



HOW ANTHROPOMORPHIC GRAPHICS SUPPORT STUDENTS' UNDERSTANDING OF ABSTRACT CONCEPTS: A QUALITATIVE STUDY IN GEOGRAPHY EDUCATION

*Como gráficos antropomórficos apoiam a compreensão de conceitos abstratos pelos estudantes:
um estudo qualitativo no ensino de geografia*

Jinya Liu¹, Mageswaran Sanmugam^{1*}, Ning Cao²

¹Centre for Instructional Technology and Multimedia, Universiti Sains Malaysia, Penang, Malaysia

²Linfen No.5 Middle School

E-mails: liujinya@student.usm.my, mageswaran@usm.my, 18335782762@163.com

ABSTRACT

Students' understanding of abstract concepts has long been a major challenge in school learning. In geography learning, visual representations are widely used, and anthropomorphic graphics have attracted attention for their potential to make abstract content more accessible. However, existing research has primarily focused on their effects on attention and affect, with limited attention to their role in supporting conceptual understanding. This study explores how anthropomorphic graphics support students' learning of complex abstract concepts and how such support varies according to learners' prior knowledge. Using a qualitative approach, semi-structured interviews were conducted with six Chinese high school students aged 16-17. The findings indicate that anthropomorphic graphics help students relate abstract concepts to everyday experiences, making complex ideas easier to understand and remember. Differences emerged across learners: students with higher prior knowledge tended to use these graphics as explanatory tools for interpreting conceptual relationships, whereas those with lower prior knowledge viewed them primarily as memory aids. The effectiveness of anthropomorphic graphics was also influenced by instructional factors such as teacher guidance and textual support. The study highlights the role of anthropomorphic graphics as instructional tools in supporting abstract concept learning and suggests their effectiveness depends on learners' prior knowledge and instructional design.

Keywords: Anthropomorphic graphics, Visual representation, Conceptual understanding, Abstract concept learning, Prior knowledge, Instructional design

SUBMETIDO EM: 18/07/2026

ACEITO EM: 10/08/2026

PUBLICADO EM: 31/08/2026



COMO GRÁFICOS ANTROPOMÓRFICOS APOIAM A COMPREENSÃO DE CONCEITOS ABSTRATOS PELOS ESTUDANTES: UM ESTUDO QUALITATIVO NO ENSINO DE GEOGRAFIA

*How anthropomorphic graphics support students' understanding of abstract concepts:
a qualitative study in geography education*

Jinya Liu¹, Mageswaran Sanmugam^{1*}, Ning Cao²

¹Centre for Instructional Technology and Multimedia, Universiti Sains Malaysia, Penang, Malaysia

²Linfen No.5 Middle School

E-mails: liujinya@student.usm.my, mageswaran@usm.my, 18335782762@163.com

RESUMO

A compreensão de conceitos abstratos pelos estudantes tem sido, há muito tempo, um dos principais desafios da aprendizagem escolar. No ensino de geografia, representações visuais são amplamente utilizadas, e os gráficos antropomórficos têm atraído atenção por seu potencial de tornar conteúdos abstratos mais acessíveis. No entanto, as pesquisas existentes têm se concentrado principalmente em seus efeitos sobre a atenção e o afeto, com atenção limitada ao seu papel no apoio à compreensão conceitual. Este estudo explora como os gráficos antropomórficos apoiam a aprendizagem de conceitos abstratos complexos pelos estudantes e como esse apoio varia de acordo com o conhecimento prévio dos aprendizes. Utilizando uma abordagem qualitativa, foram realizadas entrevistas semiestruturadas com seis estudantes chineses do ensino médio, com idades entre 16 e 17 anos. Os resultados indicam que os gráficos antropomórficos ajudam os estudantes a relacionar conceitos abstratos com experiências cotidianas, tornando ideias complexas mais fáceis de compreender e memorizar. Diferenças emergiram entre os aprendizes: estudantes com maior conhecimento prévio tenderam a usar esses gráficos como ferramentas explicativas para interpretar relações conceituais, enquanto aqueles com menor conhecimento prévio os viam principalmente como auxílios de memorização. A eficácia dos gráficos antropomórficos também foi influenciada por fatores instrucionais, como a orientação do professor e o suporte textual. O estudo destaca o papel dos gráficos antropomórficos como ferramentas instrucionais no apoio à aprendizagem de conceitos abstratos e sugere que sua eficácia depende do conhecimento prévio dos aprendizes e do design instrucional.

Palavras-chave: Gráficos antropomórficos, Representação visual, Compreensão conceitual, Aprendizagem de conceitos abstratos, Conhecimento prévio, Design instrucional

INTRODUCTION

Geography education involves understanding complex relationships between natural processes and human systems. It encompasses the broad themes of Physical Geography and Human Geography, helps students understand relationships between natural processes and human activities. However, in China, due precisely to the extensive scope of the geography curriculum, the content is often complex and abstract. The enormous volume of information and the intricate connections between different geographical concepts can lead to cognitive overload (Li, 2020). The process-based and often non-intuitive nature of physical geography, combined with the paucity of perceptual grounding in many instructional representations, can make conceptual understanding difficult for students (Bednarz et al., 2013; Fyfe et al., 2014; Kriewaldt et al., 2023).

Moreover, within the context of Chinese high school geography education, students' comprehension of abstract concepts has long been regarded as a core challenge in geography teaching (Ni, 2023). Compared with learning that emphasises the memorisation and reproduction of factual geographic information, students often face greater cognitive demands when engaging with conceptual understanding involving geographic processes, spatial relationships, and causal mechanisms. This suggests that the central challenge in geographic learning lies not in knowledge acquisition itself, but in learners' ability to integrate fragmented information into coherent and explanatory structures of geographic thinking (Bednarz et al., 2013).

Why Abstract Concepts Are Difficult to Learn

This predicament in comprehending abstract concepts stems from multiple factors. Regarding teaching content, geographical processes involve the dynamic changes of natural phenomena, spanning vast temporal and spatial dimensions. Students require strong abstract thinking and spatial imagination capabilities. However, many students demonstrate weaknesses in geographical spatial thinking, reasoning abilities, and comprehensive thinking, making it difficult for them to construct dynamic spatial models in their minds and leading to comprehension difficulties (Wang, 2025). From the perspective of conceptual features, in upper-secondary geography curricula, such concepts are often presented in highly generalised curricular forms, which can make it more difficult for students to connect them with their lived experiences (Bendl et al., 2025). These concepts frequently refer to content that cannot be directly perceived. That is to say, students cannot directly perceive these concepts and must rely on representations to support understanding. Knowledge acquisition is a prerequisite for knowledge transfer; however, learners cannot generalise information that they have not yet acquired (Day et al., 2015). When learning content is presented in highly abstract forms without sufficient concrete and perceptual grounding, learners are more likely to experience a disconnect in conceptual meaning or to engage in shallow processing. Prior research suggests that this issue is particularly pronounced among secondary school students whose prior knowledge and experience with abstraction are still developing, as abstract representations that are not explicitly linked to concrete experiences are less likely to be stably understood and integrated (Fyfe et al., 2014). This characteristic inherently elevates the threshold for comprehending abstract geographical concepts.

From the perspective of information transfer, abstract geographical concepts are primarily conveyed in teaching practice through linguistic descriptions, static diagrams, and symbolic models. For teachers with disciplinary expertise, such representations are easily understood by teachers. However, for students, they frequently demand multiple information transformations, thereby creating cognitive load (Mayer, 2014a).

At the level of cognitive processing, comprehension is a fundamental cognitive process of extracting meaning from information. It is a complex cognitive process that is necessary for virtually all higher-level cognitive activities, including learning, reasoning, problem solving, and decision making (McNamara & Magliano, 2009). However, in classroom settings, abstract concepts are frequently presented alongside multiple concurrent information streams (text, images, teacher explanations). This information overload often leads to reduced comprehension efficiency due to excessive cognitive load. Insufficient visual aids, for instance, may lead to a reliance on verbal descriptions when teaching geography, which may not effectively convey complex geographical phenomena (Abubakar et al., 2023).

Visual representations play an important role in supporting learning, however, in classroom settings, visual representations are often underutilised, occupying a secondary role in schools' text-dominated environments (Ericson & Häikiö, 2025). Instructional approaches that connect abstract concepts with concrete and visual

representations have been shown to enhance students' understanding and motivation, particularly when learning complex content (Iyamuremye & Burns, 2025). In geography teaching, visual aids play an indispensable role in helping students comprehend abstract concepts (Bansah et al., 2018). Amongst the multitude of visual aids, comics are gaining increasing popularity as teaching materials (Bach et al., 2018; Bentz, 2020; Farinella, 2018; Tatalovic, 2009; Tribull, 2017) in educational contexts. Compared to learning through more traditional media such as text, its primary advantage lies in enhancing content comprehension, manifesting in its capacity to support learners' cognitive abilities rather than merely stimulating their motivation to engage with the learning process (Von Reumont & Budke, 2023). The most distinctive feature within comics is the use of anthropomorphic elements; that is to say, anthropomorphism offers a novel approach to resolving the challenges of understanding abstract concepts within Physical Geography.

Anthropomorphism is the attribution of human characteristics to inanimate objects to depict emotions, motivations (Epley et al., 2007), intentions (Waytz et al., 2010), and abilities (Kallery & Psillos, 2004) in behaviour or tendencies. Anthropomorphism helps learners connect abstract concepts with familiar experiences, enabling individuals to comprehend and connect with abstract concepts (Amin et al., 2011), thereby reducing cognitive load while facilitating the understanding and retention of complex information (Salminen et al., 2021).

Research in educational technology also indicates that anthropomorphic expressions and motion designs can enhance task completion speed and improve information comprehension (Su & Liu, 2024). This design approach not only enhances usability but also helps unveil the mysteries of abstract concepts, making learning more intuitive (Gao & Huang, 2022). However, research findings are inconsistent. Slabbert et al. (2022) suggest anthropomorphic graphics may not significantly impact learning outcomes unless they serve pedagogical purposes rather than merely decorative functions. In addition, recent research suggests that the effectiveness of anthropomorphic features may depend on contextual factors, such as lesson content and learner engagement (Matsui, 2024).

Limitations of Previous Research on Anthropomorphic Graphics

In current research, the application of anthropomorphism in multimedia teaching has primarily focused on capturing attention and evoking emotional responses. Even where studies have examined cognitive aspects such as memory and comprehension, these have investigated cognitive enhancement arising from positive emotions stimulated by anthropomorphic graphics, rather than how anthropomorphic graphics support learning.

Moremoholo and de Lange (2018) argue that the human-centred elements embedded in anthropomorphic design are essentially intended to attract learners' attention and render the learning experience more 'memorable'. At the affective and motivational level, prior research has further shown that anthropomorphic design can enhance learning motivation (Schneider et al., 2019). The positive emotions elicited by such designs have been found to significantly influence knowledge transfer (Münchow & Bannert, 2018), while also helping to reduce learners' fear and anxiety (Menendez et al., 2024), alleviate feelings of boredom, and stimulate curiosity (Kumar, 2024). When instructional contexts incorporate anthropomorphic and other design features that evoke positive emotions, learners' engagement is often enhanced through affective responses, and this heightened emotional involvement is considered conducive to deeper information processing and retention (Özgür & Altun, 2021).

However, some studies have noted that although anthropomorphic graphics can effectively elicit learners' emotional responses, such affective arousal does not necessarily translate directly into improved learning performance (Park et al., 2015; Slabbert et al., 2022). These findings suggest that the instructional effects of anthropomorphic design may be highly contingent upon the specific learning context, content characteristics, and modes of implementation (Slabbert et al., 2022; Su & Liu, 2024). Therefore, while anthropomorphic graphics cannot directly replace learners' problem-solving steps or cognitive operations, the affective and attentional engagement triggered by vivid imagery and contextualised presentation may still exert a positive influence on the understanding and memory of abstract concepts (McRae et al., 2018).

The degree of anthropomorphism has been shown to influence cognitive load, with a moderate level of anthropomorphism being considered optimal for sustaining attention without overwhelming learners (Schneider et al., 2019; Su & Liu, 2024; Y. Zhang et al., 2023). In contrast, excessive anthropomorphism may result in information overload, increase cognitive load, and ultimately undermine learning effectiveness (Kalyuga &

Sweller, 2021; Schneider et al., 2019; Sweller et al., 2011). Variations in research findings may be attributable to differences in the design approaches and standards applied in anthropomorphic graphics (Liu & Sanmugam, 2024).

Previous research has demonstrated the cognitive effects of anthropomorphic design, yet the focus has been on the cognitive processes triggered by the emotional experiences evoked through anthropomorphism. How anthropomorphic graphics support learning remains largely unexplored.

This study focuses on the metaphorical function of anthropomorphic graphics. According to Cognitive Metaphor Theory (CMT), metaphors help learners understand abstract concepts by linking them to familiar experiences. Specifically, when a subject seeks understanding of one idea (the target domain) in terms of a different, already known idea (the source domain) (Forišek & Steinová, 2012). Visual metaphor, in this context, refers to the process of constructing, organising, and comprehending abstract concepts through visual presentation, thereby providing an intuitive and sensory means of understanding (Lakoff & Johnson, 1980). The perception of metaphorical images varies across learners, with individuals interpreting the same visual representations in different ways depending on their cognitive preferences and experiences (Lee & Lee, 2024).

Some studies on anthropomorphism have demonstrated its function as a visual metaphor, yet have not explored the mechanisms by which it works. Su and Liu (2024) found that anthropomorphic elements influence cognitive processing by providing familiar cues, helping users navigate and interpret information more effectively, and improving their understanding of complex data. The efficacy of anthropomorphic design may be diminished when visual and conversational cues are inconsistent (Chen et al., 2024). Moreover, anthropomorphism facilitates comprehension of complex subjects by reducing perceived learning difficulty (Liew et al., 2022; Wu et al., 2024).

On this basis, the present study further examines how anthropomorphic graphics support student' understanding from a CMT perspective. The research questions of the present study are:

RQ1: How do anthropomorphic graphics support students' learning of abstract concepts?

RQ2: How does this support differ across students with different levels of prior knowledge?

1 METAPHOR AND ITS ROLE IN LEARNING ABSTRACT CONCEPTS

How Metaphor Enters the Learning Context

Learners are frequently required to engage with both familiar and unfamiliar concepts in learning contexts. CMT posits that humans comprehend many abstract concepts through metaphorical means. This understanding relies upon prior experiences from daily life, particularly familiar activities and interactions (Lakoff & Johnson, 1980). The use of metaphor supports learning by enabling individuals to grasp abstract concepts through connections with familiar experience (Kovecses, 2010).

Metaphors are grounded in widely shared experiences. Recognising prior knowledge and experiences forms the basis for understanding how metaphors support learning. Successful metaphorical interpretation relies heavily on individuals' associations, presuppositions, and prior knowledge about the subject matter (Genovesi & Hesse, 2025). By enabling learners to reinterpret information through familiar experiences, metaphor can help reduce the difficulty of understanding abstract concepts (Gibbs, 1994).

Structural metaphors operate through cross-domain relationships, encompassing connections between concepts that link cognitive and experiential structures (Kovecses, 2010). Actional logic coupling represents a type of structural metaphor, encompassing not only static relationships but also dynamic processes and behaviours. It indicates that by borrowing from a domain with similar actions, learners can understand another domain more effectively, particularly when interpreting a dynamic process (Johnson, 1999).

Among the numerous subsets of metaphor, anthropomorphic metaphor presents a distinct category. This process involves attributing human characteristics, traits, or emotions to non-human entities—such as animals, objects, or abstract concepts—reflecting humanity's capacity to comprehend and communicate abstract ideas through personification (Lakoff & Johnson, 1980). Anthropomorphic metaphors manifest not only through linguistic expression but also via visual forms.

Unlike traditional metaphors, which predominantly rely on textual logic or linguistic comprehension, visual metaphors are defined by their visual structure and the interpretation processes required to understand the relation between the target and the source (Phillips & McQuarrie, 2004). However, both textual and visual metaphors

function by linking concrete experiences, thus sharing commonalities in the cognitive processing and understanding of abstract concepts.

When anthropomorphic visual metaphor elements appear in teaching contexts, and structural metaphors achieve cross-domain mapping from life experience to learning content, metaphors support learning by functioning as an instructional tool.

Cognitive Processing Mechanisms of Anthropomorphic Graphic Metaphors: From CTML and LOP

Building on the role of metaphor in supporting learners' understanding of abstract concepts, it is also important to examine how this support operates at the level of cognitive processing. While CMT explains how learners connect abstract concepts with familiar experiences, it does not fully account for the specific cognitive processes involved in learning with visual representations. To address this, Cognitive Theory of Multimedia Learning (CTML) provides a framework for understanding how learners process and integrate verbal and visual information in multimedia environments. In addition, the Levels of Processing Theory (LOP) offers further insight into how different forms of instructional support may influence the depth of information processing and long-term retention. Together, these theoretical perspectives make it possible to explain not only why anthropomorphic metaphorical graphics may support learning, but also how they influence learners' cognitive processing and information encoding during learning.

CTML indicates that meaningful multimedia learning relies on learners' active processing of textual and visual information through selection, organisation, and integration within constrained cognitive resources (Mayer, 2014b). When information enters the processing stream via multisensory input, working memory organises and encodes selected elements, linking new information to existing knowledge structures. This connection process is crucial, serving as a vital step in promoting deep understanding and constructing long-term memory (Mayer, 2005).

Learners with limited prior knowledge experience greater difficulty when integrating new information into their existing cognitive structures, thereby placing increased demands on working memory (Sweller et al., 1998). Empirical research further indicates that such learners tend to rely more heavily on external instructional support and experience greater difficulty in independently constructing principle-based connections, reflecting challenges in conceptual integration (Renkl, 2002). From an instructional perspective, this cognitive weakness can be reduced when abstract representations are grounded in concrete and perceptually accessible forms.

This pattern is also evident in research on gamification, where learners are able to activate and reconstruct prior knowledge through continuously presented visual and interactive stimuli embedded in game interfaces, linking prior knowledge with new information with ongoing learning content and thereby supporting conceptual understanding and integration (Sanmugam et al., 2014; Shawalludin et al., 2021). A systematic review by Fyfe et al. (2014) further demonstrates that instructional approaches which progressively transition from concrete to abstract representations can facilitate conceptual understanding, particularly for learners with limited prior knowledge, by reducing working memory load and supporting the gradual construction of meaningful conceptual relations.

In contrast, learners with more extensive prior knowledge are better able to map new information onto existing principles and representations in a more efficient manner, thereby reducing their reliance on instructional explanations and promoting knowledge transfer (Renkl, 2002). As demands on working memory are alleviated, these learners are able to allocate greater cognitive resources to deeper levels of understanding (Kintsch, 1998).

LOP further elaborates on the pathways through which anthropomorphic metaphorical graphics facilitate deep comprehension and the construction of long-term memory. LOP emphasises that the retention duration of information depends on the depth of its processing. Deep processing involves more complex cognitive activities, manifested in the processing of information's understanding and connections between information, thereby forming more robust and enduring memory traces (Craik, 2001). Specific strategies include reinforcing key concepts, linking new information to prior knowledge, promoting self-referential encoding, and enhancing emotional engagement, which facilitate the formation of robust memory traces and promote long-term retention (Craik & Lockhart, 1972; Galli, 2014). In this study, anthropomorphic metaphorical graphics are regarded as a potential instructional mechanism that may prompt learners to move from surface-level to deeper processing. When metaphors successfully activate learners' connections to prior knowledge, learners are more likely to increase the depth of information encoding through self-referential processing.

In summary, this study employs CMT as its cognitive foundation, using CTML and LOP to provide complementary explanations for metaphor processing conditions and depth in multimedia learning. An explanatory framework has been constructed, progressing from conceptual representation (CMT) to cognitive processing conditions (CTML) and ultimately to information processing depth (LOP).

2 METHODOLOGY

This study employs qualitative research, specifically semi-structured interviews, to understand how learners construct abstract concepts through metaphors within specific learning contexts. It also delves into students' mental processes when confronting challenging topics, capturing cognitive moments difficult to measure through quantitative data. Semi-structured interviews provide a framework focused on research questions while preserving space for students to freely express their experiences and interpretations.

A total of six students, aged 16-17, were selected from a single natural class at a high school in Shanxi, China. The participants represented differing levels of prior knowledge, selected through purposive sampling. Based on a bell curve and baseline tests of prior knowledge, three students were chosen from the top 27% of academic performance and three from the bottom 27%. Although the study grouped the sample, the aim was not to compare differences between them, but to understand how the instructional mechanism of anthropomorphic graphics assists conceptual understanding among students with varying prior knowledge levels.

Prior to the interviews, participants were informed about the purpose of the study, the voluntary nature of participation, confidentiality measures, and their right to withdraw at any time. Because the interviews were conducted remotely via an online platform, verbal informed consent was obtained before the interviews commenced.

The design of learning materials

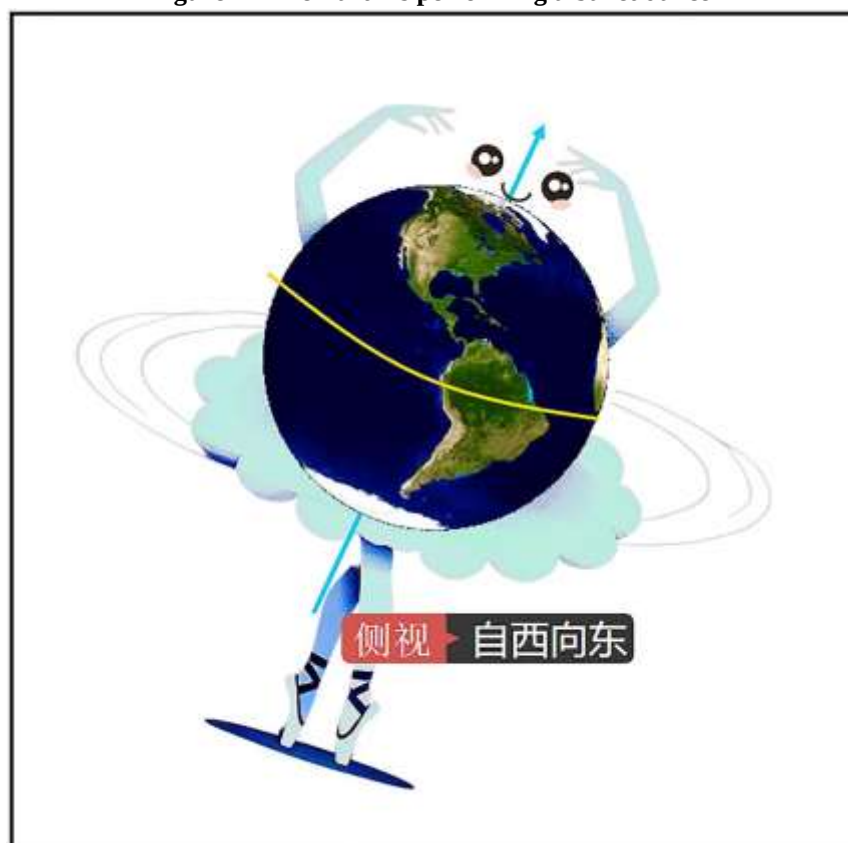
The learning materials for this study were designed based on the textbook chapter "Earth's Motions", which is taught during the first semester of the second year of high school. The teaching intervention was conducted within real classroom settings, where the teacher utilised PowerPoint slide presentations incorporating anthropomorphised graphics during their regular lessons. To prevent aesthetic and cognitive fatigue among students, the anthropomorphised designs focused specifically on key teaching points and challenging concepts. Drawing upon the teacher's pedagogical experience, researchers ultimately selected six key concepts for anthropomorphic design. These concepts and knowledge points, scattered across two to three lessons, are: 'Earth's rotation', 'Earth's revolution', 'the terminator line', 'perihelion and aphelion', 'solar altitude angle', and 'Coriolis force'. Each was presented as an animated graphic within the PowerPoint slides.

To ensure the anthropomorphised graphics served educational purposes rather than merely decorative ones, the teaching materials incorporated visual elements aligned with high school students' cognitive characteristics and daylife contexts, integrating them with the unit's core geographical concepts. For instance, when explaining perihelion and aphelion, the Earth was anthropomorphised as a passenger on a rollercoaster, linking the speed variations during the ride's progression to the Earth's accelerated and decelerated movements at perihelion and aphelion (Figure 1). When illustrating 'Earth's rotation,' the planet was depicted as a ballet dancer spinning counterclockwise (Figure 2).

Figure 1 - The Earth on a Roller Coaster



Figure 2 - The Earth is performing a ballet dancer



Through the structural metaphor design of action-logic coupling, anthropomorphic graphics appear in learning materials in concrete and contextualised ways. The aim is to deepen information processing by strengthening the connection between learning content and students' personal experiences, thereby facilitating self-referential encoding. This ensures the anthropomorphic graphics enter the cognitive processing stream, promoting knowledge comprehension and long-term retention.

Data Analysis

After anonymising the interview content, the researchers undertook multiple readings of all interview transcripts. Preliminary analysis was guided by CMT, focusing on metaphorical mapping patterns and the role of metaphor in comprehension and memory. Coding remained open and flexible, permitting multiple meanings to coexist to preserve the complexity of learners' experiences.

As analysis progressed, codes exhibiting high semantic overlap were consolidated into more interpretative analytical nodes, whilst attention was paid to descriptions recurring across multiple samples. Codes appearing sporadically in isolated interviews and lacking clear relevance to the research questions were retained as contextual information, excluded from the core analytical framework. The entire analytical process involved iterative cycles between textual interpretation and theoretical reflection, ensuring that the distilled core nodes were both grounded in learner experiences and conceptually interpretative.

Software NVivo 11 was employed throughout the analysis to manage interview transcripts and analytical work. The software served solely as a supportive tool; the formation of core nodes depended mainly on the researcher's interpretation of textual meaning and theoretical judgment.

3 FINDINGS

Following the coding and synthesis of the interview data, this study identified three core themes, each of which was further specified through first-level and second-level sub-themes to capture the different functional orientations of anthropomorphic metaphorical graphics in students' learning experiences. Table 1 summarises the results of the thematic analysis, including definitions of each theme and sub-theme, as well as the associated participants, to enhance the transparency and traceability of the analytic process.

Table 1 - Themes and sub-themes reflecting students' experiences with anthropomorphic metaphor graphics

Themes	First-level sub-themes	Second-level sub-themes	Participants ID
Foundations of understanding	Use of prior experience in understanding metaphors	Linking prior experiences to abstract concepts	L_S4
		Using everyday experiences to support understanding	H_S1, H_S2, H_S3, L_S5, L_S6
	How structural metaphors support understanding	Linking actions to conceptual processes	H_S1, H_S2, H_S3, L_S6
		Understanding relationships between concepts	L_S4, L_S5, L_S6
Support for learning	Supporting memory	Memory support cues	H_S1, H_S3, L_S4, L_S5, L_S6
		Retrieval cues	H_S2, L_S5
		Reducing memory errors	L_S6
	Supporting understanding	Supporting understanding	H_S1, H_S2, H_S3, L_S4, L_S6
		No clear support for understanding	H_S2, L_S5
Learners' perceptions	Perceived learning difficulty	Not very difficult	H_S1, H_S2, H_S3, L_S4
		It was alright	L_S5, L_S6
	Perceived cognitive load	Not tiring	H_S1, H_S2, H_S3, L_S4, L_S5, L_S6
		Feeling happy	H_S1, H_S3, L_S4
	Emotional responses	Increased learning interest	L_S5
		Fun and curiosity	H_S2, L_S6

The Origin of Anthropomorphic Metaphors: From Experiential Activation to Cross-Domain Mapping

Interview results reveal that when reflecting on how anthropomorphic graphics aided their learning, students did not merely perceive them as visual embellishments or formal innovations. Instead, they connected the metaphors presented by these graphics to their existing life experiences or prior experiences. They then transferred familiar action structures or relationships (source domain) to abstract geographical concepts (target domain), thereby linking familiar experiences to abstract geographical concepts.

Regardless of prior knowledge level, all six interviewees referenced personal experiences when explaining why the graphics were 'easier to comprehend' or 'more memorable'. Among them, four spontaneously mentioned understanding perihelion and aphelion velocity changes through roller-coaster speed variations, while 1 recalled the concept upon prompting with 'roller-coaster animations'. S5 noted that although he had never ridden a roller-coaster himself, observing others combined with the anthropomorphised diagram enabled him to understand the concept that 'Earth moves faster at perihelion and slower at aphelion' through the corresponding speed variations. Such expressions typically emerged naturally when students articulated their comprehension processes, indicating that experience functioned as a central resource in supporting understanding rather than a peripheral association.

Cognitive Processing Pathways for anthropomorphic Graphic Metaphors: From Structural Correspondence to Memory Encoding

Further analysis revealed that students did not merely remain at the level of intuitive understanding of anthropomorphic graphics. Instead, they grasped the dynamic relationships within abstract concepts through the action sequences and relational structures depicted in the graphics. Most of the students explicitly described in interviews how they linked the sequential actions shown in anthropomorphic diagrams—such as variations in speed and rotational direction—to conceptual relationships in the learning content (Table 2). For instance, S2 stated, 'The ballet dancer moves in the same direction as the Earth's rotation.' S3 remarked, 'When looking at the picture, I saw the roller-coaster moving fast as it passed the perihelion, then slowing down near the aphelion, so I memorised this knowledge point by associating it.' Such statements typically involve holistic correspondences between multiple conceptual elements rather than isolated points of understanding. Crucially, the anthropomorphic graphics do not merely provide isolated visual information. This mapping, from consistent motion logic to structural correspondence, enables students to actively integrate conceptual relationships, constituting a significant pathway through which anthropomorphic metaphors support abstract conceptual understanding, forming an important way through which anthropomorphic metaphors support students' understanding of abstract concepts.

Table 2 - Statements from participants regarding structural metaphor mapping

Students' ID	Knowledge Points	Summary of Key Statements
H_S1	Perihelion/Aphelion	".....It speeds up as it approaches perihelion, and slows down abruptly as it approaches aphelion....."
H_S2	Earth Rotation	"They are all turning....." "...all from west to east..."
H_S3	Perihelion/Aphelion	"The roller coaster goes fast when it passes perihelion, and then gradually slows down as it approaches aphelion."
L_S4	Earth Rotation	"The direction they circled...", "...clockwise or counterclockwise, etc."
L_S5	Perihelion/Aphelion	"Roller coasters helped me understand the speed of revolution."
L_S6	Perihelion/Aphelion	"Perihelion and aphelion both have different speeds, and roller coasters also have different speeds. Combining them together..."

Regarding memory support, students treated anthropomorphic graphics as memory anchors or recall cues. When recalling knowledge points, they primarily associated anthropomorphic metaphorical graphics, indicating their function as 'memory anchors' or 'recall hooks' that form prominent markers in memory, thereby supporting long-term memory formation and knowledge retrieval. Anthropomorphic graphics provide deeper visual indices with greater resistance to interference than text, and participate in the information encoding process. During recall, four interviewed students explicitly stated, 'I think of the picture first' or 'Seeing the picture makes the concept clear'. Both S2 and S5 noted that when doing exercises, recalling the anthropomorphic images helped retrieve related knowledge points. S6 added, 'I could never remember the timing and speed of perihelion and aphelion, but the roller-coaster map helped me memorise it.' 'Without this diagram, if I were simply told that perihelion is faster and aphelion slower as before, I'd easily get them mixed up. This demonstrates how anthropomorphic graphics prevent memory confusion by providing vivid retrieval cues. They enhance the retrievability of concepts within memory and improve the process of memory retrieval. These observations were present across students with varying levels of prior knowledge, though particularly pronounced among those with lower prior knowledge.

Functional Emphasis of Anthropomorphism Metaphors Among Students with Different Levels of Prior Knowledge

Although all students affirmed the positive role of anthropomorphic graphics in learning (Figure 3), their emphasised functional focuses exhibited marked differences. The results of the cluster analysis conducted in NVivo 11 indicate that participants with higher and lower levels of prior knowledge each exhibited internal consistency in their modes of expression and focal concerns(Figure 4). Students with high prior knowledge tended to view anthropomorphic graphics as tools for clarifying conceptual relationships and enhancing holistic understanding of knowledge frameworks. They frequently employed terms such as ‘correspondence,’ ‘structure,’ and ‘relationship’ to describe how these graphics helped understand the relationships within abstract concepts.

Figure 3 - Effectiveness of Anthropomorphism Graphics

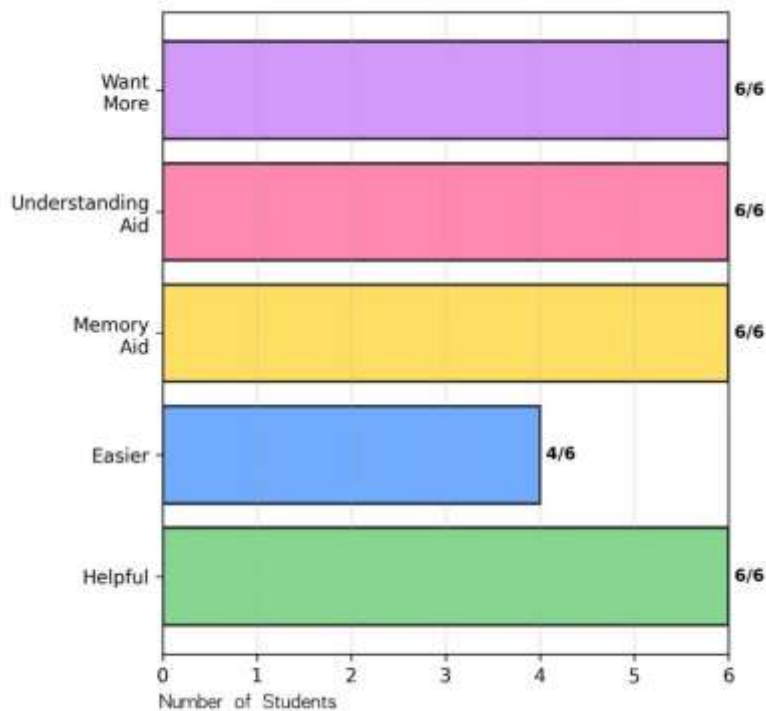
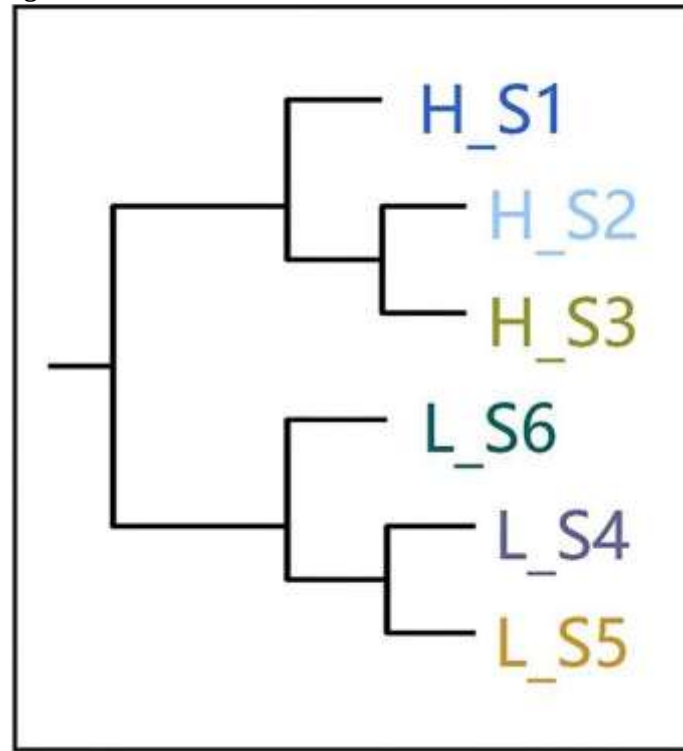


Figure 4 - Material sources clustered based on word similarity



Conversely, students with low prior knowledge more frequently characterised anthropomorphic graphics as memory support tools, emphasising their role as ‘memory anchors’ or ‘recall hooks’. These students often noted that the presence of anthropomorphic graphics prevented conceptual confusion during knowledge recall and even avoided ‘reversed recall’ errors. This finding indicates that anthropomorphic metaphors do not function singularly. Instead, their functional focus shifts between comprehension support and memory support depending on the learner’s prior knowledge level.

Mediating Role of Emotional Arousal and Cognitive Load Cannot Be Overlooked

Although emotional factors were not the main focus of this study, the mediating role of affective responses elicited by anthropomorphic graphics in moderating cognitive load cannot be disregarded. When asked, ‘How did you feel when seeing the anthropomorphic graphics?’, all six interviewed students employed positive vocabulary such as ‘happy’, ‘fun’, ‘relaxed’, and ‘novel’. Moreover, most of them indicated that these positive emotions enhanced their willingness to learn. Student S3 remarked, ‘(When seeing the anthropomorphic graphics) makes me rather pleased, it makes me feel this knowledge point easier to remember’. This demonstrates that the imagery’s novelty and playfulness evoked positive affect, making abstract concepts feel more accessible to students and encouraging students to invest more effort in understanding challenging content. For instance, S1 remarked, ‘When I couldn’t grasp the meaning conveyed by the anthropomorphic graphic, the thinking process feels exhausting, but the subsequent clarity brings a sense of relief,’ reflecting a sense of intellectual accomplishment.

Regarding the perceived difficulty, four interviewees explicitly stated it was ‘not difficult’ or ‘not very difficult.’ The remaining two students offered neutral responses leaning towards ‘not difficult,’ such as ‘it was alright.’ Overall, this presents a phenomenon of ‘reduced perceived difficulty.’

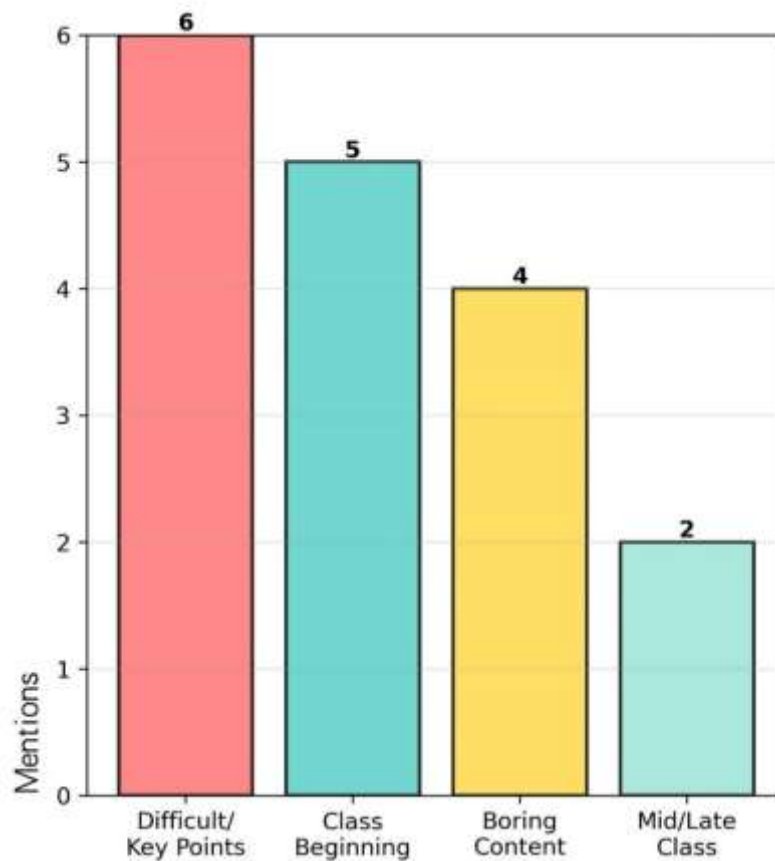
Conditions and Limitations of Anthropomorphic Metaphors in Promoting Understanding

Interview results also revealed that anthropomorphic metaphors do not automatically enhance comprehension in all contexts. Participants S2 and S5 explicitly noted that the anthropomorphic graphics alone often proved insufficient for directly grasping their intended conceptual meaning, requiring textual explanations or teacher guidance to achieve full understanding. In such instances, the graphics remained at a perceptual level rather than directly supporting understanding.

A minority of students remarked during interviews that when viewing anthropomorphic graphics in isolation, they ‘couldn’t quite grasp it’ or ‘didn’t know what it meant,’ requiring reference to the textbook or teacher’s explanations to achieve comprehension. Such statements frequently emerged when students reflected on their understanding processes or compared different learning materials. However, once the key insight (the correspondence between knowledge points and anthropomorphic metaphors) was understood, retention became significantly stronger and less prone to forgetting. For instance, S1’s statement: ‘(When struggling to grasp the meaning conveyed by an anthropomorphic graphic) the thinking process feels exhausting, but the subsequent clarity brings a sense of relief’ indicates that the cognitive efficacy of anthropomorphic metaphors depends on instructional guidance within the teaching context, rather than being inherent to the graphic itself.

Regarding recommendations for using anthropomorphic graphics, all interviewees emphasised the need for precise ‘focusing on key points and difficulties’. S2 suggested employing them during ‘learning fatigue’, specifically midway through or towards the end of a lesson, to maximise their effectiveness (Figure 5). Concerning frequency, most students felt that in a 45-minute class, anthropomorphic graphics should appear no more than three times, excessive use would diminish their novelty.

Figure 5 - Suggested Usage Scenarios by Students



DISCUSSION

From Presentation Form to Conceptual Understanding

The findings of this study indicate that the role of anthropomorphic graphics in learning varies depending on their purpose: when employed to enhance cognition, their effectiveness does not stem from visual “embellishment”. Interview results suggest that learners perceive these graphics as “helpful” because they successfully activate learners’ prior experiential resources, thereby supporting students’ understanding of abstract concepts. In other words, anthropomorphic graphics with pedagogical intent should be regarded as instructional

tools rather than instructional embellishments. This aligns with Slabbert et al. (2022) perspective that anthropomorphic graphics serving educational purposes may significantly influence learning outcomes.

This finding provides a crucial supplement to current educational research on anthropomorphic design. Previous studies often attribute anthropomorphic effects to factors such as emotional arousal, motivation enhancement, or attention capture, which are insufficient to explain how students actually 'use' anthropomorphic graphics for learning. In this study, students repeatedly mentioned in interviews not whether the graphics were interesting, but how they helped them 'figure things out', 'make connections', or 'avoid confusion'. This indicates that the educational value of anthropomorphic graphics lies in the conceptual information they convey, rather than their formal characteristics alone. This contrasts with perspectives such as those of Moremoholo and de Lange (2018), who contend that the human elements in anthropomorphic design are fundamentally intended to captivate audiences and render learning experiences 'memorable'.

From the perspective of CMT, the findings of this study clearly demonstrate how understanding abstract concepts relies upon the support of concrete experiences. That is to say, the role of anthropomorphic graphics in learning does not primarily depend on their visual appearance, but rather on their capacity to serve as experiential triggers, providing students with a familiar, perceptible cognitive starting point. When comprehending abstract geographical concepts, students do not develop understanding without prior experience. Instead, anthropomorphic graphics activate related life experiences or prior knowledge and experience, such as perceptions of speed variation, rotational direction, or continuous motion. This provides students with a familiar "source domain", allowing abstract concepts to be linked to concrete experience. Subsequently, this consistent logic is "transferred" to geographical concepts, linking complex geographical concepts onto a more intuitive logic consistent with the source domain, thereby aiding students' comprehension of abstract concepts. This finding aligns with prior research showing that linking abstract content with concrete and visual representations can support deeper understanding and enhance learner engagement (Iyamuremye & Burns, 2025).

It is noteworthy that during the design phase of the anthropomorphic graphics in this study, the logic strictly adhered to that of the abstract concept. This was crucial for triggering students' life experiences and achieving cross-domain mapping. Merely adding decorative expressions might not achieve the metaphorical effect observed in this research. This aligns with the perspective of Chen et al. (2024), who suggest that the effectiveness of anthropomorphic design may be compromised if visual and conversational cues are inconsistent.

The Core of Cognitive Processing in Anthropomorphic Graphic Metaphors: From Structural Mapping to Deep Information Encoding

More significantly, students do not merely remain at the level of experiential association. Cross-domain mapping serves only as the starting point for anthropomorphic metaphors to support cognitive processes; structural correspondence plays an important role in cognitive processing. Structural correspondence is achieved through action-logic coupling, thereby enabling the holistic transfer of relational systems from the source domain into the target concept. This process embodies the mechanism of 'structural metaphor' of CMT, wherein learners do not merely 'analogue' an image to a concept, but rather reorganise their understanding of abstract knowledge through a familiar structural framework.

In this study, students accurately mapped structural characteristics, such as the speed variations of roller coasters and the rotations of ballet dancers, onto the Earth's orbital velocity and direction of rotation. This structuring of action logic to shape abstract conceptual understanding constitutes the critical pathway through which anthropomorphic metaphors exert cognitive influence. In other words, anthropomorphic metaphors transcend isolated comprehension points, instead aiding students in constructing coherent conceptual frameworks. This facilitates a shift in geography learning from isolated factual memorisation towards systematic internalisation. This aligns with findings from Su and Liu (2024) and McRae et al. (2018), elucidating how 'familiar cues,' 'vivid imagery,' and 'contextualisation' positively influence students' memory and comprehension of abstract concepts.

Simultaneously, experimental results indicate that anthropomorphic graphics provide deeper visual indices than plain text during information encoding. All participants acknowledged their significant role in enhancing memory, particularly in stressful contexts like examinations, where such graphics functioned as 'memory hooks' and 'retrieval cues,' effectively preventing conceptual confusion. This aligns with the LOP perspective, which

posits that information enhanced with experiential connections undergoes deeper processing and is less prone to forgetting.

Notably, this enhancement in memory performance was particularly pronounced among students with lower prior knowledge levels. For this group, anthropomorphic graphics served not only as comprehension aids but also as prominent markers in long-term memory, substantially reducing the risk of forgetting and erroneous recall.

How Learners 'Employ' Metaphors: Functional Differentiation Among Learners Rather Than Differences in Effectiveness

Anthropomorphic metaphors do not exert the same influence on all students. While all students, regardless of prior knowledge level, acknowledge the value of anthropomorphic graphics, their functional emphasis differs markedly. Students with higher prior knowledge tend to utilise anthropomorphic graphics as explanatory tools to clarify structural relationships between concepts. Conversely, students with lower prior knowledge predominantly view them as memory support tools, emphasising their role in preventing confusion and facilitating recall. This aligns with previous research suggesting that the effects of anthropomorphism features may vary across contexts (Matsui, 2024; Slabbert et al., 2022; Su & Liu, 2024). Concurrently, the present study's findings corroborate perspectives within CTML: prior knowledge influences learning outcomes by moderating cognitive processing demands (Mayer, 2014a). Learners with higher levels of prior knowledge are better able to integrate new information into existing conceptual structures, often requiring less external support to establish principle-based connections (Renkl, 2002) and allocate greater cognitive resources towards deep understanding (Kintsch, 1998).

Rather than framing the efficacy of anthropomorphic graphics as 'strong or weak,' it is more accurate to view them as cognitive tools adaptable to diverse learner contexts. Metaphors do not unidirectionally generate comprehension or memory effects; instead, they are flexibly used to meet different learning needs based on learners' existing cognitive resources.

The auxiliary role of anthropomorphic graphic metaphors in emotional and cognitive processes cannot be overlooked.

According to CTML, anthropomorphic graphics can reduce students' psychological distance (Plass et al., 2014) from abstract content by evoking positive emotions (interesting, novel), making learning tasks feel manageable and comprehensible. In this study, S3's statement '(When seeing the anthropomorphic graphics) makes me rather pleased, it makes me feel this knowledge point easier to remember' aligns with this perspective. The unit on Earth's movements is considered relatively challenging content. However, interviewed students described it as 'not too difficult', regardless of prior knowledge. This indicates that anthropomorphic graphics can lower learners' perceived difficulty, consistent with (Liew et al., 2022).

The students' perceptions of a given task as being easy or difficult is a matter of personal opinion. This affects the student's level of self-efficacy, which in turn influences the strength of their self-efficacy (Bandura, 1997). Based on student accounts, the positive emotions generated by anthropomorphic graphics (feeling interesting and novel) can be viewed as an additional effect of this learning approach: students find the anthropomorphic metaphor novel and engaging due to its unfamiliar presentation. However, students' perceptions of difficulty could be different from the actual difficulty level (Street et al., 2017). This aligns with Park et al. (2015) and Slabbert et al. (2022), suggesting that while anthropomorphic graphics can stimulate learners' emotions, this does not directly lead to improved learning outcomes.

The Boundaries of Anthropomorphic Graphic Metaphors: Understanding Does Not Occur Automatically

Although anthropomorphic graphics were generally perceived as beneficial by students, this study also found that their role in facilitating understanding did not occur automatically. Some students explicitly stated that, without accompanying textual explanations or teacher guidance, anthropomorphic graphics alone were insufficient for comprehensive comprehension. This highlights the reliance of metaphor comprehension on linguistic communication (Lakoff & Johnson, 1980). This finding indicates that the effectiveness of metaphors does not depend solely on the graphics themselves but arises from the interaction between learners, metaphorical structures, and instructional guidance.

Regarding the timing and frequency of embedding personified graphics in learning materials, students also held distinct views. The majority suggested the use should focus on key teaching points and challenging concepts, aligning with the research's original design intent. Only one student mentioned employing them during learning fatigue. This further demonstrates that, from the students' perspective, the visual metaphorical function of anthropomorphic graphics takes precedence over their role in emotional stimulation.

Participants in this study comprised 16-17-year-old high school students. According to Piaget's cognitive theory (Piaget, 1976), they occupy the transitional phase from late adolescence to early adulthood, exhibiting cognitive development that retains aspects of adolescent immaturity while gradually displaying adult rational characteristics. The suggested frequency of 'three times' reflects their need for visual metaphorical support without requiring particularly high frequency.

Consequently, in geography teaching practice, anthropomorphic graphics should be used as instructional supports that help learners move from perceptual recognition to conceptual understanding under appropriate teacher guidance. Their effectiveness depends on learners' ability to identify and apply connections between familiar experiences and abstract learning content. In this process, teacher explanations and textual support play an important role in helping students interpret these connections and develop an accurate understanding. Once these relationships are made explicit, anthropomorphic graphics can effectively support both understanding and memory by providing clear and memorable reference points. Therefore, rather than functioning as standalone visual elements, anthropomorphic graphics should be integrated into instructional design in a structured and purposeful manner, aligned with learners' prior knowledge and the complexity of the content. This highlights the importance of combining visual design with pedagogical guidance to maximise their effectiveness in supporting the learning of abstract concepts.

CONCLUSION

This study, within a theoretical framework informed by CMT, examines how anthropomorphic graphics function as visual supports in learning abstract content. From this perspective, anthropomorphic metaphors reduce cognitive load by linking abstract geographical concepts to familiar life experiences. This serves as an important way to support deeper information processing, aiding students in memorising and comprehending abstract learning concepts.

Findings indicate that anthropomorphic graphics function as instructional tools, supporting learners' conceptual understanding of abstract concepts. When engaging with such graphics, students typically draw upon existing life experiences and prior knowledge to map the actions and structures depicted onto abstract concepts. This facilitates the connection between familiar experiences and abstract concepts, supports the organisation of conceptual relationships, and enhances understanding, making previously difficult conceptual relationships easier to understand and remember. Learners with differing levels of prior knowledge 'use' the same metaphor in distinct ways: for those with high prior knowledge, anthropomorphic graphics function as cognitive scaffolding, clarifying structural relationships between concepts; whereas for learners with low prior knowledge, their greater value lies as memory anchors, supporting concept recall and reducing memory interference. Moreover, anthropomorphic graphics may struggle to function as comprehension tools without the necessary explanatory support; once metaphorical relationships are explicitly revealed, their role in supporting understanding and memory becomes more effective.

This study does not dismiss the roles of visual presentation, dynamic forms, or emotional factors, but emphasises the role of anthropomorphic graphics in supporting cognitive processing in learning. Rather than focusing on "whether anthropomorphic graphics are used", attention should be directed towards "whether anthropomorphic graphics are designed in a way that supports understanding and can be effectively used in learning". Future instructional design should fully consider the learners' prior experiences, introducing anthropomorphic elements precisely at critical cognitive load points. The educational value of anthropomorphic graphics lies not in their "resemblance to humans" but in their capacity to help link prior experience with abstract concepts and support students' understanding.

It should be noted that this study, based on a limited number of interview samples, focuses on students' subjective experiences and students' processes of understanding anthropomorphic graphics, rather than quantitative comparisons of learning outcomes.

Future research could further explore the cognitive functions of different types of metaphorical graphics within broader disciplinary contexts. By incorporating process data, such studies could provide a clearer understanding of how metaphors support learning.

REFERENCES

- Abubakar, A., Bello, Z., Hussain, A., & Bello, N. I. (2023). Availability and Use of Visual Teaching and Learning Materials in Teaching Geography at Nassarawa Education Zonal Office. *The Universal Academic Research Journal*, 5(1), 17–26.
- Amin, M., Olu-Lafe, O., Claessen, L. E., Sobczak-Edmans, M., Ward, J., Williams, A. L., & Sagiv, N. (2011). Understanding grapheme personification: A social synaesthesia? *Journal of Neuropsychology*, 5(2), 255–282.
- Bach, B., Wang, Z., Farinella, M., Murray-Rust, D., & Henry Riche, N. (2018). Design Patterns for Data Comics. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, 1–12.
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. Macmillan.
- Bansah, A., Antwi, S., & Franklin, T. (2018). The Information Technology Challenge in Teaching Senior High School Geography in Ghana. *Issues and Trends in Educational Technology*, 6(1).
- Bednarz, S., Heffron, S., & Huynh, N. (2013). *A road map for 21st century geography education*. Washington, DC: Association of American Geographers.
- Bendl, T., Storrsøster, H., Madsen, L. M., Trokšiar, D., De La Martinière, R., Liu, S., Serame, S., Mitchell, J. T., Bagoly-Simó, P., Duan, Y., & Kidman, G. (2025). An international perspective on geography curricula: Paving a way forward for geographical thinking. *International Research in Geographical and Environmental Education*, 34(3), 294–317.
- Bentz, J. (2020). Learning about climate change in, with and through art. *Climatic Change*, 162(3), 1595–1612.
- Chen, J., Li, M., & Ham, J. (2024). Different dimensions of anthropomorphic design cues: How visual appearance and conversational style influence users' information disclosure tendency towards chatbots. *International Journal of Human-Computer Studies*, 190, 103320.
- Craik, F. I. M. (2001). Memory: Levels of Processing. In *International Encyclopedia of the Social & Behavioral Sciences* (pp. 9593–9597). Elsevier.
- Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, 11(6), 671–684.
- Day, S. B., Motz, B. A., & Goldstone, R. L. (2015). The Cognitive Costs of Context: The Effects of Concreteness and Immersiveness in Instructional Examples. *Frontiers in Psychology*, 6.
- Epley, N., Waytz, A., & Cacioppo, J. T. (2007). On seeing human: A three-factor theory of anthropomorphism. *Psychological Review*, 114(4), 864–886.
- Ericson, K., & Häikiö, T. K. (2025). Visuality and Multimodality as Tools for Learning in Geography and Art Education. *Journal of Aesthetic Education*, 59(2), 50–73.
- Farinella, M. (2018). The potential of comics in science communication. *Journal of Science Communication*, 17(01), Y01.
- Forišek, M., & Steinová, M. (2012). Metaphors and analogies for teaching algorithms. *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education*, 15–20.
- Fyfe, E. R., McNeil, N. M., Son, J. Y., & Goldstone, R. L. (2014). Concreteness Fading in Mathematics and Science Instruction: A Systematic Review. *Educational Psychology Review*, 26(1), 9–25.
- Galli, G. (2014). What makes deeply encoded items memorable? Insights into the levels of processing framework from neuroimaging and neuromodulation. *Frontiers in Psychiatry*, 5.
- Gao, Z., & Huang, J. (2022). Human-computer interaction emotional design and innovative cultural and creative product design. *Frontiers in Psychology*, 13, 982303.
- Genovesi, C., & Hesse, J. (2025). Deviance and the literal-metaphorical distinction revisited. *Inquiry*, 1–25.

- Gibbs, R. W. (1994). *The poetics of mind: Figurative thought, language, and understanding*. Cambridge University Press.
- Iyamuremye, E., & Burns, D. (2025). Concrete-Pictorial-Abstract instruction: Enhancing students' learning motivation and achievement in mathematics. *Cogent Education*, 12(1), 2558303.
- Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to western thought*.
- Kallery, M., & Psillos, D. (2004). Anthropomorphism and Animism in Early Years Science: Why Teachers Use Them, how They Conceptualise Them and What Are Their Views on Their Use. *Research in Science Education*, 34(3), 291–311.
- Kalyuga, S., & Sweller, J. (2021). The Redundancy Principle in Multimedia Learning. In R. E. Mayer & L. Fiorella (Eds), *The Cambridge Handbook of Multimedia Learning* (3rd edn, pp. 212–220). Cambridge University Press.
- Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. Cambridge university press.
- Kovecses, Z. (2010). *Metaphor: A practical introduction*. Oxford university press.
- Kriewaldt, J., Robertson, L., & Ziebell, N. (2023). Creating the Conditions for Geographic Conceptual Development in Post-Primary Students through Collaborative Guided Inquiry. *Education Sciences*, 13(11), 1098.
- Kumar, J. A. (2024). Facial animacy in anthropomorphised designs: Insights from leveraging self-report and facial expression analysis for multimedia learning. *Computers & Education*, 223, 105150.
- Lakoff, G., & Johnson, M. (1980). *Metaphors We Live by* (M. Black, Ed.; Vol. 40). University of Chicago Press.
- Lee, C.-R., & Lee, C.-Y. (2024). Cognitive differences in the perception of metaphorical images among Taiwanese high school students. *Cogent Arts & Humanities*, 11(1), 2408865.
- Li, X. (2020). An analysis of learning difficulties in high school geography under the new curriculum reform and corresponding strategies [in Chinese]. *Journal of International Education Forum*, 2(8), 7.
- Liew, T. W., Pang, W. M., Leow, M. C., & Tan, S.-M. (2022). Anthropomorphizing malware, bots, and servers with human-like images and dialogues: The emotional design effects in a multimedia learning environment. *Smart Learning Environments*, 9(1), 5.
- Liu, J., & Sanmugam, M. (2024). Do Anthropomorphic Graphics in Multimedia Learning Materials Help Learning by Capturing Learners' Attention?: In J. Zhang, W. A. J. Wan Yahaya, M. Sanmugam, & D. Lim (Eds), *Advances in Educational Technologies and Instructional Design* (pp. 321–340). IGI Global.
- Matsui, T. (2024). Power of 'Nekomimi': Animal-like anthropomorphic agents in environmental education. *Cogent Education*, 11(1), 2295172.
- Mayer, R. E. (2005). *The Cambridge handbook of multimedia learning*. Cambridge university press.
- Mayer, R. E. (2014a). Cognitive Theory of Multimedia Learning. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (2nd edn, pp. 43–71). Cambridge University Press. Cambridge Core.
- Mayer, R. E. (Ed.). (2014b). *The Cambridge handbook of multimedia learning* (Second Edition). Cambridge University Press.
- McNamara, D. S., & Magliano, J. (2009). Chapter 9 Toward a Comprehensive Model of Comprehension. In *Psychology of Learning and Motivation* (Vol. 51, pp. 297–384). Elsevier.
- McRae, K., Nedjadrasul, D., Pau, R., Lo, B. P., & King, L. (2018). Abstract Concepts and Pictures of Real-World Situations Activate One Another. *Topics in Cognitive Science*, 10(3), 518–532.
- Menendez, D., Richardson, E., McNeil, K., & Gelman, S. A. (2024). Discovering the world of viruses: Testing the influence of anthropomorphic representations on children's learning about COVID.
- Moremoholo, T. P., & de Lange, R. W. (2018). Anthropomorphic graphics: How useful are they as an instructional aid to facilitate learning? 13.
- Münchow, H., & Bannert, M. (2018). Feeling good, learning better? Effectivity of an emotional design procedure in multimedia learning. *Educational Psychology*, 39(4), 530–549.
- Ni, X. (2023). The Deep Teaching Exploration and Practice Pointing to the Cultivation of High School Geography Core Literacy. *Creative Education Studies*, 11(05), 1149–1156.
- Özgür, A., & Altun, A. (2021). Emotional Design and Engagement With Multimedia Learning Materials in E-Learning: In H. Ucar & A. T. Kumtepe (Eds), *Advances in Mobile and Distance Learning* (pp. 168–191). IGI Global.

- Park, B., Knörzer, L., Plass, J. L., & Brünken, R. (2015). Emotional design and positive emotions in multimedia learning: An eyetracking study on the use of anthropomorphisms. *Computers & Education*, 86, 30–42.
- Phillips, B. J., & McQuarrie, E. F. (2004). Beyond Visual Metaphor: A New Typology of Visual Rhetoric in Advertising. *Marketing Theory*, 4(1–2), 113–136.
- Piaget, J. (1976). Piaget's Theory. In B. Inhelder, H. H. Chipman, & C. Zwingmann (Eds), *Piaget and His School* (pp. 11–23). Springer Berlin Heidelberg.
- Plass, J. L., Heidig, S., Hayward, E. O., Homer, B. D., & Um, E. (2014). Emotional design in multimedia learning: Effects of shape and color on affect and learning. *Learning and Instruction*, 29, 128–140.
- Renkl, A. (2002). Worked-out examples: Instructional explanations support learning by self-explanations. *Learning and Instruction*, 12(5), 529–556.
- Salminen, J., Kaate, I., Kamel, A. M. S., Jung, S.-G., & Jansen, B. J. (2021). How Does Personification Impact Ad Performance and Empathy? An Experiment with Online Advertising. *International Journal of Human–Computer Interaction*, 37(2), 141–155.
- Sanmugam, M., Abdullah, Z., & Zaid, N. M. (2014). Gamification: Cognitive impact and creating a meaningful experience in learning. 2014 IEEE 6th Conference on Engineering Education (ICEED), 123–128.
- Schneider, S., Häßler, A., Habermeyer, T., Beege, M., & Rey, G. D. (2019). The more human, the higher the performance? Examining the effects of anthropomorphism on learning with media. *Journal of Educational Psychology*, 111(1), 57–72.
- Shawalludin, S., Sanmugam, M., Rabu, S. N. A., Salim, N. A. M., & Rahman, A. A. (2021). Gamified learning experience and adaptation of Malaysian warriors: User interface by the ADDIE model. In *The teachers' lounge: Tales told and lessons learned*. Nova Science Publishers.
- Slabbert, C., De Lange, R. W., & Mason, H. (2022). Anthropomorphisms in multimedia learning: Do they facilitate learning in primary school learners? *Cogent Education*, 9(1), 2034390.
- Street, K. E. S., Malmberg, L.-E., & Stylianides, G. J. (2017). Level, strength, and facet-specific self-efficacy in mathematics test performance. *ZDM*, 49(3), 379–395.
- Su, P., & Liu, K. (2024). Effects of anthropomorphic design on comprehension of self-monitoring test results: Integrating evidence of eye-tracking and event-related potential. *Displays*, 82, 102664.
- Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive Load Theory*. Springer New York.
- Sweller, J., Van Merriënboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive Architecture and Instructional Design. *Educational Psychology Review*, 10(3), 251–296.
- Tatalovic, M. (2009). Science comics as tools for science education and communication: A brief, exploratory study. *Journal of Science Communication*, 08(04), A02.
- Tribull, C. M. (2017). Sequential Science: A Guide to Communication Through Comics. *Annals of the Entomological Society of America*, 110(5), 457–466.
- Von Reumont, F., & Budke, A. (2023). Learning about climate change with comics and text: A comparative study. *Sustainability Science*, 18(6), 2661–2676.
- Wang, H. (2025). Instructional strategies for teaching process knowledge in senior high school geography oriented toward the development of higher-order thinking skills [Master's thesis]. Qufu Normal University.
- Waytz, A., Cacioppo, J., & Epley, N. (2010). Who Sees Human?: The Stability and Importance of Individual Differences in Anthropomorphism. *Perspectives on Psychological Science*, 5(3), 219–232.
- Wu, C.-H., Tang, K.-D., Peng, K.-L., Huang, Y.-M., & Liu, C.-H. (2024). The effects of matching/mismatching cognitive styles in E-learning. *Educational Psychology*, 44(9–10), 1048–1072.
- Zhang, Y., Cao, Y., Proctor, R. W., & Liu, Y. (2023). Emotional experiences of service robots' anthropomorphic appearance: A multimodal measurement method. *Ergonomics*, 66(12), 2039–2057.



Esta licença permite que os usuários distribuam, remixem, adaptem e desenvolvam o material em qualquer meio ou formato apenas para fins não comerciais, e somente desde que a atribuição seja dada ao criador.