The teachers did not know the colour vision testing results of the students. This was mainly because the teachers would be involved in assessing the students' performances, and knowing the result might influence them. It was not expected that the teachers or other students would stereotype or discriminate against students with a colour vision deficiency. It was very important that the testing was carried out after the students' projects had been completed. It was mainly to prevent students tackling their projects differently, especially in handling colours, after the test.

4) The students' performance in a design project consisting of the use of colour was assessed by the two teachers. The students' work was assessed based on the marking criteria for design projects in:

a) the Hong Kong Certificate of Education Examination (Hong Kong Examinations Authority, 1998a)

b) the Hong Kong Advanced Level Examination (Hong Kong Examinations Authority, 1998b).

There were three main areas to be assessed:

a) design process
b) communication and presentation
c) design solutions and realisation.

Table 1: Guidelines for the Assessment of the Design Project (adapted from Hong Kong examinations Authority, 1998b)

Marks						Student's abilities/skills/performance to be assessed: Please read the following guidelines before starting your assessment
Outstanding	Above Average	Average	Below Average	Weak		
(45)					I.	DESIGN PROCESS
5	4	3	2	0-1	1.	**Identification and Analysis of the Problem** This mark is an evaluation of the student's ability to identify, analyse and evaluate the provided problem; to formulate a design brief; to analyse the design requirements; to analyse acquired information relative to the problem; and to prepare a design specification.
5	4	3	2	0-1	2.	**Research and Investigation** This mark is an evaluation of the student's ability to gather, order and assess the information relevant to the solution of the problem.
8-10	6-7	4-5	2-3	0-1	3.	**Generation and Development of Ideas** This mark is an evaluation of the student's ability to generate, develop and evaluate a variety of design ideas and possible solution to the problem.
8-10	6-7	4-5	2-3	0-1	4.	**Synthesis** This mark is an evaluation of the student's ability to collate ideas into a coherent final design; to combine ideas and known facts in the formation of a complete design proposal; to apply known principles to design applications; and to model design solutions and partial solutions in appropriate media.
5	4	3	2	0-1	5.	**Final Solution — Fitness for Purpose** This mark should reflect the extent to which the design solution has solved the key factors of the design assignment.
5	4	3	2	0-1	6.	**Final Solution — Individuality and Originality** This mark should reflect the student's individuality in project work and personal expression; and the ability to provide innovative, original solutions.
5	4	3	2	0-1	7.	**Evaluation** The mark is an evaluation of the student's ability to appraise the design solution against the original specification; and to make recommendations for modification(s) where necessary.

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(25)					II.	COMMUNICATION AND PRESENTATION
5	4	3	2	0-1	8.	**Written communication** This mark is an evaluation of the student's ability to present their ideas concisely in words, and with a considerable amount of specific detail.
8-10	6-7	4-5	2-3	0-1	9.	**2D Communication** This mark is an evaluation of the student's ability to contribute and present ideas and data through 2D forms of communication such as sketches/drawings, graphs, charts, symbols, etc.
5	4	3	2	0-1	10.	**3D Communication** This mark is an evaluation of the student's ability to contribute and present ideas and data through 3D forms of communication such as mock ups and models, etc.
5	4	3	2	0-1	11.	**Overall Communication** This mark should reflect the student's overall ability to present their ideas effectively.
(50)					III.	DESIGN SOLUTIONS AND REALISATION
8-10	6-7	4-5	2-3	0-1	12.	**Making Techniques and Processes** This mark is an evaluation of the student's ability to use the learned techniques and processes to making the design solution.
5	4	3	2	0-1	13.	**Choice of Material** This mark is an evaluation of the student's ability to select and use appropriate materials (among provided materials) for the design solution.
5	4	3	2	0-1	14.	**Accuracy of End Product** This mark should reflect the extent to which constructional and dimensional details on the end product agreeing with the working drawings.
5	4	3	2	0-1	15.	**Finish of End Product** This mark is an evaluation of the appropriateness and quality of surface treatment (include colours) applied to the end product.
5	4	3	2	0-1	16.	**Aesthetic Quality of End Product** This marks is an evaluation of the student's ability to apply aesthetic considerations to the end product.
13-15	9-12	5-8	2-4	0-1	17.	**Function and End Product** This mark is an evaluation of the constructional soundness of the end product in terms of usability according to the defined specification.
5	4	3	2	0-1	18.	**Safety Considerations** This is an evaluation of the student's ability to design products with safety considerations.

Table 1: Guidelines for the Assessment of the Design Project (continued)
(adapted from Hong Kong examinations Authority, 1998b)

Based on design, performance did not only congruent to use of colours, the selected areas for the assessment were to assess the overall design ability of students but not only in the use of colour. After combining two sets of marking criteria, the weightings of different areas were adjusted to 45, 25 and 50 marks (total: 120 marks).

Since both sets of marking criteria were used to mark the Secondary 5 and 7 student projects, some modifications on the level of difficulty and specific requirements were made. In order to have a clear illustration of the marks between 2-dimensional and 3-dimensional communication, the element '2D and 3D Communication' was separated into two elements: '2D Communication' and '3D Communication' (see Table 1). Although an additional element was added, the main focus of the assessment was not only colour application, but the general (overall) performance in design, as colour is not the only criterion used in the assessment of design tasks. In fact, as the Graphical Illustration course in many institutes claims, colour sensitivity is only 'one' important requirement in assessment, not the 'only' one.

5) By using t test, the design performance of the students with colour vision deficiency (Group A) were examined with the other students (Group B) (both groups of students were taken as independent samples) to see whether the differences between means in the three areas were significant.

6) Two Art and Design (A&D) teachers in the same school were invited to take the *Ishihara Colour Vision Test.*

7) By mixing the work of the students with colour vision deficiency with the same number of students without the deficiency (random selected among non-deficient students), two A&D teachers joined the design and technology teachers and tried to see, by impression marking, whether there was a significant difference in colour application among all of the selected students. The reason for assessing the students' performance not just in colour application was because the emphasis of this study was to see whether or not there was a significant difference in general design performance among the students.

Results

Colour vision test result

The results showed that the design and technology and A&D teachers had no colour vision deficiency. Among 122 design and technology students, seven students (5.74 percent) had colour vision deficiency. This percentage was lower than the usual percentage of males with colour vision deficiency in the general population (about 8 percent) (Coren, Ward, Enns, 1994; Nathans, 1987; Nathans, Piantanida, Eddy, Show & Hogness, 1986).

During testing, it was found that no student was totally incapable of discriminating colours (what we usually call total *colour blindness*). The students were regarded as deficient if they could not pass the requirements listed in the *Ishihara* booklet (see Notes 2 & 3).

Six out of the seven students with colour vision deficiency had not realised that they had any problems with colour vision. And all seven students (including the ones who knew about the deficiency) stated that they did not find any great difficulty in distinguish colours for everyday purposes.

Comparison of students' performances

The two design and technology teachers marked all 122 projects and gave marks in three areas according to the marking criteria (see Table 1). After marking, the scores in each area for each student were calculated into an arithmetic mean, which constituted the final mark. As stated before, the total number of students involved in the study was 122. For 120 degrees of freedom a t (critical value) equal to 1.289 is required for significance at 0.20 level, 1.980 at the 0.05 level, and 2.617 at 0.01 level. The t observe were: 0.907, 1.131 and 1.072 (3 d.p.). Therefore, for each of the three assessment areas:

(a) design process
(b) communication and presentation
(c) design solutions and realisation

The differences between the means (the marks for the three different areas) between the students with and without a deficiency were not significant.

When asked whether there were any differences in the use of colour, the four teachers could not indicate which project(s) were designed by student(s) with a colour vision deficiency. And when the work of the seven students with colour deficiency were specifically picked out for the teachers to comment on, they still stated that there was nothing particular in terms of the design performance (compared with the other students) to comment on.

Limitations and constraints

Five limitations of this study should be noted:

1) This study only looked at 'general' performance in design, and did not

specify a design project which only relied on the uses and distinctions of colour.

2) Colour vision deficiency takes many forms. According to Coren, Ward & Enns (1994), there are at least five forms of colour vision deficiency (see Note 4). This study only looked at colour vision deficiency in general, with no detailed analysis of whether or not different forms of deficiency would affect performance.

3) The sample size was not large – only seven students with colour vision deficiency could be found. Nevertheless, as a case study, further investigation on the result is recommended.

4) As the selected students were all in the same level, the results cannot say anything meaningful about the performance of students in other years.

5) Since more than 99 percent of design and technology students in Hong Kong are boys, all of the selected students were male. The results were not therefore significant in showing that girls with colour vision deficiency would perform the same as boys. Since more males have far more colour vision problems than females (160 to 1), this limitation should not greatly affect the overall results, but a specific study of girls is still recommended.

Discussions: equal opportunities

We cannot deny that colour provides an important stimulus dimension that aids in the localisation and identification of objects. But it does not imply that we should deprive people of opportunities to learn and work with colour because of a genetically-transmitted deficiency. Quite the opposite, we should find methods of eliminating this 'barrier' to help the people with the deficiency, and everyone else as well. In fact, most of the time, discrimination comes from *ignorance.* According to the results of this case study, there is no evidence that colour vision deficiency causes poor general performance in design. Thus, using colour vision deficiency as an excuse to prevent students learning and working in design seems wrong. Such a wrong decision – ignorance – is unfair and causes inconvenience, problems and loss to the people being discriminated against.

According to the *Syllabus for Design and Technology (Secondary IV-V)* (Curriculum Development Council, 1997), students need to "apply basic design elements [including colour] and organisational principles in developing ideas and solutions in design activities" (p. 9). However, colour should not be the only element. It should be treated as one of the 'media' or 'tools' assisting students to design – communicate. There should not be a barrier between students and their learning and work. And as the most important element of design (problem solving) is creativity (Gilbert, 1998), and we, according to the results of this study, cannot significantly prove that a colour vision deficiency results in poor creativity, we should not limit the opportunities for students to learn, and later to work, in design. Even though a colour vision deficiency *may* sometimes bring inconvenience to design work (and only then *perhaps* in the use of colours), we should take this problem as a situation that we need to overcome, not something that should be neglected and ultimately given up on.

One way of overcoming a deficiency in colour vision is to allow students to find out about their deficiency as early as possible. According to the result of the discussion with the seven students with colour vision deficiency, six of them did not know about their deficiencies. Although the study shows that having a deficiency did not cause any obvious difficulties to the students' design work, only a better understanding of their own strengths and limitations can help them work better in the future.

If students find themselves getting into difficulties with a particular design task because of their colour vision deficiency, a teacher (or the curriculum design and implementation itself) should provide them with alternative ways to solve the problem. This does not mean taking the negative path of telling the student not to do the design task or asking their classmates to help them, as this does not deal with the problem. It would be the same as asking a disabled person not to move, or only letting others carry them around. This not only fails to benefit the disabled person, but it is also inconvenient for others (although we should always help). By tackling the problem in a more positive way – such as finding ways to rectify this genetically transmitted deficit – we tackle it directly. We can also minimise the inconvenience caused by this deficiency by, for example, designing items (methods or artefacts) to help this group of people view colours 'normally'. In fact, we already have some things which can assist people with some kinds of colour vision deficiency, but they have limitations, such as a bulky appearance and many application constraints, and this means that they are not particularly popular. More research and government investment is needed.

In summary, while colour vision deficiency is still a scientific and technological limitation that we cannot successfully solve, we should

not allow colour to be the only essential element in design decisions. Of course, the use of colour may be convenient for the majority, but we must also be concerned about the minority (the approximate 8.05 percent of total population). Such positive concern would allow people with a deficiency to study and work in design, and also ensures that the highest possible percentage of talent is put to work to benefit society.

Notes

1 *Ishihara* Colour Vision Test is a common and simple method to test colour vision deficiency. The tool is the *Ishihara Colour Vision Test Booklet* (24 plate – for quick screening). This test looks for congenital colour deficiency, and consists of cards on which small spots of colour varying in intensity form numbers or patterns which the patient (students) must identify (pseudo-isochromatic plates).

2 There is total colour blindness, which may be typical or atypical. According to a trichromatic theory of colour vision, people without functioning cones or with only one functioning cone type (monochromats) in retinas would be expected to have no colour discrimination ability. This is what we call (typical) total *colour blindness*. However, this situation is very rare, so that, for instance, it is estimated that only 1 in 300,00 individuals has no functioning cones at all (Sharpe & Nordby, 1989). In atypical total colour blindness, the colour sensitivity to red and green, as well as to yellow and blue, is so low that only very clear colours can be perceived.

3 According to the *Ishihara* Colour Vision Test, an assessment of the readings of plates 1 to 15 determines the normality or defectiveness of colour vision. If 13 or more plates are read normally, the colour vision is regarded as normal. If only 9 or less than 9 plates are read normally, the colour vision is regarded as deficient. However, in reference to plates 14 and 15, only those who read the numerals 5 and 45, and read them more easily than those on plates 10 and 9, are recorded as abnormal readings.

4 Most cases of colour vision deficiency are characterised by a red-green deficiency which may be of two types: (a) a *protan* type which may be absolute (protanopia) or partial (protanomalia), and (b) a *deutan* type which may be absolute (deuteranopia) or partial (deuteranomalia). In protanopia, the visible range of the spectrum is shorter at the red end compared with that of the normal, and that part of the spectrum which appears to be normal as blue-green, appears to those with protanopia as grey. The whole visible range of the spectrum in protanopia consists of two areas which are separated from each other by this grey part. Each area appears to those with protanopia as one system of colour with different brightness and saturation within each area, the colour in one area being different from that of the other. The red with a slight tinge of purple, which is the complementary colour of blue-green, appears also as grey. In deuteranopia, that part of the spectrum which appears to the normal as green, appears as grey, and the visible range of the spectrum is divided by this zone into two areas, each of which appears to be of one system of colour. The visible range of the spectrum is not contracted, in contrast to protanopia. Purple-red, which is the complementary colour of green, appears also as grey. In protanomalia and deuteranomalia, there is no part of the spectrum which appears as grey, but the part of spectrum which appears to those with protanopia as grey, appears to those with protanomalia as a greyish indistinct colour, and likewise, the grey part of the spectrum seen by the person with deuteranopia appears to those with deuteranomalia as an indistinct colour close to grey (Handbook of Ishihara Colour Vision Test, pp. 1–7).

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