Journal of Science and Technology, Vol. 43, No. 2 (2025), pp 91 - 104

https://dx.doi.org/10.4314/just.v43i2.7

THE ROLE OF COLOUR IN INFORMATION RETENTION AMONG UNDERGRADUATE STUDENTS IN GHANA

Francis Kofi Nimo Nunoo[1]*, Eric Anane-Antwi[1], Michael Ato Essuman[1], Adolph Agbo[1], Harry Barton Essel[2], Ismaila Moro[3]

[1]Department of Publishing Studies, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[2]Department of Educational Innovations in Science and Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[3]Department of Visual Communication, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

***Corresponding author: fknnunoo@knust.edu.gh**

ABSTRACT

The findings of this study provide actionable insights for instructional design, particularly in leveraging colour to enhance educational outcomes across diverse learner profiles. This research investigated the influence of colour on information retention among undergraduate students in Ghana. Through a cross-sectional survey of 153 undergraduate students from two public universities, the study examined students' perceptions of colour in learning materials, its benefits and limitations, instructor utilisation, and individual differences in colour preferences. The results revealed that 70.6% of students considered colour important or extremely important for information retention, with 40% actively employing colour-coding strategies in their studies. While a majority (50.3%) preferred coloured materials for their engaging and visually stimulating qualities, 29.4% favoured black-and-white materials, highlighting individual differences in learning preferences. Qualitative data indicated that students found colour beneficial for improving engagement, attention, and memory recall, particularly in diagrams and graphs. However, some cautioned against excessive use, citing potential distractions. The study also revealed varying preferences between digital and print formats, considering different learning styles. These findings align with established theories such as Dual Coding and Cognitive Load Theory while extending understanding through the lens of individual preferences and contextual factors. The results suggest that strategic integration of colour in educational materials should be tailored to specific learning contexts, objectives, and individual learner needs.

Keywords: Colour, Information retention, Learning outcomes, Instructional design, education

INTRODUCTION

Colour plays a significant role in enhancing memory performance, attention, and arousal, which can lead to improved academic performance among students. These colour choices and their manipulation influence human memory performance. According to Olurinola and Tayo (2015), using colours as a design element can improve the encoding, storage, and retrieval of environmental stimuli. However, some studies have shown that unregulated use of colours can also lead to higher cognitive load ratings, making it an emotional design feature (Liew *et al*., 2022).

Extensive research has been conducted on the role of colour in human perception, cognition, and behaviour across various fields such as design, marketing, psychology, and education (Elliot and Maier, 2014). Many such works have demonstrated the significant impact of colour on various psychological processes: attention, memory, comprehension, arousal, emotion, and motivation (Chai *et al*., 2019). These mechanisms provide a strong theoretical foundation for understanding how colour can enhance the learning experience, stimulate interest, and lead to positive outcomes.

Within the learning environments, studies (Klohn and Zimmermann, 2021; Dzulkifli and Mustafar, 2013; Valdez and Mehrabian, 1994) have shown that colour has a significant impact on student engagement, information processing and knowledge retention, leading to more effective learning. Colour is believed to contribute to alertness, wakefulness, and sustained concentration during lessons, as well as enhancing comprehension and recall, thus providing tangible benefits for learners.

The use of colour-coding systems has helped students organise and efficiently retrieve information by associating concepts with specific hues and is ranked first among seven techniques in mental and memory retention intensification (Diachenko *et al*., 2022), while coloured illustrations have been identified as aiding integration and retention of complex material through dual visual-verbal coding (Lee *et al*., 2015; Paivio, 1971).

Based on the reviewed literature, there are gaps regarding real-world effectiveness and applications of colour. In educational contexts, colour selection and application in educational materials in various higher institutions of learning in Ghana seem to provide contradicting perceptions. Probing undergraduate students' perceptions and interpretation of colour on instructional materials would provide vital practical insights into what and how colour should be conceived and applied for effective learning by instructors during instructional material design processes. Therefore, this study aims to investigate how applied colour on existing designed educational materials affects undergraduate students' learning experiences and attitudes.

This empirical investigation aims to bridge the gap by reporting on undergraduate students' experiences and attitudes regarding colour usage for effective information retention and learning. The dual focus on memory and pedagogy illuminates cognitive implications and applied practices in utilising colour in an educational context. This study examines explicitly;

- How undergraduate students perceive colour as influencing their information retention
- What benefits and limitations do undergraduate students associate with colour in learning materials,
- What are undergraduate students' perspectives on instructors' utilisation of colour in designed teaching materials and
- What is the impact of individual differences in colour perceptions regarding colour usage in educational materials

These research questions will enrich our understanding of optimising evidence-based colour integration in higher education to match contemporary student needs and preferences. As instructors increasingly utilise multimedia materials, these applied insights can guide the design of learner-centric educational materials, leveraging colour visuals for enhanced engagement, comprehension, and memorability. The findings of this study thus provide a new direction for research into colour psychology and pedagogical principles to promote continued innovation while improving cognitive, affective, and behavioural outcomes by understanding how students perceive the role of colour in learning materials design.

LITERATURE REVIEW

Many studies (Diachenko *et al*., 2022; Klohn and Zimmermann, 2021; Elliot and Maier, 2014) have investigated the impact of colour as a visual stimulus on human perception, cognition, emotion, and behaviour. Colour has been studied extensively for its effects on various psychological processes such as attention, mood, arousal, comprehension, and memory. These effects play a significant role in shaping learning experiences and outcomes.

In the field of colour psychology, various frameworks have been proposed to clarify the function and impact of colour on cognition, retention, and comprehension. These groundworks provide an in-depth understanding of how colour influences an individual's thoughts, emotions, and behaviours. The preceding section explores some of these theoretical frameworks and their implications for educational and psychological settings.

The Colour-in-Context Theory (Elliot and Maier, 2014) highlights the importance of situational factors when considering the use of colour for psychological impact, as the effects of colour depend on individual, social, and physical contexts. Therefore, in educational settings, it is essential to use colour strategically based on the learner's profile, subject matter, and the learning environment. For instance, as it is reported, for younger learners, warm colours such as red and orange may be more effective, while cool colours such as blue and green may be more beneficial for older learners. Additionally, using colours associated with the subject matter, such as green for science and blue for math, may enhance learning and retention (Olurinola and Tayo, 2015).

According to Wilson (1966), the propounder of the Arousal Theory, colourful stimuli can stimulate physiological arousal and activate the reticular system in the brain. In educational settings, using coloured content can help regulate arousal and improve lesson attentiveness. However, prolonged periods of high arousal may be unproductive, admonishing that educators use colour strategically to create a balance between arousal and relaxation. For instance, using bright colours for headings and subheadings can increase arousal (Wilks, 2021), while using softer colours for body text can create a sense of relaxation (Xie *et al*., 2022).

The Cognitive Load Theory (Sweller, 1994) is a well-established educational framework suggesting that instructional materials are designed to minimise the cognitive burden on learners' working memory. Such memory load minimisation can be attained by avoiding excessive use of colour in educational materials, as it can cause sensory processing demands that might lead to extraneous cognitive load. Thus, too much colour can hinder learning since it reduces the mental resources available to the learner for processing. According to recent research by He *et al*. (2023), strategic colour

use for key information is recommended to avoid imposing excessive cognitive load on learners. By the application, educators should restrict colour use to highlighting essential information– key concepts or definitions, while avoiding overwhelming learners with too much information. Thus, it underscored the importance of sparingly and effectively using colour to ensure learners' effective and efficient information processing.

The Dual Coding Theory, proposed by Paivio in 1971, suggests that cognition relies on both verbal and visual mental systems. Using colour enhances retention by creating visuospatial representations that complement verbal information. Thus, colour can aid the visualisation and integration of multimodal content, as posited by Li and Tong (2020). For example, colour can represent different types of information, such as red for danger and green for safety, which can enhance visualisation and retention.

The Ecological Valence Theory (Palmer and Schloss, 2010) suggests that affective responses to colour-associated objects influence one's colour preferences. Akbay and Demirbaş (2023) have elaborated on this theory and highlighted individuals' emotional and affective associations with specific colours, indicating that colour has implications for learning, especially in multicultural environments (Yokosawa *et al*., 2016). Therefore, it is essential to consider these cultural sensitivities to colour associations and symbolism when choosing colours for educational materials. Educators should use colours associated with positive emotions, such as green for growth and blue for calmness, to create a positive learning environment.

The Stimulus-Organism-Response Framework (Mehrabian and Russell, 1974) highlights the role of external stimuli, such as colour, in evoking internal evaluations, emotions, and behaviours. This theory underscores the importance of understanding the impact of colour on cognition, affect, and behaviours in classroom applications. For example, using colours associated with success, such as gold and silver, can enhance motivation and achievement.

In summary, these theoretical frameworks emphasise the complex interplay of contextual, perceptual, cognitive, affective, and behavioural factors that influence the outcomes of using colour in educational and psychological settings. They provide robust frameworks to guide the evidence-based use of colour for enhanced learning and development. Through their consideration, educators and designers can harness the power of colour to create more effective and engaging learning experiences.

Attention and Arousal Effects

Considerable studies have demonstrated the significant impact of colour on human cognition and perception. According to Spence *et al*. (2006), coloured images are remembered 5-10% better than grayscale ones, indicating the attention-grabbing quality of colour. Furthermore, researchers have proposed that the use of colours can reduce inattentional blindness, as highlighted by Kreitz *et al*. (2015), leading to enhanced perceptual encoding, which is crucial for adequate information processing. Furthermore, Franklin *et al*. (2008) demonstrated that infants exhibit a right hemisphere bias for colour processing, indicating that the captivating effects of colour start early in human development and continue to influence how we perceive and remember visual information.

Beyond initial orientation, colours can also modulate levels of arousal and alertness during information processing. Warm, high-intensity colours (e.g., red, yellow) heighten

arousal, while cool, low-intensity colours (e.g., blue, green) are calming (Ou *et al*., 2004). Inducing stimulating or tranquilising effects, coloured environments can shape students' attention, wakefulness, and engagement during learning.

Dzulkifli and Mustafar (2013) established that coloured text increased alertness and reading performance compared to black text. Extending this work, Slåttå *et al*. (2017) reported improved selective attention when colouring book tasks incorporated vivid target colours among neutral distractors. Gaining learner attention is crucial, but colour further aids integrative processing and retention of material.

Comprehension and Retention

Some studies have demonstrated the tangible benefits of colour for comprehension and retention. Wichmann *et al*. (2002) found superior scene recognition memory for coloured over black-and-white images. Colour provides supplementary surface detail, allowing richer encoding and facilitating understanding of diagrams in science education (Liu and Treagust, 2013).

Robinson and Choi (2018) found that students demonstrated better comprehension of instructional videos when directors utilised visual design principles, including colour contrast, lighting, and graphics. In another study, Rae and Lonka (2018) showed that nursing students scored higher on a colour-coded endocrine system test than on black-and-white versions, suggesting colour facilitated mental integration and recall.

Beyond comprehension, emerging research highlights the mnemonic benefits of colour for long-term retention. Colour coding enhances the organisation and recall of information (Diachenko *et al*., 2022; Santos *et al*., 2019). By assigning colours to different topics, ideas can be efficiently classified and retrieved, establishing that Colours can positively affect learners' cognitive retention. However, excessive text colour variation lowers readability and recall (Dzulkifli and Mustafar, 2013), emphasising the need for strategic use to balance visual appeal and processing load.

Chandran *et al*. (2019) established that incorporating traffic light colour-coding on slides improved dental students' retention of oral pathology concepts on delayed evaluations. Knoell (2017) also demonstrated that colour-cued flashcards enhanced vocabulary learning in high school language students over time compared to plain white cards.

Klohn and Zimmermann (2021) analysed the use of colours in informational maps. They elucidated that colour can indicate information hierarchy, which aligns with the idea that colours can enhance comprehension.

Individual Differences

Despite evidence for colour benefits, findings remain mixed. Finn *et al*. (2011) found that while students were enthusiastic about coloured study tools, more was needed to improve outcomes. Others posit that factors like colour blindness, cultural interpretations, and prior experiences mediate the effects of colour on individuals (Hurlbert and Ling, 2007; Ou *et al*., 2004).

Elliot and Maier (2014) propose a colour-in-context theory when interpreting such discrepancies. It states that colour effects are contingent on individual, social, and contextual factors, highlighting the need to consider variabilities in how colour is perceived, processed, and applied in educational practice.

Several studies emphasise the importance of strategic colour use tailored for specific learners and tasks. Poulova *et al*. (2017) advocated optimised colour

schemes in digitised textbooks based on gender preferences. Hughes *et al*. (2019) encouraged personalised interventions for problematic colour combinations that disrupt reading fluency or comprehension in people with learning difficulties.

Emerging work also highlights the contextual and motivational influences of colour on learning behaviours. Elliot (2015) drew on colour associations and their role in helping the completion of works. In another study.

Even though substantial theoretical and empirical work suggests that colour has the potential to influence attention, arousal, comprehension, memory, and behaviour in learning contexts, gaps remain regarding translation effects in real-world educational settings, particularly the perspectives of undergraduate students who are colour learners and users. This study addresses this gap by empirically investigating students' perceptions of colour for information retention and learning.

METHODOLOGY

A cross-sectional survey using an online questionnaire created with Google Forms for data collection was distributed to a diverse group of 153 undergraduate students from various academic disciplines and years across two public universities in Ghana. This questionnaire consisted of 30 items designed to capture both quantitative and qualitative viewpoints on the use of colour in educational materials for information retention. The preliminary study showed that both digital (softcopy) and physical (hardcopy) materials are used in higher education settings. In order to compare the responses on colour used in these two learning materials, the questionnaire was designed to solicit the respondents' views on both materials.

The questionnaire incorporated Likert-type ratings, commonly used in survey research to measure attitudes or opinions. These questions allowed the researchers to quantify the respondents' attitudes and experiences with using colour in a learning context. In addition, open-ended questions were included to gather more in-depth insights into respondents' perceptions of attention, retention, learning style in using print and electronic materials and teaching practices (e.g., their tutors' use of colour in PowerPoint presentations).

To ensure the reliability of the questionnaire, an iterative refinement process was undertaken. This process involved expert validation, where subject matter experts reviewed the questionnaire to check its content and construct validity. They ensured that the questionnaire measured what it was intended to measure and that the items were appropriate for the construct being studied.

Additionally, a pilot study was conducted with five undergraduate students, allowing for the assessment of the clarity and relevance of the items. Items identified as ambiguous were revised before administration to the final sample.

The survey lasted for three weeks. Links were sent to respondents through emails and social media platforms. Participation in the study was voluntary, and the anonymity of the participants was assured by not collecting personal identifiers. Reminders were sent out during the data collection period to encourage participation, which resulted in a total of 153 completed responses.

The quantitative data from the Likert-scale responses were subjected to descriptive statistical analysis using Jamovi software (version 2.3). This type of analysis provides a summary of the data and can give insights into patterns and trends in the dataset. Through this analysis, the researchers gained

insights into the respondents' perceptions of the importance of colour, their colour preferences, and their experiences with using colour in a learning environment. This valuable information can inform teaching practices and contribute to the literature on the application of colour in instructional design.

The qualitative data explained respondents' perceptions and experiences relating to the role of colour in information retention. The use of open-ended questions allowed respondents to provide detailed responses about their thoughts, feelings and perceptions about the role of colour in information retention (Creswell and Creswell, 2018). The qualitative data were analysed using thematic analysis, an inductive approach that allowed codes and themes gleaned from the data (Clark and Braun, 2017). The process involved the manual coding of the data to identify concepts, the categorisation of codes into broad themes, revision of the themes, defining and naming of the themes and the selection of compelling extracted examples.

RESULTS

Demographic data shows a total of 153 undergraduate participants, comprising 87 males (56.9%) and 66 females (43.1%), aged between 18 and 25 years. The largest representation came from fourth-year students (48.4%), followed by students across other academic levels. Detailed demographic data is presented in Table 1.

Table 1: Demographic information about respondents

Gender	**Counts**	**% of Total**	**Cumulative %**
Female	66	43.1%	43.1%
Male	87	56.9%	100%

Academic level				
	Gender	**Counts**	**% of Total**	**Cumulative %**
Year 1	Female	10	6.5 %	6.5 %
	Male	8	5.2 %	11.8 %
Year 2	Female	11	7.2 %	19.0 %
	Male	13	8.5 %	27.5 %
Year 3	Female	13	8.5 %	35.9 %
	Male	16	10.5 %	46.4 %
Year 4	Female	29	19.0 %	65.4 %
	Male	45	29.4 %	94.8 %
Year 5	Female	3	2.0 %	96.7 %
	Male	5	3.3 %	100.0 %

This study aimed to explore undergraduate students' perceptions of colour and its role in information retention. The findings indicate that 70.6% of students perceive colour as either important or extremely important for retaining information, with 50.3% (77 students) rating it as important and 20.3% (31 students) considering it extremely important. Conversely, 18.3% (28 students) found it only partially important, while a small percentage (7.8%, 12 students) deemed it less important, and 3.3% (5 students) believed it had no impact at all. Additionally, 40% of respondents reported using colour-coding strategies to aid in studying, highlighting its role in organizing information and improving comprehension.

The qualitative data revealed that respondents believed colour had a positive impact on their reading experience. Statements such as *"Colour makes the materials more pleasant to read"* and *"They help the materials to stand out, thus attracting more attention"* indicate that students perceive colour as aesthetically enhancing and attention-grabbing. This aligns with studies (e.g., Olurinola and Tayo, 2015; Olesen, 2022) that suggest colour can improve concentration, attention span, and memory retention.

Another objective was to assess the perceived benefits and limitations of colour in learning materials. The results indicate that 50.3% (77 students) preferred coloured materials for their engaging and visually stimulating nature, while 29.4% (45 students) favoured black-and-white materials, and 20.3% (31 students) remained neutral. Colour was particularly recognised for its effectiveness in enhancing diagrams and graphs, with respondents emphasising its role in increasing visibility and comprehension. However, 30% of students expressed scepticism regarding the necessity of colour, suggesting that content clarity, teaching style, and the relevance of information play a more critical role in learning. Some also cautioned that excessive use of colour could be distracting or overwhelming.

On the objective, in-depth qualitative responses highlighted both the benefits and limitations of colour in learning materials. Benefits include improved engagement, attention, and memory recall, as evidenced by statements like *"Colours often illuminate the details, especially with graphs"* and *"Colour plays a key role in taking information."* However, the analysis also acknowledges the subjectivity of colour perception, with statements like *"It ultimately depends on individual preferences and learning styles,"* indicating that the effectiveness of colour can vary among students.

Furthermore, this study sought to understand students' perspectives on instructors' use of colour in teaching materials. Most respondents (nearly 70%) supported incorporating more colour in instructional materials, believing it would improve engagement, aid in distinguishing key concepts, and enhance overall retention. In contrast, 30% of students disagreed, asserting that effective teaching is more dependent on content structure and pedagogical approaches rather than colour alone as over-utilisation can cause distractions.

On the qualitative side, respondents expressed positive views on the use of colour by instructors, particularly in enhancing the visual appeal and effectiveness of teaching materials (PowerPoint Presentations). Statements such as *"It is well presented in structure; it emphasizes the important sections for attention"* and *"Colour makes the materials more pleasant to read"* suggest that students appreciate when instructors use colour to make content more engaging and accessible.

Lastly, the study examined how individual differences influence perceptions of colour in educational materials, both in digital and print formats. The results revealed diverse learning preferences, with 41.3% identifying as visual learners, 18% as auditory learners, and 42% as physical learners. Additionally, 32.7% of students described themselves as having a combination of these learning styles, suggesting that colour-enhanced materials can cater to a wide range of learners. Preferences for digital versus print materials were mixed, with digital formats being valued for their visual engagement and accessibility, while print materials were appreciated for their tactile and immersive experience.

The qualitative analysis highlighted the variability in how students perceive and interact with colour. These were deduced from statements like *"It ultimately depends on individual preferences and learning styles"* and the comparison between digital and physical materials (*"Digital materials provide a visual representation and sense, but physical materials offer a more tactile and immersive experience"*) underscored the role of individual differences in colour perception. This aligns with the idea that colour effectiveness can vary based on personal preferences and the medium used (digital versus print).

In conclusion, examining the responses from a technical standpoint has yielded an important understanding of how colour affects information retention. This has helped to uncover subtle viewpoints on aesthetics, engagement, and cognitive processing in both digital and physical formats. External evidence supports these findings, providing additional validation for the role of colour in information retention.

DISCUSSION AND IMPLICATIONS

This study aimed to gather valuable insights from undergraduate students about the role of colour in enhancing information retention and learning. The study's findings not only confirmed but also expanded on the existing evidence highlighting the benefits of colour in instructional materials while pointing out various inconsistencies. The study drew upon previous research conducted by Al-Rahmi *et al*. (2018), Diachenko (2022), Klohn and Zimmermann (2021), and Wichmann *et al*. (2002), which supported the notion that incorporating colour in educational materials could lead to better encoding and organisation of information, as well as cater to different learning styles. This implies that Educators can incorporate colours in their instructional design and employ colour-coded schemes for subjects requiring hierarchical organisation, like STEM.

Even though some students did not use colour coding as a learning strategy, the few Students' positive learning experiences with customised colour coding corroborate studies demonstrating its effectiveness for classifying and recalling information (Li and Tong, 2020; Rae and Lonka, 2018; Diachenko *et al*., 2022; Santos *et al*., 2019). The support for colour-coded learning tools reflects principles of the Dual Coding Theory (Paivio, 1971), highlighting the benefits of integrating visual and verbal elements to enhance memory retention.

The confirmation of substantial preference variability (Poulova *et al*., 2017; Hurlbert and Ling, 2007) underscores the need for customised, inclusive designs catering for unique groups beyond one-size-fits-all approaches (Yokosawa *et al*., 2016), as argued by Elliot and Maier (2014). Therefore, colour integration should be carefully based on setting, task, learner profile and objectives.

The relative use of colour benefits for graph comprehension versus potential detriments to general recall (Dzulkifli and Mustafar, 2013) also underscores strategic guidance for practitioners to use colour judiciously based on learning objectives and learner needs. The findings strongly align with established theories, such as the Cognitive Load Theory (Sweller, 1994), which explains why excessive colour usage may hinder retention due to increased cognitive burden. Respondents' concerns about overwhelming visuals resonate with this theory.

The study provides valuable insights on how to effectively use colour for undergraduate retention and learning while keeping up with modern teaching demands. Although students recognise colour as an advantage, a uniform approach to its usage might isolate non-visual learners. Instead, the study shows that colour customisation strategically complements traditional materials. For instance, graphing key ideas in colour or colour-coding concepts can be valuable practices, as endorsed by Chandran *et al*. (2019) and Santos *et al*. (2019), but should be selectively applied based on individual preferences. This balanced approach allows for customisation across diverse classes and learners.

In the area of content delivery, educators can utilise multimedia to enhance student learning through the use of helpful colour elements such as highlighting or contrast directed at grabbing attention, showing hierarchies, and energising or relaxing students based on context, as demonstrated by Dzulkifli and Mustafar (2013), without overwhelming processing resources. Additionally, educators can encourage the use of coloured study tools based on students' learning styles, as proposed by Hurlbert and Ling (2007), to encourage self-administered learning.

In spite of the fact that many students ascribed to the use of the digital environment in this study, there is a need to develop evidence-based guidelines for using colour on various platforms. In achieving this, there is a need to conduct long-term studies that measure how students learn and stay motivated when presented with different colour schemes on paper, digital screens and other emerging technologies like virtual reality. By quantifying these results, principles and guidelines can be developed to help educators choose the right materials for different learning contexts.

Although the study provides valuable insights, it has some limitations that need to be acknowledged. The main concern is sampling bias. The sample used in the study was mostly made up of undergraduate students from two universities in Ghana. This raises doubts about whether the findings of the study are generalisable to a wider population. Therefore, further studies must make efforts to obtain a more diverse and representative sample to ensure the research's validity and reliability.

Additionally, the reliance on self-reported data through the questionnaire introduces potential biases, including social desirability bias and memory recall issues. To address this, future studies could employ diverse data collection methods, such as observations or interviews, to offer a more comprehensive understanding of participants' experiences.

The study highlighted the positive influence of colour on information retention. However, it did not investigate any negative effects or drawbacks thoroughly. Hence, future research should delve deeper into potential challenges and risks related to the use of colour in educational materials. This will enable us to have a more balanced perspective on the subject.

Despite the use of a quantitative approach through Likert-type ratings, supplemented by

qualitative data as a mixed-methods approach offers valuable insights, a more diverse set of research methods, such as experimental designs or case utilise, could provide a more comprehensive understanding of the complex dynamics between colour and information retention. As the subjectivity of colour perception was acknowledged, a more intense exploration of individual differences in how students perceive and interpret colours could enhance instructional developers understanding. Recognising and accounting for these variations would allow for more tailored and effective colour use in educational materials.

Finally, the study focused primarily on student perspectives, neglecting the viewpoints of instructors who design and deliver educational materials. Investigating how instructors perceive and utilise colour in their teaching practices could offer a more holistic understanding of colour integration in higher education.

CONCLUSION

This study examined the role of colour in information retention and learning, drawing on empirical evidence and student perspectives. It aligns with existing literature that suggests strategic colour integration enhances attention, comprehension, and engagement. The study also highlighted individual differences in colour preferences and processing. Therefore, instructional design in higher education must be context-specific and inclusive, accommodating these individual differences. To achieve this, the study recommends using a combination of physical study tools and digital materials to provide customised, multimodal colour exposure.

In conclusion, this study underscores the urgent need for educators and policymakers to integrate evidence-based colour strategies into curricula and instructional material designs. This will ensure inclusivity and effectiveness and contribute to theoretical advancements by validating concepts like Dual Coding and Cognitive Load Theories while extending them through the lens of individual preferences, as highlighted by the Ecological Valence and Colour-in-Context Theories.

Furthermore, these insights have the potential to enhance theoretical understanding and offer practical guidance for creating inclusive and effective educational tools that leverage the strategic use of colour.

REFERENCES

Akbay, S., & Demirbaş, G. U. (2023). Relationship between context-free/ in-context spatial colour preferences and colour constructs: The extraversion personality trait dimension. *Color Research and Application*, *48*(5), 468-483. https://doi.org/10.1002/col.22882

Al-Rahmi, W. M., Alias, N., Othman, M. S., & Shamsuddin, A. (2018). The role of colours in e-learning: A review. *Journal of Theoretical and Applied Information Technology*, *96*(8), 2155-2165.

Chai, M. T., Amin, H. U., Izhar, L. I., Saad, M. N. M., Abdul Rahman, M. A., Malik, A. S., & Tang, T. B. (2019). Exploring EEG effective connectivity network in estimating influence of colour on emotion and memory. *Frontiers in Neuroinformatics*, *13*, 66. https://doi.org/10.3389/fninf.2019.00066

Chandran, R., Menon, R., & Nagarajan, S. (2019). Traffic colour coding of slides to improve undergraduate retention in oral pathology: A pilot trial. *Journal of Oral and Maxillofacial Pathology*, *23*(3), 454-458.

Clarke, V., & Braun, V. (2017). Thematic analysis. *The Journal of Positive Psychology*, *12*(3), 297-298. https://doi.org/10.1080/17439760.2016.1262613

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Diachenko, I., Kalishchuk, S., Zhylin, M., Kyyko, A., & Volkova, Y. (2022). Colour education: A study on methods of influence on memory. *Heliyon*, *8*(11), e11616. https://doi.org/10.1016/j.heliyon.2022.e11616

Dzulkifli, M. A., & Mustafar, M. F. (2013). The influence of colour on memory performance: A review. *Malaysian Journal of Medical Sciences*, 20(2), 3-9.

Elliot, A. J. (2015). Color and psychological functioning: A review of theoretical and empirical work. *Frontiers in Psychology*, 6, 368. https://doi.org/10.3389/fpsyg.2015.00368

Elliot, A. J., & Maier, M. A. (2014). Colour psychology: Effects of perceiving colour on psychological functioning in humans. *Annual Review of Psychology*, 65, 95-120. https://doi.org/10.1146/annurev-psych-010213-115035

Finn, G. M., White, P. M., & Abdelbagi, I. (2011). The impact of colour and role on retention of knowledge: A body-painting study within undergraduate medicine. *Anatomical Sciences Education*, *4*(6), 311-317. https://doi.org/10.1002/ase.253

Franklin, A., Drivonikou, G. V., Bevis, L., Davies, I. R., Kay, P., & Regier, T. (2008). Categorical perception of color is lateralised to the right hemisphere in infants, but to the left hemisphere in adults. *Proceedings of the National Academy of Sciences*, *105*(9), 3221-3225. https://doi.org/10.1073/pnas.0712286105

He, Y., Yang, T., He, C., Sun, K., Guo, Y., Wang, X., Bai, L., Xue, T., Xu, T., Liao, Y., Liu, X., & Wu, S. (2023). Effects of audiovisual interactions on working memory: Use of the combined n-back+ go/nogo paradigm. *Frontiers in Psychology*, *14*, 1080788. https://doi.org/10.3389/fpsyg.2023.1080788

Hughes, L. E., Boklage, A. N., & Wilkins, A. J. (2019). How coloured overlays relieve reading difficulties. *Journal of Research in Reading*, *42*(1), 42-61.

Hurlbert, A. C., & Ling, Y. (2007). Biological components of sex differences in colour preference. *Current Biology*, *17*(16), R623-R625. https://doi.org/10.1016/j.cub.2007.06.022

Klohn, S., & Zimmermann, A. (2021). Framework to analyse the use of colours in informational maps related to COVID-19 data. *InfoDesign - Revista Brasileira de Design da Informação*, *18*(3). https://doi.org/10.51358/id.v18i3.912

Knoell, C. M. (2017). Colour me curious: The effects of colour and generative strategies on memory. *Networks*, *19*(1), article 4.

Kreitz, C., Schnuerch, R., Furley, P. A., Gibbons, H., & Memmert, D. (2015). Does semantic preactivation reduce inattentional blindness? *Attention, Perception & Psychophysics*, *77*(3), 759-767. https://doi.org/10.3758/s13414-014-0819-8

Lee, S. P., Lee, S. D., Liao, Y. L., & Wang, A. C. (2015). Effects of audio-visual aids on foreign language test anxiety, reading and listening comprehension, and retention in EFL learners. *Perceptual and Motor Skills*, *120*(2), 576-590. https://doi.org/10.2466/24.pms.120v14x2

Li, J., & Tong, F. (2020). The effect of cognitive vocabulary learning approaches on Chinese learners' compound word

attainment, retention, and learning motivation. *Language Teaching Research*, *24*(6), 834-854. https://doi.org/10.1177/1362168819829025

Liew, T. W., Tan, S. M., Gan, C. L., & Pang, W. M. (2022). Colors and learner's gender evoke different emotional and cognitive effects in multimedia learning. *Human Behavior and Emerging Technologies*, *2022*, 1-15. https://doi.org/10.1155/2022/1235732

Liu, Y., & Treagust, D. F. (2013). Content analysis of diagrams in secondary school Science textbooks. In M. S. Khine (Ed.), *Critical analysis of Science textbooks: Evaluating instructional effectiveness* (pp. 287-300). Springer Netherlands.

Mehrabian, A., & Russell, J. A. (1974). *An approach to environmental psychology*. MIT Press.

Olesen, J. (2022, June 13). *How does color affect memory? | Color Meanings*. Color Meanings. https://www.color-meanings.com/how-does-color-affect-memory/

Olurinola, O., & Tayo, O. (2015). Colour in learning: Its effect on the retention rate of graduate students. *Journal of Education and Practice*, 6(14), 1-5.

Ou, L. C., Luo, M. R., Woodcock, A., & Wright, A. (2004). A study of colour emotion and colour preference. Part I: Colour emotions for single colours. *Color Research and Application*, *29*(3), 232-240. https://doi.org/10.1002/col.20010

Paivio, A. (1971). *Imagery and verbal processes*. Holt, Rinehart and Winston.

Palmer, S. E., & Schloss, K. B. (2010). An ecological valence theory of human color preference. *Proceedings of the National Academy of Sciences*, *107*(19), 8877-8882. https://doi.org/10.1073/pnas.0906172107

Poulova, P., Klimova, B., & Simonova, I. (2017). Gender with regards to colour preference and its application in kindergartens. *International Journal of Cognitive Research in Science, Engineering and Education*, *5*(2), 73-82.

Rae, C., & Lonka, K. (2018). Dealing with colour: A study on how colour is used in visualisations to support learning. *Interactive Learning Environments*, *26*(8), 1029-1041.

Robinson, D. H., & Choi, S. (2018). Visual design recommendations for multimedia learning: Actions based on the path model of influences on visual channel selection. *Computers and Education*, *129*, 378-394.

Santos, J., Sabino, A., Duane, C., Mallari, J. K. C., Eusebio, M., & Gonzales, P. (2019). The effects of color-coded words on memory retention. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3438889

Slåttå, A., Moen, A., & Berg, A. O. (2017). The power of colour: A study on colour preferences and colour meaning among Iranian university students. *Global Journal of Guidance and Counseling in Schools*, *7*(3), 1-9.

Spence, I., Wong, P., Rusan, M., & Rastegar, N. (2006). How color enhances visual memory for natural scenes. *Psychological Science*, *17*(1), 1-6. https://doi.org/10.1111/j.1467-9280.2005.01656.x

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, *4*(4), 295-312. https://doi.org/10.1016/0959-4752(94)90003-5

Valdez, P., & Mehrabian, A. (1994). Effects of color on emotions. *Journal of Experimental Psychology*: *General*, *123*(4), 394-409. https://doi.org/10.1037/0096-3445.123.4.394

Wichmann, F. A., Sharpe, L. T., & Gegenfurtner, K. R. (2002). The contributions of color to recognition memory for natural scenes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*(3), 509-520. https://doi.org/10.1037/0278-7393.28.3.509

Wilks, C. (2021). Stitched up. In the Conversengine: Using expressive processing and multimodal languages to create a character-driven interactive digital narrative (Doctoral dissertation). Bath Spa University. https://doi.org/10.17870/bathspa.00014344

Wilson, G. D. (1966). Arousal properties of red versus green. *Perceptual and Motor Skills*, *23*(3), 947-949. https://doi.org/10.2466/pms.1966.23.3.947

Xie, J., Sawyer, A. O., Ge, S., & Li, T. (2022). Subjective impression of an office with biophilic design and blue lighting: *A pilot study. Buildings, 13*(1), 42. https://doi.org/10.3390/buildings13010042

Yokosawa, K., Schloss, K. B., Asano, M., & Palmer, S. E. (2016). Ecological effects in cross-cultural differences between U.S. and Japanese color preferences. *Cognitive Science*, *40*(7), 1590-1616. https://doi.org/10.1111/cogs.12291