# Managing Working Memory in Language Instructions: An Overview of Cognitive Load Theory

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**Abstract**

Cognitive Load Theory (CLT) deals with different types of load available in human working memory and how to manipulate instructional designs so that working memory can be available for learning. Designing relevant instructional materials based on CLT can help promote students' language learning based on research studies in language education when intrinsic cognitive load is hold stable, extraneous cognitive load is low, and germane cognitive load is high. Major areas of instructional designs which pose great challenges on language education include split-attention, modality effect, worked example and completion problem effect, and redundancy effect. Suggestions based on research studies in vocabulary, grammar, reading, writing, and listening-speaking are explored so that capacity in working memory can be enhanced, suitable for language learning.

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**Keywords:** Cognitive Load Theory, instructional designs, instructional materials, language education, language learning and instructions

## Introduction

In the 21st century, it is undeniable that all walks of life are always in the context where there is so much information to learn, appreciate and acquire. Learners of English as an international language are not only learning their own and/or foreign language(s) alone, but they also have to learn and acquire other skills required in the 21st century, such as digital literacy, career and life, and learning and innovation skills (Trilling & Fadel, 2009). Given the context of learning where 21st century learners are facing, it is plausible to seek an insight understanding of how human cognitive structure works and how to manipulate instructional materials to help facilitate learners' language learning. One of the most recent theories in attempting to explain this scenario is called Cognitive Load Theory, a term coined and proposed by Sweller (1994).

In this article, we will discuss the nature of Cognitive Load Theory, application of the theory in language learning, and proposed ideas of how to manage instructional materials, suitable for language learning.

## What is Cognitive Load Theory?

Cognitive Load Theory (CLT) is a 'psychological theory' dealing with how psychological constructs are related to learning. In other words, the theory deals mainly with how cognitive construct is organised, what happens when we are learning, and how we can design instructional materials to help facilitate learning (Moreno & Park, 2010).

In terms of cognitive construct, Sweller et al. (1998) postulate that people are equipped with a cognitive structure consisting of working memory and long-term memory. When we acquire new information from our senses, i.e. visual, auditory, kinesthetic, tactile and olfactory, and we pay particular attention to it, the information is registered and processed into our working memory (Thorne, 2005). According to Baddeley (1992), a person can process visual images and speech-based information concurrently and consciously as 'unitary short-time memory'. He explains further that we can process both visual images and phonological information best through the use of 'visual-spatial scratch pad' and 'phonological loop', an expanded single system over two separate storages, in our working memory. However, Sweller (1994) discusses that working memory is regarded as conscious memory with limited capacity when it is used to hold information. In fact, it can store up to only seven items or pieces of information at a time (Miller, 1956, cited in Sweller, 1994), within a time frame of 30 seconds to two minutes (Thorne, 2005). In other words, it is quite a

big challenge for a person to store conscious information via listening or reading alone (see Juffs, 2006, for example). One way to process and store new information better is by learning through both listening and reading, thus increasing working memory's capacity to store information (Baddeley, 1992).

As can be seen from the above scenario, when learning different pieces of information at a time, such as a case of learning different subjects, or specially different language topics, a student may find it difficult to remember everything since cognitive load may increase in his/her working memory.

Another type of cognitive construct is long-term memory. As far as long-term memory goes, a person who keeps practicing new information and becomes a master of a particular topic can hold the information unconsciously for a very long time, which can then be retrieved automatically when dealing with a similar kind of information (Sweller, 1994). According to Sweller et al. (1998), a person can gain long-time memory when he/she has exposed to an area of interest for a long period of time until this experience becomes a single configuration. For example, a proficient learner of English who is used to speaking English every day can converse in English more fluently and accurately than a beginner because this proficient user of English subconsciously brings his/her unconscious, single knowledge to use with one configuration. This kind of learner is said to obtain 'schema', or background information used to learn new knowledge automatically (Sweller, 2010a).

In summary, it is important to manipulate our working memory when we are learning new information so that there is as little cognitive load as possible in the working memory. Also, it is interesting to construct schemas as many as we can so that schema automation, or an automatic storage of information in long-term memory (Sweller et al., 1998), can be achieved.

In the next section, we will discuss components of cognitive load and how each type of cognitive load plays a role in learning (a language) with instructional materials.

**Types of Cognitive Load**

As we learn from the aforementioned section, Cognitive Load Theory deals with how we can organise our cognitive construct, especially in working memory so that it helps facilitate learning. In the following, we will discuss different types of cognitive load and their relations to the design of instructional materials.

Artino (2008) describes that there are three types of cognitive load as follows:

1. Intrinsic cognitive load

This type of cognitive load refers to an amount of information that must be processed simultaneously in working memory. It is regarded as a number of element interactivity, or the number of elements concurrently processed to understand what has been learnt, along with the use of learners' expertise (Sweller et al., 1998, & Sweller, 2010b). Hung (2009) accounts for this phenomenon that we cannot alter element interactivity imposed in instructional materials, and therefore we cannot control this type of cognitive load. In other words, if a material contains a high level of element interactivity, such as complex English sentences with modifying phrases, a learner of English may find it difficult to understand or process this kind of material in his/her working memory, thus causing high intrinsic cognitive load in understanding the material. However, when elements in a material do not interact with each other, or being isolated, such as learning an English word 'cat', it will be easier for a learner to process and understand the material better. This type of material is described in Pollock et al. (2002) as having low intrinsic cognitive load, thus facilitating learning and understanding.

2. Extraneous cognitive load

This cognitive load is regarded as ‘ineffective cognitive load’. In other words, Sweller (1994) explains that this cognitive load is caused by ineffective instructional techniques which do not engage learners in schema construction and automation. In addition, ineffective instructional techniques simply add more loads in working memory, resulting in less capacity in working memory to process new information (Sweller et. al., 1998). An example of this ineffective cognitive load is when a learner has to engage in searching for a problem solution or finding referents in an explanation. These activities are regarded by Pass et al. (2003a) as imposing more cognitive load in working memory without aiding in schema construction and automation, thereby hindering effective learning.

Sweller (2010b) discusses further that, besides ineffective instructional techniques that impose extraneous cognitive load, element interactivity is also the main factor causing such load. In other words, when what is learned is not changed, even though element interactivity is reduced, extraneous cognitive load still takes place. For example, when a student is reading an English text to understand its main idea, trying to understand specialised terms in the text can be considered extraneous cognitive load. If the student is trying to understand the specialised terms in the text in his/her area, however, those words are considered intrinsic cognitive load in the material.

3. Germane cognitive load

Artino (2008) describes this type of cognitive load as 'effective cognitive load' which helps promote learning. It refers to any load which is related to processes required in schema construction and automation (Pass et. al., 2003b). In other words, a learner who already acquires a simple English sentence, for instance, can learn a coordinating compound sentence more effectively, even though this imposes more loads in working memory. Schnotz & Kürschner (2007) account for this phenomenon that processes in working memory which aim at 'intentional learning going beyond simple task performance' help reduce ineffective cognitive load, and at the same time, increase effective cognitive load in promoting schema construction. This is supported by Sweller (2010b) in that when a student's working memory resources are dedicated to learn directly from element interactivity imposed in a material with intrinsic cognitive load, germane cognitive and leaning will be maximised.

In summary, when designing instructional materials for learners, a teacher should reconsider the nature of element interactivity imposed in materials, and adjust instructional techniques which help students process into a higher level without integrating unrelated learning tasks. This way, intrinsic cognitive load and germane cognitive load can work together in increasing leaners' learning experiences, or schema construction, with full capacity in working memory.

In the following section, we will explore instructional procedures which can impose great effects in cognitive load. Research studies related to each type of instructions will also be included.

**Cognitive Load Theory and Instructional Design in Language Education**

In the last section, we explored nature of Cognitive Load Theory and how each type of cognitive load affects instructional design and instructions. In this section, we will take the theory into consideration in designing language learning materials.

Sweller et. al. (1998) and Cooper (1998) propose the following list of instructional procedures, and instantiate how each type of instructions is experimented on measuring cognitive load to be effective.

**Table 1** Types of instructions which affect cognitive load in working memory (Based on Cooper, 1998, Sweller et al., 1998 & Sweller, 2010b).

| Types of instructions | Description of type of instructions | Effects on cognitive load |
|---|---|---|
| The goal-free effect | Solving a problem with specified means-ends analysis does not help facilitate learning owing to extraneous cognitive load. Alternatively, allowing students to find as many ways as possible to solve any possible problems helps them construct schema. | Goal-free problems provide students with an opportunity to focus on information provided for problem solving only. This increases germane cognitive load, thus facilitating learning. |
| Worked example and completion problem effect | Providing students with worked example will help them process steps and procedures required to solve a problem. However, students working on worked example without training will find it difficult to apply what is learned in reality. Therefore, completion problem is suggested. This completion problem means worked example is provided with blanks for students to fill in. This way, students can process worked example with completion more effectively, resulting in enhanced learning. | Learning to solve problems alone imposes students' cognitive overload. Providing students with worked example (with completion tasks) can increase germane cognitive load because students can process each problem and its associated move more systematically, rather than sparingly focusing on irrelevant moves of each point of learning. |

| Types of instructions | Description of type of instructions | Effects on cognitive load |
|---|---|---|
| Split-attention effect | When a student is required to work on two different materials at the same time, his/her cognitive load will increase, resulting in cognitive overload which fills up working memory. It is important to integrate information from different sources into one medium so that students can stay focused on a particular material. | Referring two different media or locations of materials increases students' working memory, thus there is no space left in working memory. Combining elements of material imposes intrinsic cognitive load, and thus working memory resources are available for such element interactivity, constituting germane cognitive load. |
| Modality effect | Learning via reading one material of visual forms and continuing to learn the next materials from listening, and vice versa, can help students increase cognitive load capacity, thereby facilitating learning. (cf. Baddeley, 1992) | Learning via dual loops helps learners increase cognitive capacity. |
| Redundancy effect | Materials are presented in a visual form, such as a table, and then similar information in another material is repeated in a reading text. This increases cognitive load, impeding learning. | Learning the same kind of information from two different sources increases students' cognitive load. |

As regard the aforementioned table, we understand that it is important to manipulate instructional materials and instructions which are suitable in the context of learning. In the following, we will explore research into applying Cognitive Load Theory in language education and instructions, especially in terms of vocabulary learning, grammar instructions, teaching reading comprehension, writing instructions, and listening-speaking leaning. Some of the research studies apply multiple instructional approaches into consideration in language education (for example, Sakul-Thanasakdi, 2001, Farris et al., 2008, & Hung, 2009).

1. Vocabulary learning

As for learning vocabulary, Lin & Yu (2012) carried out an experiment on vocabulary learning via mobile phones in Taiwan. They divided their selected 36 target words into four types of multimedia learning, namely text mode, text-audio mode (audio), text-picture mode (picture), and text-audio-picture mode (combined). The sample target consisted of 32 eighth graders in Taiwan. What they found in their experiment is that, after learning with four different multimedia, students could acquire and retain vocabulary with no significant difference. However, when measuring their students' cognitive load with mental load and metal effort on a seven-point rating scale (see Prass et al., 2003, on how to measure cognitive load), Lin & Yu (ibid) found that text-audio-picture mode imposed lower load than text and text-picture modes. This confirms that modality effect helps facilitate vocabulary learning.

A similar study on vocabulary acquisition by Sydorenko (2010) also confirms the effectiveness of modality effect on vocabulary learning. The researcher conducted an experiment of input modality into video with audio and captions, video with audio, and video with captions, on 26 learners of Russian. What was found in her study is that participants of video with audio and captions and those of video with captions could gain more scores than those learning with video with audio. She also reported that learners put their most attention to captions, followed by video and audio, and most words were associated with visual images. Therefore, it can be concluded that teaching vocabulary to students by considering modality effect can help them learn words more effectively.

From the above scenario, teaching vocabulary is done best when students are exposed to both reading and listening, i.e. modality effect. Also, integrating vocabulary learning with multimedia, such as computer-assisted language learning or videos, can help learners increase their capacity to remember words more effectively.

2. Grammar instructions

When it comes to grammar instructions, Sakul-Thanasakdi (2001) conducted three experiments in Thailand based on dual modality instruction and integrated instructional formats to measure their effects on split attention in learning active-passive English constructions. Her participants were taught how to convert active voice sentences to passive constructions in conventional visual 'split-attention' instructions and in dual mode of audio/visual instructions. What she found is that learners learning with integrated instructions performed better with lower cognitive load than those learning with conventional instructions. Also, the performance of students learning with integrated instructions was greater than learning through listening or reading. The researcher concluded that when materials are integrated into learning, second language learning, especially grammar instructions, can be enhanced.

Measuring grammar learning with modality effect alone may not only prove its effectiveness in teaching learners of English, but the matter of time is also counted in enhancing learners' language retention. In a study by Giumelli in 2012, split attention effects were taken into consideration in measuring grammar ability in children with specific language impairment. Her two experiments in investigating children's ability to identify verbs in a factual text of integrated format and conventional format proved to be insignificantly different when there were no time limit and fifteen-minute time on test phase. However, when the time is restricted to eight minutes, learning with integrated format was significantly different from conventional format. What the researcher suggested is that when teaching grammar to children with specific language impairment, integrated task of learning to reduce split attention can play a significant role in promoting language learning.

It can be summarised here that when designing grammar instruction materials, a teacher is suggested to integrate materials into a single design. This way, there will be less split-attention in students' working memory; thereby students can gain more understanding and retention in learning English grammar.

3. Teaching reading comprehension

Li Ping (n.d.) discusses that teaching English reading in China, most of the times, imposes high cognitive load in students' working memory. This is due to the fact that teachers of English in China teach English with split-attention instructions and redundancy effect. What was reported in her article is that teachers are prone to discuss grammar and vocabulary points during teaching reading, resulting in split-attention effects which hinder effective reading comprehension. The teaching techniques of these teachers are also similar in teaching any kinds of reading texts, thus redundancy effect of teaching instructions takes place.

To cope with a similar case scenario of split-attention in Vietnam, Hung (2009) conducted an experiment to measure the effect of split-attention in teaching reading comprehension. She had her 21 ESL students study a reading text with two different types of format: one with questions integrated in the text (integrated task), and the other with questions listed after the text (split-attention). What was found in the study of Hung (ibid) is that students spent more time learning from split-attention text than that of the integrated task. Also, the researcher found that after the learning phase, students learning with integrated text scored higher than that of the split-attention format. It can be concluded that the location of questions tends to have an effect on the learning phase, resulting in split-attention effect in reading comprehension.

It can be concluded from the above case that, when teaching reading comprehension, a teacher should adjust his/her of teaching by not including as much information as he/she can so that split-attention may not occur. Also, changing learning format of reading materials can help students retain their understanding when questions are integrated into the text. This way, split-attention effects can be reduced, allowing more capacity in working memory to process.

4. Writing instructions

In teaching writing, Si & Kim (2001) conducted a detailed experiment of how sequencing affects students' writing in Korea. The main aim of their experiment is to measure if germane cognitive load can help support students' writing using different types of sequencing effects, or the order where tasks can be introduced to intervene with instructions (Rothwell & Kazanas, 1992, cited in Si & Kim, 2001), namely whole-part sequencing with simple backward chaining, whole-part sequencing with backward chaining with snowballing, and part-task sequencing. What was found in this study is that, when students were taught how to write formal business English letters, the whole-part sequencing with simple backward chaining outperformed the other two sequences. This is due to the fact that when students are exposed to worked example with holistic approach, i.e. whole-part sequencing with simple backward chaining, learning can be transferred, thus increasing germane cognitive load and promoting schema construction.

Based on the above scenario, it can be concluded that students can learn how to write best when exposing to worked example, and working with completion problem. Also, a teacher should consider how to sequence their instructions so that worked example and completion problem can be presented holistically.

5. Learning listening-speaking

In 2008, Farris et al. reported that working contexts and learners' language proficiency play a role in the amount of capacity in working memory. This group of researchers divided their participants into three categories: English-native pilots, Chinese-speaking pilots with high English proficiency, and Chinese-speaking pilots with low English proficiency. What these participants were required to do is that they had to listen to, repeat, and respond to simulated air-traffic controller messages in high and low working conditions. In high conditions, participants are to repeat the English messages along with performing a calculation task. What was found in this experiment is that English native pilots could repeat more accurately than the other two groups in repetition task. Lower-proficiency pilots were perceived as less proficient in the repetition task in high working condition. Also, both native and low-proficient groups were less fluent in high working condition. The researchers concluded that when working in high working condition where working memory is attributed to other types of tasks, i.e. split-attention, native speakers perform better than lower proficiency speakers; however, fluency in both groups is impaired.

When it comes to learning to listen, Moussa-Inaty, Ayres & Sweller (2011) found that Arabic students acquiring English as a foreign language via read-only method outperformed those who learn through read-listen method and listen-only method. They accounted for these findings that dual modality effects on read-listen method impose high extraneous cognitive load in working memory. This is because, when listening to the same spoken text while reading, students have to use sub-vocal articulation and decode visual information in the phonological loop, thus increasing cognitive overload. In learning to listen, students cannot recall what is heard since the listening text is not static compared with a reading text. As a result, when learning to listen in an early acquisition period of a foreign language, students should expose to reading a spoken text before the actual listening.

As can be seen from the above case, it is important to understand that listening and speaking are bound to be performed best when a learner works in a low working condition, i.e. less split-attention effect. In addition, the redundancy effect of listening and reading can be minimised when a foreign language student exposes to the reading text prior listening.

It can be concluded from above studies on different types of language skills that when language education is redesigned in its materials and instructions by considering Cognitive Load Theory, learning a language can be enhanced, especially in Asian context. Split-attention should be minimised, audio/visual materials should be integrated, and sequences of worked example should be holistically designed.

In the last section of this article, recommendations from research studies will be proposed in designing effective learning materials which can help expand working memory, thus facilitating language learning.

**Implications of Cognitive Load Theory on Language Education**

With regard to information presented in the above sections, it can be implied that Cognitive Load Theory can play a role in language education, especially in terms of material design and instructions in an Asian context. In the following section, we will discuss areas of adaptation which can be applied in language learning and teaching, based on ideas presented in Kudo (2013), & Kutkut (2011).

1. Teaching vocabulary and grammar

It has been a long-time belief that teaching vocabulary and grammar requires teachers' time and expertise. A teacher is thought to process high-level knowledge in order that he/she can deliver what he/she knows to the students. Taking Cognitive Load Theory into consideration, however, a teacher can help students learn best using dual model materials, in that students can be exposed to listening and reading materials which contain target vocabulary items and/or grammar points. Also, a teacher should help students process learning points using a single material so that split-attention effect is reduced.

2. Teaching reading and writing

In order to teach reading effectively, a teacher should stop explaining every detail in a reading text to the students. Alternatively, a teacher can integrate questions in a reading text so that students can focus on reading and learning without sparing their mind to questions listed in the end of the text. In addition to this, a teacher should adjust or adapt different approaches to teaching reading. This way, redundancy effect in language instructions will be diminished, and language learning can be fun and challenged.

In terms of teaching writing, teaching students different pieces of a jigsaw, such as teaching them sentence structures, cohesive devices, etc., may not prove that students can master writing skills. Alternatively, a teacher can present them with worked examples and try every way to reverse teaching from that point, such as having students notice different pieces of writing after exposing to the worked example. This way, students can increase germane cognitive load, and schemas can be constructed in their long-term memory.

3. Teaching listening and speaking

Since listening and speaking tend to be one of the most difficult language skills to teach, it is important for a teacher to consider learning environment over other factors. Also, a teacher can present students with listening text first, and then have them listen and repeat and generate their speaking based on what they hear. This way working environment will not increase working memory capacity, and the redundancy effect will be minimised.

All in all, it can be implied that managing students' working memory by adapting or adjusting instructional materials can help enhance their language learning.

## Conclusion

Learning a foreign language seems to be difficult when considering how a human brain can contain huge amount of information in working memory, and then transfer it to long-term memory for schema construction. Different types of cognitive load should be carefully studied so that designing instructional materials can really help facilitate language learning, not impeding it. Several factors, such as split-attention effect, modality effect, worked example and completion problem effect, and redundancy effect, tend to play a role in language learning and instructions, especially in Asian context. However, Cognitive Load Theory has not yet been widely researched in the Asian context, especially in Thailand. Therefore, it is important for language teachers in Asia, especially in Thailand, to turn back to what is in their students' brains.

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