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Enhancing L2 Listening Through TED-Ed: GAI Mind Mapping Versus Captions

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ABSTRACT

This study explores the effectiveness of video captions versus generative artificial intelligence (GAI) mind mapping for enhancing English as a second language (L2) listening skills among 79 EFL undergraduates in Macau. Using TED-Ed videos, the study employed pre-/post-tests and thematic analysis of reflective journals. Results indicated that the GAI mind mapping group significantly outperformed the captions group, demonstrating greater improvements in listening skills, efficacy, and strategy development. In contrast, the captions group experienced cognitive overload and limited engagement. This research offers valuable insights for educators seeking to optimise L2 listening instruction in EMI settings.

KEYWORDS

L2 listening, EMI, TED, Generative Artificial Intelligence, Captions, Mind Mapping

INTRODUCTION

Second language (L2) listening is vital in second language acquisition (SLA) (Flowerdew & Miller, 2005). As universities worldwide continue to offer English as a Medium of Instruction (EMI) courses, the importance of English listening skills has soared among English learners (Macaro et al., 2018). However, many English as a Foreign Language (EFL) learners are accustomed to learning English in native (L1) environments which are deficient in L2 learning opportunities. The sudden transition to a full L2 environment can be challenging since L2 listening involves complex cognitive activities, including both bottom-up and top-down processing (Vandergrift, 2007a). According to Kissling (2018), L2 learners generally struggle with bottom-up processing, finding it challenging to divide the listening material into meaningful segments. They have difficulty maintaining sufficient information in their working memory to link related units, recognize familiar words and distinguish homophones based on the immediate context among other tasks. Meanwhile, top-down processing, which encompasses background knowledge and contextual awareness, plays a crucial role in

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comprehending the listening situation, topic and related vocabulary. This is essential for activating the schemata in the human brain (Richards, 2008). Moreover, a multitude of factors also mediate the process of L2 listening, such as unfamiliar accents, unknown linguistic expressions, subject-specific knowledge, distracting environmental noise and a fast speed of speech. They could cause learning difficulties in lecture comprehension and classroom participation (Macaro et al., 2018; Rintaningrum, 2018).

To become fluent L2 listeners, learners and teachers need to take particular listening strategies into account. Vandergrift (1997b) discussed three major strategies for L2 listening, including cognitive (e.g., recall and summarize key information), metacognitive (e.g., plan, monitor, and evaluate the listening material) and socio-affective strategies (e.g., seek assistance, manage negative emotions). Cognitive strategies are more often used by learners with limited linguistic fluency as they "involve lower processing practices such as translation, repetition and summary" (Bao & Guan, 2019, p. 2). On the other hand, fluent listeners are generally more inclined to use metacognitive strategies to monitor and evaluate their learning. This distinction shows the tendency for listeners with lower proficiency levels to predominantly rely on bottom-up processing, whereas fluent listeners more frequently employ top-down processing. Socio-affective strategies are often overlooked in L2 listening practice. However, they are equally essential with the recognition of the role of interactions and positive psychology for EFL learners (Bao & Guan, 2019).

In Macau higher education, the classic grammar-translation method for teaching remains popular and is widely promoted within English courses. Lecturers dedicate most of class time to helping learners memorize grammatical rules through repetitive and decontextualized drills. This focus on grammar often results in the neglect of developing listening skills because most local textbook exercises do not require the use of such skills. Yet, in EMI, understanding learning content and lecturers' instructions is a prerequisite for learners to become more engaged and willing to participate in learning.

Recently, studies have explored the use of technology in enhancing L2 listening comprehension. According to Zhang et al. (2023), most current listening studies make use of e-learning tools, systems, e-books and CDs to develop listening and language knowledge. For example, Cross (2014) documented the application of podcasts in improving L2 listening with an adult EFL learner from Japan. Alm (2021) reported an exploratory study on learners' German listening practice with Netflix from New Zealand. With advanced technology, Tai and Chen (2021) compared the use of immersive virtual reality (VR) and videos in practicing L2 listening. Their study suggested the authentic, interactive and immersive nature of VR in supporting the development of listening skills. However, it should be acknowledged that most language lecturers have limited access to such high-level technology, given the cost of both hardware and software for VR. Thus, videos remain a feasible and widespread tool for lecturers in classrooms.

Among various free online video resources, Technology, Entertainment, Design (TED) talks are commonly used in current language classrooms. In particular, the TED company offers TED-Ed videos for educational purposes. However, the effective use of these resources remains underexplored (Liu, 2023). Simply providing learners with access to TED videos is insufficient for constructing meaningful learning experiences. Instead, a well-structured pedagogical approach and support are essential in maximizing the potential of video watching in listening comprehension. Previous research efforts have been made to understand the use of captions and mind maps in watching videos in language learning. However, mixed findings have been reported. In addition, with the emergence of generative artificial intelligence (GAI), lecturers have started to explore the use of it in improving writing. However, little understanding has been gained associated with L2 listening. The present study thus aims to explore two different ways, namely captions and GAI mind maps to enhance English learners' academic listening skills using TED-Ed videos. We focus on two groups of EFL learners from a Macau university and make use of captions generated by TED-Ed and mind maps generated by Mapify.

LITERATURE REVIEW

L2 Listening With Captioned Videos

The use of captions in video viewing is a central topic in current SLA research on listening. Dual coding theory (Paivio, 1990) and the cognitive theory of multimedia learning (Mayer, 2001) have been used to explain why captioned videos may support L2 comprehension. Dual coding theory proposes that verbal and non-verbal information can be processed in partly independent but interconnected systems. When images and words are aligned, this dual pathway can optimize memory resources and facilitate retention (Teng, 2022). Cognitive theory of multimedia learning further argues that learners benefit when information is distributed across complementary auditory and visual channels, provided that working memory is not overloaded.

Recent empirical work has begun to identify more precisely which subskills of listening benefit from captions (Lee et al, 2021; Boltiziar & Munkova, 2024). Studies have shown that captions can support lower-level processes such as lexical recognition and word segmentation because written text can help learners map the speech stream onto known forms and stabilize word boundaries (Rafiq et al., 2023; Kaderoğlu, K., & Esquerré, 2021). Captions can also help with parsing clause boundaries and tracking discourse markers, which supports the construction of propositional meaning and gist. In some cases, captions have also been linked to improved inferencing because learners can re-check key phrases and connect them to contextual cues. These findings help to clarify the claim that captioned videos are useful in facilitating listening comprehension by specifying that benefits tend to be strongest for form–meaning mapping and for the integration of key details into a coherent representation.

However, the empirical evidence is mixed. Several studies highlight boundary conditions. While many investigations report positive effects of captions on listening performance (Boltiziar & Munkova, 2024), other work has found no significant differences across caption conditions. Aldukhayel (2021) reported no differences among learners viewing L1 captions, L2 captions or no captions. Similarly, Hsieh (2020) compared five caption formats and found no effect of caption type on comprehension. These studies point to important moderating variables such as learners' proficiency, the lexical and conceptual difficulty of the videos, the degree of redundancy between audio and text. When input is dense and learners' language resources are limited, captions may increase cognitive load rather than reduce it.

The redundancy issue is visible in research using TED talks. Hao et al. (2022) compared four conditions (L1 + L2 captions, L1 captions, L2 captions, no captions) with Chinese EFL learners. They found that intermediate learners did not differ across conditions, while advanced learners benefitted most from L1 captions and experienced redundancy effects when using L2 captions. They argued that for advanced learners, extra written input can overload working memory when it simply duplicates what is already accessible through listening. Therefore, these findings suggest that captions can support form-level and integrative aspects of listening, but their effectiveness depends on careful alignment between task difficulty, learners' proficiency and the complexity of audiovisual input. They also indicate that captioning is not a neutral "add-on". It actively reshapes cognitive processing and may either support or hinder comprehension.

The past studies provide an important starting point for the present study. Captions are a well-established form of visual support in L2 listening. Nevertheless, they primarily duplicate the verbal input in written form and require learners to manage multiple streams of information in real time. The mixed findings and cognitive load concerns suggest a need to compare captions with other forms of visual support that do not simply repeat the audio verbatim but instead reorganize information into more stable and conceptually structured representations, such as mind maps.

L2 Listening With Mind Mapping

Mind mapping is a widely used tool for notetaking, thought organization and concept development. Shi and Tsai (2024) describe mind mapping as a way to activate the whole brain by visualizing

associative thinking. In a typical mind map, a central concept is placed at the center of the page. Related ideas are represented as branches and sub-branches. They often use colors, images and keywords. This non-linear structure reflects the associative nature of human cognition and helps learners to cluster related information, highlight hierarchical relationships and see the "big picture" of a topic. Chiu and Hwang (2024) argue that mind mapping can support understanding of complex content by organizing information graphically, integrating new and prior knowledge and promoting higher-order thinking.

Empirical work confirms that mind mapping can enhance cognitive performance in various domains. Shi et al. (2023) found that mind mapping tends to improve learning outcomes in STEM subjects. The technique has been applied to vocabulary learning, reading and writing. For vocabulary, technology-enhanced mind mapping has been shown to support long-term retention by prompting repeated retrieval of word–meaning associations and their relationships (Shi & Tsai, 2024). In writing, Fu et al. (2019) reported that mind mapping fostered idea generation, coherence, positive affect and creativity. At the same time, several studies have reported non-significant or mixed results to indicate that mind mapping is not a universal solution and that its benefits depend on thoughtful implementation, explicit training and alignment with task demands (Shi et al., 2023).

The potential of mind mapping for listening has begun to receive attention but remains under-researched in L2 contexts. Boerma et al. (2022) examined its use in L1 listening and reading among Dutch primary pupils and found that mind mapping did not outperform comparison conditions statistically. However, it still yielded qualitative indications of improved organization and recall. Polat et al. (2022) reported similar patterns with Turkish preschoolers. These studies suggest that mind mapping can help young learners structure information they hear, but effects may be modest without extended practice or explicit strategy instruction. In L2 listening, the theoretical rationale for mind mapping is strong, even if empirical evidence is still limited. Listening comprehension requires segmentation of the speech stream, identification of main ideas and supporting details and integration of information across time. Mind mapping directly targets these processes by encouraging learners to extract key words, group related ideas and represent macrostructure visually. In English for academic purposes (EAP), where learners must handle dense terminology, complex argumentation and references to disciplinary knowledge (Miller, 2014), mind maps may provide a concrete scaffold for organizing and rehearsing information that would otherwise be transient.

Self-efficacy offers an additional lens for understanding the potential role of mind mapping in L2 listening. Drawing on social cognitive theory, Bandura (1997) defined self-efficacy as individuals' beliefs about their capability to organize and execute actions required to achieve specific goals. In L2 listening, Graham (2011) described listening self-efficacy as learners' beliefs about their ability to understand spoken input and manage listening tasks. These beliefs influence which activities learners are willing to attempt, the effort they invest and their persistence when they encounter difficulty. Self-efficacy is shaped by mastery experiences, vicarious experiences, verbal persuasion and interpretations of affective states. Strategy-based listening instruction can therefore influence self-efficacy by providing opportunities for successful strategy use and by making progress visible. In principle, mind mapping may support listening self-efficacy by helping learners see that they can capture main points from a challenging text, organize them coherently and use this representation to answer questions or discuss content. Such experiences can strengthen learners' sense of control over EAP listening and prepare the ground for the role of self-efficacy in the findings and discussion of the present study.

L2 Listening With GAI

GAI has rapidly become a prominent topic in language education research (Zhang et al., 2024). Recent reviews show that most empirical work has focused on writing support (Zhang et al. 2025), feedback (Ren et al., 2026) and task design, with fewer studies targeting receptive skills such as reading and listening. Lo (2024) concluded that majority of studies examine writing assistance, while

quantitative evidence on reading, listening and speaking remains scarce. Li et al. (2025) synthesized 144 empirical GAI studies in language learning and teaching and found that research has expanded quickly but is uneven across skills, with a relative lack of listening focused interventions. Lee et al. (2025) also reported that GAI is most often used as a text generator and feedback provider in classroom contexts and called for more theoretically grounded designs that leverage its multimodal and interactive affordances.

Despite this imbalance, a small but growing body of empirical work has begun to explore GAI for receptive and multimodal learning. Çelik (2024) investigated ChatGPT simplified blog texts and found positive effects on university learners' reading comprehension, inference and reading strategies compared with unsimplified authentic texts. Al-Obaydi (2025) examined the role of ChatGPT in developing core language skills and highlighted its potential to support reading and listening by providing adaptive input, though listening outcomes were less fully explored. Jantakoon (2025) reviewed GAI tools for speaking and listening and concluded that, although many studies report positive effects, heterogeneous designs and measures make it difficult to draw firm conclusions about the overall impact on listening skills. A larger review of GAI in SLA by Bao et al. (2025) suggested that most AI applications to date primarily enhance existing tasks rather than fundamentally transform the nature of language learning activities. Together, these studies show that GAI can support receptive and multimodal learning but also reveal that listening remains under investigated and theoretically underspecified.

The nature of GAI mind-mapping tools illustrates this gap. Conceptually, it can act as co-authors, evaluators and learning-material providers. They can extract key concepts, propose preliminary structures and generate summaries from user prompts or transcripts. In many past studies, GAI is used to support reading or writing by producing outlines, summaries, model texts or feedback. Learners engage with these outputs primarily through written modalities. However, in listening, GAI mind-mapping can function more directly as a scaffold if the generated maps are explicitly tied to oral texts. Learners can input titles, keywords from their notes or partial transcripts into a GAI system. The system then produces an initial map of main ideas and relationships. Learners evaluate and revise this map and then use it as a visual organizer before, during or after listening. In this way, the tool supports listening comprehension not simply by summarizing written input but by externalizing the conceptual structure of spoken texts and linking it to repeated listening cycles.

Theoretical Synthesis and Rationale for the Present Study

The literature on captioned videos, mind mapping and GAI points to several theoretical distinctions that underpin the rationale for the present study. From the perspective of dual coding theory and cognitive theory of multimedia learning, captions and mind maps both introduce visual elements alongside audio. However, captions replicate the verbal channel in written form and are synchronized with the speech stream. They primarily support lower-level processing such as lexical recognition, segmentation and immediate meaning construction, but they also increase the amount of information that must be processed in real time. When language and cognitive resources are limited, this duplication can produce redundancy effects and overload working memory

In contrast, mind mapping does not mirror the speech verbatim. It transforms the content into a spatial and hierarchical representation that foregrounds relationships between ideas. This transformation shifts some processing from online decoding to offline organization. It is well aligned with models of L2 listening that emphasize the interplay between bottom-up and top-down processing and the importance of metacognitive control. Bottom-up processes are supported when learners extract key words and details from the speech stream to populate map branches. Top-down processes are supported when learners use the map to identify main ideas, predict upcoming information and integrate new content into an emerging global structure (Vandergrift, 2007a). Hence, mind mapping operates not only as a mnemonic device but also as a strategy scaffold that can help listeners plan, monitor and evaluate their comprehension.

GAI intensifies these affordances by automating parts of the mapping process and by allowing rapid iteration on map structure. In GAI mind mapping, learners do not begin with a blank page. Instead, it proposes an initial conceptual network based on prompts or partial input. Learners then critically evaluate this output, correct inaccuracies and refine the map to match their understanding. This division of labor has two implications. First, it reduces the cognitive cost of constructing an initial representation, freeing resources for listening and reflection. Second, it foregrounds higher-level strategic and metacognitive work because learners must decide which nodes are central, how they relate and how to revise the AI suggestions. These operations resonate with research on listening self-efficacy. When learners see that strategic engagement with tools leads to successful comprehension, their beliefs about their listening capabilities are more likely to strengthen (Graham, 2011).

Against this theoretical backdrop, comparing captioning and GAI mind mapping is not a simple contrast between traditional and innovative technologies. Rather, it is a comparison between two distinct ways of combining visual and verbal information. Captioning enriches the input channel by adding written text to audio, but it may also heighten real-time processing demands. On the other hand, GAI mind mapping restructures content at the representational level. It supports learners in building a stable and reusable scaffold for listening that can extend beyond a single text. Existing research on captions has shown both potential benefits and risks linked to cognitive load and proficiency, while research on mind mapping and GAI has indicated promising but underexplored affordances for organizing complex information and supporting strategy use. At the same time, listening remains a relatively neglected skill in GAI research.

The present study is positioned at this intersection. It investigates whether GAI mind mapping can offer an alternative to captioning for supporting EAP listening. It also examines how these two forms of support may differentially influence learners' use of listening strategies and their emerging self-efficacy in handling demanding academic input. In doing so, the study seeks not only to compare two tools, but to contribute to a more integrated theoretical account of how visual scaffolding, GAI and listening self-efficacy interact in L2 listening development. In light of this, the present study sets the goal of understanding GAI in enhancing L2 listening by answering the specific questions:

RQ 1: To what extent do the video captions and the GAI mind mapping affect EFL learners' English listening skills before and after the intervention? Are there any differences in the outcomes between the two learning groups?

RQ 2: How do EFL learners' perceptions differ regarding the use of captions and GAI mind mapping in relation to the improvement of English listening skills?

METHODOLOGY

Project Procedure

The study incorporated ten TED-Ed videos selected according to the learners' English proficiency. Each video was approximately five minutes long. The aim was to balance accessible language with cognitively engaging content. The videos covered a range of interdisciplinary topics, including psychology, science and technology, engineering and design, philosophy and ethics, and history. These topics were chosen to enhance learners' academic listening skills, broaden their interdisciplinary knowledge and build their academic vocabulary. Topic interest was also a key criterion as research in EMI has shown that content relevance is central to learners' motivation and engagement (Miller, 2014).

The participants were divided into two intact classes: (1) a caption group ($n = 38$), which watched TED-Ed videos with captions, and (2) a GAI mind-mapping group ($n = 41$), which used the Mapify platform during the intervention. The design was therefore quasi-experimental with non-random group assignment. Each video was integrated into three separate class meetings across the semester, with

approximately one week between sessions. It was in line with the normal timetable. This spacing created opportunities for partial forgetting, consolidation and reflection between viewings.

For each video, both groups followed the same basic sequence. During the first and second viewings, learners watched the video without any external support such as captions, transcripts or mind maps. They were encouraged to take brief notes in their own language or in English. For the third viewing, the two conditions diverged. In the caption group, learners watched the same video again with English captions turned on and then completed a short quiz based on the video content. In the GAI mind-mapping group, learners first created a GAI mind map of the video content and then watched the video a third time using the mind map as a visual organizer before completing the same quiz.

Mapify is an online mind-mapping tool that incorporates GAI. Instead of requiring users to build a map entirely from scratch, it allows learners to input a short prompt, such as the video title and several keywords, and then automatically generates a draft mind map. This draft includes a central node, main branches and sub-branches that reflect estimated relationships between concepts. Learners can then edit the GAI map by adding new nodes, deleting irrelevant ones, renaming labels and rearranging the structure. In this way, Mapify differs from traditional mind-mapping software, where users typically design the entire structure manually and the tool mainly functions as a drawing canvas.

Figure 1. Research procedure

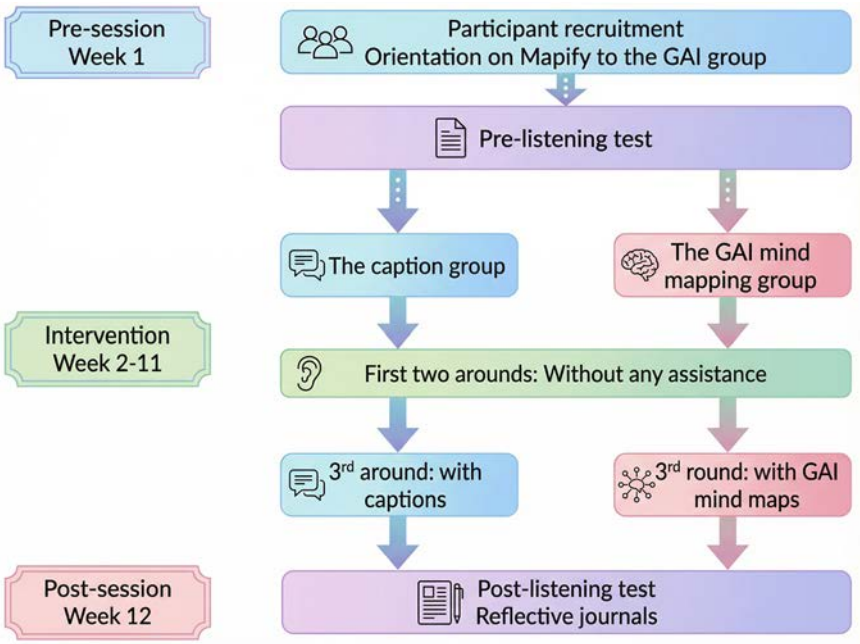
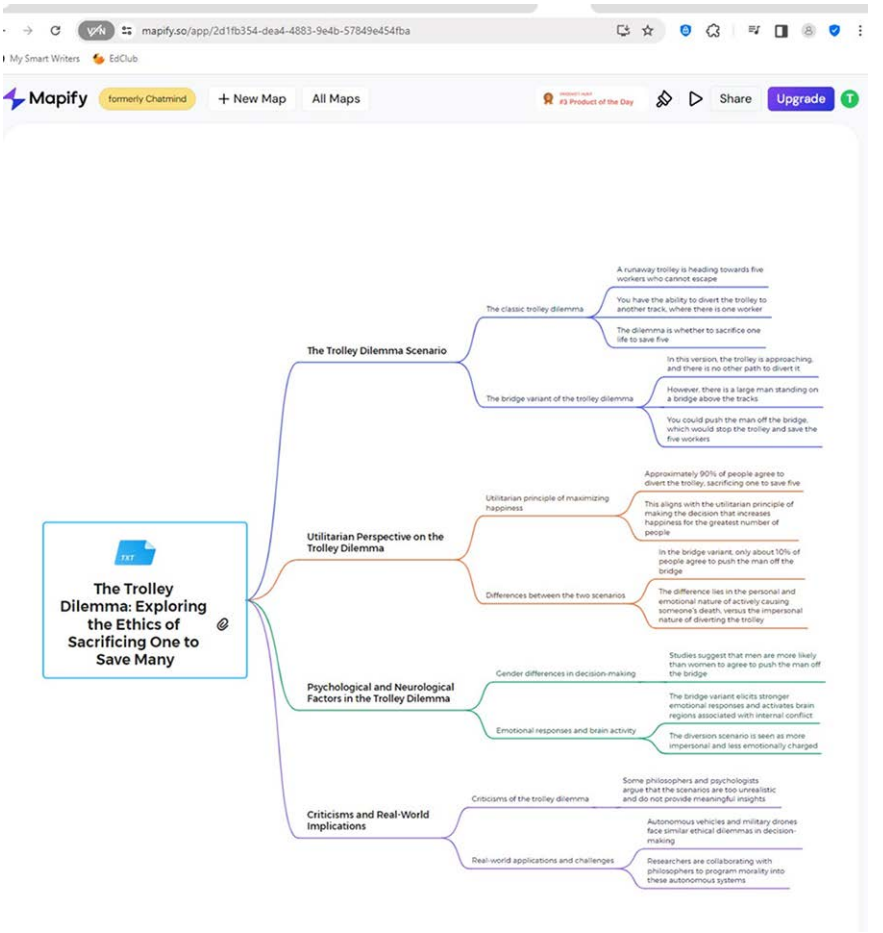


Figure 2. A mind map generated by Mapify based on the listening material



Participants

Seventy-nine Year-1 university learners from BSc in Computer Science programs in an EAP course were recruited from a university in Macau. The participants in this study were pre-intermediate level English learners (around IELTS 4.5) with less developed listening skills. They were divided into groups with two different learning conditions: one watched TED-Ed with captions (n = 38) while the other group watched videos with GAI mind maps (n = 41). The caption group consisted of 38 learners with a gender distribution of 9% female and 91% male, including 19 learners from Macau and 19 learners from Mainland China. The GAI mind mapping group included 41 learners with a gender distribution of 28% female and 72% male, comprising 16 learners from Macau and 25 learners from Mainland China.

Based on the lecturer's in-class observations, most participants were not highly motivated in listening practice as the EAP course did not include any formative or summative assessment on listening, with the main focus of the course on grammar instruction, in line with the prescribed syllabus. Moreover, none of them had used GAI for practicing listening or generating mind maps before the study.

DATA COLLECTION AND ANALYSIS

Data were collected from two main resources. First, pre- and post-listening tests were conducted with the participants in two different groups. Quizzes from TED-Ed were adopted as they were well designed by the TED company to check the comprehension level of the audience. Each test comprised eight multiple-choice questions with a single correct answer and two essay questions, which were evaluated by two language teachers.

First, to address *RQ 1*, a total of 79 sets of valid data were obtained for each learner in both classes regarding the two listening comprehension tests, which were analyzed by a two-way mixed ANOVA using Jamovi 2.6.19, a free and open-source statistical analysis software based on R language (https://www.jamovi.org/). The two-way mixed ANOVA is appropriate for designs with both between-subjects and within-subjects factors (Field, 2024). In the current study, Group (GAI mind mapping *versus.* Video captions) served as the between-subjects factor, while Time (pre-test *versus.* post-test) served as the within-subjects factor. This analysis examined three effects: (i) the main effect of Group, indicating whether the two instructional methods differed overall; (ii) the main effect of Time, indicating whether learners' listening scores changed from pre-test to post-test; and (iii) the Group × Time interaction effect, indicating whether the magnitude of change differed between the two instructional methods.

Second, to address *RQ 2*, at the end of the semester, participants were given prompt questions to reflect on the benefits and challenges of watching TED-Ed videos with captions or mind maps. In total, 79 reflective essays were gathered. Thematic analysis (see Braun & Clarke, 2006, for detailed steps) was applied to understand the in-depth understanding of both instructional methods in relation to L2 listening. The second and third authors analyzed the data set and agreed on the codes generated from the texts with an inter-rater reliability of over 95%. To protect privacy, pseudonyms were used for reporting the findings.

FINDINGS

Listening Comprehension Tests

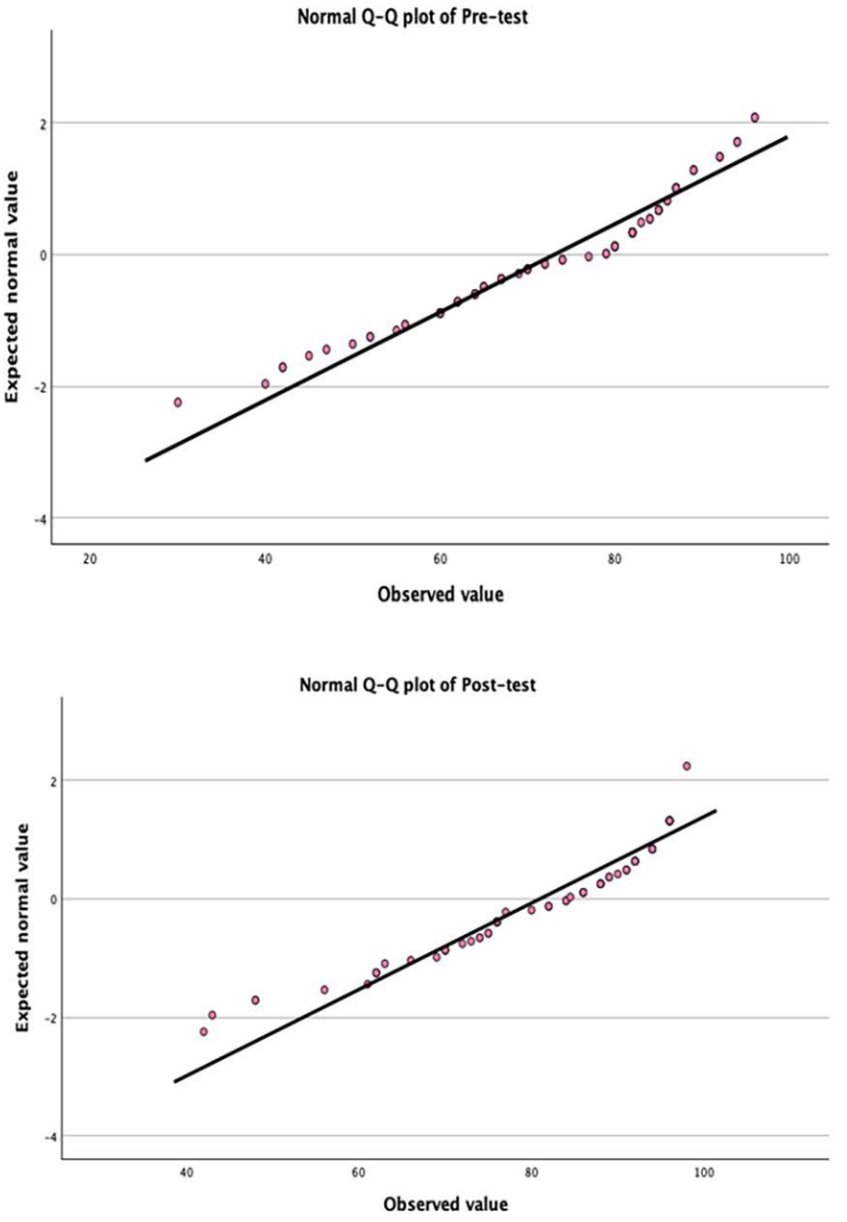
RQ1 centers on the effects of two instructional methods in supporting learners' performance in listening comprehension. Table 1 shows the descriptive statistics for learners' listening comprehension scores in the pre- and post-tests. The group utilizing GAI mind mapping exhibited a pronounced enhancement of 12.54 in terms of the mean score, while the other group taught by video captions exhibited a slight improvement of 2.91 regarding the mean score. Furthermore, Q-Q plots in Figure 3 suggested a normal distribution for learners' scores in pre- and post-tests regarding listening comprehension in both groups.

Table 1. Descriptive statistics for learners' pre- and post-listening test scores in the two classes.

Instructional method		Mean	SD	*N*
Pre-test	Video captions	73.84	13.43	38
	GAI mind mapping	72.31	16.37	41
	Total	73.05	14.95	79
Post-test	Video captions	76.75	15.26	38
	GAI mind mapping	84.85	10.91	41
	Total	80.95	13.71	79

Note: The full marks of pre- and post-test are 100.00 points.

Figure 3. Normal Q-Q plots of Pre-Test and Post-Test



In addition, a two-way mixed ANOVA was conducted to examine the effects of instructional method (Group: GAI mind mapping *versus.* Video captions) and test time (Time: pre-test *versus.* post-test) on learners' listening comprehension scores. The assumptions of normality and homogeneity of variance were satisfied. As shown in Table 2, the results revealed a non-significant main effect of Group, $F(1, 77) = 1.53$, $p = .220$, $\eta_p^2 = .02$, indicating no overall difference in listening scores between the two groups. A significant main effect of Time was observed, $F(1, 77) = 20.40$, $p < .001$, $\eta_p^2 = .21$, suggesting that learners' listening scores improved significantly from pre-test to post-test

regardless of group. Most importantly, a significant Time × Group interaction effect was found, F (1, 77) = 7.55, $p = .007$, $= .09$, indicating that the magnitude of improvement differed significantly between the two instructional methods. According to Miles and Shevlin (2000), the effect sizes can be interpreted as small ($\eta_p^2 \approx .01$), medium ($\eta_p^2 \approx .06$) and large ($\eta_p^2 \approx .14$). Thus, the Time main effect showed a large effect size, while the interaction effect demonstrated a medium effect size.

Table 2. Results of Two-Way Mixed ANOVA for listening comprehension scores

Source	df	F	p	η_p^2
Group	1, 77	1.53	.220	.02
Time	1, 77	20.40	< .001	.21
Time * Group	1, 77	7.55	.007	.09

Note. η_p^2 = partial eta-squared.

Given the significant interaction effect, follow-up pairwise comparisons were conducted to examine the nature of this interaction. Researchers employed the Bonferroni correction, adjusting the alpha level from the conventional 0.05 to 0.025 for each test to maintain the overall significance level and reduce the risk of Type-I errors due to multiple comparisons (Bender & Lange, 2001). The results are presented in Table 3 below.

Table 3. Follow-up pairwise comparisons for the Time × Group interaction

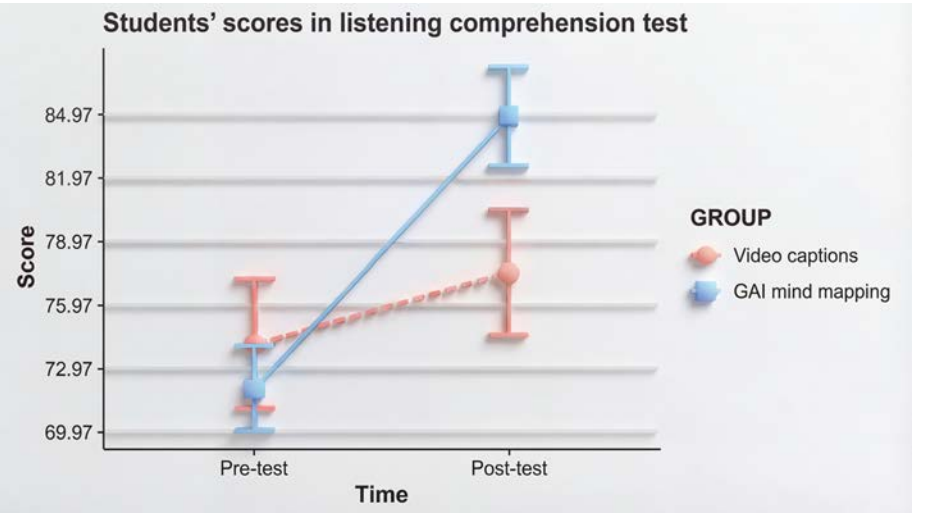
Test time	Instructional method (I)	Instructional method (J)	Mean Difference (I–J)	*t*	*p*
Pre-test	GAI mind mapping	Video captions	-1.53	-.450	.654
Post-test	GAI mind mapping	Video captions	8.10**	2.729	.008
Instructional method	**Test time (I)**	**Test time (J)**	**Mean Difference (I–J)**	***t***	***p***
Video captions	Pre-test	Post-test	-2.91	-1.201	.238
GAI mind mapping	Pre-test	Post-test	-12.54***	-4.981	.000

Note:p < .05*; p < .01**; p < .001***

Based on the results by conducting an independent sample t-test, there was no significant difference between the two groups prior to the intervention, MD (I-J) = - 1.53, $t = - .450$, $p = .654$. However, a significant difference in the scores post-intervention was also found, MD (I-J) = 8.10, $t = 2.729$, $p = .008$. Further paired-sample t-tests indicated a significant increase in learners' scores regarding listening comprehension pre- and post-tests in the GAI mind mapping group, MD (I-J) = - 12.54, $t = - 4.981$, $p < .001$. In contrast, no significant change was found in the video captions group, MD (I-J) = - 2.91, $t = - 1.201$, $p = .238$.

To sum up, the initial levels of learners' listening comprehension were comparable between the two groups before the teaching intervention. However, following the experimental intervention, the GAI mind mapping group showed a significant increase in terms of learners' listening performance, surpassing the video captions group (As shown in Figure 4).

Figure 4. Time (Test Time) x Group (Instructional Method) Interaction Effects



Learner Reflections

RQ2 uncovers the deep influencing factors of incorporating captions and GAI mind mapping into listening practice. Our analysis suggested there were some shared advantages associated with using either captions or mind maps, including reducing learning difficulties and alleviating learning anxiety. Learners in both groups remarked that they felt listening was easier when watching TED-Ed videos and completing listening questions compared to watching without captions or mind maps. They argued that since they had limited English proficiency and were unfamiliar with EAP listening, captions or mind maps provided valuable textual support. Without visual aids, they tended to encounter major learning difficulties in understanding the messages delivered, which could lead to less willingness to participate in listening practice.

Although both groups discussed certain affordances of the two instructional methods, there were major disparities between captions and mind maps in supporting L2 listening. 1) Visualization and cognitive load: GAI mind maps helped clarify complex ideas by visualizing key points and showcasing their relationships. The participants appreciated the visualization function of mind mapping because it vividly depicted the interconnections among various facets of the listening materials' topics. For instance, Luk reflected that "*mind mapping helps me better organize and remember information by breaking it down into smaller parts and visually displaying how they relate to each other.*" This statement highlighted how mind maps generated by Mapify facilitated a bottom-up processing approach to listening. They scaffolded the participants by breaking originally complex information into manageable chunks and providing a general picture of the listening material. Additionally, the participants mentioned that mind maps generated by GAI supported the use of top-down processing in L2 listening as mind maps were straightforward and easy to understand, causing minimal confusion. This point was echoed by several learners in the GAI mind mapping group:

> *"Using mind mapping helps me organize information quickly and identify key themes" (Chu).*
>
> *"Mind mapping techniques help me to find out the main point, allowing me to find the answer quickly" (Yu).*

Contrary to this, the participants in the caption group encountered major challenges. Though the participants agreed that captions helped reduce the difficulty of TED-Ed videos, watching with captions increased an unnecessary cognitive load because the participants lacked enough listening strategies to process the extensive multimodal information simultaneously. They further stated that the TED-Ed videos played faster than anticipated, making it challenging to listen to and watch the

video while reading the captions. They argued that using captions required a sophisticated mastery of listening strategies and an advanced level of English reading proficiency. For instance, Chan said, "*I had a hard time coordinating ears, eyes and hands! There were just too many words when I needed to read captions.*" Similar expressions included "*I cannot read and listen at the same time" (Chu), "My English is not good enough to allow me to multitask*" (Leung), and "*I felt frustrated as captions made the task challenging*" (Ho).

2) Strategy use and development: Second, the development of listening strategies was more probable in the GAI mind mapping group. As mentioned, learners in the caption group met with greater challenges when reading captions due to their lack of listening strategies to process multimodal information. Moreover, they reflected that they had no opportunities to develop transferable learning strategies for future learning tasks. Learners reflected that "*Captions are just a bunch of words so I am not sure how I could prepare for similar listening tasks*" (Tsai), "*Watching TED-Ed videos is different from listening to the traditional listening materials but I didn't know how to advance my learning in this new technological development*" (Siu), and "*What's essential is how we develop listening strategies but listening with captions on does not contribute much for that*" (Shi). Evidently, the participants in the caption group expected more explicit guidance on the effective use of captions, hopefully preparing them for future listening tasks. However, watching with captions alone led to slow progress, as shown in the statistical analysis.

In contrast, learners in the GAI mind mapping group were positive that they developed some learning strategies over the semester. Wong highlighted that "*I build skills in organizing thoughts. By using the mind maps, I become better at extracting key points, understanding structures, and thus more confident and equipped for future listening tasks.*" He revealed that using GAI mind maps could potentially improve learners' cognitive and meta-cognitive strategies in top-down information processing. Furthermore, Lo commented that "*mind mapping provides a structured approach to organizing information, which is particularly useful for listening tasks.*" Lo recognized the importance of logically organizing information and visualizing essential details with mind maps, which enlightened them to adopt the same approach in future listening activities. Similarly, Ng argued that "*it helps me to catch up the points that I cannot catch while listening to the video, and it also teaches me usually what and where is the main point.*"

3) Emotional response: Third, GAI mind maps instilled more confidence and motivation in learners compared to using captions. The participants in the GAI group reported mostly positive emotions associated with L2 listening in this project, while the caption group reported mixed feelings. For example, Lau in the GAI group commented, "*Mind mapping helps me organize information quickly and identify key themes, while summarizing reinforces my understanding of the material. This preparation boosts my confidence and allows me to engage more effectively with new information, making similar tasks easier to tackle*" while Lee in the caption group said "*anxiety was reduced a bit but it did not help us build long-term confidence. In Chinese, we say yǐn zhèn zhǐ kě or drinking poison to quench thirst.*" Interestingly, the excerpts reflected two opposite attitudes as Lau seemed to improve their self-efficacy with a positive future outlook, while Lee used a Chinese proverb to emphasize the nature of captions, which was to seek a temporary solution. Similar affective statements were observed from other participants from the two groups.

DISCUSSION

The findings of this study suggest that while learners in both conditions improved their L2 listening comprehension in the post-tests, only the GAI mind mapping group demonstrated statistically significant progress in the listening tasks. Since both groups exhibited some improvement in listening performance, watching TED-Ed videos with captions or with GAI mind maps can serve as useful tools for supporting EFL learners. Paivio (1990) dual coding theory and Mayer (2001) cognitive theory of multimedia learning help to explain this effect because the human mind tends to benefit from

multimodal representations of information. However, the present study also showed that the caption group experienced cognitive overload. Cognitive overload is closely related to working memory limitations and has a direct impact on learning performance. Higher cognitive load usually leads to more negative emotions and reduced motivation to continue learning.

The findings for the caption group were consistent with Malakul and Park (2023), who reported that Thai learners experienced cognitive overload because of the demands placed on working memory and the extra attentional resources needed to process verbal and visual information in real time. Our data further suggested that learners faced working-memory channel redundancy (Trypke et al., 2023). Because images, sounds and written words all competed for processing within the same limited-capacity system, learners in the caption group had to manage listening, viewing, reading, and note-taking at the same time (Mayer, 2001). This required them to match written words to sounds and to integrate multiple streams of input, which demanded a high level of cognitive effort and sophisticated listening strategies.

Researchers have also stressed the importance of learners' language levels in captioned listening (e.g., Lin et al., 2016). In contrast to Hao et al. (2022), who reported that captions benefitted low proficiency EFL learners, our study suggests that learners with limited proficiency can also suffer from redundancy effects. Since our participants were not fluent in English, processing verbal and visual annotations and establishing referential connections between them posed an even greater challenge (Plass et al., 2003). As cognitive load increased, negative emotions were also triggered. As shown in the reflective data, participants felt that listening with captions became more challenging. Also, their motivation for future learning did not improve.

Conversely, the GAI group appeared to experience a reduced cognitive load with the assistance of GAI mind maps. The findings suggested that by segmenting EAP listening material into manageable visual chunks of interconnected key words, learners were more inclined to engage in bottom-up processing during L2 listening (Kissling, 2018). Because EAP listening was new to the participants and their listening skills were limited, this bottom-up scaffolding helped them decode and stabilize local meaning. At the same time, a top-down approach emerged as learners used the mind maps to develop new schemata by visualizing the relationships between key words and main ideas in the listening texts (Vandergrift, 2007a). The GAI mind maps made these relationships salient and provided contextual clues. This affordance seemed important for listeners with limited linguistic resources because it allowed them to build a quick and contextualized understanding of the material more effectively than captions.

For learners in the present research, both bottom-up and top-down approaches helped develop efficacy in EAP listening. Though both groups reported a decrease in anxiety, the reflective data from the GAI group offered more evidence of their confidence and motivations in applying knowledge and skills in future listening tasks. EAP listening is challenging and usually elicits negative feelings, such as anxiety. Against this backdrop, self-efficacy in EAP listening plays a vital role in the way individuals decide which activities to engage in, along with their level of perseverance (Graham, 2011).

In EAP listening, self-efficacy also heightens learner awareness of the causal link between strategy implementation and achievement (Graham, 2011). In current research, GAI mind mapping promoted the adoption of listening strategies whereas captions merely offered immediate assistance. Given that the videos were purposely selected to enhance EAP knowledge, they imposed a greater intrinsic cognitive load compared to everyday English conversations. Higher levels of listening strategies are thus necessary to manage the increased cognitive demand (Bao & Guan, 2019). Our research indicated that learners in the GAI group believed that they were able to develop some cognitive, metacognitive and socio-affective listening strategies. The GAI mind maps served multiple purposes: as a tutor to offer scaffolding during the listening process (cognitive strategies), as a model to demonstrate how keywords can be organized (metacognitive strategies) and as a companion to lower anxiety and increase confidence in L2 listening (socio-affective strategies). In comparison, captions failed to offer such strategic support in the study. Learners argued that captions had a narrow, immediate

utility and their listening skills were not truly developed. As discussed, learners experienced cognitive overload and their attention was split, resulting in their superficial and passive engagement with the listening materials (Mayer, 2001).

CONCLUSION

The present study has provided valuable insights into the effects of two distinct instructional strategies, namely GAI mind mapping and video captions on the listening comprehension skills of EFL learners in higher education. The significance of L2 listening in the broader landscape of SLA cannot be overstated because educational institutions increasingly adopt the EMI framework. The results from current research offer both theoretical implications for the understanding of L2 listening strategies and practical implications for educators seeking to improve listening comprehension among their learners.

Pedagogical implications are put forward based on the findings. First, the concept of cognitive balance must be pivotal in course or task design in some complex learning tasks such as listening comprehension. Integrating GAI into multi-modal resources, such as generating learning mind-maps by GAI tools to provide structured visual support can break down complex information into manageable pieces. Thus, it allows learners to engage more with learning materials rather than entangling with excessive invalid information (Moon & Ryu, 2021). Second, over the past two decades, various approaches and models for promoting listening strategies have been proposed (Flowerdew & Miller, 2005). Nevertheless, situated within the new era of multimedia and multi-modal learning, the useful cognitive, metacognitive and socio-affective listening strategies should be carefully re-evaluated for EFL learners, especially those with limited language resources. For instance, some traditional learning approaches, such as captioning could not yield the expected benefits for modern EFL learners anymore due to their limitations in fostering deeper engagement and skills development (Chen et al., 2020). Third, while GAI mind mapping in this study showed pronounced benefits, its effectiveness heavily depends on the accuracy and flexibility of tools. EMI lecturers in this case play an important role in assessing the content and information provided by GAI tools. Fourth, different educational stakeholders could consider incorporating distinct tools and techniques that support self-assessment and reflection to enable learners to take ownership of the learning process in future EFL classrooms (Flowerdew & Miller, 2005). Thus, they facilitate more effective participation in L2 listening tasks. This enables learners to perceive higher levels of readiness and adaptability in coping with more difficult listening learning tasks.

Though the study offers some valuable insights, there are some limitations. On the one hand, the sample size of 79 undergraduate learners studying at a Macau university, while sufficient for preliminary analysis, may not be representative of the broader population of EFL learners. Future research could consider organizing extended and heterogeneous samples instead, which is helpful to enhance the generalization of the findings by including learners from different language backgrounds and educational contexts. On the other hand, the current research investigated two specific instructional strategies but did not explore some potential interactions between these strategies and other psychological variables such as learners' prior knowledge, learning motivation, language mindset and cognitive loads. Thus, future research could consider investigating how these factors influence the effectiveness of GAI tools in enhancing learners' listening comprehension skills.

Looking ahead, the application of GAI in L2 listening is promising when it is seamlessly integrated with other cutting-edge technologies such as extended reality (XR). While GAI has the capacity to generate customized and purposeful learning content, XR can help create an immersive and contextualized learning context (Teng & Wu, 2025). This ecological blend is being envisaged by educators as a visionary pathway for the future of language education (Wu et al., 2024).

CONFLICTS OF INTEREST

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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