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Comparing the legibility of different coloured chalk in teaching on a blackboard

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ABSTRACT: Blackboard teaching is the most prevalent teaching method in classrooms. Teachers clarify their lectures and motivate students to learn by writing on blackboards with chalk and through oral discourses. Different chalk colours exhibit different legibility for students. In this study, three unique red-green-blue (RGB) measurement software programs were used to compare the RGB values of pure colours with their related chalk colours. Finally, the legibility of the different coloured chalk was investigated using a questionnaire survey and statistical analysis. According to the RGB value analysis, the colour of the chalk was profoundly affected by their white calcium compound ingredients. By statistical analysis, it was revealed that writing in yellow and orange chalk was more legible for the students, followed by writing in green. Red and blue writing was revealed to be the least legible. These results provide a reference to teachers for choosing chalk for classroom teaching.

INTRODUCTION

Chalk remains prevalently used by teachers as a writing tool in modern teaching activities [1]. Although the conventional blackboard teaching method is not as vivid and diverse as multimedia teaching methods, blackboard writing is simple, convenient and time-efficient. Teachers can increase the attention of students through concise blackboard writing, as well as by employing effective underlining and emphases through the use of chalk with different colours [2]. Because of the limited sizes of blackboards, teachers must organise course contents and outline the focal points of the teaching materials most essential for students to understand [3]. Therefore, chalk use when teaching encourages students to pay attention to the focal points of learning materials and follow the pace of teachers in class, thus encouraging student comprehension, remembering and accurate learning.

Colours profoundly influence the daily living of people; colours are a medium used by people to express emotions and a vital element for creating visual forms [4]. Colours exhibit deep and rich symbolic powers; each colour instigates unique emotional responses and has its own cultural meaning. The critical and tremendous power of colours influences the emotional and psychological images and principles of people. Therefore, colours have played a crucial role in the development of human cultural history. Colours are not only related to individual emotions, but are also critical for cognitive development. Colours are one of the basic elements of human cognitive and memory structures and play a critical role in conveying information. The use of different colours as visual hints to connect textual with pictorial information enhances the learning outcomes of learners [5].

The most prevalently used chalk colours are white, red, orange, yellow, blue and green. Generally, teachers use white chalk as the main chalk and colours are used as supplementary tools. The clarity of blackboard writing with different colours profoundly affects the learning outcomes of learners. In chromatology, the colours opposite each other on the hue colour wheel are complementary colours. For example, red and green are complementary to each other [6]. Complementary colours generate visual accents. Accordingly, red chalk writing on green blackboards is theoretically substantially legible. However, the blackboard reading experience of students has indicated otherwise. This study applied the perspectives of both chromatology and scientific investigation to establish the sequential order of the clarity of blackboard writing colours. Thus, teachers can understand the colour-matching techniques for blackboards, and students can easily read the blackboard writing by teachers, thereby improving their learning outcomes.

LITERATURE REVIEW

The Oxford dictionary defines colour as …*the appearance that things have that results from the way in which they reflect light.* Accordingly, when an object is irradiated by sunlight, some waves of light are reflected and enter the human eye rather than are absorbed by the object, thus, displaying the colours of the object; because of their varying wavelengths, the waves display various colours such as red, yellow, green, blue and purple [7]. Bohren and Clothiaux indicated that the cone cells in retinae generate visual sensations when excited by visible light with wavelengths ranging from 380 to 780 nm [8]. Red light exhibits the longest wavelengths (700-610 nm); blue light exhibits shorter wavelengths than red light (500-450 nm); and violet light features the shortest wavelengths (450-400 nm). The excited cone cells generate pulses because of chemical reactions, and the pulses enter the cerebral cortex through the nervous systems, thus, formulating visual cognition. This is consistent with the findings by Isaac Newton, who performed the crucial 1666 spectrum experiment of casting a white light through a prism [9]. Because of its varying refractive indices, the light was divided into red, orange, yellow, green, blue and violet specks of light, which were displayed in a sequential order in a spectrum [10].

Young developed the red-green-blue (RGB) theory [11]. Helmholts reported that humans' RGB perceptions are caused by the effects of the three types of colour-sensitive nerves in retinae; namely, R (long wavelengths), G (medium wavelengths) and B (short wavelengths), and the incredibly varied colour scheme is stimulated in human eyes because of the colour shade combinations by the three types of colour-sensitive nerves; thus, confirming the RGB theory [12].

In his spectroscopy experiment in the early 17th Century, Newton confirmed that the aforementioned three colour shades can be combined to produce all types of colours [9]. For example, in that experiment, yellow light could be extracted from the spectrum; in the colour mixing experiment, combining green and red light also generated yellow light with the same visual condition. Most of the colours of light are produced through additive colour mixing [13]. Accordingly, the mixed colour I is calculated through the proportions of the three primary colours, r for red light (R), g for green light (G), and b for blue colour (B); the function is expressed as $I \equiv rR + gG + bB$. Each colour has a predetermined RGB value (r, g, b) and the maximal value of each primary colour is 255 [14].

All colours exhibit three basic attributes; namely, hue, value and chroma, the three dimensions which are collectively referred to as the elements of colour [15]. Hues refer to the names of colours and are defined by the wavelengths of visible light, such as red, orange, yellow, green, blue and violet. Values indicate the lightness of colours, which varies according to their content of black and white. Increasing the content of white in a colour raises its lightness. Yellow is the brightest visible colour, and blue and violet are the darkest visible colours. Chroma indicates the saturation and purity of colours. For each hue, the pure colour without any mixture of other colours is the most saturated and purest colour. Colours with high purity are bright colours; those with low purity are dark colours. Understanding the characteristics of the three elements of colour is crucial to accurately identifying colours and using them in communication.

Vision enable a person to identify the existence of an object because of the difference between the object and its surrounding objects regarding their shapes, colours and brightness. Legibility involves the formation of a clear, identifiable image through a contrast of shapes and colours and its perceptual transmission through the eyes [16]. High legibility indicates that an object can be easily identified. Investigating legibility involves examining the difficulty of a reader to acquire information through perception, rather than cognitive ability. Legibility can be increased through the use of different colours, boldness, shapes, contrasts and brightness of texts, as well as text and number intervals, row and column spacing, and marginal spaces. Conversely, legibility is reduced when words are embellished or excessively capitalised, italicised, bolded, bracketed or shaded.

The effect of colours on legibility has been prevalently explored through experiments. Colours are the most legible when placed against grey backgrounds. In a grey background, white, blue-green and yellow texts are the most legible texts, followed by green, blue and red texts; violet texts are the least legible. Brightness and contrast also profoundly affect the legibility of colours [17].

The most critical factor that affects colour legibility is the brightness difference between the foreground and the background, followed by foreground and background saturation and hue differences [18]. Samples with high-legibility colour combinations are easier to read than other samples when viewed at an equal distance. The figure-ground combinations of the commonly identified complementary colours, red and green, are highly illegible and they may lead to visual fatigue and damage to readers. Similarly, red-blue and blue-green combinations are unsatisfactory colour combinations [19].

The conventional blackboard teaching method is a type of visual learning, which features colours as one of its essential factors [20]. Texts and diagrams are created through the use of chalk with different colours to strengthen learning outcomes. This type of visual learning facilitates the visual sensations of learners and their interest to participate in learning activities.

Colours enable learners to memorise information; the use of appropriate colours enhances learners' attention and memorisation. For example, prohibition symbols are typically marked in intense red [13]. Colours are also used to highlight focal points for learners to instantly identify. For example, key sentences are typically highlighted in yellow or orange. Colours have also been employed to illustrate blood circulation systems, pulsing hearts and molecular structures in biological courses. Moreover, the photographs or coloured illustrations in textbooks, which feature bright colours and high verisimilitude, facilitate the formation of profound impressions in students [21].

The use of different colour combinations may enhance learning outcomes. Readers tend to read materials with colour combinations of black and white, respectively used for the foreground and background, which enhances their reading speed and understanding of the material contents. Marking focal points with colours effectively enables readers to search diagrams with ease. However, when the foreground colour is darker than the background colour, visual sensation is hindered. When the brightness contrast between the texts and the background colour is notable, and the background colour is darker than the text colour, readers can more accurately identify the characters on the screen. According to the diagram and background colour combination comparison by Huang [22], the white and yellow and white and blue combinations enhanced the visual identification results by learners, but the black and blue and black and yellow combinations increased the reading difficulty for learners.

METHODOLOGY

This study explored the impact on students' visual clarity of using chalk of different colours. This research can be diagrammed as in Figure 1. The calcium content of the chalk was measured, and the RGB values of the different coloured chalk was determined. Finally, a questionnaire survey was conducted to investigate the visual clarity of the different coloured blackboard writing for 350 high school students.

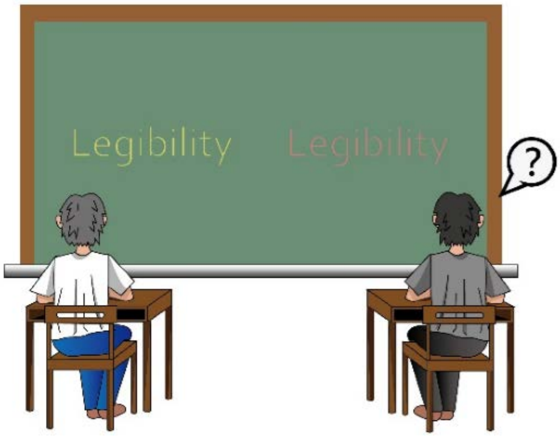

Figure 1: The diagram of the research.

In addition to dyes, the primary ingredients of chalk include calcium carbonate ($CaCO_3$) or calcium sulphate ($CaSO_4$). Both these chemical substances are white; when they are mixed with dyes, their calcium content profoundly affect the brightness and saturation of chalk colours. The calcium contents of the chalk was tested in accordance with examination methods No. 07014 and 07003 of the Food and Drug Administration, Taiwan Ministry of Health and Welfare. First, 1.0 grams of chalk was dried at 200°C for 4 hours and, then, completely dissolved in 10 mL of 6.0-M dilute hydrochloric acid. The mixture was, then, combined with deionised water to create a 100-mL solution for examination. Exactly 10 mL of the solution was extracted and added to 50 mL of water. Subsequently, 10 mL of potassium hydroxide solution was added. The solution was left to stand for 1 minute. Subsequently, approximately 0.1 g of hydroxy-naphthol blue was added as an indicator, and 0.05-M disodium ethylenediaminetetraacetic acid (EDTA) was titrated into the solution until all the magenta dye changed to cyan. Each millimetre of 0.05-M disodium EDTA reacted to 5.004 mg of $CaCO_3$ or 8.609 mg of $CaSO_4 \cdot 2H_2O$. Finally, the titration result was used to assess the $CaCO_3$ or $CaSO_4$ contents in each colour chalk. Each test was repeated three times.

The three most prominently used brands of red, yellow, green, blue, orange and white chalk were purchased for the experiment. The chalk was crushed into powder with a mortar and pestle and, then, spread evenly on a sheet of white paper. The RGB value of each chalk colour was measured using three RGB measurement software programs; namely, Picklor, Color Capture and Identifier, and Color Meter. Each measurement was repeated three times. In addition, the RGB value of the blackboard was measured using the RGB programs.

To clarify the differences between the chalk colours on their legibility according to the students' opinions, a questionnaire was devised and distributed to the students for response (Figure 2). The questionnaire consisted of the following three sections:

a) Colour blocks: for the purpose of this experiment, the background colour was set as pure green, and blocks coloured yellow, blue, red, orange and green were placed against the background; the students were asked whether they were able to identify the colours clearly.
b) Colour lines: for the purpose of this experiment, the background colour was set as pure green, and text in yellow, blue, red, orange and green were placed against the background; the students were asked whether they were able to identify these colour texts clearly.
c) Chalk writing: three Mandarin characters were written on the blackboard in yellow, blue, red, orange and green; the students were asked whether they were able to identify clearly this chalk writing.

A total of 350 questionnaires were distributed to students at three high schools. If any questions were left unanswered, or if the same answer was given to all the questions, then, the questionnaire was considered invalid. A 5-point Likert scale was used for scoring the answers (5 for *very clear*, 4 for *clear*, 3 for *average*, 2 for *unclear* and 1 for *very unclear*). The SPSS Version 12.0 software was employed for conducting a statistical analysis. By using a one-way analysis of variance and post hoc comparison, the significance of the differences among the chalk colours concerning their legibility for students was determined; the clarity of the chalk colours for the students was then ranked.

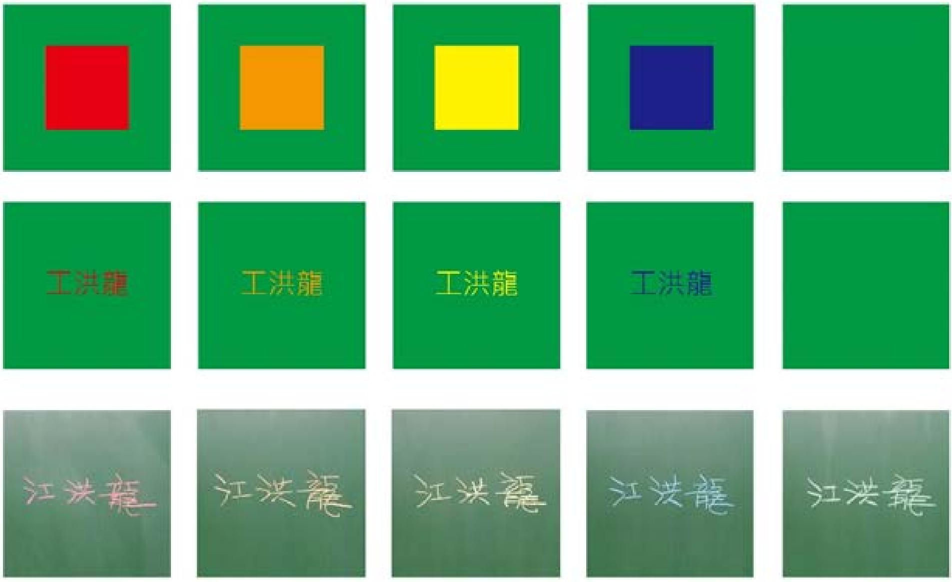

Figure 2: Questionnaire design (colour blocks, colour lines and chalk writing).

EXPERIMENTAL RESULTS AND ANALYSIS

Generally, the primary ingredient prevalently used for manufacturing chalk is $CaSO_4$, which exhibits a larger particle size than that of dust and causes discomfort in the nose, pharynx and larynx when inhaled. Therefore, $CaCO_3$ is used to replace $CaSO_4$ when manufacturing environment-friendly chalk. $CaCO_3$ is a nontoxic substance, which produces less powder dust and can be metabolised normally in the human body. $CaCO_3$ and $CaSO_4$ have also frequently been mixed together when manufacturing chalk.

To ensure the accuracy of the experiment, the EDTA was titrated into the solution to evaluate its calcium content and subsequently its $CaSO_4$ or $CaCO_3$ content. The balanced chemical equation for the reaction between calcium ion (Ca^{2}+) and EDTA is shown below:

$$Ca^{2+} + H_2EDTA^{2-} \rightarrow CaEDTA^{2-} + 2H^{+} \quad (1)$$

The mole ratio of Ca^{2+} and EDTA is 1:1. That is, at the equivalence point, the moles of EDTA added to the testing sample equal the moles of Ca^{2+} originally present in the testing sample. The moles of Ca^{2+} in testing sample also equal the moles of $CaCO_3$ or $CaSO_4$. Thus, the mass of $CaCO_3$ or $CaSO_4$ can be obtained by moles times molecular weight. Finally, the CaCO3/$CaSO_4$ contents were calculated using following equation:

$$\frac{\text{The mass of } CaCO_3 \text{ or } CaSO_4}{\text{The mass of chalk powder (1.0 g)}} \times 100\% \quad (2)$$

Table 1 lists the experiment results. The results revealed that the calcium content of all the different coloured chalk ranged from 32.34% to 34.36% and were, thus, nearly identical. Chalk of the same colour, but of different brands also showed little difference between one another (all SD < 1%). As revealed by the reverse inference through the calcium content, all the chalk, regardless of its colour, comprised at least 80% $CaSO_4$ or $CaCO_3$, both of which were white powders. Consequently, the colours of the chalk was profoundly affected by the calcium compounds.

Table 1: Test results for the calcium contents of the chalk.

	Red	Orange	Yellow	Blue	Green	White
Average calcium content (%)	34.36	33.34	33.19	34.15	32.34	32.55
Standard deviation	0.22	0.73	0.16	0.31	0.33	0.27
Minimum $CaCO_3$/$CaSO_4$ content (%)	85.90	83.35	82.98	85.38	80.85	81.38

All the colours on the colour circle are additive colours, which are obtained by mixing the three primary colours (red, green and blue); all the complementary colours discussed in this article are additive colours. However, because the chalk comprises more than 80% white $CaSO_4$ or $CaCO_3$, the lightness and chroma of their colours were considerably affected. Differences between the visual sensations of the learners and the chromatology might have resulted as a consequence. Therefore, the RGB values of the yellow, blue, red, orange, green and white chalk, as well as of the $CaCO_3$, $CaSO_4$, and blackboard were measured. For accuracy, the aforementioned three RGB measurement software programs were incorporated. Table 2 lists the measurement results.

Table 2: RGB values of the pure and chalk colours.

		R	G	B			R	G	B
Red	pure	255	0	0	Green	pure	0	255	0
	chalk	241	117	127		chalk	134	187	140
Orange	pure	255	127	0	White	pure	255	255	255
	chalk	245	165	90		chalk	232	235	227
Yellow	pure	255	255	0	Black		0	0	0
	chalk	221	217	99	Blackboard		109	146	117
Blue	pure	0	0	255	$CaCO_3$		236	235	231
	chalk	88	172	199	$CaSO_4$		235	236	233

For the accuracy of the results, an outlier test based on the 4d rule was conducted. No outliers were detected in the RGB values, indicating that all the RGB values exhibited favourable credibility. The RGB values of all the white chalk, $CaSO_4$, and $CaCO_3$ were nearly equal to that of pure white (255, 255, 255). Therefore, the colours of the three objects were regarded as pure white. The RGB value of the blackboard differed substantially from those of both pure black (0, 0, 0) and pure green. The colour rendering of the non-white coloured chalk writing was examined on the basis of the RGB value of the blackboard.

The red chalk exhibited G and B values because of their $CaCO_3$ and $CaSO_4$ content, in contrast to pure red that only features an R value. The legibility of pure red and pure green is low; the red chalk, which exhibited G and B values, featured an RGB value nearly equal to that of the blackboard. Therefore, the legibility of the red chalk writing on the blackboard was even lower compared to pure colours, and the writing was illegible.

The orange chalk exhibited a higher G value than that of pure orange because of their $CaCO_3$ and $CaSO_4$ content. Pure orange is a secondary colour. However, the orange chalk, which featured the aforementioned G value, exhibited a colour closer to that of yellow. Consequently, the colour rendering of the orange blackboard writing was close to that of the yellow writing and was highly legible.

The yellow chalk featured an RGB value close to that of pure yellow, which contains high R and G values. Because of their $CaCO_3$ and $CaSO_4$ contents, the chalk exhibited a high B value, but their R and G values were still more notable. The B value of the chalk was nearly equal to that of the blackboard, but the R and G values of the chalk were considerably higher than those of the blackboard. Consequently, the yellow chalk writing on the blackboard were substantially legible.

The RGB value of the blue chalk differed markedly from that of pure blue. Because of the profound influence from their $CaCO_3$ and $CaSO_4$ contents, the R and G values of the chalk were respectively 88 and 172. The R value of the chalk was slightly lower than that of the blackboard, and their G value was slightly higher than that of the blackboard.

The B values of the chalk and blackboard differed by 80. The RGB value of the chalk differed substantially from those of pure blue and pure green. Consequently, the blue blackboard writing was illegible. The green chalk, because of their $CaCO_3$ and $CaSO_4$ contents, exhibited significant R and B values, both of which were close to 127. Therefore, in addition to the green element, the rendering of the green blackboard writing contained the elements of yellow (red–green mixture) and cyan (blue–green mixture).

Consequently, because of the profound influence of the yellow element, the green writing was less legible than the yellow and orange writing. However, the learners were still expected to be able to identify the green writing. In summary, the yellow writing was the most legible, followed by the orange writing. The green writing was still reasonably legible. The blue and red writing were expected to be difficult for the students to identify.

A total of 350 questionnaires was distributed. The questionnaires with unanswered questions or that featured the same answer on all questions were considered as invalid. Out of the 345 returned questionnaires, 331 were valid, thus, constituting a valid return rate of 94.57%.

Table 3 depicts the questionnaire survey results. Yellow and orange scored more than 4.50 points on the colour block, colour line and chalk writing sections, indicating that these two colours were highly legible for the students. Blue and red scored more than 4.00 points on the colour block and line sections, but 2.20-2.48 on the chalk writing section, indicating that they were relatively illegible for the students. In correspondence with the blackboard experiment, the background colour for the colour blocks and texts were pure green. Consequently, green was extremely illegible on the colour block and line sections. However, green scored a legible 3.87 points on the chalk writing section.

Table 3: Descriptive statistics of the colour questionnaire.

		Mean	Std. deviation	Clarity (%)	95% Confidence interval for mean	
					Lower bound	Upper bound
Red	Block	4.7976	0.45871	98.79	4.7480	4.8472
	Line	4.1631	0.81499	73.72	4.0750	4.2513
	Chalk writing	2.1994	1.28728	16.92	2.0602	2.3386
Orange	Block	4.7795	0.50121	98.19	4.7253	4.8337
	Line	4.5619	0.55454	96.98	4.5020	4.6219
	Chalk writing	4.6465	0.54396	96.68	4.5877	4.7053
Yellow	Block	4.7674	0.45088	99.40	4.7186	4.8161
	Line	4.6465	0.52698	98.79	4.5895	4.7035
	Chalk writing	4.7402	0.51539	98.49	4.6845	4.7959
Blue	Block	4.7492	0.49294	97.89	4.6959	4.8025
	Line	4.6042	0.51977	98.49	4.5480	4.6604
	Chalk writing	2.4804	1.29874	22.36	2.3399	2.6208
Green	Block	1.0483	0.29760	0.60	1.0162	1.0805
	Line	1.0332	0.21059	0.00	1.0105	1.0560
	Chalk writing	3.8731	0.94496	75.23	3.7709	3.9753

From the 331 valid questionnaires, the ratio of the answers for clear and very clear checked on each section was regarded as the level of clarity for the section. A higher level of clarity indicated more favourable legibility. For the colour block and line sections, green featured a clarity level lower than 1%, red lines featured a clarity level of 73.72%, and the other three colours featured clarity levels higher than 90%. In the chalk writing section, the clarity levels of yellow and orange were higher than 90% that of green decreased to 75%, and those of red and blue were lower than 25%. As revealed by both the average scores and levels of clarity, the yellow and orange chalk writing were the most legible; the green chalk writing was identifiable by the students; and the blue and red writing were illegible.

To verify the significance in the differences among the five colours, the SPSS 12.0 statistical software was employed to perform a one-way analysis of variance, variance homogeneity test and *post hoc* comparison. Regarding the colour block section, significant differences were observed among the clarity of colour blocks according to the participants ($F = 4609.737$; $p = 0.000 < 0.05$). The F value indicated that the mean difference of at least one pair of colour blocks was significant. Subsequently, a *post hoc* comparison was conducted to determine, which pair attained the significant mean difference. Table 4 shows the *post hoc* comparison results for the clarity of the colour blocks for the participants by using the Games–Howell method, in which the asterisks indicate the mean differences that reached the level of significance. The table shows that the mean differences between the green block and the other colour blocks attained the level of significance ($p = 0.000 < 0.05$), but those of the other pairs were nonsignificant. In other words, only the pairs that included the green block showed considerable clarity differences between the pairs.

Table 4: Games–Howell *post hoc* comparison of the colour blocks.

(I)	(J)	Mean difference (I-J)	Std. Error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
Red	Orange	0.01813	0.03735	0.989	-0.0840	0.1203
	Yellow	0.03021	0.03535	0.913	-0.0665	0.1269
	Blue	0.04834	0.03701	0.688	-0.0529	0.1496
	Green	3.74924(*)	0.03005	0.000	3.6670	3.8315
Orange	Yellow	0.01208	0.03706	0.998	-0.0893	0.1134
	Blue	0.03021	0.03864	0.936	-0.0755	0.1359
	Green	3.73112(*)	0.03204	0.000	3.6434	3.8188
Yellow	Blue	0.01813	0.03672	0.988	-0.0823	0.1186
	Green	3.71903(*)	0.02969	0.000	3.6378	3.8003
Blue	Green	3.70091(*)	0.03165	0.000	3.6143	3.7875

* Mean difference is significant at the 0.05 level

For the colour line section, significant differences were observed among the colour texts regarding their clarity according to the participants ($F = 2574.328$; $p = 0.000 < 0.05$). The F value indicated that the mean difference of at least one pair of colour texts was significant. Subsequently, a *post hoc* comparison was conducted to determine which pairs attained the significant mean differences. Table 5 illustrates the *post hoc* comparison results of the clarity of the colour texts for the participants. The table shows that the mean differences between the green and red lines and the other colour lines attained the level of significance (p = 0.000 < 0.05), but those of the other pairs were nonsignificant. This verified that the green and red combination were particularly illegible.

Table 5: Games-Howell *post hoc* comparison of the colour lines.

(I)	(J)	Mean difference (I-J)	Std. Error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
Red	Orange	-0.39879(*)	0.05418	0.000	-0.5471	-0.2505
	Yellow	-0.48338(*)	0.05334	0.000	-0.6294	-0.3374
	Blue	-0.44109(*)	0.05313	0.000	-0.5865	-0.2957
	Green	3.55589(*)	0.03690	0.000	3.0031	3.2567
Orange	Yellow	-0.08459	0.04205	0.261	-0.1996	0.0304
	Blue	-0.04230	0.04178	0.850	-0.1566	0.0720
	Green	3.52870(*)	0.03260	0.000	3.4394	3.6180
Yellow	Blue	0.04230	0.04068	0.837	-0.0690	0.1536
	Green	3.61329(*)	0.03119	0.000	3.5278	3.6987
Blue	Green	3.57100(*)	0.03083	0.000	3.4866	3.6554

* The mean difference is significant at the 0.05 level

In the chalk writing section, significant differences were observed among the different coloured chalk writing regarding their clarity according to the participants (F = 490.157; p = 0.000 < 0.05). The F value indicated that the mean difference of at least one pair of chalk writing with different colours was significant. Subsequently, a *post hoc* comparison was conducted to determine which pairs attained the significant mean differences. Table 6 lists the *post hoc* comparison results regarding the clarity of the chalk writing for the participants. The table shows that the mean differences between the yellow writing and the orange writing were nonsignificant (p = 0.155 > 0.05), but those of the other pairs were significant (p = 0.000 < 0.05). The yellow and orange writing were both legible, and their difference was nonsignificant (mean difference = 0.09366; p = 0.155 > 0.05); the orange writing was significantly more legible than the green writing (mean difference = 0.77341; p = 0.000 < 0.05); the green writing was significantly more legible than the blue writing (mean difference = 1.39275; p = 0.000 < 0.05); and the blue writing was significantly more legible than the red writing (mean difference = 0.28097; p = 0.010 < 0.05). The SPSS results revealed that the level of clarity of the yellow writing was the highest for the students, followed sequentially by the orange, green, blue and red writing; the difference between the clarity of the yellow and orange writing was nonsignificant.

Table 6: Games-Howell *post hoc* comparison of the chalk writing.

(I)	(J)	Mean difference (I-J)	Std. Error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
Red	Orange	-2.44713(*)	0.07681	0.000	-2.6575	-2.2367
	Yellow	-2.54079(*)	0.07622	0.000	-2.7496	-2.3320
	Blue	-0.28097(*)	0.10051	0.042	-0.5559	-0.0060
	Green	-1.67372(*)	0.08777	0.000	-1.9139	-1.4336
Orange	Yellow	-0.09366	0.04119	0.155	-0.2063	0.0190
	Blue	2.16616 (*)	0.07739	0.000	1.9542	2.3781
	Green	0.77341 (*)	0.05993	0.000	0.6094	0.9375
Yellow	Blue	2.25982(*)	0.07680	0.000	2.0494	2.4702
	Green	0.86707(*)	0.05916	0.000	0.7051	1.0290
Blue	Green	-1.39275(*)	0.08828	0.000	-1.6343	-1.1512

* Mean difference is significant at the 0.05 level

According to the aforementioned RGB and SPSS test results, the clarity of the five colours of chalk was consistent. The use of yellow and orange chalk enables students to clearly identify the writing on blackboards, followed by the use of green chalk; the use of blue or red chalk diminish students' ability to read the writing on blackboards.

CONCLUSIONS

Coloured chalk is created by mixing calcium compounds and dyes. According to the EDTA calcium test results, each chalk tested comprised at least 80% calcium compounds, which indicated that the colours of the chalk were profoundly affected by their calcium contents. This was further confirmed through the RGB analysis. The RGB value of pure red (255, 0, 0) was different from that of the red chalk (241, 117, 127). In addition to the R value, the red chalk exhibited G and B values. The RGB value of the calcium compounds was 236, 235 and 231. These indicated that the colours of the chalk employed in this study were influenced by their calcium compound contents.

According to the RGB values of the coloured chalk and blackboard, the yellow and orange blackboard writing were the most legible, followed by the green writing; the red and blue writing were the least legible. The statistical results of the questionnaire survey were consistent with the RGB value analysis; within the 95% confidence interval, the clarity difference between the yellow writing and the orange writing was nonsignificant ($p = 0.155 > 0.05$), but those of all the other pairs were significant ($p = 0.000 < 0.05$). On the basis of the Games–Howell *post hoc* comparison, the order of the legibility of the coloured writing for the students was yellow > orange > green > blue > red.

Through the scientific comparison and statistical analysis of the legibility of the coloured chalk for learners, the results from this study are aimed at providing teachers with a reference for choosing chalk colours to use. White chalk is used for writing general content; focal points should be written using yellow or orange chalk; green, blue and red chalk can be applied for underlining or marking symbols. Further research should focus on exploring and comparing the differences among the chalk colours regarding their influence on learning outcomes, thereby providing a reference to teachers and students to jointly improve learning outcomes.

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