Univerzita Karlova
Pedagogická fakulta
Katedra anglického jazyka a literatury

DIPLOMOVÁ PRÁCE

Enhancing EFL Students' Vocabulary Retention through the Application of Brain-Compatible Teaching Strategies

Zlepšení zapamatování slovní zásoby u studentů EFL pomocí ‘Brain-Compatible’ výukových strategií

Bc. Daria Hartinger

Vedoucí práce: Mgr. Martin Mikuláš, Ph.D.
Studijní program: Učitelství anglického jazyka pro 2. stupeň základní školy a střední školy
Studijní obor: N AJ 20

2024

Odevzdáním této diplomové práce na téma *Zlepšení zapamatování slovní zásoby u studentů EFL pomocí 'Brain-Compatible' výukových strategií* potvrzuji, že jsem ji vypracovala pod vedením vedoucího práce samostatně za použití v práci uvedených pramenů a literatury. Dále potvrzuji, že tato práce nebyla využita k získání jiného nebo stejného titulu.

Praha, 14. 4. 2024

ABSTRACT

This thesis is aimed at researching effective teaching strategies that enhance vocabulary learning among English language students aged 13 to 16 years old, with a particular focus on vocabulary related to electricians' and mechanics' tools. Teaching this kind of vocabulary is a challenge that demands innovative teaching strategies that take into consideration the specific functioning of the adolescent brain.

The study is based on a review of modern learning theories and teaching methods, as well as on the implementation of practical lessons using different vocabulary strategies.

The theoretical part of the study explores the concept of Brain-based teaching and reviews previous studies that have been conducted successfully in this area. The work showed that strategies such as Frayer Model, Semantic Mapping and Chunking have a considerable positive effect on the process of vocabulary acquisition.

These strategies were then employed successfully in a teaching process carried out with four different groups of students. The empirical part shows various statistics that are based on the results of a vocabulary assessment pre-test and two types of post-test, immediate and delayed. These data illustrate the effectiveness of the treatment used. Although statistically insignificant in some cases, the results showed a noticeable improvement in vocabulary learning.

KEYWORDS

Brain-based strategies, vocabulary, the Frayer model, chunking, semantic mapping, tools, memory

SHRNUTÍ

Tato práce je zaměřena na výzkum efektivních výukových strategií, které zlepšují osvojování slovní zásoby u studentů anglického jazyka ve věku 13 až 16 let, se zvláštním zaměřením na slovní zásobu týkající se elektrikářského a mechanického nářadí. Výuka tohoto druhu slovní zásoby je výzvou, která vyžaduje inovativní výukové strategie zohledňující specifické fungování mozku dospívajících.

Studie je založena na přehledu moderních teorií učení a vyučovacích metod a na realizaci praktických lekcí s využitím různých strategií výuky slovní zásoby.

Teoretická část práce zkoumá koncept výuky "Brain based" a podává přehled předchozích studií, které byly v této oblasti úspěšně provedeny. Práce ukázala, že strategie jako Frayerův model, sémantické mapování a chunking mají značný pozitivní vliv na proces osvojování slovní zásoby.

Tyto strategie pak byly úspěšně použity ve vyučovacím procesu prováděném se čtyřmi různými skupinami studentů. V empirické části práce jsou uvedeny různé statistiky, které vycházejí z výsledků hodnocení slovní zásoby v pre-testu a dvou typů post-testu, okamžitého a opožděného. Tyto údaje ilustrují účinnost použitého postupu. Ačkoli v některých případech byly výsledky statisticky nevýznamné, ukázaly nezanedbatelné zlepšení v osvojení slovní zásoby studenty.

KLÍČOVÁ SLOVA

Brain-based strategie, slovní zásoba, Frayerův model, chunking, sémantické mapování, nástroje, paměť

I would like to express my sincere gratitude to the thesis supervisor for their guidance and support throughout the course of the thesis. The supervisor's time, patience, and advice were valuable in achieving a high-quality result.

Table of contents

I. THEORETICAL PART

1. Teaching English as a Foreign Language

The development of effective strategies for improving the retention of keywords in students who learn English as a Foreign Language is an important area to focus on when teaching language at school. In this process, the use of brain-compatible learning strategies will play an important role.

Brain-based education considers how the brain learns best. The brain does not learn on demand according to the rigid and flexible schedule of a school. It has its rhythms. If you want to maximise learning, you first need to discover how students' natural learning engine works. Many classroom elements that we used to think were critical to learning may, in fact, not be essential at all. (Jensen, *Brain-Based Learning: A Reality Check* 76)

The use of interactivity techniques that encourage active participation of students in their learning activities is a key aspect. (Lee; Hannafin 11) Better understanding and learning of new words, as well as their more efficient memorization, is promoted using play and communication tasks.

The integration of learning content into the context that is relevant to students' everyday lives also constitutes a key strategy. This allows them to recognise and use new words more easily in real-life situations, which contributes to more persistent memorisation and application in practice. (Jensen, *Brain-Based Learning: A Reality Check* 77)

Furthermore, Jensen (Jensen, *Brain-Based Learning: A Reality Check* 77) stated that creating a positive learning environment in which students feel secure and motivated is an additional aspect. Therefore, it is necessary to foster interest in learning a language, thus contributing to the achievement of better vocabulary retention. To ensure optimal conditions for adequate vocabulary acquisition and retention of students, there is a novel approach that uses English learning in schools through brain compatibility strategies

Assuming that the learner perceives the second language as hard and complex, his attitude toward the learning process is complicated, this leads to Krashen (Krashen 255) calls a 'mental' block that could prevent compressible input from being used in language acquisition (Schütz 3). In other words, the more negative the learner's attitude towards

the language and the learning process of that language, the stronger the mental block becomes and the more difficult language acquisition becomes.

Fakeye (Fakeye 205) stated that the attitude towards the language or its learning process was one of the most critical factors that affect the learning of a language. Several researchers have attempted to define and explain an individual's attitude towards learning a foreign language. For example, H. D. Brown (Brown 33) largely defined it as emotional involvement such as self-confidence, feelings toward others, and relationship in the community".

2. The essence and significance of vocabulary

The simple definition of a vocabulary is 'the words of the language', but this is an oversimplification.

A functional lexicon generally refers to the ability to access and retrieve words automatically for comprehending and producing ideas in all four modalities. Such an advanced fluency requires knowledge of multiple aspects of word knowledge that Nation (Nation 44) described as follows:

- Word form includes the spoken form (pronunciation), and written form (spelling), and word parts (e.g., prefixes and suffixes).
- Word meaning includes the availability of the context-specific meaning of a word form (e.g., *file* refers to organizing papers in the context of paperwork, whereas file refers to a surface-smoothing tool in the context of fixing or building something), the knowledge of the concept and referents (e.g., in English, the concept of *riding* includes the riding of a horse, bike, and bus); and the ability to access associations of words that could be used in a particular context (angry, irate, furious, outraged).
- Word use includes the understanding of grammatical functions (e.g., the verb *love* always requires an object, whereas the construction in love does not, and if an object is used with the latter the preposition with is required), conventionalized expressions, such as collocations (one rides a bike and does not *drive a bike); and constraints in usage (a priori is used in written texts and less in oral discourse).

Vivian Cook in her book "Second Language Learning and Language Teaching" (Cook 241) stated that vocabulary acquisition is much more than the acquisition of words. Over the last 20 years, there has been a large explosion in research into vocabulary acquisition, as evidenced by books like Nation (Nation 25). Thus, a large part of this is related to the acquisition of isolated words in laboratory experiments, and it tests whether people remember them or are not able to use them.

In the classroom, a frequency of vocabulary has been used, in particular, to choose words to teach. The words that are commonly spoken will be the best ones to use for a student. Nevertheless, it is pointless to worry so much about frequency. Common words will be provided automatically when students have a reasonable understanding of English in their textbooks and teachers. (Cook 64)

Recite Noam Chomsky (Chomsky 24): 'language acquisition' is in essence a matter of determining 'lexical idiosyncrasies'. It is never enough to learn a single word and its meaning in isolation for the effectiveness of vocabulary acquisition.

Wilkins (Wilkins 111) agreed that 'while' without grammar very little can be conveyed, without vocabulary; nothing can be 'conveyed'. As Schmitt (Schmitt 201), noted ELLs have come to understand the value of learning vocabulary because of its significance in helping them communicate with others and express their ideas; therefore, students carry dictionaries and not grammar books.

The research showed that in reading you cannot be sure of accurately comprehending the main idea of a text without knowing between 95% and 98% of its words in advance and that you need to know about 8000 words to be able to perceive an unsimplified text in English. (Schmitt 199)

This means that students who learn English as an additional language and want to reach this level, and who usually study this language for an average of 30 weeks per year for eight or nine years, have to learn an average of around 30 new terms per week, without considering the required review.

English language skills have been classified by Schmitt into both receptive and expressive (productive) knowledge competence. He asserts that proficiency in acquiring information through listening and reading pertains to receptive knowledge skills, whereas competence in expressing oneself through speaking and writing is associated with productive knowledge skills (Schmitt 227). Receptive vocabulary knowledge is the ability to understand a word when the learner hears or sees it, while productive vocabulary knowledge is the ability to produce a word when the learner can use it in their writing or speech. It is claimed that the learner learns language words by receptiveness first and only

after he has deliberately learnt them and they become available for productive use (Schmitt 228).

The fact that learners of an additional language have relatively little exposure to the target language in formal courses would explain why, as research has shown (Laufer 224), extensive reading is not enough: it alone cannot provide a satisfactory basis for learning the extensive vocabulary that these students need. An optimally effective programme must also include the targeted teaching of lexical items.

One of the reasons for the need for an extensive component of vocabulary teaching in the classroom is the fact that we do not usually learn a new item through a single encounter with it: we have to encounter it several times (probably between six and sixteen) to memorise it - and our second encounter has to be before we have forgotten the first. This is not a problem with the basic, frequently occurring words: we will probably encounter a word like "go" very often in everyday conversation and reading. However, as soon as we go beyond the first few hundred most common words, this is no longer a matter of course. (Zahar 555).

2.1 Psychological aspects of learning and memorising words of children 13 to 16 years

In this part, we will look at the psychological characteristics of children ages 13 to 16 who learn and memorise new words in the context of brain-compatible teaching strategies. Not only physical changes but also unique psychological features that can have an impact on learning and memory processes characterise this period of adolescent development.

Defined as the maturational period spanning the onset of puberty to early adulthood, adolescence is associated with significant neurobiological, physical, cognitive, social, and behavioural changes (American Psychological Association).

Children are in a phase of significant change and active cognitive development between the ages of 13 and 16. It is an extremely complex task that involves several psychological

aspects in learning and memorising new words when learning English as a foreign language.

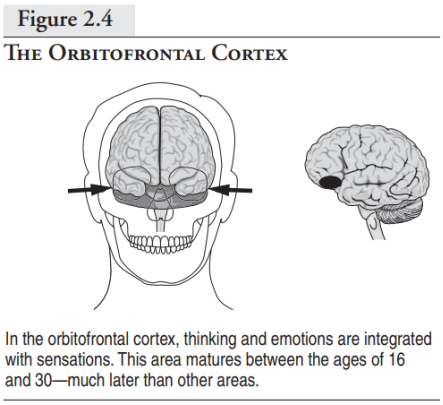

Figure 1.The orbitofrontal cortex (Jensen 31)

2.1.2 Biological factors in the learning process

Jensen states that, at the gross anatomical level, most areas of the brain are under major construction during adolescence. These changes are similar to those that occur in a child's brain. The parietal lobes are undergoing significant changes, with areas doubling or tripling in size. The last areas of the brain to mature are the frontal lobes, a large piece of grey matter responsible for thinking and reflection ability (Jensen, *Brain-Based Learning: A Reality Check* 16).

At the age of 11 to 13, brain cells are thicker and then shrink by 7 to 10 per cent at ages 13 to 20. This process can last up to 30 years in some cases, suggesting that the adolescent brain is very immature.

A study that used magnetic resonance imaging to examine the developing brain (Durston 1012) suggests that the thickening of adolescent brain cells is caused by massive changes in synaptic reorganisation, meaning that many more connections are being formed. New information becomes much more accessible to cells involved in the restructuring process. However, the nearly exploding brain is often paralysed by inefficiency, even though it has more choices. The adolescent brain depends on synaptic pruning to make more

effective decisions, as the infant brain does. The work of Elizabeth Sowell at UCLA suggests that girls' frontal lobes grow faster than men's do during puberty (Sowell 312). These processes suggest that the areas of the brain that are under construction may be very dense. It is unstable, volatile, and unpredictable.

At the molecular level, teenage brains are affected by volatile levels of feel-good dopamine neurotransmitters. Some researchers argue that dopamine levels are too low in adolescence, while others argue that dopamine levels are very high during this period, even higher than in adults. We can see from the various brain research findings that even more changes are likely to occur in adolescents than we have been aware of.

Another extensively recognized viewpoint on cognitive growth originates from the cognitive stage theory formulated by Jean Piaget, a renowned psychologist from Switzerland. Piaget meticulously constructed and examined a narrative detailing the progression of logical and scientific thinking in children and adolescents. Given its widespread acceptance among educators, we will primarily concentrate on Piaget's theory in the subsequent section (Piaget 13).

Cognitive development then progresses through four stages. We are mainly interested in the formal operational stage (from ages 12 or 13 to 16, on average), people are capable of abstract reasoning; for example, and they can understand that: 'If p, then q; it is not the case that p; Therefore, nothing can be concluded about q.'

In this age, the focus on new words can change according to personal interests, social context, and emotions. These aspects of psychology are taken into account when designing brain-compatible learning strategies that result in optimal conditions to acquire knowledge. Creating imaginative associations that stimulate visual and emotional reactions is one of the keys. The ease of memorisation and retention is enhanced by the presentation of new words in contexts that use images or scenarios.

2.1.3. Memory

Language processing is one of the main obstacles to the access of information provided for in this list, in addition to environmental factors. Working memory, as described by

Baddeley (Baddeley 247), is the most important construct in language processing in psychology studies. Therefore, working memory should have a significant influence on the linguistic learner's access to information.

Working memory is instrumental in acquiring new vocabulary and more general measures of learning languages. Daneman and Green (Daneman 16) found that it played a key role in determining how easy it was for learners to understand the meaning of words from their context. Observing that readers utilize context to enhance comprehension of partially known words, Daneman and Green also suggested that working memory could indirectly support the expansion of vocabulary.

Firstly, working memory supports the ability to associate and align new words with a related concept. Individuals create a mental network to strengthen their language skills in general and aid word retention and recall by connecting new vocabulary to existing knowledge.

Secondly, individuals can adapt their vocabulary to different contexts by using working memory. Working memory facilitates the use of newly acquired words in a variety of situations and contributes to a flexible and expanding vocabulary through active retrieval and manipulation of linguistic information.

From 13 to 15 - 16 years of age, there is a more rapid growth of memory. In adolescence, memory is restructured, moving from the dominance of mechanical memorisation to semantic memory. In this case, the semantic memory itself is restructured, it acquires a mediated, logical character, and thinking is necessarily included. Along with the form changes and the content of the memorised, it becomes more accessible to remember abstract material. Memory works by mediating already assigned sign systems, primarily speech (Piaget 26).

The main characteristic of adolescence is the strengthening of the arbitrary side of mental functions. There is an increase in the ability to organise, control their mental functions, and manage them. This is a peculiar form of second-signal regulation. Memory and attention gradually acquire the character of organised, regulated, and controlled processes. Finally, a characteristic of adolescent memory is the ability to establish more

complex associations, link new material to old materials, and incorporate new material into the knowledge system.

2.1.4. Additional variables affecting brain-based learning

Moreover, it is also important to take into account the motivation aspect when teaching vocabulary. Interest in the study of language, including relevant and interesting topics, can provide a strong incentive for new linguistic material to be learned. The establishment of positive links with language education is influenced by openness to dialogue and exchange of views.

Motivation or attitude toward a specific word type (i.e., high frequency, mid-frequency, and low-frequency words) was expected to prevent the learner from advancing in learning new vocabulary. Blum (Blum 133) pointed out that "the motivation for avoidance at this stage can be morphological (preferring a regular verb to an irregular one), phonological (preferring the word that is easier to pronounce), graphological (preferring in writing the word one knows how to spell) or avoidance (preferring a word that has a clear translation-equivalent in the mother tongue to one that does not)".

In 2010, Ambrose (Ambrose 4) wrote about the conditions under which students are encouraged to learn, suggesting seven learning principles and offering guidelines for learning strategies students can use to improve the quality of learning for them. The influence of prior knowledge, the importance of goal-directed practice, coupled with targeted and timely feedback, and the impact of student attitude and motivation on learning were addressed in some of the principles.

In our research, we would be mostly interested in principle 2: "How students organize knowledge influences how they learn and apply what they know", as this principle could be directly connected with the brain-compatible learning strategies for teaching new vocabulary, which are going to be used in the empirical part of our diploma thesis such as chunking, Frayer model and semantic mapping. The authors of the principle suggested that when students understand how they organise knowledge, they are better prepared to model strategies for developing deeper, more meaningful knowledge structures for

students. In addition, the authors focus on helping instructors helping students to gain depth and breadth of knowledge through the building of effective knowledge organisations. In the second principle, Ambrose (Ambrose 8) declared that it is important to consider the activities and experiences of students when developing knowledge organisations that are based on their tasks. It is necessary to examine the tasks carried out by students to understand what knowledge organisations will emerge.

All of the above strategies are consistent with this principle and can be applied to better organise new words in the students' working memory.

Students come to school with more than knowledge and skills, as Ambrose (Ambrose 5) stated. They also bring personal and emotional experience, how they think about themselves and other people as well, as how they are going to participate in learning processes (Ambrose 5). Furthermore, the authors noted that students might not be aware of the factors that affect their learning process, such as the transition from L1 to L2. These factors could “impede learning if the new language operates according to fundamentally different grammatical rules, such as a subject-object-verb configuration as opposed to a subject-verb-object structure” (Ambrose 21). Therefore, teachers must be aware of the types of previous knowledge that may have an impact on students' learning.

3. Brain-Based Learning

In the field of brain-based learning and research, Erick Jensen is one of the best-known authors. He stated that you have to become familiar with the brain so that you can figure out how people learn. Many authors in the field of cognitive science began their career with a section on brain physiology and explained to readers why we must have an understanding of primary interdependencies and functions within our brains. (Jensen, *Teaching with the Brain in Mind* 68).

3.1 Definition of brain-based learning

Brain-based training is a process of focusing primarily on the learner's learning with an understanding of their brain function, which assimilates new information in its schema. To meet learners' emotional and academic needs, the teacher establishes an environment where events are organised. The key concept of Brain-Based Learning is that the learner needs a supportive, challenging learning environment and an educator makes it easier to learn as education activities start to take off. (Erlauer 46).

Brain-based learning accommodates the learning style of individual students. It is learning with the brain in mind stated Jensen. In his text, Teaching with the Brain in Mind, Eric Jensen (Jensen, *Teaching with the Brain in Mind* 48) explained, 'brain learning is a reality check'. Thirty years ago, good teaching was defined as lectures, content classes, and quiet students sitting still at their desks. Educators needed to combine the findings of brain research to improve their teaching techniques. 'The brain is what we have; the mind is how we use it.' Jensen declared that intense emotions associated with celebrations, competitions, and plays have been shown to stimulate the release of adrenaline, which significantly improves memory when learning (Jensen, *Teaching with the Brain in Mind* 49)

Typically, new learning creates new synapses, especially when the subject matter is challenging (Black 112). It indicates that the level of difficulty for our students needs to be managed constantly.

There are three main ways in which **we can achieve this:**

• By varying the learning resources available (allowing students to work with friends, providing access to information or tools, varying the time allowed).

• By varying the learning expectations (asking for more or less quality, making the final output more public or more private).

• By varying the learning context (allowing students to work at home as well as in class to complete work over periods of days or weeks).

(Jensen, *Teaching with the Brain in Mind* 117)

The principles established above can be applied in a systematic research approach to empirical investigation of brain-incompatible learning techniques to teach new vocabulary. For instance, it can help us in identifying knowledge organisations. If we think about the tasks students will have to perform when learning vocabulary, it will ensure consistency between the way information is organised in the brain and the demands of learning activities, matching the identified knowledge organizations with the cognitive demands of these tasks.

Furthermore, it is necessary to evaluate the effectiveness of different knowledge organizations. This process may involve comparing traditional learning methods with brain-adapted techniques in ongoing research.

Besides the comparison of the methods, it is vital to assess students' learning outcomes and performance based on the applied techniques. By comparing the effectiveness of brain-compatible learning approaches, we can see the difference in results in memorisation, comprehension and vocabulary use.

Based on the empirical findings, we will be able to iteratively refine brain-compatible learning methods. Our task will also be to adapt instructional strategies to better align them with observed cognitive processes and maximise vocabulary-learning outcomes.

Implementing strategies based on the identified effective brain-compatible techniques will allow us to more thoroughly evaluate their impact on vocabulary acquisition in real educational settings.

Brain-based learning is about the idea that everybody learns, and a brain can handle this kind of learning very well. It also provides students with the opportunity to strengthen their ability to learn by stimulating brains from classroom strategies and activities, so that they become capable of keeping a high level of knowledge, thereby enabling them to reach their fullest potential in this area. In addition, for students to learn effectively it is not enough just to show them something. They need to take part in the learning process actively, as they connect prior knowledge with existing knowledge and will be able to maintain it for future use. (Wolfe 12)

3.2 Origin of brain-based learning

The term "neuroeducation" appeared almost simultaneously in different parts of the world, so it is difficult to say who first used this term. The term "neuroeducation" is attributed to the American scientist O'Dell. His first serious work on neuroeducation was published in 1981 and was called "Neuroeducation: Brain Compatible Learning Strategies." (Odell 57)

The work of O'Dell was followed by Leslie Hart's book "Human Brain and Human Learning", dedicated to how the brain "learns". L. Hart writes that creating safe understandings of the brain is like making gloves without understanding the human hand. «Anyone who does not have a structure corresponding to the basic processes of the brain is outdated. After all, he is like a car designer who does not fully understand how the engine works (Hart 118).

Then in their 1991 book, "Making Connections: Teaching and the Human Brain," Caine and Caine discussed the concept of brain-based learning, marking the initial stages of what is currently recognized as brain-based learning (Caine and Caine, 44).

Since the 1990s, pioneers in the brain-based learning movement, including educators and psychologists Caine, Goleman, Jensen, and Sousa, have played key roles in advancing this approach. Their contributions involve translating neurological research into evidence-based academic best practices.

In the United States, brain-based techniques have been used by several regular and special education teachers over the past fifteen years to gain access to an ever-increasing range of learners. Curiously, brain-based methods are also being used in schools by other countries all over the world, like Turkey, Chile, England and Thailand.

3.3 Brain-based learning principles essential for teaching vocabulary

Finally, a feature of the ever-changing educational environment is the increasing emphasis on the integration of neuroscientific approaches to learning. The principles of brain-based learning are an innovative way to link educational practice to the ever-evolving understanding of the human brain. This paradigm shift recognises the interconnectedness of neurological processes and effective learning principles. The adolescent's memory can make more complex associations, link new material to old material, and incorporate new material into the knowledge system.

Moreover, according to a study published by Sprenger (Sprenger 50), students perceive new information as being more meaningful about their own lives. Thus, the use of materials must be inseparable from daily life for them to have any meaning. "It is easy to imprint real-life experiences and events into your consciousness; the brain seeks meaning from experience," said Sprenger. To ensure a meaningful education, Caine and Caine (Caine and Caine 17) argue that each system of the entire brain appears to be working together. They see that the brain plays a crucial role in meaningful learning and adjusts their teaching methods accordingly. Three important phases of the teaching and learning process, which have a major impact on preparing lesson plans for students, were proposed by Caine and Caine in 1994. These include orchestrated immersion, relaxed alertness, and active process. We will provide the definitions of the terms below.

- Orchestrated immersion: Orchestrated immersion means to create learning environments that fully immerse learners in an educational experience.
- Relaxed alertness: Relaxed alertness means trying to eliminate fear in learners while maintaining a highly challenging environment.
- Active processing: Active processing means the consolidation and internalization of information by the learner in a way that is both personally meaningful and conceptually coherent. It is the path to understanding, rather than simply to memory.

Each stage does not constitute a separate entity from the others. Each has a role to play in the teaching and learning process so that students can gain experience with no threat. "One of the characteristics of brain compatible learning is a lack of threat and an absence of relaxation alertness" Caine & Caine stated (Caine and Caine 21). Students engage well when they feel respected and know they will not be ridiculed, even if they make mistakes, which gives them the confidence to participate in class. "This approach should provide instant feedback to enable students to understand the stages of their education."

The 12 Brain-Based Learning (BBL) Principles:

The 12 principles of Brain-Based Learning were deemed a foundation for the activities carried out in this study. The tasks were created according to the Brain Compatible Learning Principles developed by Cain and Caine (Caine and Caine 18), which are as follows:

- Each brain is unique.
- Learning is enhanced by challenge and inhibited by threat.
- The search for meaning occurs through “patterning”.
- The search for meaning is innate.
- The brain is a parallel processor.
- Learning involves both focused attention and peripheral perception.
- Learning engages the entire physiology.
- Emotions are critical to patterning and drive our attention, meaning and memory.

- We have at least two types of memory: spatial and rote.
- Learning involves both conscious and unconscious processes.
- The brain simultaneously perceives and creates parts and wholes.
- We understand and remember best when facts are embedded in natural, spatial memory.

Additionally, Jensen (Jensen, *Teaching with the Brain in Mind* 147) identified the essential stages of the teaching and learning process that are necessary to create lessons for students and which could be applied to the current research as well. All tasks and lesson plans in this study were designed with BBL principles and the five important stages of teaching and learning in mind. The learning of material occurs in a specific sequence. This sequence consists of five stages: preparation, assimilation, elaboration, memory formation, and functional integration.

Firstly, the preparation phase provides a base for learning new material and enables students to make potential connections. The more basic information a student has about a topic, the faster he or she will acquire new knowledge. At this stage, students were asked questions and shown pictures so that they could convey their feelings about what they were to learn and discuss. Moreover, they were informed about what would happen at this stage. It is related to the BBL principle, which states that emotions have a crucial influence on pattern formation and regulate our attention, meaning and memory. In our case, the students encounter various electrical and mechanical terms daily in practical lessons, but they learn them in Czech. Nevertheless, they are already familiar with most of them and have a basic idea of what they are called in their native language and what function they fulfil. This is in line with the BBL principle that states that the search for meaning is natural as the teacher gives students an idea of what they can learn and how it can affect them in real life.

The second stage is acquisition. This is the formation of new connections, during which neurons communicate with each other. These connections are formed when experiences are coherent yet novel. If the inputs are incoherent, only tenuous connections are formed. Alternatively, if the inputs are coherent, existing connections are strengthened and yield learning outcomes. The sources of connections can be varied: visual aids, lectures and

discussions. At this stage, students were engaged in a learning process that helped them understand the lesson material and made them apply the words they had learnt. Since the students were involved in the process, the researcher believes that the words will be more easily consolidated in their memory as they will use them during the practice sessions. This is due to the BBL principle that states that learning involves the whole physiology.

The elaboration phase should be considered to ensure that the brain retains the neurons' connections formed by learning new information. The teacher should work with their students to improve understanding and provide feedback through various learning strategies to help consolidate them.

The fourth stage, memory formation, is the stage that helps students retain long-term memories. At this stage, it is very important to consolidate the material and repeat what has been learnt. For example, as a five-minute warm-up, students could be asked to talk about their last practical session in an electrical engineering class and the tools they were able to use at the time. This supports the BBL principle that when facts are consolidated in our natural memory, and learning is strengthened by challenge and avoidance of danger, we can remember and understand better.

The fifth stage is functional integration, which forces us to use new knowledge to provide additional opportunities for teachers to consolidate and expand it.

In conclusion, it should be noted that the principles of learning based on brain research provide a valuable scientific basis for developing effective teaching strategies. Taking into account individual differences in learning, these principles can be adapted to the different needs of students. Introducing brain-based learning principles into educational practice can contribute to more successful and deep learning, the development of critical thinking and skills necessary for successful adaptation to a rapidly changing society. Thus, the introduction of brain-based learning principles is an important step towards modern and effective education in the sphere of teaching vocabulary.

4. Brain-compatible learning techniques for teaching new vocabulary

Various factors have been identified which could affect vocabulary growth, including learner language awareness, their needs, their learning strategies, and the learning environment. ESL teachers can help their students by analyzing these factors and their teaching approaches (Bruzzano 51).

Researchers define the strategies of language learning in different ways. In general, learning strategies are ways and techniques learners use to acquire new information. Oxford (Oxford 18) defined language-learning strategies as “specific actions taken by the learners to make learning easier, faster, more enjoyable, more self-directed, more effective, and more transferable to new situations”.

Researchers use different definitions of vocabulary learning strategies (VLS) based on their observation points. Some of them are as follows: Cameron (Cameron 92) defines VLSs as "the actions that learners take to help themselves understand and remember vocabulary items".

Catalan (Catalan 58) provides the following working definition of VLSs: "Knowledge of the methods (processes and strategies) used to learn vocabulary and the steps or actions learners take to (a) find out the meaning of unknown words, (b) store them in long-term memory, (c) recall them at will, and (d) use them orally or in writing".
Intaraprasert (Intaraprasert 56) considers VLS as "any set of techniques or learning behaviors that learners say they use to learn the meaning of a new word, retain the meaning of recently learned words in memory, and expand their vocabulary".
Based on the above definitions of the term 'vocabulary learning strategies', it can be concluded that the term 'VLS' refers to purposeful steps, actions or mental processes that learners use more or less consciously to facilitate vocabulary learning.

Different scholars identify different vocabulary learning strategies, for example, Cohen sees them as following: 1) memorization strategies, 2) repetition strategies, 3) association strategies, 4) keyword method, 5) inferencing strategy, 6) dictionary use semantic grid strategies and 8) word lists (Cohen 83). He believes that the use of certain types of strategies shapes the approach to vocabulary learning, which affects the level of foreign

language proficiency. In other words, the use of appropriate strategies leads to better results in terms of specific skills or competencies. In addition, the use of specific lexical strategies is also influenced by language skills.

In teaching vocabulary, brain-compatible techniques are important because they correspond to how the brain naturally processes information and keeps it. Teachers can effectively enhance students' ability to learn and remember new vocabulary by incorporating brain-compatible strategies. For example, visual aids, such as images and diagrams, can help engage visual learners and create a visual perspective of vocabulary words, allowing students to use both sides of their brains. In addition, kinesthetic learners may be better able to understand and retain vocabulary by incorporating movement and kinesthetic activities. Teachers can create a learning environment that is tailored to the different learning styles and preferences of students, thereby improving their vocabulary acquisition and retention through understanding and implementing brain-compatible methods.

Direct and explicit instructions make it easier for ELLs to retain new words in addition to developing their student vocabulary levels. Smith (Smith 367) explained, ‘direct instruction with target words leads to 90% better retention in terms of receptive meaning knowledge compared to 59% of production word form’. In her study, Laufer (Laufer 230) claimed that 70% of the words were learned through explicit vocabulary exercises in comparison to 41% via informal learning methods.

This study examines the effects of different vocabulary teaching strategies on students' brain function and their effect on learning to speak, to increase our knowledge about vocabulary improvements. Learners may be able to take on new or unknown words easily if they are equipped with a variety of VLSs since it helps facilitate the learning process for learners who do not have any experience in this area.

The researcher briefly discusses some of the innovative research techniques included in this section. Techniques that correspond to the way our brains process and store information are used to effectively learn a new vocabulary. In this context, there are three important approaches to vocabulary acquisition and understanding; chunking, semantic mapping, and Frayer models each a unique approach.

4.1 Chunking

At the highest level of skill, chunking is of particular importance. The ability to deploy a wide range of lexical chunks both accurately and appropriately is probably what distinguishes advanced learners from intermediate ones (Thornbury 115).

According to Thornbury, (Thornbury 115), different types of chunks are:

- Collocations (widely travelled, rich and famous, set the table)
- Phrasal verbs (get up, log on, run out of)
- Idioms, catchphrases and sayings (get cold feet, as old as the hills, mind your own business, takes one to know one)
- Sentence frames (would you mind if ….?, the thing is ….)
- Social formulae (see you later, have a nice day, yours sincerely)
- Discourse markers (frankly speaking, on the other hand, I see your point)

Chunking is the process of organizing or grouping information into familiar units or chunks based on syntagmatic relations that will allow us to increase our ability to store and remember data according to Miller (Miller 575).

In Miller's view, chunking is an important tool for the teaching of vocabulary because it allows learners to organize new words into meaningful groups and make them easy to remember. Learners can create a larger amount of information that is easier to remember by grouping words into categories based on their meaning or context. For example, instead of trying to memorise individual words like "apple," "banana," and "orange," learners can group them as "fruits," creating a larger chunk of information that is easier to remember and that is based on paradigmatic relations.

In general, Miller (Miller 576) considers that chunks are a powerful tool to enhance cognitive capacity, improve our ability to process, and remember information. We can get through the limitations of our working memory and enhance our ability to learn and recall new information if we organize it in greater, more meaningful fragments.

Several academic research papers such as Lindstormberg and Boers (Boers and Lindstromberg 7) and Zhao (Zhao 69) have examined the use of lexical fragments and bundles in language learning. Lindstormberg and Boers (Boers and Lindstromberg 11) explored additional means of facilitating the learning of lexical items. The results provided evidence that learners are able to memorise L2 fragments with alliteration much more easily than similar but non-repetitive fragments.

Based on the empirical data from "An empirical study of L2 learners use of lexical chunks and language production" by Ying Zhao (Zhao 72) statistical analysis allowed us to conclude that subjects with a higher level of mastery of lexical chunks show higher results in the written test, and vice versa. It has been proved that lexical chunks have a positive effect on learners' L2 language development. In addition, they can increase the motivation of L2 learners because chunks will allow learners to create expressions that they cannot yet construct in their language system, which means that this strategy falls under the principles of brain-based learning.

Overall, the importance of lexical chunks in improving language skills and fluency has been confirmed in several previous studies. In some studies, they have been correlated with language skills and long-term memory. The use of lexical units was found to be effective for vocabulary learning and language skills, even though they were investigated at different levels.

4.2 Semantic mapping

The next strategy that is going to be applied to the research is called semantic mapping. Semantic mapping is the next strategy that will be used in research. It is a visual tool to help learners organize their prior knowledge and connect it with new information, according to Johnson and other researchers.

The word mapping strategy, or semantic mapping, is one of the most effective approaches to teaching vocabulary because it gets students thinking about word relationships (Johnson 96).

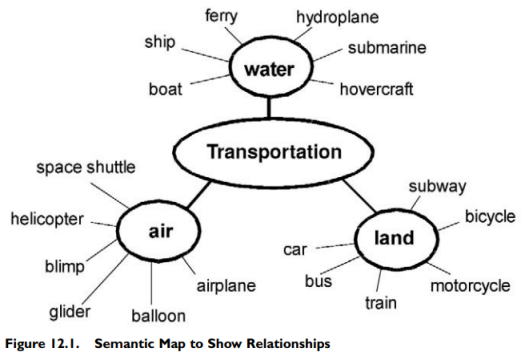

Figure 2.Semantic map to show relationships (Johnson 97)

Studies (Matthews 160) show that it is the analysis of the material that aids in the recall of it. Several successful teachers have found that mind maps and other graphic organizers not only improve students' understanding of the material but also keep them learning new things. The mind map has a central organizing theme (such as an author, a science topic, or a math concept). Studies show that when students organise the material (instead of the teacher doing it for them), they recall it better (McDaniel et al 521).

Learners will be able to recognise the most important words and activate their previous knowledge of this subject, thanks to a semantic map. They can see how words are related to each other and their previous knowledge when they insert new words and categories into the map. This can help them remember words and apply them to the context.

The most widely known use of semantic mapping as a learning strategy is vocabulary development. As part of this strategy, the semantic map process enables learners to understand, interpret and analyse what they have learned. Johnson and Pearson (Johnson and Pearson 37) adapted the semantic mapping procedure for vocabulary development:

1. Choose a word or topic related to classroom work.
2. List the word on a large chart tablet or the whiteboard.
3. Encourage the students to think of as many words as they can that are related to the selected keyword and then list the words by categories on a sheet of paper.

4. Students then share the prepared lists orally and all words are written on the class map in categories.
5. Students can gain further practice in classification by labelling the categories on the semantic map.

Furthermore, visual representations of words and concepts such as pictures or symbols may be used to modify semantic mapping for ESL learners. For learners who do not have a good understanding of the English language, this can help them to understand how words and concepts are connected. The strategy of allowing students to create their own visual images is a great strategy of analysis-focused recall (Weinstein and Mayer 315).

Nilforoushan (Nilforoushan 164) investigated the impact of vocabulary learning through semantic mapping on the perception of the two affective dimensions, evaluation and potency of deep lexical knowledge and total vocabulary in English as Foreign Language (EFL) learners. Sixty adult students participated in this study and were randomly divided into two groups, experimental and control groups of 30 students each. At the end of the study, the students completed a vocabulary knowledge test and an awareness test on the evaluative and power aspects of vocabulary knowledge. The results indicate that semantic mapping significantly increased students' familiarity with the two dimensions. Abdollahzadeh and Amiri (Abdollahzadeh and Amiri 28) also confirmed the findings of Nilforoushan (Nilforoushan 165). They compared semantic mapping with traditional methods of vocabulary instruction in Iran. The study included 264 adult Iranian intermediate-level EFL learners from different language schools in Orumieh. They formed two equal groups: the control group had nine classes and the experimental group had eight classes. The posttest showed that the groups that used the semantic mapping strategy prevailed.

Ossen (Ossen 51) also investigated the effects of two different approaches to vocabulary instruction on how Spanish and English language learners recognised and understood the content of a science textbook. The study included 136 students from a control group as well as 2 experimental groups for semantic mapping and contextual identification. The effect of semantic mapping on vocabulary learning demonstrated a marked difference in mean scores.

In addition, the findings of previous studies also support this thesis. First, the study by Dilek and Yuruk (Dilek and Yuruk 1536) showed that using a semantic mapping strategy could improve students' vocabulary. They were more effective and motivated when using the semantic mapping strategy compared to traditional learning strategies. Based on these studies, it was found that semantic mapping is one of the effective foreign language learning strategies.

4.3 Frayer model

The Frayer Model (Frayer diagram) is a graphic organiser. Dorothy Frayer and her colleagues at the University of Wisconsin (Frayer Technical Report No. 16) in 1969.

The purpose of the Frayer Model (Buehl 84) is to identify and define unfamiliar concepts and vocabulary. Students define a concept/word/term, describe its essential characteristics, provide examples of the idea and suggest non-examples of the idea (knowing what a concept does not help define what it is).

To provide students with a visual representation of this information, it shall be displayed on a chart that is divided into four parts. The model encourages students to understand words in a broader context of reading selection by asking them to evaluate the concept of "word definition" and its characteristics and synthesise this information with examples or non-examples before applying it. It is also a way of activating existing knowledge on the topic and building up relationships.

Let us briefly explain each category of the scheme provided based on the definitions given in the book Frayer, D., Frederick, W. C., & Klausmeier, H. J. (1969), which is called “A schema for testing the level of cognitive mastery.” (Frayer Technical Report No. 16)

1. Definition

These are characteristics that cannot be done without, moreover, without them; the concept in the middle is already wrong and not justified.

2. Characteristics (additional information)

These are characteristics that are consistent with the concept in question; however, even if these characteristics are not present, we cannot question the validity of the concept under study.

3. Examples

It is necessary to give a valid example of the given concept.

4. Non-examples (opposite examples)

Something that contains the characteristics given above, but that cannot be classed as an example or something that represents the opposite of the concept.

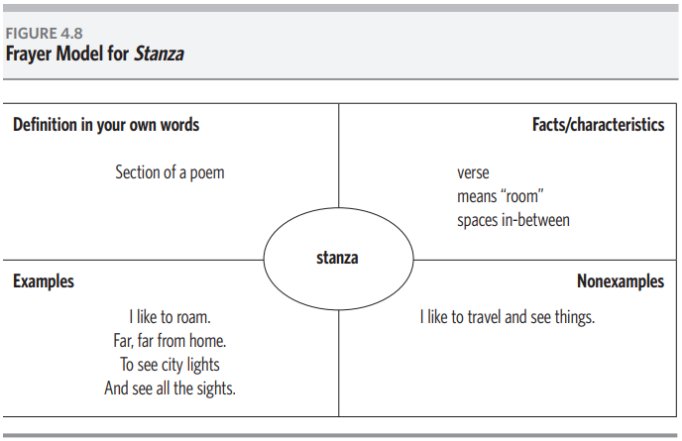

Figure 3.Frayer Model for stanza (Sprenger 110)

The use of the Frayer model allows students to think more in-depth about the terms they are learning. According to Frayer, Fredrick, & Klausmeier (Frayer Technical Report No. 16), the processes of the Frayer Model had seven steps:

1. Give the word and name its relevant attributes.
2. Eliminate irrelevant attributes.
3. Give examples.
4. Give examples of what the word is not (non-examples).
5. List subordinate terms.
6. List superordinate terms.
7. List basic terms.

These steps are a schema to learn an advanced concept and assess its knowledge. Early research on the Frayer Model did not involve a graphic organizer, as is commonly used today.

Moreover, it is necessary to provide the reader with the terms ‘subordinate’, ‘superordinate’, and ‘coordinate’ that were taken from Eleanor Rosch’s prototype theory (Rosch 7). According to the prototype theory, the first words children learn are the basic ones, because they reflect aspects of the world that stand out automatically from the rest of what they see—prototypes. Compared to the term “'superordinate level”, such as the term 'bird', or the term “subordinate level”, such as the term 'house sparrow', the term ‘sparrow’ is a basic level term. It is easier to use and learn the basic level of vocabulary. Children develop a higher and lower level of vocabulary on this basis.

The original model was later adapted by Graves (Graves 8) for broader use in direct vocabulary instruction. The adaptation reduced the framework to six steps:

1. Define the concept and give its essential attributes.
2. Distinguish between the concept and similar concepts.
3. Give examples and explain why they are examples.
4. Give non-examples and explain why they are non-examples.
5. Ask students to distinguish between other examples and non-examples given by the teacher and to explain why they are examples or non-examples.
6. Ask students to present their examples and non-examples and discuss why they are examples or non-examples.

According to Billmeyer & Barton (Billmeyer and Barton 69), the Frayer model is a strategy to help students understand a concept word and to improve their vocabulary. By using a framework consisting of four elements definition, characteristic, example, and non-example examples, it can help students to be actively involved in learning the meaning of that word. In short, the fact that the Frayer model strategy contributed significantly to language learning could be explained by this factor.

Based on the results built on several previous studies it was concluded that using the Fryer model in vocabulary learning was effective in increasing students' vocabulary knowledge. A study by Ilter (Ilter 1108) found that the Frayer model helps and promotes students' vocabulary development. Nahampun (Nahampun 3) also examined the effects of Frayer models on students' vocabulary learning. The author declared that teaching vocabulary using the Fryer model was more effective than traditional vocabulary teaching methods.

The key aspect of effective new vocabulary teaching is the development and application of learning strategies that are in line with brain function. Powerful tools for enhancing students' understanding, acquiring and retaining vocabulary are the Chunking method, Semantic Mapping methods as well as Frayer model.

The use of these strategies in the field of teaching allows for the creation of educational environments that promote the active participation of students in the process of learning new words. We will be able to consider how these techniques can be used on the ground during practical training. For example, it will help to organise the material and make it easier to understand if the lessons are structured in chunks. The use of semantic maps will allow students to see the links between words, which will help them to better understand and remember the vocabulary. The Frayer model, which contributes to deeper learning, will be able to stimulate discussions and contextualization of new words.

Therefore, the implementation of these strategies in the classroom will not only improve the acquisition of new vocabulary but will also create a stimulating and interactive learning environment that supports students' active participation and development of their language skills.

II. EMPIRICAL PART

5. Research aim

In this chapter, we investigate the effect of brain-based learning strategies on students' vocabulary growth. Our findings will be analysed to confirm the hypothesis that the use of strategies has a positive effect on the vocabulary acquisition of secondary school students. The null hypothesis that the use of these strategies does not lead to an increase in the vocabulary of secondary school students will also be examined.

For this study, a quasi-experimental quantitative design method was used to test the effectiveness of brain-based vocabulary learning methods by comparing four groups. Namely three experimental groups and one control group. In the experimental groups, students were taught using brain-based strategies while the control group used non-brain-based or traditional teaching strategies. Three kinds of tests were administered to the students in both groups, namely pre-test, post-test and delayed post-test.

6. Research methodology

The research methodology applied in this study is one of the most common types of research, namely the quasi-experimental approach. This method gives the author practical opportunities to evaluate impacts in actual contexts, which is why it was chosen, defined as “a comparison group that is as similar as possible to the treatment group in terms of baseline (pre-intervention) characteristics” (White and Sabarwal 1). Precisely because of this, four randomly selected groups were included in the study. They were randomly divided and determined three experimental groups and one control group respectively.

A quasi-experimental approach involves pre-test, treatment and post-test. For students in all groups, the pretest was administered before treatment. Richard and Schmidt (Richard and Schmidt 409) stated that the pre-test is a "test which has been administered before the commencement of instruction to determine pupils' current level of vocabulary." This was followed by treatment in the secondary vocational school COPG (Střední odborná škola Centrum odborné přípravy a Gymnázium, Poděbradská 179/1, Vysočany, 190 00 Praha 9, IČ: 14891212, Redizo: 600170063).

This took us two and a half weeks, with 3-4 English lessons per week for each group. The control group was taught using standard lexical learning strategies, whereas the experimental groups were taught with brain-based learning methods and strategies. All groups underwent two types of post-testing to assess improvements in vocabulary memorisation and acquisition.

6.1 Participants and research context

The participants of the experimental group are three subgroups from 1EL and 1M classes of 45 students. The control group includes 15 students from the fourth subgroup of class 1M. All participants are students of the Secondary School located in Prague at Podebradska. The age of the participants is approximately 14-16 years old. These students attend a technical secondary school and thus have their schedule, slightly different from that of a regular school. One week is spent in classrooms where students study subjects

from the general school programme, such as English, for example. The second week, which is practical, is spent in technical classes, depending on the subject area.

1M is a class of students who study electro-mechanics. There are about 15 people in each subgroup. The peculiarity of working with one of the subgroups of this class is the fact that on Thursdays, we have three consecutive lessons with them from 8 am, and, naturally, it is almost impossible to keep their attention during the whole learning process. The most difficult thing for me as a teacher is to prepare lesson plans for this period.

1EL is a class of students studying electrical engineering. The students in this class have a slightly lower level of English than the previous class. In addition, it can be said that one of the subgroups also has problems with attendance, since English is most often the last lesson in the timetable. However, both classes are attended by students with a higher level of language and, in addition, a higher level of knowledge of technical terms in their specialty. They often take the most active part in discussions and are the leaders of pair and team assignments.

I have been working as a teacher in this school for about 4 months and I can say that I have managed to make a contact with the children, despite my young age; I have a rich experience of working in different schools, both in the Czech Republic and in my home country - Russia.

It is worth mentioning that all the students are active and in their adolescence, which is perhaps the most difficult thing for a teacher, nevertheless, I consider that I managed to win their respect. It is often the case that it is not easy for me as a teacher to manage the noise in the class and keep the students interested, although when we began to study new words relating to a topic that was relevant to them, which they would be able to apply in their practical lessons, their enthusiasm for English lessons increased.

It is important to note that the choice of vocabulary to be taught in English lessons was selected not only based on brain-based learning but also taking into account the technical profile of the students and in accordance with the vocabulary used by them in practical lessons at school. An interesting detail that should be mentioned by the researcher when describing the participants is that all participants in both the control and experimental groups are male.

In addition, in this paragraph, I would also like to look at the description of ŠVPs - the School Education Program, for the two classes I have chosen. The prerequisite for this course is knowledge of English at level A1 according to the Common European Framework of Reference for Languages - according to the ŠVP of 2022 for the fields of study of electro-mechanic and electrician. It is also mentioned that the student's knowledge of English and ability to communicate in a foreign language will increase his/her chances in the labour market and help him/her to find his/her way in the labour market (drawing up a CV, job application, answering an advertisement and an interview). The language group can also use the workshops on the school premises with the assistance of the vocational teacher to learn vocational terminology. Foreign language education takes place in all three years of study for 2 hours per week, i.e. 66 hours in each year.

6.2 Research problem

In many schools, education is most commonly structured around teaching basic English from a textbook, with no use of specialised terminology or any technical terms. Furthermore, teaching in lower secondary schools often ignores the importance of developing students' metacognitive skills that motivate them to reflect on the learning process. Hence, the content of learning is not adequately addressed and the individual differences of students are often not taken into account. Learning can therefore happen under conditions that are not supported by the brain's natural processes and circumstances in which it is innately capable of learning.

Brain-based learning is an educational approach that tackles these constraints and considers the way the brain functions. It puts the results of scientific research into practice in the teaching process. In the theoretical part, I have covered only a limited number of issues, as the scope of application of brain-based strategies is very wide, relating only to the teaching of vocabulary. The issues I have focused on in the theoretical part find their application in practical activities, relating to the teaching of vocabulary, that are elaborated according to some of the findings that were mentioned in the theoretical part. It was my goal to give students new vocabulary that they could immediately apply in

practical classes, and thus make learning for students much more engaging and meaningful.

These brain-learning principles as mentioned in paragraph 3.3 of the theoretical part are applied to the activities:

1. Recognise diverse learning styles and intelligences. Offer activities that cater to visual, auditory, kinesthetic, and other preferences.
2. Personalize teaching content and relate the material to students' lives.
3. Engage students in activities that stimulate both the left and right hemispheres. Balance analytical tasks (left hemisphere) with creative tasks (right hemisphere).
4. Teach students memory techniques. Mnemonics, visualization, and spaced repetition can improve memory recall. Encourage them to create vivid mental images related to the content.
5. Connect learning experiences to positive emotions. When students feel excited, curious, or passionate, their brains are more receptive to retaining information.
6. Encourage collaboration among students. Cooperative learning fosters a sense of community and allows pupils to learn from one another. When working together, they can share ideas, solve problems collectively, and develop social skills.

The study aims to implement these principles in English lessons in the above-mentioned secondary school through strategies for teaching new vocabulary that are based on them.

6.3 Research instruments

In the study, pre and post-testings of pupils' vocabulary knowledge were used on the selected topic before and after teaching. In addition, two tests were conducted: the first one immediately after the treatment and the second one a few weeks later, to check how firmly the newly acquired vocabulary had been consolidated and subsequently to draw conclusions about effective or neutral learning with the help of brain-based learning methods.

6.3.1 Description of Pre-Test

To test the participants' prior knowledge of vocabulary learning and memorisation, a pre-test was developed for all groups (experimental and control) before the treatment. The pre-test contained 3 different tasks and was designed to assess the vocabulary of ESL students aged 14 to 16 years old on the topic "Electrician's Tools" based on the textbook "Carrier Paths. Electrician. Book 1" (Dooley 6).

The tasks included fill-in-the-blank sentences, open-ended questions, and multiple-choice questions. The first task required students to choose the correct word from a list based on its definition, to make the task more difficult and eliminate random word choice, the researcher added two additional words not related to the task. The second task was multiple-choice questions, each question contained four choices, and in addition, two questions were to test if the students could identify an electrician's tool from a picture. In the third task, students had to answer three open-ended questions to test their understanding of the basic differences between electrician's tools and their basic functions. All tasks in the test were formulated in the students' native language, i.e, Czech. For the first two tasks, students could receive one point for each correct answer, totalling 8 points for the first task and 6 points for the second task. In the third task, each correct answer to one of the questions was valued at 2 points. The maximum number of points for the whole test was 20.

6.3.2 Description of Post-Tests: Immediate and Delayed

To test the participants' knowledge after teaching the vocabulary, two post-tests were developed for all four groups (experimental and control) after the treatment. Both tests (immediate and delayed) contained three different tasks and was designed to assess the vocabulary of ESL students aged 14 to 16 years old on the topic "Electrician's Tools" based on the textbook "Carrier Paths. Electrician. Book 1" by Virginia Dooley.

The tasks included fill-in-the-blank sentences, open-ended questions, and multiple-choice questions.

The first immediate post-test was given to the students after 2.5 weeks of treatment. The tasks in the post-test were identical to the tasks in the pre-test and matched the stated vocabulary that I tested. In order to ensure that the tests were not 100 per cent identical, answer choices were changed or swapped in some tasks. In addition, some changes were made in the first task; other words from the list were chosen to find definitions. In addition, the pictures in the second task, in which it was necessary to find the corresponding correct variant, were changed. The open-ended questions remained almost unchanged, but the wording of the question itself was changed. The number of points for the tasks and the test as a whole remained unchanged, as well as the test writing time.

The delayed post-test was designed to test the long-term retention of vocabulary acquired by learners after a one-week period. The data obtained will be used to analyse the effectiveness of the treatment in terms of long-term learning gains in the ongoing study. The second post-test was conducted with students after a week of completing the first post-test. It is worth noting that during the week we almost did not return to the vocabulary learnt earlier, moreover, the students did not repeat this lexis in any way and did not perform any tasks related to it.

The delayed post-test replicated the initial post-test in terms of overall appearance and content. This ensured consistency in the assessment of vocabulary knowledge while minimizing possible interfering indicators arising from differences in test design.

The tasks in both tests are identical, except for the questions in task 2, where the pictures were changed. In addition, apart from the above mentioned changes, the words and their definitions in the first task, the answer choices in the second task, and the questions in the final third task were swapped.

6.4 Treatment procedure and individual vocabulary activities

This section will visually describe the tasks that were given to the students in their English lessons, as part of the two and a half weeks of learning new words. The section is divided into three subsections, each of which focuses on one of the techniques for teaching vocabulary based on the brain-based principles described in the theoretical section. The textbook "Carrier Paths. Electrician. Book 1" by Virginia Dooley was chosen as the basis for teaching the new material. The rest of the tasks were selected by the researcher taking into account the brain-based principles and the lexical topic - “Electrician's tools”.

6.4.1 Semantic mapping

Activity 1.

As a warm-up for the first lesson, I decided to choose a semantic map. Firstly, I explained to the children how to use and how to create a semantic map. One of the problems we encountered with this task was the lack of pens and notebooks for the students, in the end, everyone was ready and we started. I aimed to find out which specific tools the students were already familiar with and if they knew their names and functions in English, so at the beginning of the warm-up we had a small brainstorming session. In the centre of the semantic map on the board, I drew the word tools and the boys named different things they use in their practical classes. There were about 5-7 concepts. In addition, I asked the students to leave a free space next to the name of each tool so that they could add their contextual characteristics and functions later on.

Then we worked on the tasks from the textbook and gradually supplemented our semantic maps as new terms, their descriptions, or functions emerged. One of the difficulties I encountered when implementing this assignment was that it was the first time the children developed a semantic map and many of them wrote just terms instead of a scheme. Despite these problems, many students were able to make colourful semantic maps and received encouragement from me in the form of stickers.

I also used the picture dictionary at Languageguide.org (Languageguide.org/tools) to help students visualise concepts. In addition to sounding out all the tools, there are two types of tasks. The first task is to listen to the audio and correctly select the instrument named on the recording, and the second task is to name the instrument that appears on the screen. In this way, we learnt how each instrument looks visually and practised pronunciation.

Brain-based principles that were employed: cooperative work, auditory and visual learning style respected, familiarize pupils with another way of organising vocabulary.

Activity 2.

The second task that reflects the use of semantic maps was the task with a description of tools and their basic functions for solving real practical situations. For this task, I asked the students to use their ready-made semantic maps from the previous lesson. First, we chose a few situations from the work of mechanics and electricians in which we could use the tools we already know. Then the students were divided into groups, each group was given a different situation and the task of repairing or fixing something depending on what happened and clearly describing the tools involved and their functions needed to solve the problem.

A small obstacle to the implementation of this assignment was that it took students in several groups a long time to come up with practice problems in which the new vocabulary could easily be used. In the end, we decided to use basic situations such as a motor not running, a burnt-out light bulb or an unplugged socket as examples. However, since I am not a professional in this field and hoped that the students would be able to easily come up with scenarios that I assumed they would encounter in practical classes;

this assignment took longer than I thought it would. Nevertheless, most students were able to clearly describe the use and function of each tool and their use in basic life situations.

Brain-based principles that were employed: activation of both hemispheres in the learning process, learning through patterns (mind maps), personalised learning content, and involvement of conscious and unconscious processes in learning.

Activity 3.

As a warm-up exercise in one of the lessons, I also used an exercise on the correlation between the names of tools and their visual representations, as one of the basic principles of brain-based techniques is visualisation, which was mentioned several times in the theoretical part. After students correctly named an instrument, I asked additional questions about its function or what the instrument consisted of.

Brain-based principles that were employed: focus on memory, the importance of review, visualization.

Activity 4.

One of the tasks that took us quite some time to prepare was making visual semantic maps. I divided each group into small subgroups of 3-5 people, and then each group received a piece of paper, scissors, glue and most importantly a catalogue with different tools for mechanics and electricians. The hardest part for me was to find several different catalogues that would show the tools we were taking apart in the lessons. The students' task at this stage was to cut out the necessary tools from these catalogues and place them on a sheet of paper to create a visual semantic map. I did not set any conditions for this task that is why each group decided in what order and sequence to place the pictures. The only task I formulated before distributing the material was that the word tools should be

placed in the centre of each map, and then the rest could be placed in any order based on this.

In the end, most groups chose the strategy of dividing the tools into subgroups. For example, they first labelled a group of different screwdrivers and then created branches and added different types of screwdrivers and did the same with types of wrenches. The second task, after cutting out the pictures and placing them on the map, was to sign each tool and its type and then briefly sign the function that the tool fulfils. I purposely did not assign roles in the team and did not tell the students who was responsible for what, so these roles were assigned spontaneously during the activity. Some children took on the role of outside observers and cut out pictures, most likely so that during the difficult work there would be no claims that they were not doing anything. Further, the leaders were clearly visible, in some groups they were not the ones who were the leaders in the class, but the ones who had the best knowledge of the topic and could identify the tools and their functions. There were also those who did nothing and hardly interacted with the others, even despite my comments. In addition, there were self-selected leaders who only commented and gave advice. Teamwork ran more successfully in some groups and less so in others. At the end of the semantic map-making process, I invited each group to the board where they had a chance to explain the location of their tools and comment on their choices.

Brain-based principles that were employed: focus on memory, the importance of review, and cooperative learning, personalised learning content.

Activity 5.

I used the bingo game as a final assignment before writing the first post-test. Since the test was supposed to have several tasks to correlate the picture and the correct name of the tool, I thought it was important to test the students' skill of recognising the tools visually. All the tools we learnt throughout the two units were used as fields in the bingo game. The students' task was to recognise the tool that I showed on the screen using the projector and cross out the square with its name on their card. To do this, I made a list of

the tools and the order in which I showed the pictures to the students. The winner was the one who filled in all the squares first. The main difficulty in carrying out this task was that some of the tools looked quite similar and the students were lost, confused about their names and started to react very noisily and get upset. Besides, in some groups pupils did not quite understand that the task is not to cross out only one line, but to fill in the whole sheet with the bingo table, and only then the game is considered to be finished. To ensure that the assignment was not just a bingo game, but specifically a repetition and working through the proper terms before the final test, when the game was over, together with the students, we named each tool shown in the picture and just repeated the functions that a particular tool performs.

Brain-based principles that were employed: focus on memory, the importance of review, visualization.

6.4.2 Chunking

Activity 1.

I used the chunking technique for the most part either as a warm-up for the class or to reinforce what we had learnt. The task was to divide some compound nouns and say them to the students one by one for them to say the second part. For example, I would say wire and the boys would have to add stripper. We repeated this exercise in different variations, the first time the students worked orally all together, and another time they were the initiators and worked in a chain. For instance, one student would say part of the name of a tool and the name of a classmate who would continue the name. In this way, all students were ready and no one was distracted. In the same way, we practised the functions and characteristics of each tool. In this case, I gave the students the name and in response, I expected a verb that describes the function that the tool fulfils.

Brain-based principles that were employed: focus on memory, the importance of review, and cooperative learning.

Activity 2.

I also used the chunking method to practise new vocabulary at the end of the lesson. The students had to complete my sentence by adding the missing part of the sentence. For this task, I used kinesthetic technique, as I did not just call out the name of the student who had to answer, but threw them a ball, thus everyone was ready. The sample sentence for this task was "A screwdriver is a tool that...", so students had to complete the sentence by naming the function of the tool. The obstacle in the realisation of this task, as always, was the excessive activity of some students, who practically did not give other students a chance to think and speak, but since all my groups consisted mainly of teenage boys, this was understandable.

Brain-based principles that were employed: activation of both hemispheres in the learning process, spaced repetition techniques.

6.4.3 Frayer model

Activity 1.

One of the techniques for teaching new vocabulary that had proven to be quite difficult to implement in the classroom was the Frayer model. Perhaps the description of the model structure did not apply to the required vocabulary, or the instructions were not clear, but this exercise took quite a long time to complete and I do not consider it a success. Students worked in groups of 3-4 students, each given one instrument. The task was to break down each definition into the four categories specified in the Fryer model and then present the information to the rest of the group. The non-examples category proved to be the most difficult, as neither, the students nor I were 100 per cent sure what exactly fits or does not fit into this category. In addition, it became clear that some instruments had no examples or specific subspecies, so it was not possible to fill in the examples category. Analysing

the progress and results of this task, I concluded that it was not possible to repeat all the vocabulary items on the topic of electrician's tools using my chosen technique of learning new words. Based on this conclusion after conducting the task in the first group, I modernised the word choice and in the second group, the task was conducted more successfully.

Brain-based principles that were employed: focus on memory, the importance of review, and cooperative learning, familiarize pupils with another way of organising vocabulary.

7. Data analysis

This analysis examines the potential effect of training in four groups using paired sample t-tests. We will compare pre-test results with immediate and delayed post-test results in each group to determine whether the treatment had a significant effect on improving students' vocabulary.

A paired sample t-test is a statistical method to assess the difference between the mean scores of the same participants measured at different times. Here, we use the t-test formula to calculate the t statistic (t), which determines the mean difference between pre- and post-test scores, as well as the variability in each group. The p-value, a key element of the t-test, reflects the probability of obtaining the same (or even more extreme) results if there is indeed no difference between the pre- and post-test scores (null hypothesis).

A low p-value (usually less than 0.05) means that we can reject the null hypothesis and conclude that there is a statistically significant difference between the pre- and post-test scores in the group. This indicates that the treatment may have had a learning effect.

By analysing the p-values for each group and test (immediate vs. pre-test, delayed vs. pre-test), we can get an idea of the effectiveness of the treatment and the sustainability of learning over time.

7.1 Comparison of the pre-test and the immediate post-test results of all groups

The data reflect the results of a paired sample t-test, which is used to compare the average performance of two groups of the same participants measured at two different points in time. In this case, groups are evaluated on pre-test and immediate post-test results.
The figure shows the data for the four groups: Group 1 (1M G2 CONT), Group 2 (1M G1 EXP), Group 3 (1EL G2 EXP), and Group 4 (1EL G1 EXP). The diagram shows the data for all three tasks, each of which is labelled T1, T2 and T3, respectively, describing the task numbers. The word SUM reflects the final number of points for all three assignments. The letter H corresponds to the word hypothesis.

GROUP 1	CONTROL	1M G2 CONT		
	T1	T2	T3	SUM
p-val	0,08035587233	0,00494184035	0,04383530036	0,001300676061
H0 rejected	NO	YES	YES	YES
H1 confirmed	NO	YES	YES	YES

GROUP 2	EXPERIMENT	1M G1 EXP		
	T1	T2	T3	SUM
p-val	0,001072267484	0,09590640413	0,001606969715	0,000328384765
H0 rejected	YES	NO	YES	YES
H1 confirmed	YES	NO	YES	YES

GROUP 3	EXPERIMENT	1EL G2 EXP		
	T1	T2	T3	SUM
p-val	0,3122220924	0,04554128411	0,019870785	0,04304579159
H0 rejected	NO	YES	YES	YES
H1 confirmed	NO	YES	YES	YES

GROUP 4	EXPERIMENT	1EL G1 EXP		
	T1	T2	T3	SUM
p-val	0,6601111055	0,2058544833	0,07017029643	0,2875135498
H0 rejected	NO	NO	NO	NO
H1 confirmed	NO	NO	NO	NO

Table 1. Comparison between means of pre-test and immediate post-test

We will first examine Group 1 (1M G2 CONT), which was control. The p-value for the comparison between the pre-test and the immediate post-test is 0.0803. Given that the p-value is greater than 0.05, we cannot reject the null hypothesis, which assumes that the mean values of the two sets of results are equal. There is insufficient evidence to claim that there is a statistically significant difference between the pre- and post-test in this group.

Moreover, this pattern is repeated in group 4 (1EL G1 EXP), where the p-value is 0.6601. In groups 2 (1M G1 EXP) and 3 (1EL G2 EXP), the p-values are less than 0.05, so we reject the null hypothesis. This indicates that there is a statistically significant difference between the pre-test and immediate post-test results.

Some remarks are presented below:

- Hypothesis (H1) is that the mean values of the two sets of scores are not equal.

- In all groups except the last experimental group, hypothesis H1 is confirmed for total scores, but not always for each of the tasks.

Generally, the data indicate that in some groups, although not all, there is a difference between pre-test and immediate post-test scores. Further analysis would be required to identify the reasons for these variations.

7.2 Comparison of the pre-test and delayed post-test results of all groups

The data in the table show the results of a paired sample t-test, which is used to compare the mean scores of two groups consisting of the same participants measured at two different points in time. In this case, the groups are compared on pre-test and delayed post-test scores.

GROUP 1	CONTROL	1M G2 CONT		
	T1	T2	T3	SUM
p-val	0,2438283524	0,4591159855	0,03527084234	0,0366243636
H0 rejected	NO	NO	YES	YES
H1 confirmed	NO	NO	YES	YES
GROUP 2	EXPERIMENT	1M G1 EXP		
	T1	T2	T3	SUM
p-val	0,002256014149	0,5884493383	0,00419121721	0,0008390370663
H0 rejected	YES	NO	YES	YES
H1 confirmed	YES	NO	YES	YES
GROUP 3	EXPERIMENT	1EL G2 EXP		
	T1	T2	T3	SUM
p-val	0,4916564111	0,3068760901	0,00427043405	0,06784071139
H0 rejected	NO	NO	YES	NO
H1 confirmed	NO	NO	YES	NO
GROUP 4	EXPERIMENT	1EL G1 EXP		
	T1	T2	T3	SUM
p-val	0,6554050663	0,7051292361	0,02494346823	0,3518482622
H0 rejected	NO	NO	YES	NO
H1 confirmed	NO	NO	YES	NO

Table 2. Comparison between means of pre-test and delayed post-test

The figure shows the data for the four groups: Group 1 (1M G2 CONT), Group 2 (1M G1 EXP), Group 3 (1EL G2 EXP), and Group 4 (1EL G1 EXP).

We will again at first look at Group 1 (1M G2 CONT), which was the control group. The p-value for comparing the pre-test and delayed post-test is 0.0353. Because the p-value is less than 0.05, we do not accept the null hypothesis, which assumes that the mean values of the two sets of results are equal. There is evidence that there is a statistically significant difference between pre-test and delayed post-test in Group 1. In this case, the mean score on the pre-test was higher than the mean score on the delayed post-test.

The same dynamic is repeated in groups 2 (1M G1 EXP) and 3 (1EL G2 EXP), where p-values are also less than 0.05. In these groups, there is also a statistically significant difference between pre-test and delayed post-test scores.

In group 4 (1EL G1 EXP), the p-value is 0.4917. Since the p-value is greater than 0.05, we cannot reject the null hypothesis. There is not enough evidence to claim a statistically significant difference between pre-test and delayed post-test in group 4.

Here are a number of other additional points:

- Hypothesis (H1) assumes that the mean values of the two sets of scores are not equal.
- In the control group, the H1 was confirmed, as well as one of the experimental groups
- In two experimental groups, H0 was not denied, thus not proving significant improvements

Specifically, the data indicate that in two of the four groups there was a statistically significant difference between the pre-test and post-test scores. This suggests that the treatment may have had a learning effect that persisted in these groups over time. There is insufficient evidence to say the same for groups 1 and 4.

Group 4 is also an experimental group, which means that we have two experimental groups with statistically significant improvement and one control group, which together with one experimental group does not show a statistically significant improvement. We thus cannot say with 100% certainty that the treatment had a positive effect on all the experimental groups in comparison to the control group, which was taught traditionally.

7.3 Mean score differences between Pre-Tests and Post-Tests of Experimental Groups and Control Group

This analysis examines possible learning effects from the previously provided data by comparing pre-test scores to immediate and delayed post-test scores for the experimental and control groups.

We will inspect the mean and median total scores to assess the difference between the performances of the same participants measured at different times (pre-test versus immediate post-test and pre-test versus delayed post-test).

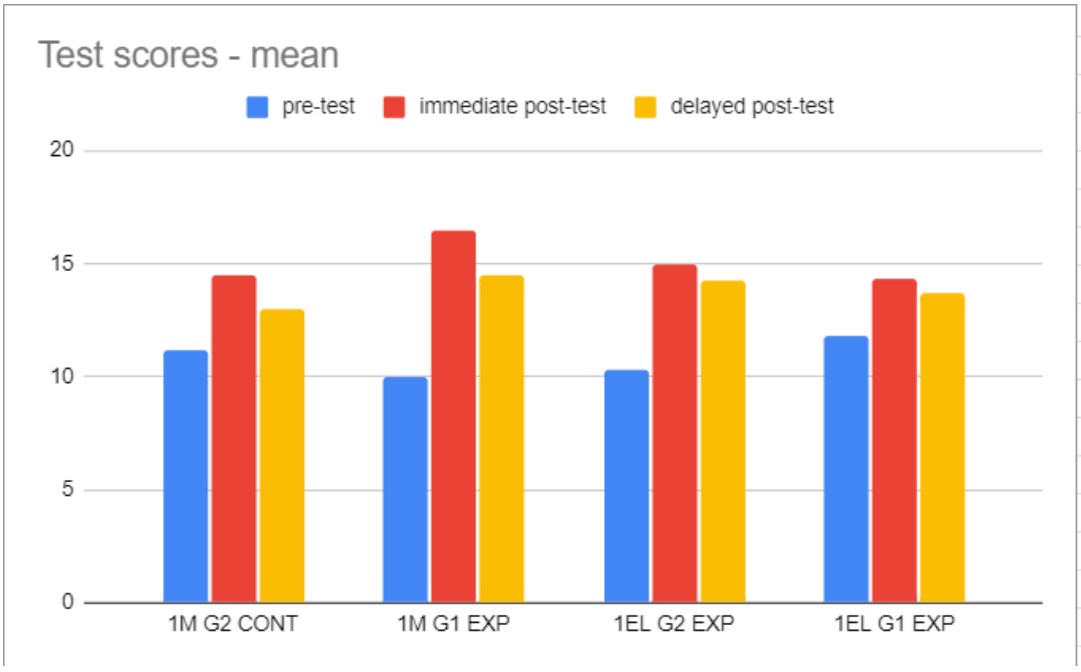

Table 3. Test scores (mean)

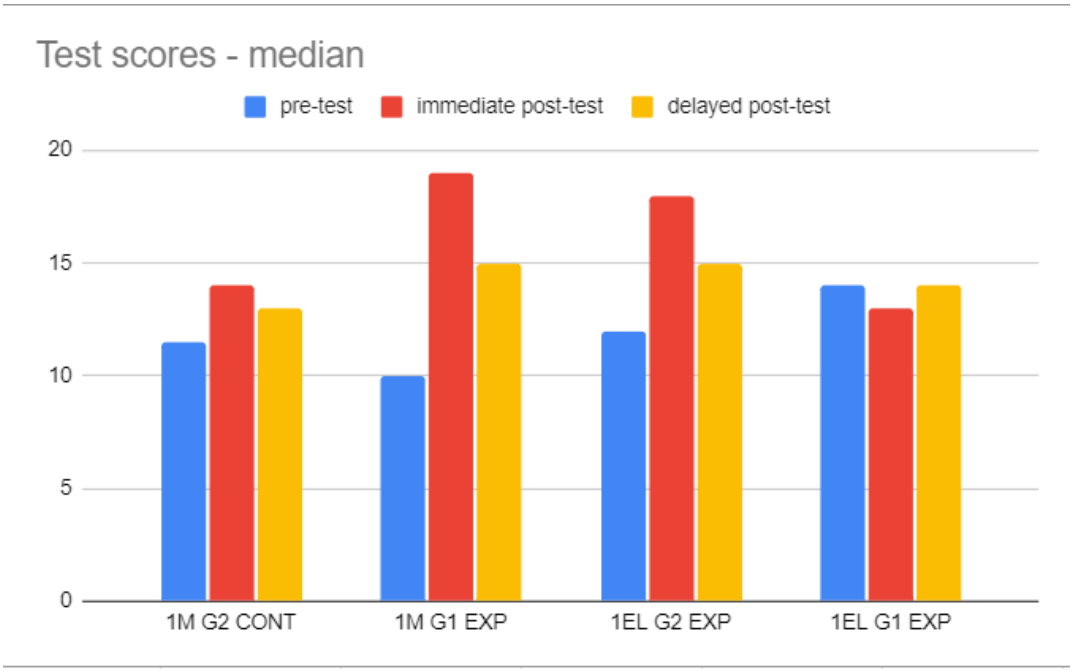

Table 4. Test scores (median)

Pre- and immediate post-test comparison:

Judging by the graphs above, we can see that there is a noticeable improvement of mean scores across all groups.

Based on the calculation of p-values of the data provided in the previous chapter, we already know that this is statistically not true for the fourth group, 1EL G1 EXP.

In groups 1 (1M G2 CONT), 2 (1M G1 EXP) and 3 (1EL G2 EXP), the p-values are less than 0.05, indicating an immediate learning effect in these groups. We can see that the absolute scores improved noticeably.

Pre- and delayed post-test comparison:

The findings demonstrate a slight decline in performance in comparison to the immediate post-test, and also support the calculations from the previous chapter, where we assessed that the improvement for groups 3 (1EL G2 EXP) and 4 (1EL G1 EXP) was not statistically significant.

7.4 The most frequent mistakes in the tests

One of the important parts of the conclusion is the analysis of the most frequent mistakes in the pre-test and subsequent post-tests, because from this we can infer the most difficult terms for students from the whole vocabulary that was selected for treatment.

The following graphs show the total amount of mistakes per definition for tasks 1 and 2 for all groups in total. Task 3 is individually analysed in another chapter and is thus omitted, also because it was a task with an open-ended answer.

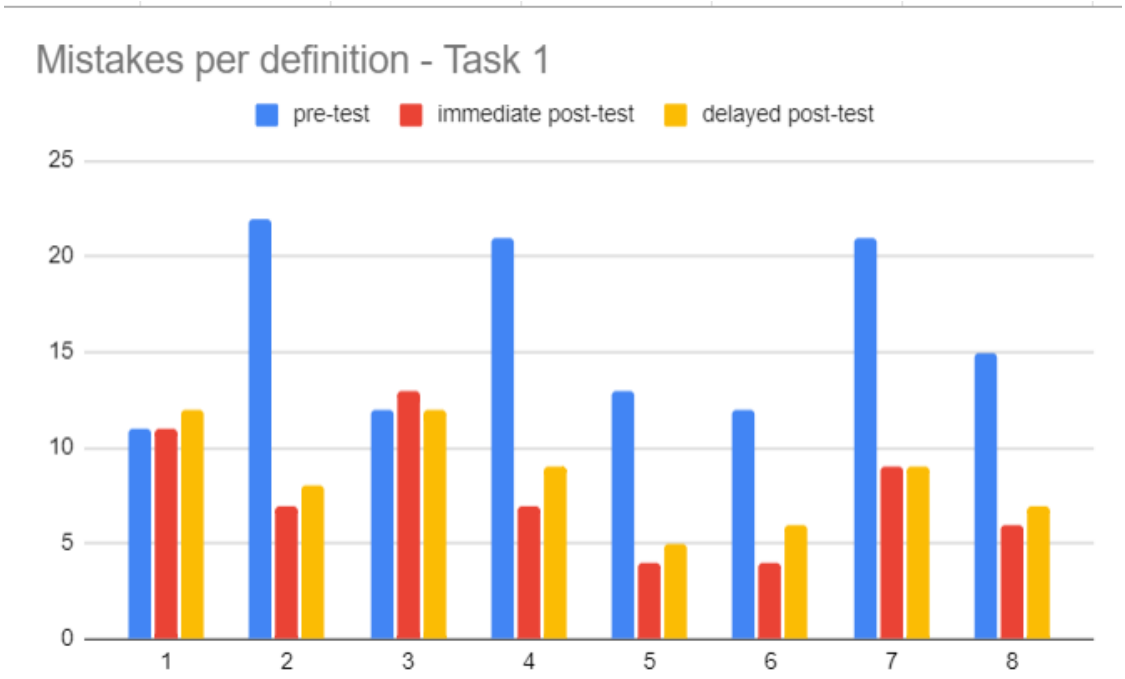

Table 5. Mistakes in task 1

Table 6. Mistakes in task 2

Upon analyzing the pre-test results, it can be concluded that in the first task the students struggled the most with defining the words numbered 2, 4, and 7. These words received incorrect answers or were left unanswered 22, 21, and 21 times respectively.

If we look closely at the words in the first task in the pre-test under these numbers *(side cutters, utility knife, end cutting pliers and long nose pliers)*, we can conclude that all these tools have similar functions and thus it was difficult for students to distinguish them from each other.

In the second task, question number 3 was the most difficult: 26 students could not choose the correct option. Question 3 was a picture with *a crimper* on it. It is possible that the students had not encountered the use of this tool in their practical classes and therefore could not recognize it.

Regarding the post-tests and their results, we can conclude that this time in the first task the most complications appeared with the word number 3 *(utility knife - a tool with a thin, sharp blade, is used to cut).* This may be because the definition given in the test was not precisely accurate and this may lead to difficulties. However, based on the fact that the definition was taken from the textbook on which the treatment was based (Dooley 4), it is reasonable to assume that students should be familiar with the definition of the instrument.

On the example of task 1 in the delayed post-test, it can be seen that students still have troubles with the differentiation between some tools. For instance, they keep confusing *long nose pliers* and *utility knife*, as both tools are defined as sharp-bladed tools.

In the second task, the most problematic was again the question number 3 with picture, seven students failed to answer it. Based on the analysis of answers, it is suggested that the majority of students confused the answers under *a) socket wrench* and under *b) allen wrench*, since both answers contain the word *wrench*, despite the fact that they refer to two completely different tools.

A similar tendency of mistakes remained in the delayed pre-test as can be seen from the graph, so in the second task under numbers 3 and 5 there were pictures and we can conclude that students still have difficulties in recognising some tools and their types, in this case it was *a screwdriver* and *a crimper*.

Based on these findings, it is evident that the analysis of mistakes in both the pre- and post-test stages provides valuable evidence of students' difficulties with the content. These data highlight the importance of developing teaching strategies to tackle misconceptions and enhance students' mastery of technical vocabulary.

7.5 Main findings of the study

Based on analyzing the data provided and the concept of paired sample t-tests, the main conclusions of the study were made. Although there are no individual p-values in the above data to directly compare the experimental and control groups, we can identify trends:

- In group 2 (1M G1 EXP), the experimental group showed a larger difference between pretest and immediate post-test compared to the control group. However, in the delayed posttest, both groups showed similar results.
- The findings suggest that treatment may have had a mixed effect on immediate learning progress. However, in most groups, with the exception of group 4, there was a more sustained learning effect that persisted over time (based on the delayed post-test).
- Group 4 is different in that there was no statistically significant difference between pre-test and immediate post-test scores. Further research should be conducted to find out why this group did not demonstrate the same learning patterns as the others. The pattern was very similar in the comparison between pre- and delayed post-test scores.
- Task 3 serves as a clear indicator of the treatment's success. It was an open-ended question task, in which each question cost 2 points. If we look at the results of task 3 in the pre-test, we can see that a large number of students left the task unanswered and received the corresponding number of points, i.e. zero, so we can conclude that task 3 was the most difficult for the students. Nevertheless, after the treatment, there were more positive answers, receiving at least some points in all groups, that indicates a deeper understanding of the questions and that students were able to consolidate the acquired material and apply the knowledge when performing the tests.

The graph shows the results of task 3 for four groups – 3 experimental and 1 control. The results are shown at three different points in time: pre-test that was conducted before the

treatment, immediate post-test, that was conducted immediately after the treatment, and delayed post-test, that was conducted one week after the treatment.

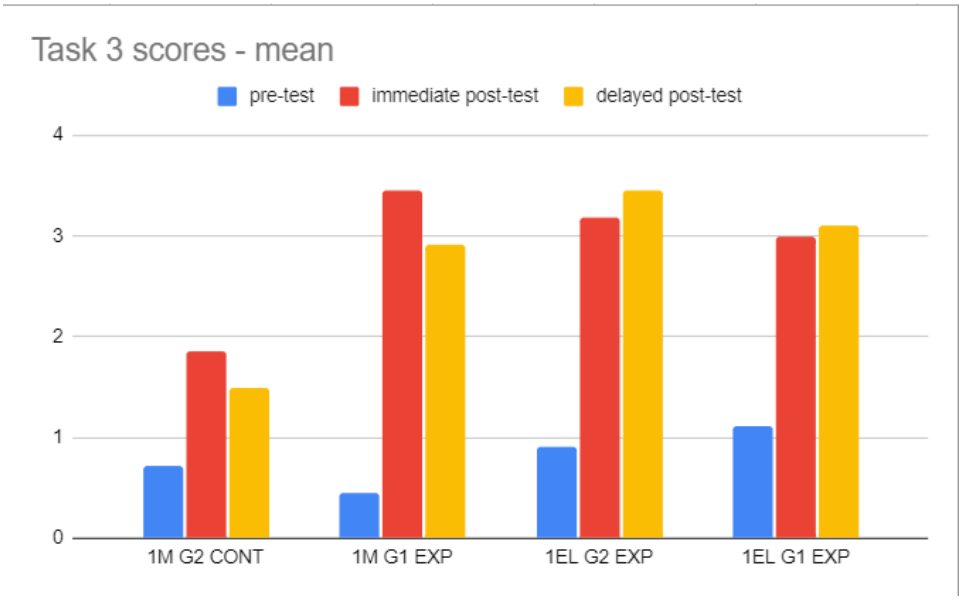

Table 7. Task 3 scores (mean)

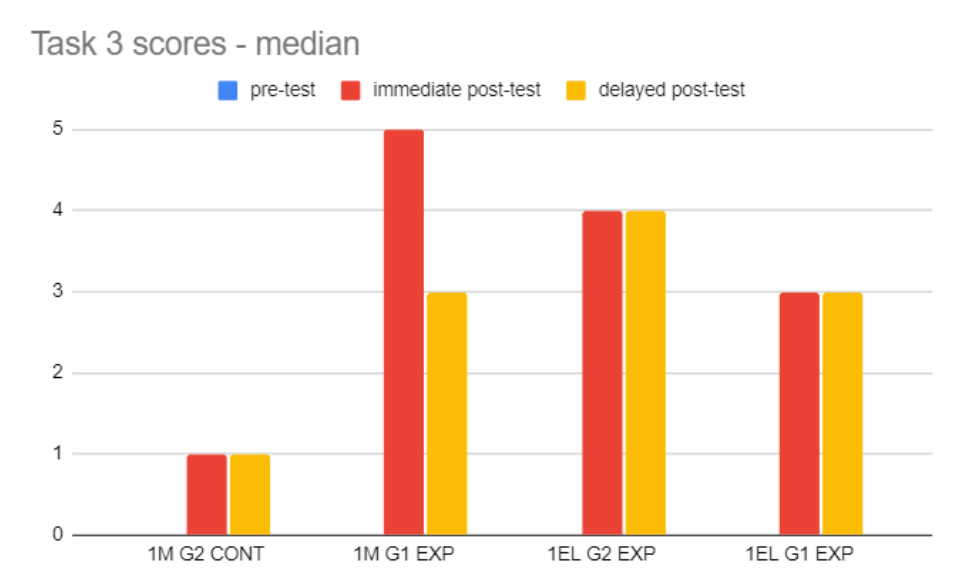

Table 8. Task 3 scores (median)

The x-axis shows the time of test performance, and the y-axis shows the students' scores. Blue bars represent pre-test scores, red bars represent immediate post-test scores, and orange bars represent delayed post-test scores.

Table 8 does not show the median values of the third task in the pre-test results because they were all zero among the groups.

The results show that the experimental group 1M performed better than other groups in all 3 phases of the test.

It is also important to note that the experimental group's scores decreased slightly between the immediate post-test and the delayed post-test, while the control group's scores increased slightly. This suggests that the control group may have learnt more than the experimental group during the week following the test. In this case, the results may have been influenced by the schedule of all the groups and the fact that the experimental groups had a week without English lessons and no direct treatment before the delayed post-test.

In addition, in the course of analysing the results of the study, several conclusions were drawn for each group based on the data on the mean and median of all tests performed by the students:

PRE	MEAN	MEDIAN
1M G2 CONT	11,14285714	11,5
1M G1 EXP	10	10
1EL G2 EXP	10,27272727	12
1EL G1 EXP	11,77777778	14
POST_IMM	MEAN	MEDIAN
1M G2 CONT	14,5	14
1M G1 EXP	16,45454545	19
1EL G2 EXP	15	18
1EL G1 EXP	14,33333333	13
POST_DEL	MEAN	MEDIAN
1M G2 CONT	13	13
1M G1 EXP	14,45454545	15
1EL G2 EXP	14,27272727	15
1EL G1 EXP	13,66666667	14

Table 9. Comparison of aggregated results of experimental and control groups

1. **Control group (1M G2 CON)**:

- The mean score in both post-tests increased significantly compared to pre-test
- The median score showed a similar improvement
- The scores between immediate and delayed post-test fell a bit, still were significantly higher than in the pre-test

2. **Experimental Group 1 (1M G1 EXP)**:
    - Similar trends as in the control group
    - The improvement was stronger than in the control group
    - The decline between delayed and immediate post-test was also stronger, but the improvement remained significant
3. **Experimental Group 2 (1EL G2 EXP)**:
    - Overall similar development as in the first experimental group
    - The absolute improvement was lower than in the first experimental group, but still stronger than in the control group
    - The decline between the immediate and delayed post-test was lower than in the previous two groups
4. **Experimental group 3 (1EL G1 EXP)**:
    - Unlike all other groups, the median score remained practically the same in all tests – pre-test, immediate post-test and delayed post-test
    - This group shows the least improvement between pre- and both post-tests

Additional observations:

The consistent mean score of the control group indicates the persistence of electrician's tool vocabulary knowledge.

The minor decrease in delayed post-test scores across groups may be due to forgetting or natural fading of knowledge over time. As Ebbinghaus stated in his research about the Forgetting Curve: “Under normal circumstances, frequent repetition is indeed indispensable for the reproduction of a given content. Vocabulary cannot be learned by a single repetition, even with the greatest concentration of attention on the part of an individual of very great ability. By a sufficient number of repetitions their final mastery

is ensured, and by additional later reproductions gain in assurance and ease is secured (Ebbinghaus 4).”

The possible reasons for such treatment results will be discussed in more detail in the next chapter of our study.

7.5.1. Value added comparison

For further analysis of the improvement, we can study the table below. It shows the mean scores for each test for each group, followed by the last two columns showing an absolute improvement between the mean scores of the pre-test and the immediate post-test, and the pre-test and the delayed post-test, respectively.

	PRE	IMM_POST	DEL_POST	IMM/PRE	DEL/PRE
1M G2 CONT	11,14285714	14,5	13	3,357142857	1,857142857
1M G1 EXP	10	16,45454545	14,45454545	6,454545455	4,454545455
1EL G2 EXP	10,27272727	15	14,27272727	4,727272727	4
1EL G1 EXP	11,77777778	14,33333333	13,66666667	2,555555556	1,888888889

Table 10. Value added comparison

In the above table, we can observe that the absolute improvement of the experimental groups seem overall larger than of the control group, with the exception of the fourth group – 1EL G1EXP. This result hints on the fact that the brain-based teaching strategies seem to have been more effective in the other two experimental groups, which also outperformed the control group. However, because the absolute improvement of the fourth group is almost the same as of the control group, it is not possible to claim this as with certainty.

Another intriguing metric in the statistics is the decline. Whereas the experimental group 1EL G2 EXP managed to maintain a 4-point improvement in the delayed post-test in comparison to the immediate test result of 4.73, the group 1M G1 EXP, which showed the biggest improvement between the immediate post-test and the pre-test, displayed a decline of 2 points when comparing the pre-test to the delayed post-test.

It is also worth noticing that the control group taught traditionally showed a decline of nearly 50 percent, by far the largest decline among the four groups.

In conclusion, the analysis of value-added data alone provides evidence for the higher effectiveness of brain-based teaching strategies in enhancing the vocabulary acquisition of adolescent English learners, in comparison to traditional teaching approaches.

8. Conclusion

As a conclusion to this thesis, it can be said that the aim of the study was to investigate effective brain-based learning strategies that enhance the vocabulary acquisition of English language learners aged between 13 and 16 years, with a particular focus on vocabulary related to the tools of electricians and mechanics, as the participants were students of a vocational secondary school. The study attempted to investigate vocabulary teaching in the context of innovative learning strategies that take into account brain functioning.

The study was based on a review of current theories and strategies of brain-based learning, as well as practical implementation of lessons using different vocabulary teaching strategies. In the theoretical part of the research, the concept of brain-based learning was explored and previous successful studies in this area were reviewed, highlighting such strategies as Frayer's model, semantic mapping and chunking as effective ones to facilitate vocabulary learning.

These strategies have been applied in teaching four different groups of learners. However, the results of the empirical part of the study showed that despite some improvements, a number of factors might have had a negative impact on learning performance. For example, despite a marked improvement in vocabulary acquisition, the statistical findings were not always significant, which may indicate that there are other variables affecting the outcome.

One of the factors that influenced the course and results of the study to a greater extent was the fact that the students did not actually have uninterrupted learning, as English lessons at the school take place a week apart. This is why it is difficult to consider the results of the study to be consistent, as the duration of the experiment was not properly observed. Perhaps if this study had been conducted for a longer period of time, the results would have been more conclusive and perceptible.

In addition, taking into account the fact that all groups are composed entirely of teenagers aged 13-16 years old, it cannot be denied that there are often problems with behaviour and noise during lessons, which naturally has a negative impact on the teaching process.

Another factor is that there is little or no homework at school and the students are not used to do it, therefore as a teacher, I did not have the opportunity to give vocabulary review tasks at home, which would probably have improved the results of the study.

Furthermore, it is probable that the selection of vocabulary words to be taught was quite extensive and complicated for the students, as many of them had only A1 level of English according to ŠVP.

Besides, it was also difficult to teach because some of the groups have problems with attendance, for which reason the teaching was not conducted properly.

It was very important for me to know the opinion of the students after the teaching, which is why after writing the last test, I allocated time for a short feedback. I handed out small pieces of paper to the students, on which I asked them to describe their impressions of the lessons and add their comments. The survey was anonymous. Some of the results will be presented in Appendix 9.

Moreover, when comparing the absolute improvements between the control group and the experimental group, it is noticeable that the experimental groups generally showed more progress. This would suggest that the brain-based teaching strategies might have been more successful than traditional teaching methods.

While the general improvement in the fourth experimental group (1EL G1 EXP) was similar to that of the control group, the overall trend suggests that brain-based teaching methods were more consistently effective, particularly in the other two experimental groups. The sustained improvement observed in the delayed post-test highlights the long-term benefits of brain-based teaching strategies.

Hence, the research cannot be fully considered a success in fulfilling all of its aims. Nonetheless, it represents useful findings for further improvement of teaching strategies and points out the importance of further research in this field to design more effective Brain-based strategies for vocabulary teaching among adolescent learners of English.

9. List of Sources

1. Abdollahzadeh, E.and N. Amiri. *The Effect of Semantic Mapping as a Vocabulary Instruction Technique on EFL Learners with Different Perceptual Learning Styles*. 1, The Journal of Applied Linguistics, 2009.
2. Ambrose, S. A., et al.. *How Learning Works: Seven Research-based Principles for Smart Teaching*. 2010.
3. American Psychological Association, ., et al.. 2002.
4. Baddeley, A.. *Working Memory*. Claredon Press, 1986.
5. Billmeyer, R.and M. L. Barton. *Teaching Reading in the Content Areas: If Not Me, Then Who?*. MCREL Research Laboratory, 1998.
6. Black, J., et al.. Proceedings of the National Academy of Sciences of the USA, 1990.
7. Blum, S.. *Universals of Lexical Simplification*. 1978.
8. Boers, F.and S. Lindstromberg. *Cognitive Linguistic Approaches to Teaching Vocabulary and Phraseology*. Mouton de Gruyter, 2008.
9. Brown, H. D.. *Teaching by Principles: An Interactive Approach to Language Pedagogy*. 2nd ed., 2001.
10. Bruzzano, C.. *4 Counterproductive Learner Beliefs and How to Tackle Them*. TESOL Connections, 2018.
11. Buehl, D.. *Classroom Strategies for Interactive Learning*. 2nd Ed., International Reading Association, 2001.
12. Caine, R. N.and G. Caine. *Making Connections: Teaching and the Human Brain*. Addison-Wesley Publishing Company, 1994.
13. Cameron, L.. *Teaching Languages to Children*. Cambridge University, 2001.
14. Catalan, R.. *Sex Differences in L2 Vocabulary Learning Strategies*. 2003.
15. Chomsky, N.. *Language in Mind*. Cambridge University Press, 2006.
16. Cohen, C.and E. Macaro. *Language Learner Strategies*. Oxford University Press, 2007.
17. Cook, V.. *Second Language Learning and Language Teaching*. 5th Edition, eBook, Routledge, 2016.
18. Daneman, M.and I. Green. *Individual Differences in Comprehending and Producing Words in Context*. Journal of Memory and Language, 1986.
19. Dilek, Y.and N. Yuruk. *Using Semantic Mapping Technique in Vocabulary Teaching at Pre-intermediate Level*. Procedia - Social and Behavioral Sciences, 2012.
20. Durston, S., et al.. *Anatomical MRI of the Developing Human Brain: What Have We Learned?*. J Am Acad Child Adolesc Psychiatry, 2001.
21. Ebbinghaus, H.. *Memory: A Contribution to Experimental Psychology*. 1885.
22. Evans, V., et al.. *Career Paths: Electrician*. Express Publishing, 2012.
23. Fakeye, D. O.. *Students' Personal Variables as Correlates of Academic Achievement in English as a Second Language in Nigeria*. no. 3, Mar. 2010, https://doi.org/10.1080/09718923.2010.11892803.
24. Farhady, H.. *Twenty-five Years of Living with Applied Linguistics: Collection of Articles*. Rahnama press, 2006.

25. Frayer, D. A., et al.. *A Schema for Testing the Level of Concept Mastery*. Technical Report No. 16, University of Wisconsin, 1969.
26. Graves, M. R.. *A Word Is a Word . . . Or Is It?*. Scholastic, 1985.
27. Hart, L. A.. *Human Brain and Human Learning*. Longman, 1983.
28. Ilter, I.. *The Investigation of the Effect of Frayer Model on Vocabulary Knowledge in Social Studies*. 2015.
29. Intaraprasert, C.. *A Preliminary Investigation of Vocabulary Learning Strategies Employed by EST Students*. Suranaree Journal of Science and Technology, 2005.
30. Jensen, E.. *Brain-based Learning: A Reality Check*. 2000.
31. Jensen, E.. *Teaching with the Brain in Mind*. 2nd ed., Association for Supervision and Curriculum Development, 2005.
32. Johnson, A. P.. *Teaching Reading and Writing: A Guidebook for Tutoring and Remediating Students*. Book, 2008.
33. Krashen, S. D.. *Second Language Acquisition Theory and the Preparation of Teachers: Toward a Rationale*. 1983.
34. Laufer, B.. *Focus on Form in Second Language Vocabulary Learning*. EUROSLA Yearbook, 2005, https://doi.org/10.1075/eurosla.5.11lau
35. Lee, E.and M. J. Hannafin. *A Design Framework for Enhancing Engagement in Student-centered Learning: Own It, Learn It, and Share It*. 64(4), Educational Technology Research and Development, 2016, doi:10.1007/s11423-015-9422-5.
36. Lessard-Clouston, M.. *Teaching Vocabulary*. TESOL International Association, 2013.
37. Matthews, R. C.. *Semantic Judgments as Encoding Operations: The Effects of Attention to Particular Semantic Categories on the Usefulness of Interim Relations in Recall*. Journal of Experimental Psychology: Human Learning and Memory, 1977.
38. Miller, G.. *The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information*. Psychological Review, 1956.
39. Nahampun, E.. *The Effect of Using Frayer Model on Students' Vocabulary Mastery*. 3, Journal of Applied Linguistics, 2014.
40. Nation, P.. *Learning Vocabulary in Another Language*. Cambridge University Press, 2013.
41. Nilforoushan, S.. *The Effect of Teaching Vocabulary Through Semantic Mapping on EFL Learners' Awareness of the Affective Dimensions of Deep Vocabulary Knowledge*. 2012. *English Language Teaching*, https://doi.org/10.5539/elt.v5n10p164.
42. O'Dell, J.. *Neuroeducation: Brain Compatible Learning Strategies*. 1981.
43. Ossen, V. M.. *An Examination of the Effects of Semantic Mapping for Improving Vocabulary Recognition and Comprehension of Scientific School Students (english Speaking)*. Unpublished Ph.D. Dissertation, 2004.
44. Oxford, R. L.. *Language Learning Styles and Strategies*. Ed., Mouton de Gruyter, 2003.

45. Piaget, J., et al.. *The General Problems of the Psychobiological Development of the Child*. pp., Tavistock, 1960.
46. Richard, C.and R. Schmidt. *Dictionary of Language Teaching and Applied Linguistics*. Pearson Education, 2002.
47. Rosch, E., et al.. *Principles of Categorization*. essay, L. Erlbaum Associates, 1978.
48. Schmitt, N.*Instructed second language vocabulary learning.* Language Teaching Research, 2008, https://doi.org/10.1177/1362168808089921
49. Schütz, R.. *Stephen Krashen's Theory of Second Language Acquisition*. English made in Brazil, 2007.
50. Smith, B.. *Computer-mediated Negotiated Interaction and Lexical Acquisition*. 2004.
51. Sowell, E., et al.. *In Vivo Evidence for Post-adolescent Brain Maturation in Frontal and Striatal Regions*. 1999.
52. Sprenger, M.. *Teaching the Critical Vocabulary of the Common Core: 55 Words That Make or Break Student Understanding*. ASCD, 2013.
53. Thornbury, S.. *How to Teach Vocabulary*. Pearson Education Limited, 2002.
54. Weinstein, C.and R. Mayer. *The Teaching of Learning Strategies*. 3rd ed., Macmillian, 1986.
55. White, H.and S. Sabarwal. *Quasi-experimental Design and Methods*. 2014.
56. Wilkins, D. A.. *Linguistics in Language Teaching*. 1972.
57. Wolfe, P.. *Brain Matters: Translating Research into Classroom Practice*. Association for Supervision and Curriculum Development, 2001.
58. Zahar, R., et al.. *Acquiring Vocabulary Through Reading; Effects of Frequency and Contextual Richness*. 2001.
59. Zhao, N.. *An Experimental Study on the Effects of Different Reading Tasks on L2 Vocabulary Acquisition*. English Language Teaching Journal, 2009.

10. List of Appendices