

الجمهورية الجزائرية الديمقراطية الشعبية  
PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA  
وزارة التعليم و البحث العلمي  
MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC  
RESEARCH  
جامعة عمار تليجي بالاغواط  
UNIVERSITY OF Ammar Telidji LAGHOUAT



كلية العلوم  
FACULTY OF SCIENCES  
قسم الاعلام الالي  
DEPARTMENT OF COMPUTER SCIENCE  
MASTER Thesis

**Field :** Mathematics and Computer Science

**Option :** Computer Science

**Specialization :** Information And Decision System (Business Intelligence)

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**Theme**

**LLM support to Arabic Pedagogical Tool**

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Academic Year 2023/2024

# Dedications

*In the Name of Allah the Most Merciful, the Most Compassionate First and foremost, I must acknowledge my limitless thanks to Allah, for His help and bless by giving me the opportunity, courage and enough energy to carry out and complete the entire thesis work. To the first two heroes in my life, to those who sacrificed their lives for mine, to those who paved the way for me at the expense of their happiness and comfort, to those whom I have not done enough for, to those who inspired me with their strength and patience, to the two individuals i am most proud of, to the two people who are the reason i have reached this point — My beloved parents. A simple "thank you" is far less than what you deserve, but i will express my gratitude nonetheless. Thank you for being the shelter and home i could always rely on. Thank you for silently bearing so much. Thank you for supporting me even when i didn't deserve it. Simply put, thank you for being my parents. To the person who unwaveringly believed in me when no one else did, to the one who saw my strength before i could see it, to the first person who supported me on this journey, Laateur Ines. Your support and faith in me have been the driving force behind my accomplishments. Thank you. I am forever grateful for your presence in my life. To those who shared the journey with me through its ups and downs, to my best friends and brothers, Akram, Salah, Housseem, Yacine. Thank you for your support. Your honesty and genuine support have been invaluable to me. And finally, to the one who deserves the most thanks and love, to myself. Thank you for believing in me. Thank you for overcoming everything that has come my way. I am extremely proud of you, you did great! Yet, this is only the beginning. Graduation day has arrived ... Finally i can confidently proclaim ... I did it .*

*Aouissi Abdelnour .*

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*In the name of Allah, the Most Gracious, the Most Merciful. , whose guidance and blessings have made this work possible.*

*I dedicate this work to everyone I hold dear in my life, to my parents, whom without this work would've been outright impossible, but their guidance, wisdom, support and unconditional love make everything possible*

*I dedicate this work to my siblings, who have always been there for me when I needed them, and who showed me I can count on their support for many more years to come.*

*I dedicate this work to my friends who have been supportive and encouraging throughout this journey.*

*To every Man or Woman who has answered a question I had or provided an information I needed,I dedicate this work to you.*

*Brik Djamel Eddine .*

# Acknowledgments

We are with great pleasure that we reserve these few lines as a sign of gratitude to all those who have contributed directly or indirectly to the development of this work. First of all, we would like to address our most sincere thanks to our supervisor Mme. Cherroun Hadda for her availability, patience, and precious follow-up throughout the realization of this work. We would also like to thank the members of the jury for having devoted part of their time to reading this thesis and for their interest in this work. Our thanks extend to all our teachers in the Computer Science department of the Amar Telidji The University of Laghouat. Finally, we would like to thank all the people who contributed directly or indirectly to the accomplishment of this work.

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Aouissi & Brik, June 2024

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# Abstract

Arabic, a language of worldwide significance, poses challenges for non-native speakers due to dialectal variances and limited resources. In response, we have sought to develop modern language learning activities tailored specifically for non-native Arabic speakers. Leveraging robust Large Language Models and Natural Language Processing technologies, our platform integrates interactive quizzes and pedagogical Conversational Partner to create dynamic and engaging learning environments. Our Conversational Partner, serving as pedagogical tools, embody the principles of constructivism and utilize Deep Learning techniques, including large language models and transformers, to facilitate language acquisition. Through text translation capabilities, learners can engage with Arabic content seamlessly, while Conversational Partners guide them through interactive exercises, fostering a personalized and effective learning experience.

The evaluation of the performances of our tool are realized through a human evaluation using a handmade sample of 100 quizzes. The result shown that our tool is suitable for Arabic learning

**Keywords :** Pedagogical Tool, Constructivism, Deep Learning, Large Language Models, Transformers, Text Translation, Chatbot Assistant.

## ملخص

اللغة العربية، لغة ذات أهمية عالمية، تشكل تحديات للمتحدثين غير الناطقين بها بسبب الاختلافات اللهجات والموارد المحدودة. استجابة لذلك، سعينا لتطوير أنشطة تعلم اللغة الحديثة الموجهة خصيصاً للمتحدثين غير الناطقين بالعربية. باستخدام نماذج اللغة الكبيرة وتقنيات معالجة اللغة الطبيعية القوية، تدمج منصتنا بين الاختبارات التفاعلية والشريك المحادثي التعليمي لإنشاء بنيوي لتعلم ديناميكي وجذاب. يعمل شريك المحادثة، كأدوات تعليمية، على تجسيد مبادئ البناء المعرفي ويستفيد من تقنيات التعلم العميق، بما في ذلك نماذج اللغة الكبيرة والمحولات، لتسهيل اكتساب اللغة. من خلال قدرات الترجمة النصية، يمكن للمتعلمين التفاعل مع المحتوى العربي بسلاسة، بينما يقوم شريك المحادثة بتوجيههم عبر التمارين التفاعلية، مما يعزز تجربة تعلم شخصية وفعالة. كما قمنا بقياس مدي نجاعة و أداء أدواتنا من خلال تقييم بشري باستخدام عينة مكونة يدويًا من ٠٠١ اختبار. وأظهرت النتيجة أن أدواتنا مناسبة لتعلم اللغة العربية،

**الكلمات المفتاحية:** اللغة العربية، أداة تربوية، الترجمة الآلية، ، التعلم العميقة ، النشاطات البيداغوجية، النماذج الكبيرة اللغة .

## Résumé

L'arabe, une langue d'importance mondiale, pose des problèmes aux locuteurs non natifs en raison des variations dialectales et des ressources limitées. En réponse, nous avons cherché à développer des activités d'apprentissage des langues modernes spécialement conçues pour les locuteurs non natifs de l'arabe. S'appuyant sur de grands modèles de langage et des technologies de traitement du langage naturel, notre plateforme intègre des quiz interactifs et un partenaire conversationnel pédagogique pour créer des environnements d'apprentissage dynamiques et attrayants. Nos partenaires conversationnels, qui servent d'outils pédagogiques, incarnent les principes du constructivisme et utilisent des techniques d'apprentissage profond (Deep Learning), notamment de grands modèles de langage et des transformateurs, pour faciliter l'acquisition de la langue. Grâce aux capacités de traduction de texte, les apprenants peuvent s'engager dans le contenu arabe de manière transparente, tandis que les partenaires conversationnels les guident à travers des exercices interactifs, favorisant une expérience d'apprentissage personnalisée et efficace.

L'évaluation des performances de notre outil est réalisée par une évaluation humaine à l'aide d'un échantillon de 100 quiz faits à la main. Les résultats montrent que notre outil est adapté à l'apprentissage de l'arabe.

**Mots-clés :** Outil pédagogique, Constructivisme, Apprentissage profond, Grands modèles de langage, Transformateurs, Traduction de texte, Assistant Chatbot.

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# Introduction

## Context

Language learning is crucial in today's globalized world, offering numerous opportunities for communication and advancement. Proficiency in a language requires honing listening[1] [2], writing[3] [4] [5], reading[6], and speaking skills[7] [8], necessitating the use of effective pedagogical approaches and tools. Traditional and modern pedagogical methods, aided by advancements in AI play a vital role in language education. Despite the cultural and historical significance of Arabic, learners often encounter challenges due to the scarcity of resources and materials [9] compared to more widely spoken languages. This scarcity makes the learning process more demanding, requiring innovative solutions to support Arabic language learners effectively.

## Problematic

Due to dialectal variances and limited resources, Arabic, a language of worldwide significance, can be difficult for non-native speakers to acquire[10]. Despite its cultural and historical importance, Arabic is considered a low-resourced language regarding learning materials, documents, and sources. This creates a significant challenge for non-native speakers who wish to learn Arabic, as they face difficulties in accessing quality learning tools and materials tailored to their needs. Furthermore, there is a notable rarity of advanced AI-based tools specifically designed for learning Arabic. Most existing AI-driven educational applications focus on widely spoken languages like English and Chinese, leaving Arabic underrepresented and underserved in the realm of AI-enhanced language learning.

## Objectives and Contribution

Our research work is part of a sustainable project called *Smart -Arabic-Learning* that aims harnessing recent advanced Deep Learning models and Active Learning Paradigms to enhance pedagogical tools that facilitate Arabic Learning for non-native Learners, by means of usage and deployment of advanced AI Technologies.

The Project functionalities are illustrated in [11]. Its grantees are essentially Arabic Language Learners called L2-Learners.

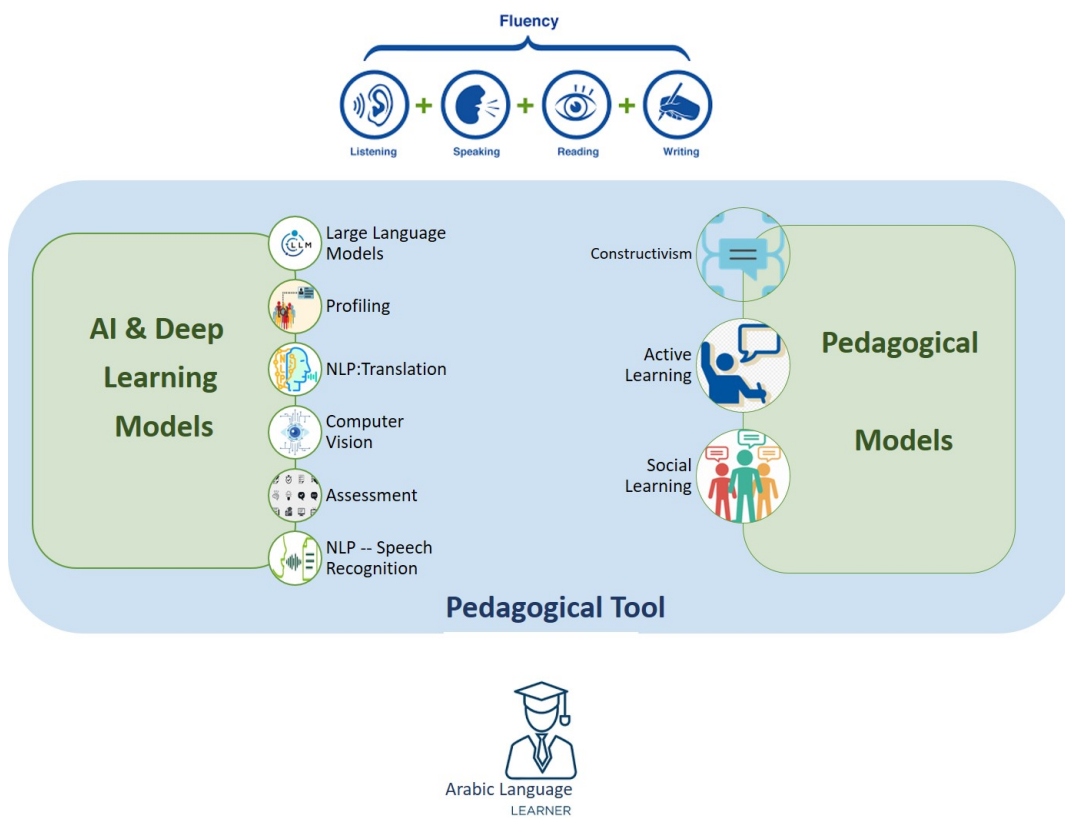


Figure 0.1: Smart Pedagogical Tool Project

The goals of the project are to monitor auto-training through high quality pedagogical activities, profile analysis, the main ones are:

- Creation of many learning contexts from real world situation,
- improving the learning outcomes,
- Providing learner by customized learning context,
- Providing remediation processes,
- Providing learning feedbacks,
- Deployment of optimized Deep Learning Models that can boost the nature and the diversities of the offered Pedagogical Activities.
- Deployment of State-Of-The-Art (SOTA) of Large Language Models

Our contribution in this substantial project has many goals. In a nutshell, the following are the objectives of the work:

- Deployment of State-Of-The-Art (SOTA) of Large Language Models to use them in our pedagogical tool, in order to offer **varied, several and unlimited** questions;
- To design and develop a Web application that can be used in learning the Arabic language by assisting students in attaining a variety of learning goals, such as improved language skills
- To evaluate our pedagogical tool and show its effectiveness in helping students learn the Arabic language

## Theses Structure

This thesis is structured as follows:

- **Chapter 1** covers generalities, including how to learn a language by mastering the four skills : speaking, writing, listening, and reading methods and comparing language learning tools.
- in **Chapter 2** discusses related work, then we talk about natural language processing (NLP) by Understanding NLP and the best ways to use NLP in education, along with an overview of Large Language Models (LLM)
- **Chapter 3** outlines our conception, including an overview of our approach, the proposed architecture, the LLM deployed , and system diagrams such as use case, class, and sequence diagrams.
- **Chapter 4** goes into the Implementation of our approach, the technologies leveraged and an Evaluation of our system.

# Chapter 1

## Generalities

in The Learning Language Science, The brain's flexibility challenges the idea of a "critical period"(the critical period hypothesis, or sensitive period hypothesis, proposes that there exists an optimal time-frame during brain development for acquiring language in an environment abundant with linguistic stimuli. After this period, the acquisition of additional languages becomes more challenging and requires greater effort) for language learning, suggesting that individuals of all ages can effectively learn new languages due to the brain's lifelong ability to adapt and form new connections[11]. Studies show that age plays an important role, however, motivation and exposure to good language input are just as significant for the achievement of language skills. Children are less cautious than adults who tend to worry about themselves due to such mental barriers as self-doubt and fear of embarrassment. As a result, knowing the most effective learning approaches based on the findings of the research is vital for adults who learn foreign languages.

### 1.1 How to Learn a Language

#### 1.1.1 Setting Your Language Learning Goals

It is important to set concrete and realistic language learning objectives to support learners in their language acquisition processes. This process involves several key steps :

##### **Defining Clear Objectives**

Establishing goals will help you establish your direction when learning a new language. It is a good strategy to understand from the beginning what you want to accomplish with your language knowledge. Objectives should be SMART: Specific, Measurable, Achievable, Relevant, and Time-bound [12]. For instance, the I want to learn Spanish is not specific like the I want to be able to speak Spanish fluently in six months [12].

##### **Long-term vs Short-term Goals**

There is a need to determine whether the language learning goals are long-term or short-term. General goals are the final outcomes that a student may hope to achieve, such as reaching proficiency in language use and passing a proficiency test. Here short-term goals are smaller, more easily achievable and lead to the achievement of long-term

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<sup>2</sup>Image taken from <https://www.recbound.com/recruitment-agency-blog/example-smart-goals-for-recruiters>



Figure 1.1: SMART Goals, <sup>14</sup>

goals. For example, a one-week goal could be to learn 50 new vocabulary words in a week or to read a chapter of a language textbook in one month, until it becomes a long-term goal like learning 1500 new vocabulary in 1-month [13].

### Creating a Realistic Study Plan

After the goals are set in linguistics, the subsequent step involves the creation of a study plan for attaining these goals. The study plan summarizes the steps that you need to take to achieve the learning targets including the number of hours for daily or weekly studies, the materials and resources that you intend to use, and the learning strategies that you intend to utilize. In formulating your study plan you should take into account factors like current level of knowledge, time available for study, the way you like to learn best, and if there are other obligations and commitments in your life that will affect your study time [12].

## 1.1.2 Building a Strong Foundation

Establishing a solid foundation is essential for success in language learning. This foundation serves as the groundwork upon which more advanced language skills can be developed. Several key components contribute to building this strong foundation:

### Mastering Basic Vocabulary

Another very important facet in the development of language learning skills is the mastery of vocabulary. These are words or phrases that are primary units of communication. Special attention: learning common nouns, verbs, adjectives, and adverbs used in everyday contexts. Let it begin with the fundamental words associated with the greets, the numbers, the colors, the family members, the food, and the activities of the day [8].

**Learning Essential Grammar Structures** Understanding essential grammar structures is fundamental to constructing meaningful sentences and expressing yourself accurately in the target language. Begin by familiarizing yourself with basic grammar concepts such as sentence structure, verb conjugation, noun-adjective agreement, and word order. Practice using these structures in context through exercises, drills, and example sentences. As you progress, gradually expand your knowledge of more complex grammar rules and sentence patterns, but ensure a solid grasp of the foundational struc-

tures first [14]. **Practicing Pronunciation and Intonation:**

Proper communication, means being able to pronounce words properly and inflect the right intonation. Spend some time working on the pronunciation. Listen to the native speakers and repeat after them. Notice ties among the sounds, the stress, and the language's rhythm. Take part in activities such as shadowing, imitating dialogues, and tongue twisters to help you develop the correct pronunciation patterns for your accent. You can accomplish this sharpened communication ability by putting in efforts in accent practice and intonation training [15].

### 1.1.3 Developing Listening Skills

Listening skills are crucial for effective communication and language proficiency. Here are some strategies to enhance your ability to understand spoken language:

#### **Active Listening Exercises**

Active listening exercises use a wide variety of listening activities during which students are actively involved and focused on listening tasks. These exercises often involve listening to audio recordings or live interactions and actively responding or reflecting on the content. Examples of active listening exercises include listening to dialogues and summarizing key points, transcribing spoken sentences, shadowing native speakers to mimic pronunciation and intonation, and participating in language exchange sessions or conversation practice with peers [16].

**Utilizing Podcasts and Audio-books** Podcasts and audiobooks are valuable resources for improving listening skills in a foreign language. Podcast helps learners to turn to different authentic spoken texts such as interviews, discussions, speeches, stories, and news. Audio books offer longer-form content that can help learners practice sustained listening comprehension [17].

**Watching Movies and TV Shows with Subtitles** Watching movies and TV shows with subtitles is a popular method for improving listening skills while also reinforcing vocabulary and comprehension. Learners can start by watching content in their target language with subtitles in their native language to aid understanding. As their listening proficiency improves, they can gradually switch to subtitles in the target language or even watch without subtitles to challenge themselves further. Additionally, learners can use subtitles as a tool for vocabulary acquisition by pausing the video to look up unfamiliar words or phrases and practicing pronunciation by repeating dialogue aloud [18].

### 1.1.4 Improving Reading Comprehension

The ability to read is an essential language skill. Here are some strategies to enhance your ability to understand written texts:

**Reading Techniques** Practice active reading techniques to engage with the text actively. These include scanning the text before reading to have an idea of what is coming, paraphrasing while reading to comprehend what the text has, or summing up the ideas captured from the text post reading [19].

**Vocabulary Expansion** Expand your vocabulary to improve reading comprehension. Develop dictionary skills to help the reader determine the meanings of unfamiliar

words and maintain a vocabulary resource for new words that are studied to reinforce vocabulary. Consider using vocabulary-building tools such as flashcards or language learning apps to reinforce your word knowledge[7].

### **Reading Aloud**

Try reading a text aloud for better fluency and understanding. Reading aloud forces you to pay closer attention to the text and helps reinforce pronunciation and intonation patterns. It can also aid in the retention of information by engaging multiple senses simultaneously [6].

## **1.1.5 Enhancing Writing Proficiency**

Writing proficiency in a foreign language can be significantly improved through various strategies like :

- **Daily Writing Practice**

Consistent practice is key to enhancing writing skills. Set aside time each day to write in the target language. It is advisable to begin with only a few paragraphs of writing followed by slightly larger segments and continue with progressively longer assignments. Practice also enables learners to memorize new words, grammatical constructs, and structure sentences that eventually boost learners' fluency levels [18].

- **Feedback and Revision:**

Seek feedback on your writing from teachers, language exchange partners, or online communities. constructive criticism helps indicate strengths and weaknesses and also teaches a person that mistakes ought to be corrected to improve a person. Incorporate feedback into your revisions to refine your writing skills further [3] [4].

- **Diverse Writing Tasks:**

It is important to engage in a wide range of writing assignments to further improve different aspects of writing. Start writing different kinds of texts, essays, e-mails or letters, stories, or summaries. Different genres of writing have their unique vocabulary patterns, structures, and conventions, which give you the necessary bases for studying and writing in different settings [5].

## **1.1.6 Technology for Language Learning**

### **Utilizing Language Learning Apps**

Educational/ Language learning mobile device applications are one of the many ways of practicing the subject in the comfort of the learners homes and offices. The focus of these apps is generally on vocabulary review and games; grammar exercises and practice; speaking practice; and interactive lessons. Sometimes they use gamification in the form of incentives and monitoring measures that help to make sure that the learners are involved and challenged. Now there are lots of popular language learning applications that include:

Duolingo, Babble, Rosetta Stone, and Memrise. They are easy to implement and use, and with proper selection of apps, you can create a custom curriculum that can be used as a compensatory language program and which can be personalized according to the training style of the learner

### **Exploring Online Resources and Courses**

The internet is filled with many websites, blogs, forums, and internet courses to assist the learner. Whether you want to learn the short or long course you can check in portals like Coursera, Udemy, and edX, which offer to learn the desired language via their specialists from all over the world. Moreover, numerous tools are available on the Internet that are specifically designed to assist individuals in language learning including FluentU and iTalki, which offer interactive videos and audio records, language exchange, and personal tutors. Read Online: Use these websites to locate content based on your particular interests, level of proficiency, and learning outcomes.

### **Incorporating Language Learning Software**

Language learning software provides comprehensive tools and resources for improving language skills. These software programs often feature interactive lessons, multimedia content, speech recognition technology, and personalized learning plans. Examples include Rosetta Stone, Pimsleur, Fluenz, and Transparent Language. By incorporating language learning software into your study routine, you can benefit from structured lessons, immersive experiences, and feedback mechanisms that facilitate language acquisition.

Finally, one can say that technology offers a number of opportunities that may be useful for learners that learn a new language This can leverage technology regarding language learning apps or programs that make learning easier, more interactive to the learner as well as more effective. Technology has been successfully used to start learning another language and wherever they go, through language learning applications, Internet pages, or programs.

## **1.1.7 Comparison of Apps Learning a Language**

In today's globalized world, communication in several languages has become a valuable feature. In light of the increasing demand, there are currently a variety of apps and websites that offer various approaches and learning tools for a second or third language. These digital platforms allow learners the convenience of learning at their own time and convenience, offering them a great variety of languages as well as usage of interactive and engaging methods of learning. This table will present a comparison of some of the most popular language learning applications and websites both in terms of their similarities and differences and in terms of some common approaches and components in the learning of a foreign language:

Tool	Description	First Release	AI based	Levels	Cost	Methods	Supported Languages
<b>Duolingo</b>	A language-learning platform that offers interactive exercises and lessons to help people learn new languages for free.	was officially launched on June 19, 2012	Yes - Continually adjusting lesson difficulty to match individual progress	Levels 1-5	-Free -Super Duolingo is \$13 per month or \$84 annually	- Translate with word puzzle - Transcribe audio in foreign language - Transcribe audio in native language - Pronounce word - Multiple Choice	There are 43 languages including arabic
<b>Kaleela</b>	is an arabic app for any non-native speaker or writer to learn arabic	was officially launched on 2021	no - Continually simple quiz	Levels A1-C2	-Free	- Pronounce word to answering- Multiple Choice	There is only one language to learn "Arabic".
<b>Rosetta Stone</b>	A language-learning software that uses immersive methods to teach users new languages through visual and auditory cues, without translation.	in 1992 with the first version of its CD-ROM language learning software	Yes - TruAccent speech recognition technology.	Levels 1-3	Paid lifetime subscription \$199	Immersion-Based Learning Method	There are 24 languages including arabic
<b>Pimsleur</b>	An audio-based language learning method that focuses on teaching language through listening and repeating exercises, gradually increasing in complexity.	The Pimsleur app in 2018	Yes - new AI-based pronunciation feedback	Levels 1-3	Paid \$20 a month	an audio based course that presents phrases in the target language first, and then in your mother tongue for you to translate into that language.	There are 59 languages including arabic
<b>Busuu</b>	A language-learning app that offers interactive lessons, exercises, and opportunities to practice with native speakers through a social networking feature.	in 2008 by N. Bernhard and A. Hilti.	Yes - AI algorithms to personalize lesson plans and review exercises.	Levels 1-4	- Free - Premium From \$3,49 per level \$14,99 full course	- Revision - Word puzzle - Word matching - Multiple Choice - Dialogues - Writing texts	There are 14 languages including arabic

Table 1.1: Comparison between apps and websites specialized in teaching languages

## 1.2 Natural language processing (NLP)

The concept of humans and machines working together in a smooth manner has become a common phenomenon. Ever wondered how your virtual assistants like Siri or Cortana or Bixby decipher your commands effortlessly? Or marveled at how your spell checker detects errors you might have missed? The reason behind these marvels is a fascinating field called Natural Language Processing (NLP), which is the connection between human language and intelligent machines.

### 1.2.1 Understanding NLP

NLP delves into the realms of understanding, manipulating, and generating natural language by machines, positioning itself at the intriguing intersection of computer science and linguistics. At its core, NLP empowers machines to directly engage with humans, enabling a wide array of applications across various domains. [11]

### 1.2.2 Natural Language processing applications

There are different methods of utilizing Natural Language Processing for working with text data. The fact that there are not many systems using NLP is just downright weird considering that text is everywhere. Here are some ways NLP is used:

- **Information Retrieval:** This means finding information in the text. Some systems, like those by Liddy and Strzalkowski, use NLP to do this better.
- **Information Extraction (IE):** This involves finding and tagging important information in text, like names of people or places. This info can be used for different things, like answering questions or analyzing data.
- **Question-Answering:** Instead of just showing documents that might have answers, NLP can directly give answers or parts of answers to questions.
- **Summarization:** NLP can take big pieces of text and make shorter summaries that still capture the main ideas.
- **Machine Translation:** NLP has been used for a long time in systems that translate languages. Some systems look at individual words, while others analyze text more deeply.
- **Dialogue Systems:** These are like talking to a computer, maybe in your home appliances. Right now, they focus on basic language stuff, but using all levels of language processing could make them even better in the future.

support for pedagogical tools in e-learning and distant learning

### 1.2.3 What are the most effective ways to use NLP in education

I believe that NLP has the power to change some of the important aspects of education. Here are some of the big effective ways to use NLP in education and our lives:

- **Adaptive Learning:**

There are many such examples of NLP being of use in education it can be used to create personalized learning systems that can tailor the content of lectures, their duration, and level of difficulty based on the response of students to the previous material. This approach includes the use of pre-assessment to set individual learning for each student based on what the student has learned in the past and how the student learns For instance, NLP can assist in generating tailored exercises and quizzes, providing immediate feedback, and recommending relevant resources like videos and articles.

- **Chat-bots and Virtual Assistants:**

An example of how NLP is useful in education is the use of chatbots and assistants that engage students and teachers in natural language. These tools offer support, guidance, and motivation, answering questions, providing reminders, and assisting with administrative tasks. By employing NLP-driven chat-bots, education becomes more interactive, with real-time assistance and feedback for both students and teachers.

- **Text Analysis and Summarization:**

NLP can also be used to analyze and summarize large volumes of text, helping students and teachers extract key insights efficiently. Text analysis tools identify themes, topics, and sentiments from diverse sources while summarizing tools condense texts into concise summaries. These tools enhance reading and writing skills, improve comprehension, and save time by presenting essential information in a clear and coherent manner.

- **Natural Language Generation:**

In education, natural language generation tools enable the creation of original and engaging texts using natural language. By utilizing data, keywords, images, or audio inputs, these tools produce relevant and creative texts such as captions, summaries, and stories. They aid in improving vocabulary, grammar, and expression, encouraging imagination and enhancing communication skills for both students and teachers.

### 1.2.4 Evaluating Language Models in NLP

Language models are pivotal in natural language processing (NLP), tasked with predicting subsequent words or characters in texts. Their performance is measured through different metrics such as perplexity, cross entropy, and bits per character (BPC). This approach represents the comparison of models and evaluates the models effectiveness in performing NLP operations. There are two primary evaluation approaches: latent and explicit. The

intrinsic evaluation entails the ability of the model to acquire information on the linguistic features of a language while the extrinsic evaluation centers on how the model effectively applies to the linguistic aspects. The model comparison may be done as follows: Every model used for the assignment is subjected to the overall data; the training and the testing data sets are partitioned; and the performance of each model is achieved through the ability to fit the data used for testing. The model that assigns higher probabilities to the test set is generally considered superior. However, it's essential to prevent test sentences from contaminating the training set to avoid biased evaluations and inaccuracies in metrics like perplexity. By ensuring rigorous evaluation protocols, researchers can effectively assess the capabilities of language models in NLP applications.

# Chapter 2

## Related Work

In this chapter, we will look over what has been done in the field of Arabic language learning using natural language processing (NLP), understanding past research helps us see what has been achieved and what gaps remain open for us to be able to explore, in the hope that helps us better steer our work

We will start by looking at the history of NLP in education. Then, we will explore different approaches used in NLP, focusing on methods and architectures that have been effective in language learning. We will also discuss how neural networks play a role in these tools.

Next, we will review tools specifically designed for Arabic language learners. We will examine their features and see how well they work in teaching Arabic. We will also look at recent advances in this area and discuss the challenges these tools face.

Finally, we will identify gaps in current research. This will help us understand where there is still work to be done.

### 2.1 Historical Context of NLP in Education

NLP has a very long history in education. Early tools were designed to perform simple tasks such as checking grammar and spelling. These tools made use of rule-based NLP systems, which were built around predefined sets of rules, while they were certainly helpful semi-automated evaluation tools (for things like grammar checking and test scoring), they did not provide the necessary context to unlock the potential of NLP

As technology advanced, statistical methods gained popularity. These methods relied on scouring large amounts of text to learn patterns. This enabled more accurate language processing. Tools such as automated essay scoring and vocabulary learning programs have emerged. They assisted students in developing their writing skills and expanding their vocabulary. They were way more developed than older system and managed to provide personalized help for students beyond a binary right or wrong or a score at the end.[\[19\]](#)

In recent history, Machine Learning Algorithms have been able to transform the field of NLP, as these algorithms are able to learn through data and improve themselves without the need for explicit programming for each particular task (improving versatility) this

has lead to the appearance of more advanced tools like Tutors or conversational agents that can hold conversations with learners and provide instant feedback and practice opportunities.

Throughout this evolution, the goal for NLP in education has remained the same, to use NLP to enhance and automate as many use cases and scenarios as possible, by understanding this trend in it's history, we can appreciate the progress made and understand what is expected of us in the future

## 2.2 General NLP Approaches

NLP has evolved through various approaches throughout the years, each of these approaches has been able to contribute uniquely to language learning, we're going to discuss three main approaches: Rule-Based approach, Statistical analysis approach, and the Neural Network approach.

### 2.2.1 Rule-Based Approaches

Rule-based systems were some of the earliest NLP tools, they relied essentially on sets of hard-coded linguistic rules, which were then used to analyze and process textual data, these syntax rules, morphology and semantics would be involved on capturing certain data or extracting information, for example, grammar checkers would use these rules to identify texts in the text, other use cases include regular expression, widely used in programming, although Rule-based approaches were useful for these sort of specific and linear tasks in the early age of NLP, they often struggled with the complexity and intricacies of natural language. The steps in rule based NLP approaches could be generally described as such:

- **Rule Creation:** Domain-specific linguistic rules such as grammar rules, syntax patterns, semantic rules, and regular expressions are developed based on the tasks at hand.
- **Rule Application:** Predefined rules are applied to inputted data to identify matched patterns.
- **Rule Processing:** The text data is processed based on the results of the matched rules in order to extract information, make decisions, or perform other tasks.
- **Rule Refinement:** is the iterative refinement of created rules through repetitive processing to improve accuracy and performance. The rules are modified and updated as needed in response to previous feedback.

### 2.2.2 Statistical and Machine Learning Approaches

Statistical approaches in NLP have been very important in changing how machines understand and generate human language, these methods instead of relying on the classical

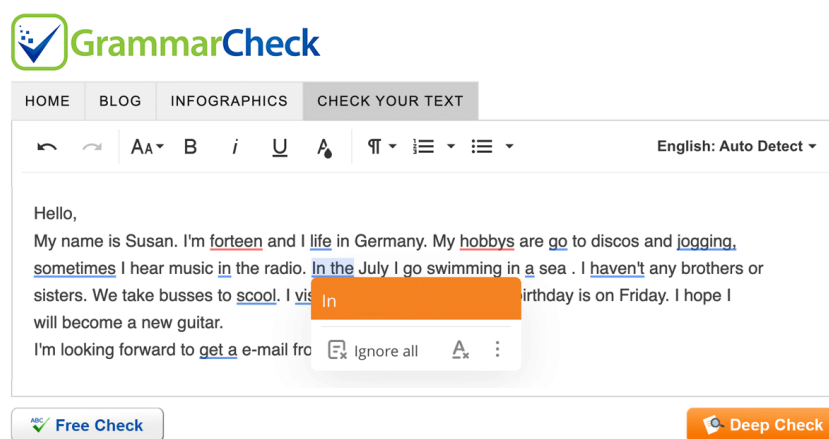


Figure 2.1: Rule-Based Grammar Checker [20]

predefined linguistic rules, rely instead on probabilistic models and a large corpora of text that they're able to infer things like Patterns, Structures and Semantics from. Using mathematical and statistical techniques to model and analyse natural language data.

The phases of a statistical approach in NLP are generally described as such:

## A. Data Collection and Preprocessing

Data collection and preprocessing are essential components of any Natural Language Processing (NLP) project. These phases are critical because they have a direct impact on the quality, relevance, and suitability of data for future analysis and model building.

**Data Collection:** The process of data collection in NLP involves gathering textual data from various sources in order to create a dataset suitable for the context of our project. The choice of data sources is heavily influenced by the specific NLP task at hand, the field of interest, and the availability of relevant datasets.[9] Listed below are some common data collection sources and considerations:

- **Web Scraping:** Many NLP systems rely on vast amounts of text data from websites, forums, social media platforms, and news stories. Web scraping approaches entail programmatically gathering content from web pages while following to ethical principles and legal issues for data use and intellectual property.
- **Text corpora:** These are curated collections of text documents that are useful for linguistic study and NLP training. Examples include the Brown Corpus, the Gutenberg Project, and domain-specific corpora like medical literature or legal papers.
- **Databases and APIs:** Accessing data from structured databases or APIs (Application Programming Interfaces) enables the extraction of specific types of textual information, such as customer reviews, product descriptions, or financial reports.

- **Domain-Specific Data:** Depending on the application, data may need to come from specialized fields like biological research, judicial proceedings, financial markets, or social media analytics. Each discipline brings unique obstacles and opportunities for data collecting and preprocessing.
- **Ethical Considerations:** Ensuring ethical data gathering procedures entails acquiring relevant permissions, preserving user privacy, and anonymizing sensitive information where appropriate. Compliance with data protection legislation (such as GDPR) is critical for protecting individuals' rights and upholding ethical standards in NLP research.

**Preprocessing:** After getting the raw text data, editing is the next very important step. Text preprocessing changes unstructured text into a clean file that can be used for further modeling and analysis. This step deals with some problems that come with natural language data, like text formats that don't always match up, subtleties in language, and noise that was introduced during data collection. [21] [22]

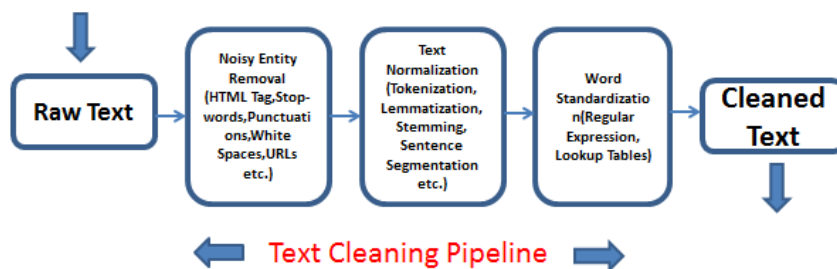


Figure 2.2: A basic text cleaning pipeline

[22]

- **1- Noise Removal:**

- **HTML Tags and Formatting:** Text obtained from web sources often contains HTML tags, JavaScript code, or CSS formatting, which are irrelevant for NLP tasks and should be removed.
- **Special Characters and Punctuation:** Non-alphabetic characters such as punctuation marks, emojis, and symbols can be removed or replaced with appropriate text equivalents.

- **2-Tokenization:**

- **Sentence Tokenization:** Breaking text into individual sentences. This step is crucial for tasks requiring sentence-level analysis, such as sentiment analysis or machine translation.
- **Word Tokenization:** Segmenting sentences into individual words or tokens. Tokenization ensures that each word or token is treated as a separate entity for subsequent analysis.

- **3-Normalization:**

- **Lowercasing:** Converting all text to lowercase ensures uniformity and simplifies subsequent text processing steps. This step prevents the model from treating words with different cases (e.g., "Apple" vs. "apple") as different entities.
- **Handling Contractions:** Expanding contractions (e.g., "can't" to "cannot", "don't" to "do not") improves consistency and readability in the text data.
- **Removing Accents and Diacritics:** Normalizing text by removing accents or diacritical marks from characters (e.g., converting "résumé" to "resume") reduces variations in textual representation.

- **4-Stopword Removal:** Common words such as "the", "is", "and", which occur frequently in text but carry little semantic meaning. Removing stopwords reduces noise in the data and improves the efficiency of subsequent analysis by focusing on more informative words.

- **5-Stemming and Lemmatization:**

- **Stemming:** Reducing words to their root form by removing suffixes. For example, stemming converts "running", "runs", and "ran" to the base form "run". Porter's algorithm and Snowball stemmers are commonly used algorithms for stemming in English.
- **Lemmatization:** Similar to stemming but considers the context of the word to determine its lemma or base form. Lemmatization uses lexical knowledge bases to accurately reduce words to their canonical form (e.g., converting "better" to "good"). It is more computationally intensive but yields more accurate results compared to stemming.

- **6-Handling Rare Words and Spelling Errors:**

- **Rare Words:** Removing or replacing rare words that appear infrequently in the dataset can reduce model complexity and improve generalization.
- **Spelling Errors:** Correcting spelling errors using spell-checking algorithms or techniques such as edit distance (Levenshtein distance) ensures that the text data is accurate and consistent.

Several programming libraries and tools facilitate efficient data collection and preprocessing in NLP projects:

- **Python Libraries:** **NLTK** (Natural Language Toolkit), **spaCy**, and **TextBlob** provide comprehensive tools for tokenization, stopwords removal, stemming, lemmatization, and other text preprocessing tasks.
- **Regular Expressions:** Regex is invaluable for pattern matching and text manipulation tasks such as removing special characters or extracting specific information from text.

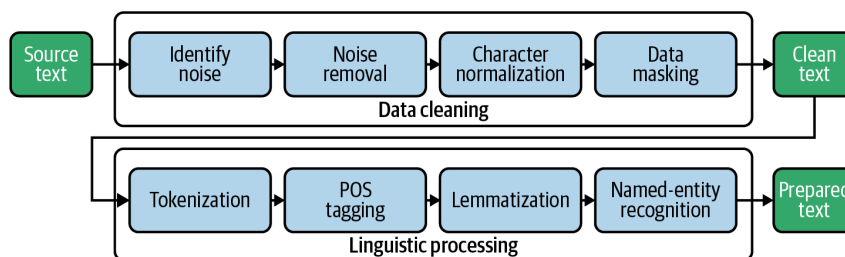


Figure 2.3: Basic Sentiment Analysis process with NLTK Example [23]

- **Open Source Corpora:** Access to open-source corpora such as the Brown Corpus or WordNet enhances data diversity and quality in linguistic research and model training.

Fundamental NLP processes, data collecting and preprocessing have a big influence on how accurate and useful later analyses and models are. Practitioners can guarantee that the text data is cleaned, normalized, and organized for best performance in NLP tasks by carefully gathering pertinent data from many sources and using strong preprocessing methods. The continual improvements in tools and technology allow researchers and developers to take on ever more difficult problems related to comprehending and processing natural language.

## B. Feature Extraction

An essential step in Natural Language Processing (NLP), feature extraction converts unprocessed text data into numerical features that machine learning models can interpret and efficiently process. The several methods, algorithms, and technologies employed in feature extraction in natural language processing are discussed in this section along with their importance and practical applications.

**Importance of Feature Extraction** Text data, which is inherently unstructured and high-dimensional, must be transformed into a structured format with numerical features for machine learning algorithms. Effective feature extraction improves model performance by extracting useful information from text while removing noise and irrelevant details. The key objectives of feature extraction in NLP are:

- **Dimensionality Reduction:** A high-dimensional space results from the abundance of features (words or n-grams) found in text data. Techniques for feature extraction lower this dimensionality to increase computational effectiveness and avoid overfitting.
- **Information Representation:** Tasks including classification, clustering, sentiment analysis, and information retrieval are made easier for models to learn patterns and relationships between words or phrases when text is converted into numerical features (vectors).

- **Semantic Understanding:** By using contextual usage of words in a corpus, feature extraction techniques like word embeddings record semantic relationships between words. This semantic comprehension improves the generalization and meaning inference capabilities of the model from text data.

**Techniques for Feature Extraction** Several techniques and algorithms are used for feature extraction in NLP, each suited to different types of textual data and tasks.

**Bag-of-Words (BoW)** Bag-of-Words is a simple yet effective technique that represents text as a multiset of its words, disregarding grammar and word order but retaining multiplicity. [21]

- Process:
  - **1- Tokenization:** Segmenting text into individual words (tokens).
  - **2- Count Vectorization:** Counting the frequency of each word in the document. [24]
  - **3- Sparse Matrix Representation:** Representing documents as sparse vectors, where each dimension corresponds to a unique word in the vocabulary.
- Applications: BoW is commonly used for tasks such as document classification, sentiment analysis, and topic modeling, where word frequency is informative.

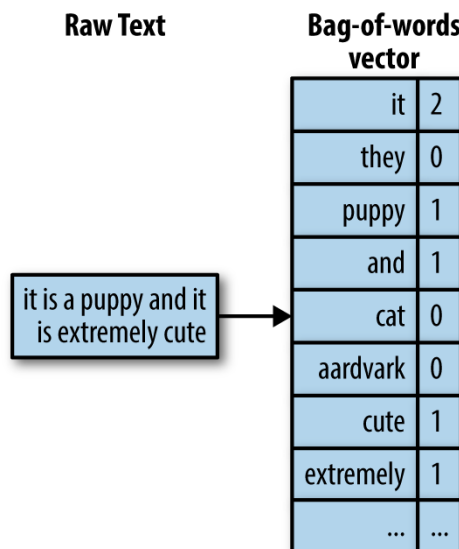


Figure 2.4: Turning raw text into a bag of words representation. Courtesy Zheng & Casari (2018).

**N-grams** N-gram models, by capturing local dependencies in text sequences, represented a major breakthrough. An n-gram model estimates a word's likelihood using the words that came before it by n-1. A trigram model, for instance, predicts based on the previous two words, but a bigram model predicts the next word based on the word before it. [21]

- Process:
  - **1- N-gram Generation:** Extracting sequences of adjacent words or characters from text.
  - **2- Vectorization:** Representing N-grams as feature vectors, often using count or TF-IDF weighting.
- Applications: N-grams are useful for capturing context and syntactic structures in tasks like language modeling, machine translation, and speech recognition.

**Term Frequency-Inverse Document Frequency (TF-IDF)** TF-IDF is a statistical measure that evaluates the importance of a word in a document relative to a collection or corpus. [25] It balances the frequency of a term (TF) with its inverse document frequency (IDF), which measures how rare or common a term is across documents.

- Process:
  - **Term Frequency (TF):** Measure the frequency of a term within a document.
  - **Inverse Document Frequency (IDF):** Measure the informativeness of a term by considering its occurrence across documents.
- Applications: TF-IDF is widely used in information retrieval, search engines, and document clustering, where rare and informative terms are emphasized, as well as the extraction of keywords and summarizing large texts.

$$w_{x,y} = tf_{x,y} \times \log \left( \frac{N}{df_x} \right)$$

**TF-IDF**  
Term x within document y

$tf_{x,y}$  = frequency of x in y  
 $df_x$  = number of documents containing x  
 N = total number of documents

Figure 2.5: Term Frequency Inverse Document Frequency [24]

**Word Embeddings** are dense vector representations of words in a continuous vector space, capturing semantic relationships between words based on their contextual usage in a corpus. [21]

- Techniques:
  - **Word2Vec:** Generates word embeddings by predicting neighboring words in a large corpus (Skip-gram or Continuous Bag-of-Words).
  - **GloVe (Global Vectors for Word Representation):** Learns word embeddings by factorizing the word co-occurrence matrix.
- Applications: Word embeddings are used extensively in tasks such as semantic similarity, named entity recognition, machine translation, and sentiment analysis, where understanding word meanings and relationships is critical.

**Character-level Embeddings** represent words as sequences of characters rather than whole words, capturing morphological and spelling variations.

- Process:
  - **1- Character Tokenization:** Splitting words into individual characters.
  - **2- Embedding Representation:** Learning vector representations of characters or character sequences.
- Applications: Character-level embeddings are beneficial for languages with complex morphology, entity recognition in noisy text, and tasks requiring robustness to spelling variations.

Several technologies and tools support feature extraction in NLP by implementing these techniques and facilitating efficient data transformation:

- Scikit-learn is a Python library that implements BoW (CountVectorizer, TfidfVectorizer), N-grams, and TF-IDF vectorization, providing flexibility and ease of use for feature extraction in classification and clustering tasks.
- Gensim is a library that supports topic modeling, word embedding techniques such as Word2Vec, and document similarity using TF-IDF.
- SpaCy is an NLP library that includes pre-trained word embeddings and tools for efficient tokenization, dependency parsing, and named entity recognition, which improves feature extraction capabilities in complex tasks.
- TensorFlow and PyTorch are deep learning frameworks that support advanced techniques such as neural network-based embeddings (e.g., LSTM and Transformer models) for sequence modeling and text generation tasks.

## C. Model Building

A crucial stage of Natural Language Processing is model building, where machine learning models are trained using preprocessed and transformed text data. This section provides a thorough understanding of the procedure by delving into the selection of appropriate models, the complexities of training them, and the optimization techniques involved.

**Model Selection** The particular task, the type of data, and the intended results all influence the model that is selected in natural language processing. Various tasks call for different modeling strategies, and a model's efficacy frequently depends on how well it matches the features of the data and the problem at hand.

### Classification Models [\[9\]](#)

- **Basic Bayes:** a probabilistic classifier with the assumption of feature independence based on the Bayes theorem. For text classification tasks like sentiment analysis and spam detection, it works especially well. The two variations are Bernoulli Naive Bayes and Multinomial Naive Bayes.
- **Support Vector Machines (SVM):** a supervised learning model that determines the ideal hyperplane for class division. SVMs work well and are reliable in spaces with many dimensions. Kernel Tricks: Radial Basis Function (RBF), Linear, Polynomial.
- **Logistic Regression:** A statistical model that forecasts the likelihood of a binary result. For binary classification tasks like sentiment analysis, it is widely used.
- **Random Forests and Decision Trees:** nonlinear models that divide data into subsets according to feature values in a recursive manner. An ensemble technique called Random Forests combines several decision trees to increase accuracy and robustness.
- **Neural Networks:** For more complex tasks like text generation, sequence labeling, and picture captioning, deep learning models like Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTM) networks, and Convolutional Neural Networks (CNNs) are utilized.

### Sequence Models

- **Recurrent Neural Networks (RNNs):** RNNs are meant to handle sequential data; they keep a state that records data from earlier time steps. They are employed in speech recognition, machine translation, and language modeling tasks.
- **Long Short-Term Memory (LSTM) Networks:** a kind of RNN that works well for long-term dependencies in sequences by reducing the vanishing gradient issue.
- **Gated Recurrent Units (GRU):** an LSTM variant that is more straightforward and has fewer parameters, allowing for faster training.

**Transformer Models** The Transformer architecture, introduced by Vaswani et al. (2017), revolutionized Natural Language Processing (NLP) by addressing limitations in recurrent neural networks (RNNs) and Long Short-Term Memory (LSTM) networks. Transformers utilize self-attention mechanisms to process input data, enabling parallelization and efficient handling of long-range dependencies within sequences.

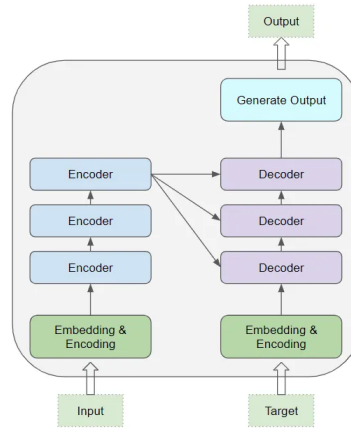


Figure 2.6: Basic transformer architecture

Key components of the Transformer architecture relevant to LLMs include:

- **Self-Attention Mechanism (Scaled Dot-Product Attention):** This mechanism allows the model to understand the relationships between different words in a sentence. It works by:
  - **Calculating Scores:** For each word in the sentence, the model calculates a score for every other word. This score represents the relevance of the other word to the current word, considering factors like word similarity and syntactic position.
  - **Softmax Function:** A softmax function is applied to the scores, converting them into probabilities. These probabilities indicate the relative importance of each word in the context of the current word.
  - **Weighted Representation:** The model creates a new representation for the current word by attending to (focusing on) the other words in the sentence, weighted by their corresponding probabilities. This creates a richer understanding of the word’s meaning based on its context.
- **Multi-Head Attention:** By employing multiple attention heads in parallel, the model can learn to attend to different aspects of the sentence simultaneously. Each head focuses on a specific type of relationship between words, capturing various contextual nuances.
- **Positional Encoding:** Since Transformers lack inherent knowledge of word order (unlike RNNs), positional encodings are added to input embeddings. These encodings incorporate information about the position of each word, allowing the model

to understand the sequence of words and how their relative positions contribute to meaning.

- **Feed-Forward Networks:** Each layer in the Transformer architecture contains fully connected feed-forward networks. These networks apply non-linear transformations to the data, allowing the model to learn complex patterns and relationships within the language that go beyond simple attention between words.
- **Layer Normalization and Residual Connections:** Transformers leverage layer normalization and residual connections to address challenges in training deep neural networks. Layer normalization helps stabilize the learning process by normalizing the activations of each layer, while residual connections ensure that information from earlier layers is preserved as the data flows through the network. This allows the model to effectively learn from long sequences.

## D. LLM Model Training

Training a model on the prepared data comes next after it has been chosen. During training, data is fed into the model so that optimization techniques can help it discover patterns and relationships.[\[21\]](#) A few crucial elements of the training procedure are:

### Data Splitting

- **Training Set:** The subset of the data that the model was trained on.
- **Validation Set:** a different set that is used during training to adjust model parameters and choose the optimal model.
- **Test Set:** the last set that was used to assess the generalizability and performance of the model.

### Loss Functions

- **Cross-Entropy Loss:** frequently used to calculate the discrepancy between expected probabilities and actual class labels in classification tasks.
- **Mean Squared Error (MSE):** Measures the average squared difference between the values that were predicted and those that were observed in regression tasks.

### Optimization Methods

- **Gradient Descent:** This is an iterative optimization algorithm that updates model parameters in the direction of the negative gradient in order to minimize the loss function.
- **Variants:** Adam (Adaptive Moment Estimation), Mini-batch Gradient Descent, and Stochastic Gradient Descent (SGD).

- **Regularization:** By penalizing large model coefficients, regularization techniques such as L1 and L2 regularization are employed to prevent overfitting.
- **Learning Rate Schedulers:** Techniques that enhance convergence by modifying the learning rate during training. Step decay, exponential decay, and cosine annealing are three common schedulers.

## Hyperparameter Tuning

- **Grid Search:** A thorough search across a predetermined grid of hyperparameter values.
- **Random Search:** Usually more effective than grid search, a randomized search across hyperparameter space.
- **Bayesian Optimization:** A sophisticated method that iteratively narrows the search space by modeling the hyperparameter optimization problem as a probabilistic model.

## E. Difficulties and Considerations

NLP model building and particularly building a capable Arabic NLP models involves a number of issues that need to be resolved in order to guarantee the effectiveness and dependability of the models:

- **Data Quality:** It is essential to guarantee the representativeness and quality of the training data. Unbalanced, biased, or noisy data can cause problems with generalization and model performance.
- **Computational Resources:** Deep learning models in particular need a large amount of memory and processing power to train. Realistic training times require effective hardware utilization, especially with GPUs and TPUs.
- **Overfitting:** When a model does well on training data but poorly on unknown data, it is said to be overfitted. Early stopping, dropout, and regularization are some strategies that help lessen this problem, the large scope of the Arabic language would be expected to worsen overfitting.
- **Interpretability:** Certain models deep learning models in particular are frequently viewed as "black boxes." Ensuring the interpretability of a model is crucial for comprehending decision-making procedures and fostering confidence in the model.

## F. Final Thoughts

In natural language processing, model building is a complex procedure that includes choosing suitable models, training them with data, and maximizing their functionality. The capabilities of NLP models have greatly increased, allowing them to handle tasks that are getting more and more complex, thanks to developments in machine learning and

deep learning. These models can produce accurate, dependable, and significant results in a range of natural language processing (NLP) applications by utilizing the appropriate tools, technologies, and techniques.

## 2.3 Large Language Models

Large Language Models (LLMs) are not a monolithic entity but rather a diverse landscape of models with varying architectures and capabilities. A primary distinction lies in their fundamental architecture[25]:

- **Decoder-Only Models:** These models, exemplified by the GPT and LLaMA families, are based on the transformer decoder architecture. This design makes them particularly adept at text generation tasks, as they are trained to predict the next token in a sequence. However, their ability to understand the full context of a sentence might be somewhat limited compared to encoder-decoder models.
- **Encoder-Only Models:** This architecture is primarily used for tasks that require understanding the full context of the input text, such as sentence classification or named entity recognition. These models are trained to generate a fixed-length representation of the input text, which can then be used for various downstream tasks. Prominent examples of encoder-only models include BERT and its variants.
- **Encoder-Decoder Models:** This architecture, employed by the PaLM family and others, incorporates both an encoder and a decoder. The encoder processes the input text to understand its meaning, while the decoder generates the output text. This dual mechanism allows for a more comprehensive understanding of context, making these models suitable for tasks that require both text understanding and generation, such as translation and summarization.

Within these architectural categories, different LLM families have emerged, each with its own unique characteristics and focus:

- **The GPT Family (OpenAI):** Known for its closed-source nature and impressive performance on a wide range of tasks. GPT-3, with its 175 billion parameters, was a pioneering model that showcased the potential of LLMs. Subsequent models like InstructGPT and ChatGPT have further refined the ability to follow instructions and engage in conversations. GPT-4, the latest iteration, is a multimodal model capable of processing both text and images.
- **The LLaMA Family (Meta):** In contrast to GPT, the LLaMA family is open-source, fostering a collaborative research environment. This has led to the rapid development of various LLaMA-based models, each fine-tuned for specific tasks. Alpaca, for instance, is designed for instruction following, while Vicuna and Koala excel in dialogue tasks.

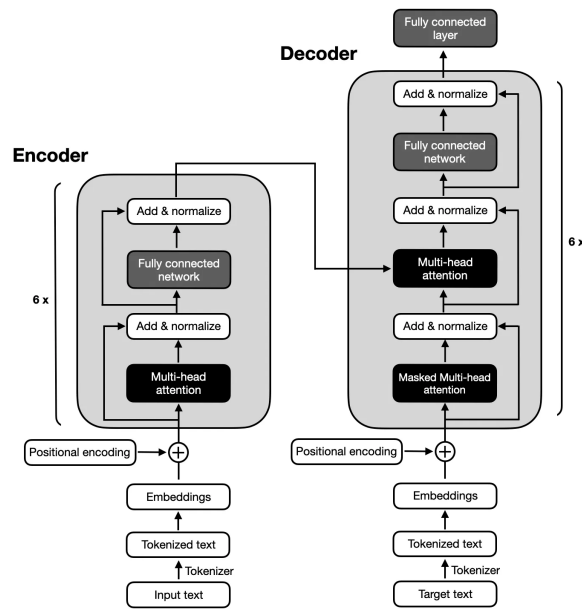


Figure 2.7: Transformer Architecture Showing Encoders and Decoders

- **The PaLM Family (Google):** This family is characterized by its massive scale and diverse training data. PaLM, with its 540 billion parameters, is a testament to the power of scaling in LLMs. The family also includes specialized models like Med-PaLM, designed for medical question answering.
- **The BERT Family:** This family of encoder-only models is widely used for various natural language understanding tasks. BERT, with its bidirectional training approach, revolutionized the field by demonstrating the effectiveness of pre-training on large amounts of text data. Variants like RoBERTa, ALBERT, and DeBERTa have further improved upon BERT’s architecture and performance.

The choice of which LLM to use depends heavily on the specific task, the desired performance, and whether open-source or proprietary solutions are preferred. Understanding the architectural and technological differences between these models is crucial for making informed decisions and harnessing the full potential of LLMs in various applications.

## 2.4 NLP Technologies for Arabic Language Learning

In this section, we will delve into the existing landscape of Natural Language Processing (NLP) tools specifically designed to aid learners in their journey to learn the Arabic language. Exploring a range of tools, from machine translation systems that bridge language barriers to speech recognition and synthesis technologies that refine pronunciation and listening skills. By understanding the capabilities and technologies behind these tools, better appreciation of their potential impact on Arabic language education can be achieved.

### 2.4.1 Overview of Existing Tools and Their Technologies

Natural Language Processing (NLP) has seen significant advancements in recent years, leading to the development of various tools designed to facilitate language learning. For the Arabic language, these tools leverage complex computational technologies to address the unique linguistic features of Arabic. The following section provides an overview of some prominent NLP tools for Arabic language learning and the underlying technologies that power them.

#### Machine Translation Systems

Machine Translation (MT) systems like Google Translate and Microsoft Translator are widely used tools for Arabic language learners. These systems employ statistical models, neural networks, and deep learning techniques to translate text between Arabic and other languages. Recent advancements in neural machine translation (NMT) have significantly improved the accuracy and fluency of translations, making these tools more reliable for educational purposes.[\[26\]](#)

#### Speech Recognition and Synthesis

Speech recognition technologies, such as those used by Google Assistant and Apple's Siri, are crucial for learners practicing pronunciation and listening skills. These systems utilize deep learning models, particularly recurrent neural networks (RNNs) and convolutional neural networks (CNNs), to transcribe spoken Arabic into text accurately. Additionally, text-to-speech (TTS) systems provide learners with audio feedback, helping them understand the correct pronunciation and intonation of Arabic words and sentences.

#### Intelligent Tutoring Systems

Intelligent Tutoring Systems (ITS) like Duolingo and Rosetta Stone incorporate NLP techniques to create personalized and adaptive learning experiences. These platforms use natural language understanding (NLU) to assess learners' proficiency levels, generate customized exercises, and provide immediate feedback. The adaptive algorithms and data-driven insights derived from user interactions enable these systems to offer tailored learning paths for Arabic language students.

### 2.4.2 Specific Challenges for Arabic NLP

Despite the advancements in NLP technologies, the Arabic language presents unique challenges that complicate the development of effective language learning tools. The following sections discuss the primary linguistic and orthographic issues faced by NLP systems when processing Arabic.

#### Grammar Complexity

Arabic grammar is famously complex, with a rich morphological structure that includes a variety of inflections, derivations, and syntax constructions. The language exhibits signif-

icant morphological richness, with nouns and verbs undergoing numerous modifications to convey gender, number, case, and tense. This complexity poses challenges for NLP systems in parsing and generating grammatically accurate sentences.

Arabic verbs, for instance, can have a plethora of different forms based on tense, mood, pronouns and voice. Additionally, the use of infixes, prefixes, and suffixes in word formation necessitates sophisticated morphological analysis to accurately decompose and generate words. The agreement rules between nouns, adjectives, and verbs further add to the complexity, requiring NLP models to have a deep understanding of the syntactic structure to maintain grammatical correctness.

مصدر	حكميه	جاری		مستقبل		مضارع		ماضي		باب
		مجهول	معلوم	مجهول	معلوم	مجهول	معلوم	مجهول	معلوم	
بدلتا رَبَّتَا بَيْنَ /	افعل	مَفْعُول	فَاعِل	سَيَفْعَل	سَيَفْعَل	يُفْعَل	يُفْعَل	فُعِلَ	فُعِلَ	1
تَفَعَّلَ /	فعل	مَفْعَل	مَفْعَل	سَيَفْعَل	سَيَفْعَل	يُفْعَل	يُفْعَل	فُعِلَ	فُعِلَ	2
فَعَال /	فَاعِل	مُفَاعِل	مُفَاعِل	سَيُفَاعِل	سَيُفَاعِل	يُفَاعِل	يُفَاعِل	فُوِعِلَ	فَاعِلَ	3
أفعل	أفعل	مُفْعَل	مُفْعَل	سَيُفْعَل	سَيُفْعَل	يُفْعَل	يُفْعَل	أفْعِلَ	أفْعِلَ	4
تَفَعَّل	تَفَعَّل	مُتَفَعَّل	مُتَفَعَّل	سَيُتَفَعَّل	سَيُتَفَعَّل	يُتَفَعَّل	يُتَفَعَّل	تُفَعَّلَ	تَفَعَّلَ	5
تَفَاعَل	تَفَاعَل	مُتَفَاعَل	مُتَفَاعَل	سَيُتَفَاعَل	سَيُتَفَاعَل	يُتَفَاعَل	يُتَفَاعَل	تُفَوِعَل	تَفَاعَلَ	6
إِنْفَعَل	إِنْفَعَل	مُنْفَعَل	مُنْفَعَل	سَيُنْفَعَل	سَيُنْفَعَل	يُنْفَعَل	يُنْفَعَل	أُنْفَعِلَ	إِنْفَعَلَ	7
إِفْتَعَل	إِفْتَعَل	مُفْتَعَل	مُفْتَعَل	سَيُفْتَعَل	سَيُفْتَعَل	يُفْتَعَل	يُفْتَعَل	أُفْتَعِلَ	إِفْتَعَلَ	8
إِفْعِلَال	إِفْعِلَ	مُفْعَل	مُفْعَل	-	سَيُفْعَل	-	يُفْعَل	-	إِفْعِلَ	9
إِسْتَفْعَال	إِسْتَفْعَل	مُسْتَفْعَل	مُسْتَفْعَل	سَيُسْتَفْعَل	سَيُسْتَفْعَل	يُسْتَفْعَل	يُسْتَفْعَل	أُسْتَفْعِلَ	إِسْتَفْعَلَ	10

Figure 2.8: A figure showing the possible different verb forms in Arabic

## Dialects and Diglossia

One of the most significant challenge in Arabic NLP is the phenomenon of diglossia, whereas Modern Standard Arabic (MSA) coexists with various regional dialects. MSA is used in formal writing and speech, while dialects are used in everyday communication. These dialects vary significantly across different Arab-speaking regions, with differences in vocabulary, pronunciation and grammar.

NLP tools must therefore account for this language diversity to be effective for language learners. Developing strong models that can handle the nuances of both MSA and regional dialects is a very difficult task. Furthermore, the lack of standard orthography for dialects [10] complicates the development of resources and corpora necessary for training LLM models.

## Script and Orthography

The Arabic script presents several orthographic challenges for NLP systems. Arabic is written from right to left and has a cursive script where the shape of a letter changes depending on its position in a word. Additionally, the script includes diacritical marks,



Figure 2.9: Different variations of the same English phrase in different Arabic dialects [27]

which indicate short vowels and other phonetic nuances but are often omitted in everyday writing. This omission leads to ambiguity and difficulties in automatic text processing.

Moreover, Arabic script has numerous homographswords that are spelled the same but have different meanings based on context. This requires NLP systems to incorporate context-aware algorithms to disambiguate word meanings accurately. The integration of advanced optical character recognition (OCR) technology is also necessary for processing handwritten or printed Arabic text, further complicating the development of comprehensive NLP tools.

## 2.5 Applications of NLP in Arabic Language Education

Leveraging NLP technologies for pedagogical purposes has led to the creation of various educational tools specifically designed for Arabic language learners. These tools harness the capabilities of NLP to address the linguistic complexities and provide learners with interactive and effective learning experiences. The following sections highlight some existing educational tools and their functionalities.

### 2.5.1 Syntax and Grammar Checkers

Tools like Microsoft Word's and Google's Arabic grammar checker and Google's are equipped with NLP algorithms to analyze and correct syntax and grammar errors in Arabic text. These checkers use rule-based and can identify misspelling and basic errors easily, however there is no sufficiently advanced tool that could be considered as a proof reader for Arabic, despite GPT models being perfectly capable of this task.

## 2.5.2 Morphological Analyzers

Morphological analyzers, such as Farasa and MADAMIRA, are essential tools for understanding the rich morphological structure of Arabic words. These analyzers decompose words into their constituent morphemes, providing insights into root forms, prefixes, suffixes, and inflectional patterns.

Morphological analysis is crucial for language learners to grasp the rules of word formation and derivation in Arabic. By breaking down complex words into simpler components, these tools aid learners in expanding their vocabulary and improving their understanding of Arabic grammar.

## 2.5.3 Named Entity Recognition (NER) Systems

Named Entity Recognition (NER) systems like Stanford NER and Polyglot are employed to identify and classify proper names, locations, organizations, and other entities within Arabic text. NER systems utilize machine learning algorithms and linguistic features to accurately extract named entities from unstructured text.[\[9\]](#)

For language learners, NER systems can be integrated into reading comprehension tools to highlight and explain named entities, thereby enhancing their understanding of the text. These systems also aid in building cultural and contextual knowledge by providing additional information about the identified entities.

## 2.5.4 Intelligent Tutoring Systems

Intelligent Tutoring Systems (ITS) such as Duolingo, Rosetta Stone, and Babbel have revolutionized language learning by incorporating NLP technologies to create personalized and adaptive learning experiences. These platforms leverage various NLP components to offer interactive exercises, immediate feedback, and tailored learning paths for Arabic learners.

**Adaptive Learning:** ITS platforms use machine learning algorithms to analyze learners' performance data and adjust the difficulty and type of exercises accordingly. This ensures that learners are consistently challenged and can progress at their own pace.

**Natural Language Understanding (NLU):** By employing NLU techniques, ITS platforms can interpret learners' input, whether written or spoken, and provide accurate feedback. This includes correcting grammatical errors, suggesting alternative phrasing, and offering explanations for mistakes.

**Interactive Dialogues:** Some ITS platforms incorporate conversational agents that simulate real-life interactions. These agents use NLP to understand learners' responses and engage in meaningful dialogues, helping learners practice their conversational skills in Arabic.

## 2.5.5 Integration of NLP in Language Learning Platforms

Integrating NLP technologies into language learning platforms has the potential to transform Arabic language education by making it more interactive, personalized, and effective. By leveraging the capabilities of NLP, these platforms can address the unique challenges of Arabic and provide learners with tools that cater to their specific needs.

**Vocabulary Acquisition:** NLP-driven lexical resources and morphological analyzers help learners build their vocabulary by providing detailed information about word meanings, usage, and derivation. Interactive exercises that incorporate NLP technologies can further reinforce vocabulary learning by generating contextually relevant practice sentences.

**Grammar Mastery:** Syntax and grammar checkers equipped with advanced NLP algorithms assist learners in understanding and applying Arabic grammar rules. These tools offer real-time feedback on written exercises, highlighting errors and providing explanations to aid learners in mastering complex grammatical structures.

**Reading Comprehension:** NER systems and contextual analysis tools enhance reading comprehension by identifying and explaining named entities, cultural references, and complex sentence structures. This enables learners to better understand and interpret Arabic texts, facilitating deeper engagement with the language.

**Pronunciation Practice:** Speech recognition and synthesis technologies provide learners with valuable pronunciation practice. By comparing learners' spoken input to native speaker models, these tools offer feedback on pronunciation accuracy, helping learners improve their speaking skills.

**Conversational Skills:** Interactive dialogues and conversational agents powered by NLP technologies enable learners to practice their conversational skills in a simulated environment. These tools provide realistic interactions, helping learners build confidence and fluency in spoken Arabic.

The integration of NLP technologies into Arabic language learning tools has the potential to revolutionize language education if used properly, in regard to the gaps it has the possibility to fill as well as the advancements that it unlocks.

# Chapter 3

## Approach

This study investigates the potential of Natural Language Processing (NLP) models, particularly Large Language Models (LLMs), to create interactive activities for Arabic language learning. Recognizing the effectiveness of Content and Language Integrated Learning (CLIL) and Task-Based Learning (TBL) methodologies in language acquisition, we designed two activities within a constructivist framework that leverage recent advancements in NLP technology. These activities aim to provide learners with a hands-on experience to supplement their existing Arabic language curriculum.

### 3.1 Overview of the approach

The limitations of traditional Arabic language learning materials, including passivity, lack of engagement, and one-size-fits-all approaches, hinder student motivation and acquisition. This approach explores NLP models as a potential solution. NLP models can create interactive activities, enhance engagement through personalized content, and utilize data to customize the learning experience. By using NLP models in such a way, the approach aims to create pedagogical tools that can effectively supplement current Arabic language curriculums and teaching methodologies.

As a first step in outlining our approach, we set to formulate an architecture that seeks to describe the tasks that the system strives to achieve and the workflow inside said system.

#### 3.1.1 Architecture

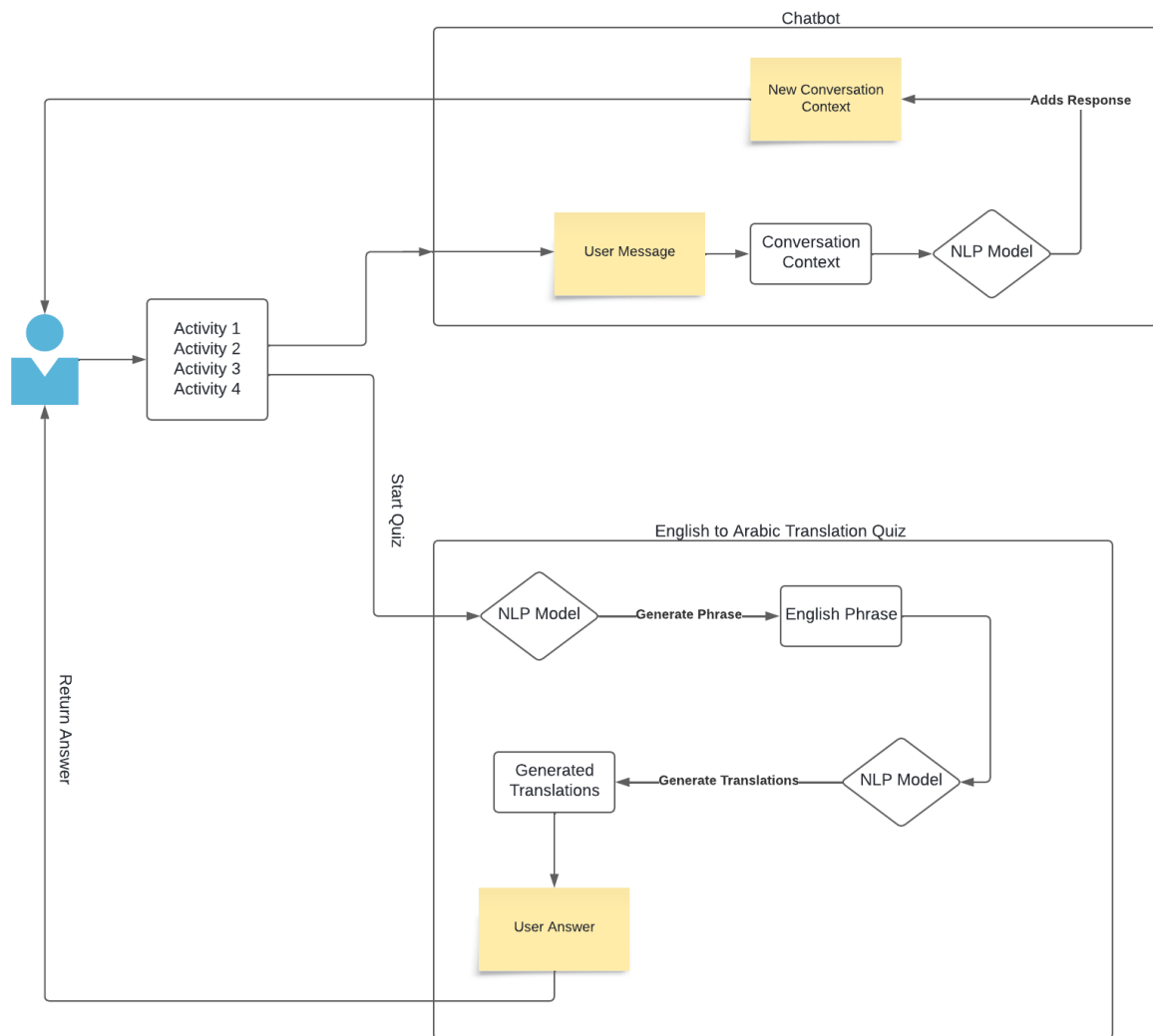


Figure 3.1: LLM Arabic Language Learning App Architecture

The Arabic language learning app architecture consists around a simple and modern web interface that features two core components: an interactive conversation practice (Conversational Partner) and an English-to-Arabic translation quiz. The conversation practice module develops language fluency by enabling learners to engage in dynamic conversations within a selection of different real world contexts, while the translation quiz module reinforces vocabulary and comprehension skills through targeted exercises. Both modules leverage LLMs and advanced natural language processing (NLP) techniques to provide real-time feedback and personalized learning experiences. This integrated approach, combining communicative practice with focused translation activities, aims to create a comprehensive and effective platform for Arabic language acquisition.

**Conversational Partner (Chatbot)** The Conversational Partner module serves as an interactive chatbot designed to simulate real-world conversations in Arabic. Its primary goal is to enhance learners' fluency and communicative competence. Here's how it works:

- **User Input:** Learners type their messages in English or Arabic, engaging in a dialogue with the chatbot.
- **Conversation Context:** The chatbot maintains a context of the ongoing conversation, remembering previous user messages and responses. This allows for more natural and coherent interactions.
- **NLP Model:** A sophisticated natural language processing (NLP) model processes the user's input, understanding the intent and meaning behind the message.
- **Response Generation:** The NLP model generates contextually relevant and grammatically correct responses in Arabic, providing learners with valuable language practice.
- **Diverse Scenarios:** The chatbot offers various conversation scenarios, such as ordering food in a restaurant, asking for directions, or discussing daily routines. This exposes learners to a wide range of vocabulary and expressions.

**English to Arabic Translation Quiz** The English to Arabic Translation Quiz module is a game-like learning experience designed to reinforce vocabulary and comprehension skills. It focuses on the practical application of language knowledge. Here's how it functions:

- **Phrase Generation:** The NLP model generates English phrases relevant to the learner's level and the chosen topic.
- **Translation Challenge:** Learners are presented with the English phrase and prompted to provide the Arabic translation.
- **Multiple Translations:** The NLP model generates several possible Arabic translations for each English phrase. This helps learners understand the nuances of the language.

- **User Answer:** Learners select the translation they believe is most accurate.
- **Scorekeeping:** The quiz tracks the learner's progress, providing a score and highlighting areas for improvement.
- **Personalized Practice:** The quiz adapts to the learner's performance, offering more challenging phrases as their skills develop.

Overall, the combination of the Conversational Partner and the English to Arabic Translation Quiz modules creates a cohesive learning environment that pays attention to different aspects of language acquisition, fostering fluency, comprehension, and practical application skills.

### 3.2 Conception

This section presents the different diagrams needed to accurately describe and conceptualize the Arabic language learning app, UML was chosen to modelise the different diagrams.

#### 3.2.1 Use Case Diagram

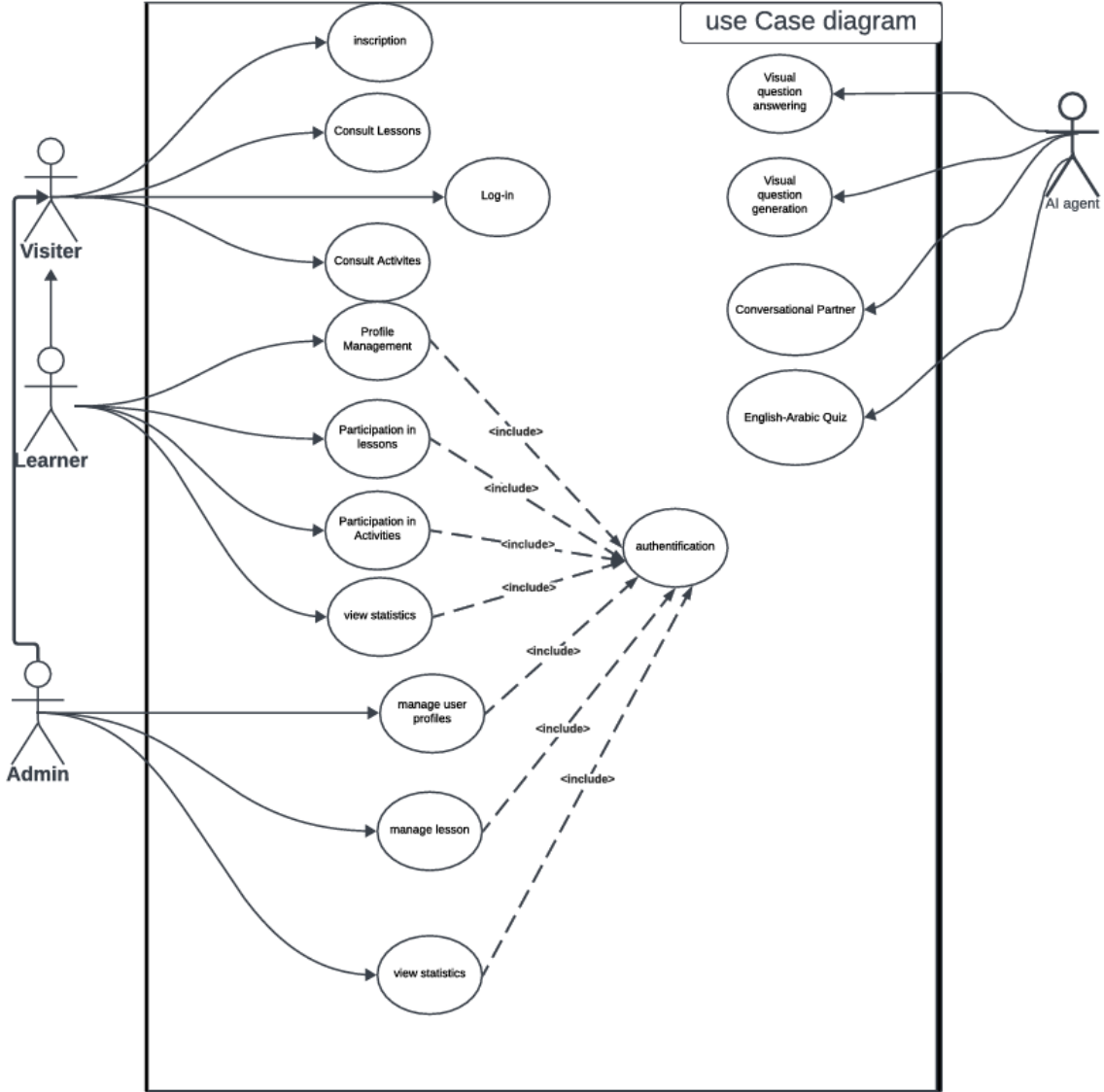


Figure 3.2: Use Case Diagram

The use case diagram illustrates the various interactions between different types of users (visitor, user, admin) and the system. This diagram helps in understanding the functionality provided by the system and the roles of different users.

- **Visitor:**

- **Consult Lessons:** A visitor can consult available lessons.
- **Consult Activities:** A visitor can also consult available activities.
- **User:**
  - **Profile Management:** A user can manage their profile, which includes updating personal information.
  - **Participation in Lessons:** A user can participate in lessons, which includes enrolling and accessing lesson content.
  - **Participation in Activities:** A user can participate in activities, which includes enrolling and accessing activity content.
  - **View Statistics:** A user can view statistics related to their participation in lessons and activities.
  - All user activities include an authentication process to ensure the user is properly authenticated.
- **Admin:**
  - **Manage User Profiles:** An admin can manage user profiles, which includes creating, updating, and deleting user accounts.
  - **Manage Lessons:** An admin can manage lessons, which includes creating, updating, and deleting lesson content.
  - **View Statistics:** An admin can view system-wide statistics related to user participation in lessons and activities.
  - Similar to users, admin activities include an authentication process for security purposes.

This use case diagram provides a clear visualization of the system’s functionality, outlining the roles and actions available to different types of users and emphasizing the importance of authentication for accessing certain features.

This section provides an overview of the conceptual framework and design of our language learning platform.

### 3.2.2 Class Diagram

The class diagram illustrates the structure of the system, showing the relationships between different classes and their interactions. It serves as a blueprint for the implementation phase.

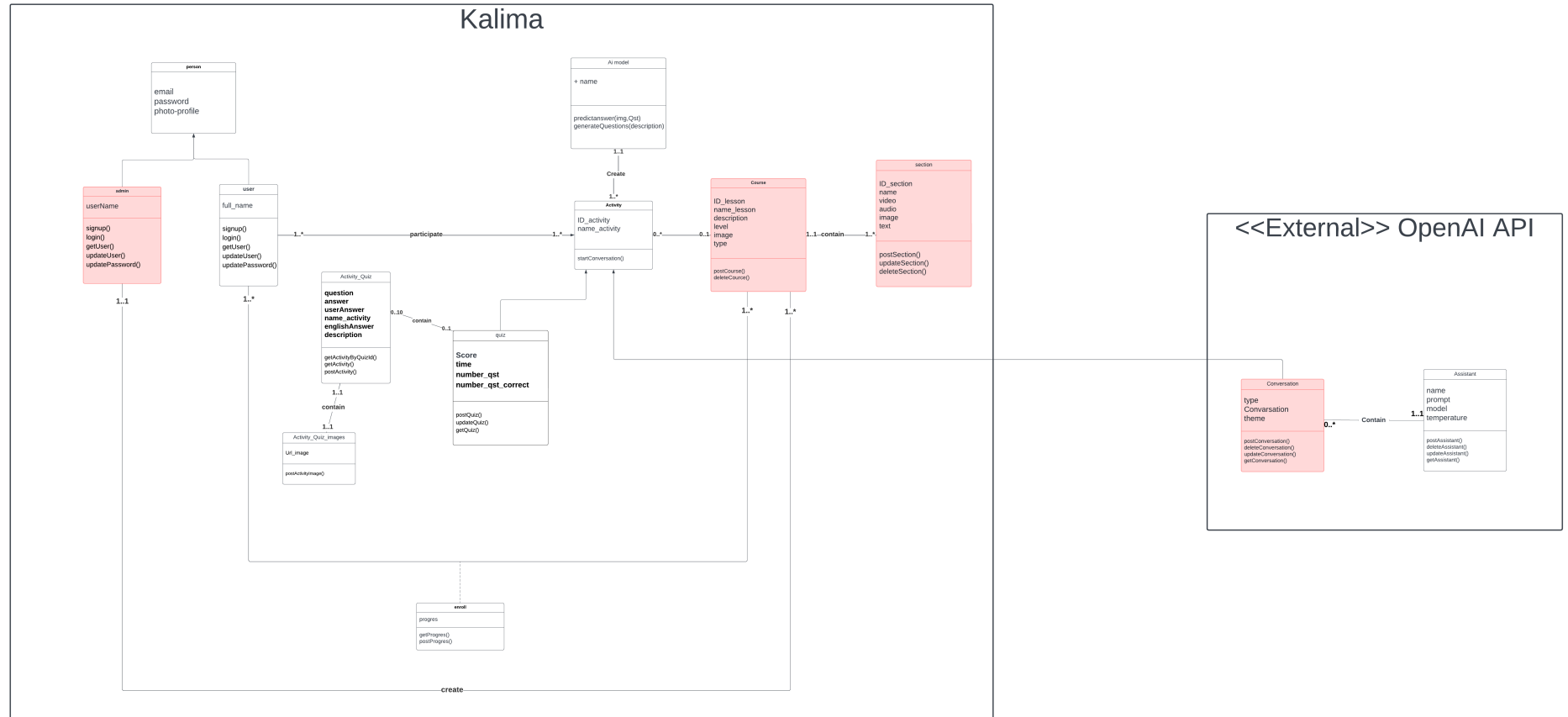


Figure 3.3: Kalima Class Diagram

### 3.2.3 Sequence Diagrams

This section details the sequence diagrams that illustrate the interactions between different components of the system for both the quiz and chatbot functionalities.

#### Quiz Sequence Diagram

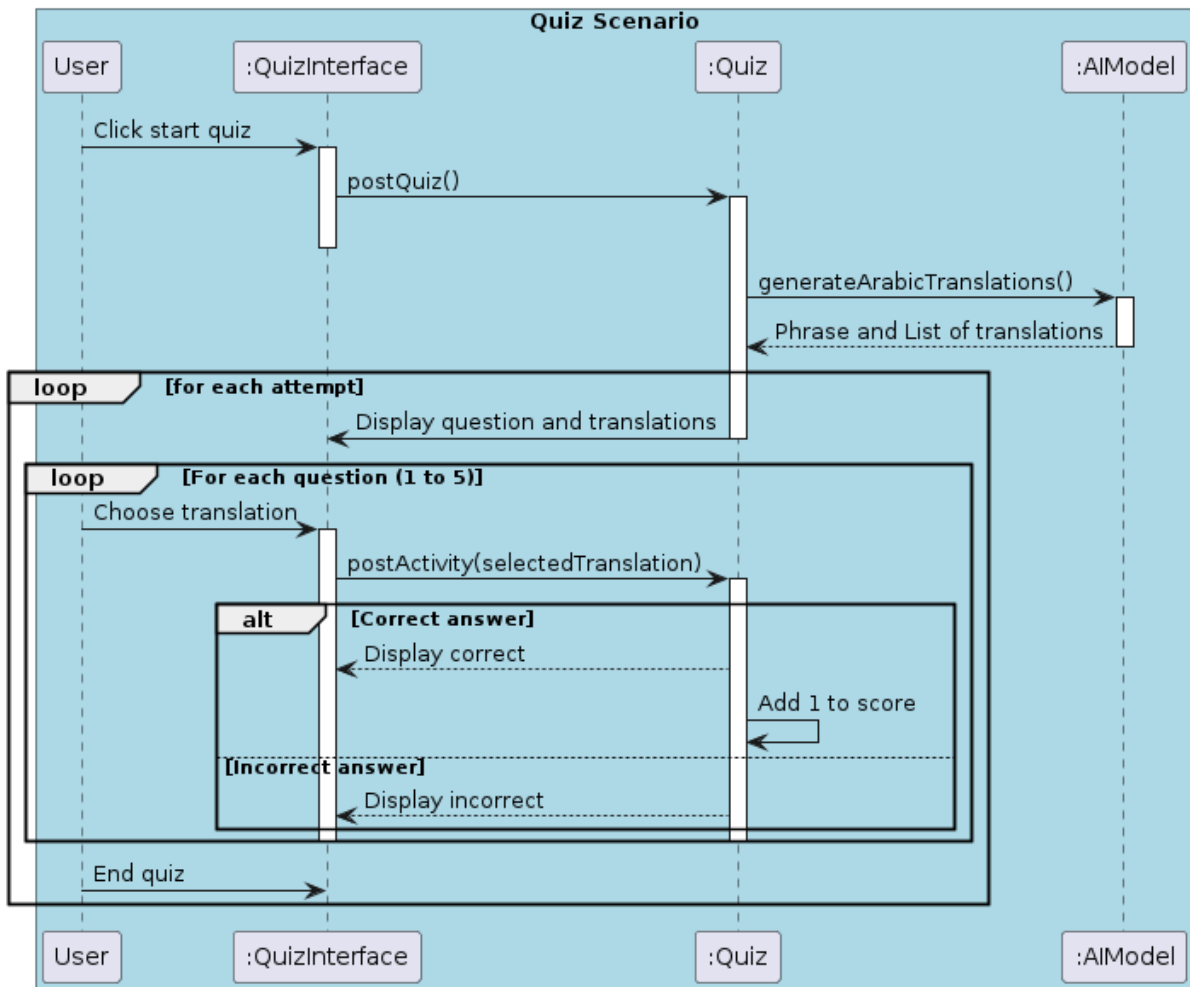


Figure 3.4: Quiz Sequence Diagram

The first sequence diagram illustrates the flow of a quiz application that generates an English phrase and provides Arabic translations for the user to choose from. Here is a detailed explanation of the steps involved:

1. **User Initiates Quiz:** The user starts the quiz by clicking a button in the QuizInterface.
2. **Quiz Initialization:** The QuizInterface sends a `postQuiz()` request to the Quiz to initialize the quiz.
3. **Translation Generation:** The Quiz requests an English phrase and corresponding Arabic translations from the AIModel by calling `generateArabicTranslations()`. The

AIModel responds with the phrase and a list of translations (one correct and three incorrect).

4. **Display Question and Translations:** The Quiz sends the phrase and translations to the QuizInterface to be displayed to the user.

5. **Answer Selection:** For each of the five questions:

- The user selects a translation and sends it through the QuizInterface.
- The QuizInterface sends the selected answer to the Quiz via the postActivity() method.
- The Quiz checks the answer. If the answer is correct, it sends a response back to the QuizInterface to display a correct message and adds 1 point to the score. If incorrect, it sends a response to display an incorrect message.

6. **Quiz Progression:** This process repeats for each of the five questions, with the score being updated for each correct answer.

7. **Quiz Completion:** After the fifth question, the user ends the quiz.

This diagram represents a detailed interaction between the user and the quiz system, emphasizing the generation of language translation questions and the scoring mechanism.

### Chatbot Conversation Sequence Diagram

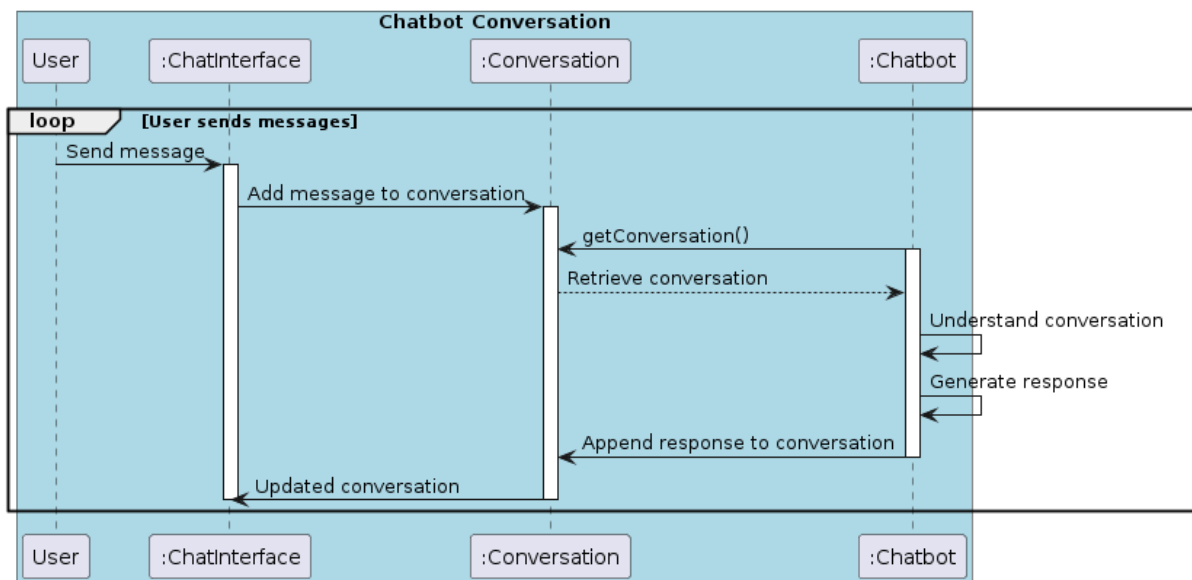


Figure 3.5: Chatbot Conversation Sequence Diagram

The second sequence diagram depicts a conversation flow between a user and a chatbot. This diagram explains how messages are exchanged and processed within the system. Heres a step-by-step description:

1. **User Sends Message:** The user sends a message through the ChatInterface.
2. **Message Addition:** The ChatInterface adds the user’s message to the Conversation.

3. **Conversation Retrieval:** The `Chatbot` requests the current state of the conversation from the `Conversation` by calling `getConversation()`.
4. **Chatbot Processing:** The `Chatbot` processes the conversation in three steps:
  - Understands the current conversation context.
  - Generates an appropriate response.
  - Appends this response to the conversation.
5. **Update Conversation:** The updated conversation, including the chatbot's response, is sent back to the `ChatInterface`.
6. **User Interaction Loop:** This process is repeated for every message the user sends, allowing for an unlimited exchange of messages between the user and the chatbot.

This diagram captures the continuous interaction loop between the user and the chatbot, highlighting how the chatbot processes each message and maintains the conversation context.

### 3.2.4 Web Application Architecture

The selection of specific tools and technologies for the development of our web application was guided by a combination of factors, including project requirements, performance considerations, developer expertise, and the evolving landscape of web development best practices.

#### Frontend Development

- **HTML (HyperText Markup Language):** The foundational language for structuring the content and layout of the web app's user interface.
- **CSS (Cascading Style Sheets):** Used to define the visual appearance, styling, and responsiveness of the interface across various devices and screen sizes.
- **JavaScript (JS):** The dynamic scripting language that enables interactivity, animations, and real-time updates within the frontend.
- **React.js:** A leading JavaScript library for building user interfaces. React's component-based architecture promotes code reusability and maintainability, facilitating a more efficient development process. Its virtual DOM efficiently updates only the necessary parts of the UI, resulting in a smoother user experience.

#### Backend Development

- **Node.js:** A runtime environment that allows JavaScript to be executed on the server-side. Node.js is known for its asynchronous, event-driven nature, making it well-suited for building scalable, high-performance web applications.

## Database

- **MongoDB:** A NoSQL database that stores data in a flexible, document-oriented format (BSON). This schema-less approach is advantageous for applications where the data structure may evolve over time. MongoDB's horizontal scalability and ability to handle large volumes of unstructured data align well with the requirements of a modern web app.

## Technology Choices

The combination of React.js, Node.js, Express.js, and MongoDB forms a robust and popular technology stack often referred to as the MERN stack. This stack offers several advantages[28]:

- **Full-Stack JavaScript:** Using JavaScript for both frontend and backend development streamlines the development process, reduces context switching for developers, and promotes code reusability between the client and server.
- **Performance and Scalability:** Node.js's non-blocking architecture and MongoDB's ability to scale horizontally make the MERN stack a strong choice for building applications that need to handle a large number of concurrent users and data requests.
- **Community and Ecosystem:** The MERN stack has a vibrant developer community and a rich ecosystem of libraries, tools, and resources, providing extensive support and accelerating development.
- **Rapid Development:** The modular nature of React components, the streamlined API development with Express.js, and MongoDB's flexible schema contribute to a faster development cycle.

## Considerations and Future Enhancements

While the MERN stack has proven effective for the current needs of our Web App, the thesis may also discuss potential future enhancements or alternative technologies that could be considered as the application evolves.

### 3.2.5 User Interface Design

The user interface (UI) design focuses on creating an intuitive and engaging learning environment. Key features include:

- **Sign-Up and Log-in:** A simple, intuitive and modern authentication screens to ensure the safety of users' data and learning progress.

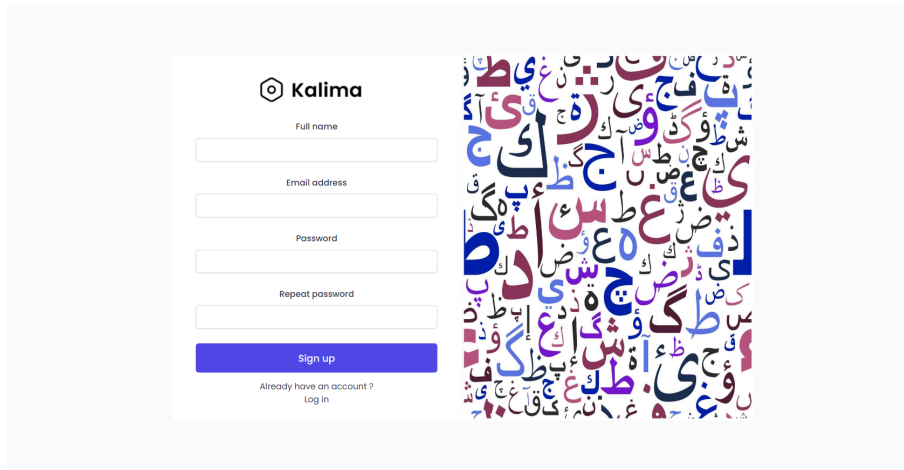


Figure 3.6: Kalima Sign Up Screen

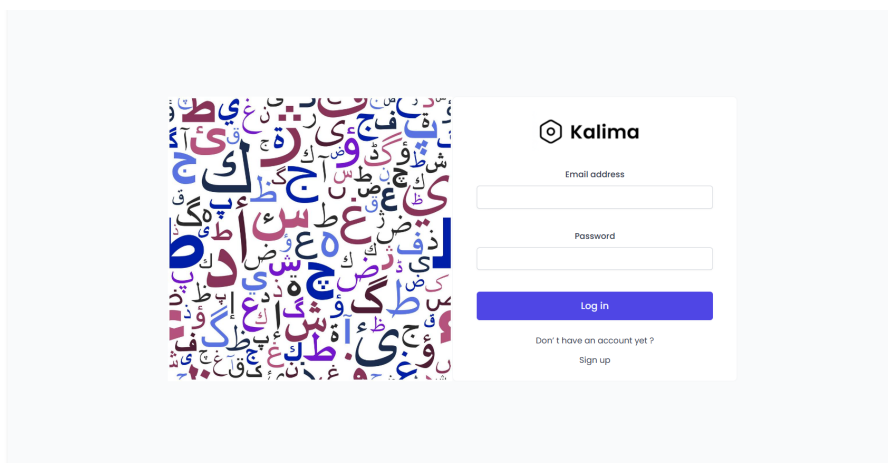


Figure 3.7: Kalima Log In Screen

- **Dashboard:** An incomplete central hub where users can access learning activities, and in the future track progress, and receive personalized recommendations.

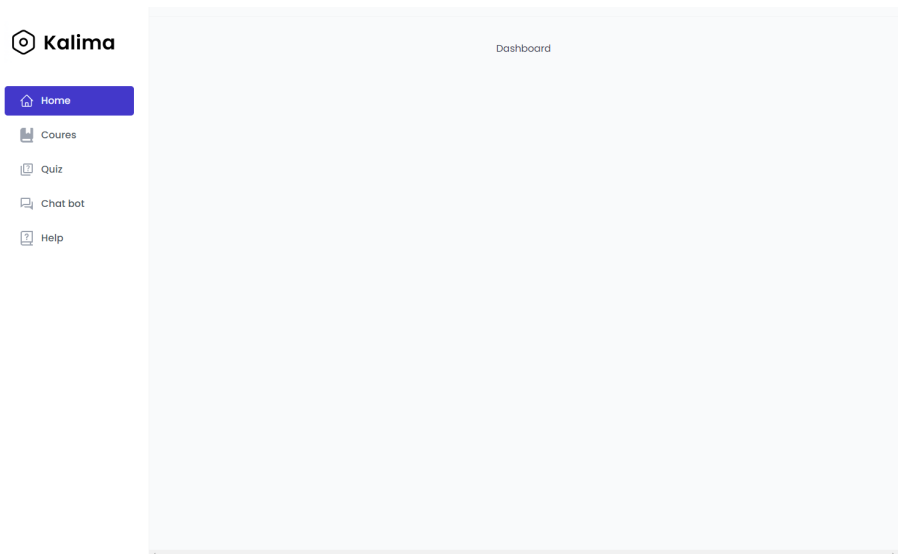


Figure 3.8: Kalima Dashboard

- **Conversational Partners:** Activities designed to practice Arabic language mastery with a curated list of available chatting scenarios powered by LLMs

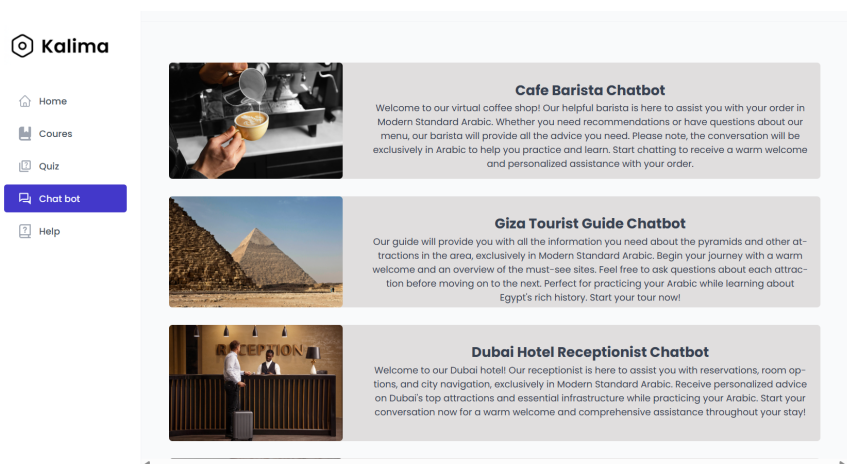


Figure 3.9: List of Conversational Partners



Figure 3.10: Conversation Screen with Conversational Partner

- **Translation Quiz:** A scored quiz where the user is given a phrase in English and a list of choices for the correct translation in Arabic.

### 3.3 Summary and Future Work

In this chapter, we described the tools, conceptual framework, and implementation of our Arabic language learning platform using LLMs. This approach integrates cutting-edge NLP technologies to provide an enriched learning experience. Future work will focus on refining the platform based on user feedback, expanding the range of learning activities, and exploring additional NLP advancements to further enhance language acquisition.

# Chapter 4

## Implementation and Experimentation

In this chapter, we detail the implementation of our proposed pedagogical tools and outline the experiments conducted to evaluate their effectiveness in aiding Arabic language learners. We begin by outlining the technologies employed in developing the platform, followed by a description of the methods we used to test. We then present the results of our evaluation, analyzing the performance of both the conversational partners and the English-to-Arabic quiz based on predefined criteria. Finally, we discuss the implications of our findings and suggest potential avenues for future research and development in this domain.

### 4.1 Implementation

In this section, we detail the implementation of our Arabic language learning platform, highlighting the specific tools and technologies employed to bring the architecture from theory to application.

#### 4.1.1 Used Technologies

In this section, we outline the key tools and technologies that were instrumental in developing our language learning platform.

##### **OpenAI Assistants API**

The OpenAI Assistants API offers a robust framework for constructing intelligent ChatBots and virtual assistants within applications. This API extends beyond simple question-answering capabilities, empowering developers to create specialized AI companions that engage in multi-turn conversations and manage complex tasks. Core to this functionality lies context management, enabling the assistant to maintain a coherent understanding of the ongoing dialogue.

Unlike traditional ChatBots that treat each user utterance independently, the Assistants API leverages "threads." A thread functions as a container for the entire conversation

history between a user and the assistant. Each user message and corresponding assistant response are appended to this thread, forming a chronological record of the interaction. This allows the assistant to track the evolving context of the conversation, including discussed topics, references made, and user intent.

The integrated context management enables us to massively streamline our implementation, since the context window is managed internally within the API we can forego our applying our own context management and rely on threads to simulate a natural conversation flow in our conversational partners.

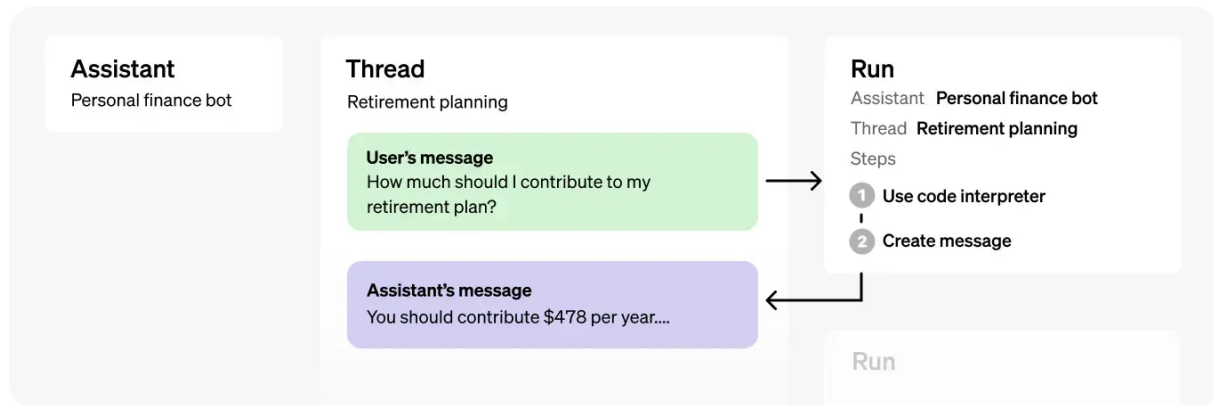


Figure 4.1: Assistants API

Furthermore, the Assistants API provides a high degree of control over the assistant's behavior through configurations. These configurations define the specific capabilities and functionalities of the assistant. Allowing us to specify the large language models (LLMs) the assistant should utilize for generating responses, alongside any additional instructions or guidelines that tailor the assistant's personality and communication style. This allows for the creation of specialized ChatBots catering to specific project goals.

In conclusion, the Assistants API surpasses the limitations of rudimentary ChatBots. By employing a sophisticated system of threads, runs, and context management, it fosters the development of intelligent conversational AI that can engage in meaningful dialogues and offer personalized assistance. This framework, coupled with the ability to define configurations and leverage various LLMs, opens doors for us to construct specialized ChatBots that cater to diverse needs of the learner. The Assistants API stands as a powerful tool for building interactive and intelligent conversational experiences to enhance Arabic Language learning.

## Completions API

One avenue explored for quiz generation leverages OpenAI's Completions API. This API is typically used for creative text formats, but by defining a specific format that helps us get all the data necessary to populate the quiz, the API can generate complete quiz entries. The prompt instructs the API to populate the format with an English phrase, its corresponding Arabic translation, and three incorrect translations. While this approach offers an innovative way to create dynamic quizzes, it is crucial to acknowledge potential limitations. The API may generate grammatically correct yet unnatural-sounding

phrases, and the quality or difficulty level of generated content might be inconsistent. To mitigate these limitations, further research was done on steering the API towards more correct and natural language output through model selection (for example GPT 3.5 was used at first but it gave often unnatural or slightly incorrect translations, until we transitioned to GPT 4), as well as conducting further research on refining goal oriented prompts that help us extract the most viable options for our goals by incorporating a human review process to select the most effective API-generated entries.

## Prompt Engineering

We investigate the application of prompt engineering techniques to create an immersive Arabic learning experience. For the conversational partner powered by OpenAI's Assistants API, we utilize a multifaceted approach. First, we define the character of the conversational partner. This involves establishing its personality, background, and communication style through prompts. Second, we establish context by providing the Assistant with relevant information about the conversation topic and the user's learning goals. Third, to guide the conversation flow and response quality, we equip the model with examples of desired responses. For instance, prompts might showcase informative, humorous, or culturally relevant ways to respond to user queries. Fourth, we implement a chronological flow by incorporating past conversation elements into subsequent prompts. This ensures a coherent and engaging dialogue. Finally, to maintain a safe and appropriate learning environment, we set clear guidelines and limitations on the topics the conversational partner can engage in. [29]

For the Arabic translation quiz, we focus on crafting clear and concise prompts that explicitly explain the task at hand. This includes providing a pre-defined answer format, outlining the number of answer choices and their structure (e.g., multiple choice with three options). Furthermore, we incorporate an illustrative example to demonstrate the expected format and level of difficulty. By employing these techniques, we ensure the prompts effectively guide users through the quiz and facilitate their Arabic language learning journey.

## 4.2 Evaluation of Conversational Partners and Translation Quiz

In order to evaluate the performances of our proposed pedagogical tools, we have evaluate separately the quality of both proposed pedagogical Activities.

### 4.2.1 Conversational Partner Activity Evaluation

As language enthusiasts, we recognize the immense value of effective and accessible language learning tools, especially in mastering languages as rich and diverse as Arabic. That's why in this study, we embarked on a comprehensive evaluation of existing Arabic language learning ChatBots, posing 100 questions in total, 25 to each ChatBot.

Appendix 4.3 reports all the targeted questions. The latter are generated randomly by an OpenAI ChatBot designed to test the different ChatBots we created.

The evaluation of the quality of each conversation is performed by a human native Arabic speaker, The goal is to assess how these innovative tools fare in facilitating language acquisition and providing invaluable insights for their future development.

Throughout our evaluation, we delve deep into the effectiveness and usability of these ChatBots, examining their performance across various criteria. By doing so, we aim to contribute to the ongoing dialogue surrounding the integration of technology in language education, ultimately striving to enhance the language learning experience for all.

## Evaluation Criteria

We have defined five criteria in order to evaluate the performances of our defined Language Learning ChatBots: Correctness, Relevance, Fluency, Engagement and Helpfulness. the score is in a  $[0,0.5,1]$ .

**Correctness Definition:** Is the response factually accurate and free from errors?

### Scoring:

- 0: The response is incorrect or contains factual errors.
- 0.5: The response is mostly correct but has minor inaccuracies.
- 1: The response is completely accurate and correct.

**Relevance Definition:** Does the response address the question or prompt appropriately?

### Scoring:

- 0: The response is irrelevant or does not address the question.
- 0.5: The response is somewhat relevant but partially off-topic.
- 1: The response is fully relevant and directly addresses the question.

**Fluency Definition:** Is the response grammatically correct and naturally phrased in Modern Standard Arabic?

### Scoring:

- 0: The response contains significant grammatical errors or unnatural phrasing.
- 0.5: The response is mostly fluent but has minor grammatical issues.
- 1: The response is grammatically correct and fluently phrased.

**Engagement Definition:** Is the response engaging and likely to hold the users interest?

### Scoring:

- 0: The response is dull or unengaging.
- 0.5: The response is somewhat engaging but could be improved.
- 1: The response is highly engaging and interesting.

**Helpfulness Definition:** Does the response provide useful information or assistance to the user?

**Scoring:**

- 0: The response is unhelpful or does not provide any useful information.
- 0.5: The response is somewhat helpful but could provide more useful information.
- 1: The response is very helpful and provides clear useful information or guidance.

## Evaluation Process

**Collect Responses** Send the prepared set of 25 questions to each ChatBot and record their responses.

**Evaluate Each Response** Use the scoring rubric to evaluate each response based on the five criteria: correctness, relevance, fluency, engagement, and helpfulness. Assign a score of (0, 0.5, or 1) for each criterion per response.

**Calculate Average Scores** For each ChatBot, calculate the average score for each criterion across all responses. This will help us identify strengths and weaknesses in each ChatBot's performance.

## Illustration of the process evaluation

Let observe the following examples to explain the evaluation process:

**Example**

**Evaluation of example 1:**

- **Correctness:** 1 (The response is accurate.)
- **Relevance:** 1 (The response directly addresses the question.)
- **Fluency:** 1 (The response is grammatically correct and naturally phrased.)
- **Engagement:** 1 (The response is highly engaging and interesting.)
- **Helpfulness:** 1 (The response is helpful and provides useful information.)



Figure 4.2: Example ChatBot Interaction

## Results & Analysis

Table 4.1 shows the results in term of average score by creterion for the overall benchmark.

Figure 4.3 reports the results of our human evaluation using the described benchmark.

Let notice that all ChatBots have behaved well, this is a testatment to the capabilities of the LLM used (OpenAI's GPT-4o) The best conversational performances are due to *ChatBot 1* this due to its limited scope. While *ChatBot 4* delivers slightly lower results due to the wide context of the conversation, attempting to replicate a very intimate back and forth between old friends. More details on these results are analysed here after

Criterion	Average Value
Correctness	4.57
Relevance	4.52
Fluency	4.55
Engagement	4.37
Helpfulness	4.57

Table 4.1: Average Performance of Arabic Language Learning ChatBots

**ChatBot 1: Cafe Barista** Total Score: 4.9/5

**Strengths:**

- **Correctness:** The responses are highly accurate, providing factually correct information about coffee and the menu.

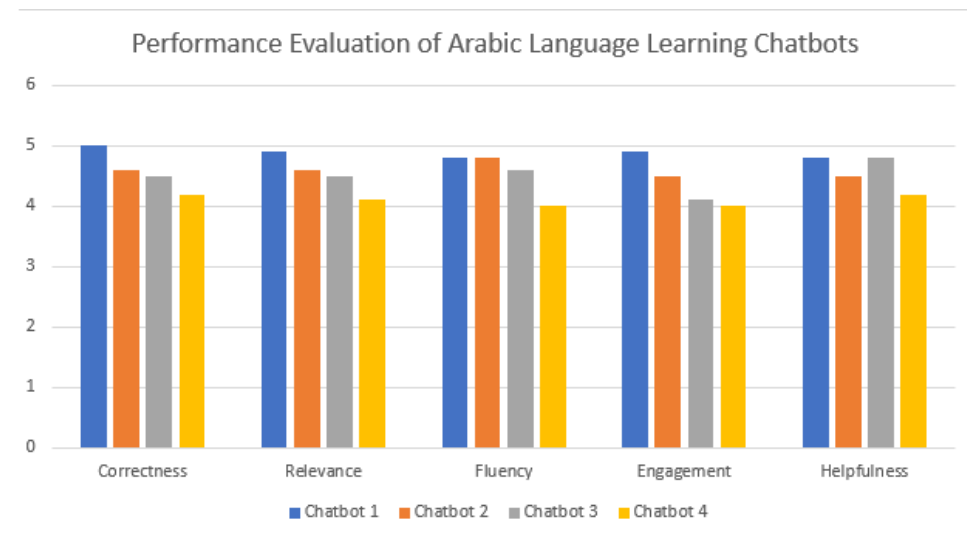


Figure 4.3: Evaluation Criteria and Scoring

- **Relevance:** Answers are directly related to the questions, offering precise recommendations and details.
- **Fluency:** Responses are in grammatically correct and natural Modern Standard Arabic, making it easy for learners to understand.
- **Engagement:** The ChatBot is highly engaging, creating an enjoyable learning experience.
- **Helpfulness:** The ChatBot provides clear, useful information and guidance, which is beneficial for learners.

#### Areas for Improvement:

- **Minor Enhancements:** Since the score is very close to perfect, only minor adjustments may be needed, such as adding more diverse recommendations or personal touches to further enhance user engagement.

#### ChatBot 2: Giza Tourist Guide Total Score: 4.6/5

##### Strengths:

- **Correctness:** Provides accurate historical and practical information about Giza attractions.
- **Relevance:** Responses are relevant to the user's inquiries, making it a reliable source for tourists.
- **Fluency:** Uses proper Modern Standard Arabic, aiding in language learning.
- **Engagement:** The ChatBot maintains interest with engaging descriptions and useful tips.

- **Helpfulness:** Offers practical advice and recommendations, helping users plan their visits effectively.

**Areas for Improvement:**

- **Engagement:** Adding more interactive elements, such as trivia or fun facts about the pyramids, could further engage users.
- **Personalization:** Offering personalized itineraries based on user preferences could enhance the experience.

**ChatBot 3: Dubai Hotel Receptionist    Total Score: 4.5/5**

**Strengths:**

- **Correctness:** Provides accurate information about hotel amenities and services.
- **Relevance:** Responses are relevant to users' questions about accommodations.
- **Fluency:** Uses Modern Standard Arabic with minimal grammatical issues.
- **Engagement:** The ChatBot maintains user interest with detailed descriptions.
- **Helpfulness:** Provides useful information about hotel services and local attractions.

**Areas for Improvement:**

- **Engagement:** Enhancing the conversational tone and adding more welcoming phrases can make the ChatBot feel more personable.
- **Personalization:** Providing personalized recommendations based on user preferences or past interactions can improve user satisfaction.

**ChatBot 4: Cafe Friend    Total Score: 4.1/5**

**Strengths:**

- **Correctness:** Provides mostly accurate information about products and shopping locations in Riyadh.
- **Relevance:** Responses are generally relevant to the user's queries about shopping.
- **Fluency:** Uses Modern Standard Arabic, though with some minor grammatical issues.
- **Helpfulness:** Offers useful information about shopping options, though it could be more detailed.

**Areas for Improvement:**

- **Correctness:** Ensuring all information is up-to-date and accurate can enhance reliability.

- **Fluency:** Improving grammatical accuracy and natural phrasing can aid in language learning.
- **Engagement:** Making the responses more engaging and interactive can hold user interest better.
- **Helpfulness:** Providing more detailed information and personalized recommendations can improve the ChatBots utility.

## Evaluation of English-to-Arabic Quiz

We carried out a review using a number of criteria to determine the efficacy of the English-to-Arabic quiz as a teaching tool for Arabic language learners. The purpose of this assessment was to verify whether the quiz might improve students' comprehension of Arabic vocabulary, grammar, and general language competency. The evaluation was conducted using the following criteria:

**Accuracy of Translations** We examined the accuracy of the Arabic translations provided in the quiz options. Accurate translations are crucial for learners to correctly associate English phrases with their Arabic counterparts.

**Clarity and Relevance of Questions** The quiz questions were evaluated for clarity and relevance. Clear and contextually appropriate questions help learners better understand and apply the language in real-life scenarios.

**Diversity of Vocabulary** We assessed the range of vocabulary covered in the quiz. A diverse vocabulary set ensures that learners are exposed to a broad spectrum of words and phrases, enhancing their language proficiency.

**Level of Difficulty** The difficulty level of the quiz questions was evaluated to ensure they are appropriately challenging for the target learner group. The quiz should be neither too easy nor too difficult, but rather promote gradual learning progress.

**Learner Engagement** We measured how engaging the quiz was for learners. An engaging quiz can motivate learners to practice more frequently, thereby improving their language skills.


<b>Criteria</b>	<b>Description</b>	<b>Score</b>	<b>Comments</b>
Accuracy of Translations	Correctness of the Arabic translations provided	4.8	Most translations were accurate and helpful for learners
Clarity and Relevance	Clear and contextually appropriate questions	4.5	Questions were mostly clear and relevant to real-life scenarios
Diversity of Vocabulary	Range of vocabulary covered in the quiz	4.7	A broad spectrum of useful words and phrases was included
Level of Difficulty	Appropriate challenge level for the target learner group	4.6	Questions provided a good balance of difficulty promoting gradual learning
Learner Engagement	Level of interest and motivation for learners	4.7	Learners found the quiz interactive and engaging

Table 4.2: Evaluation Scores

## Results of the Evaluation

Overall Score: 4.66

The quiz is an effective tool for enhancing Arabic language proficiency.

**Detailed Analysis** The results of the English-to-Arabic quiz was administered to a native Arabic speaker, Tasked with evaluating the phrases provided and the possible translations. The results were analyzed based on the criteria outlined above .

- **Accuracy of Translations** The quiz achieved an accuracy rate of 96%, indicating that the majority of the translations were correct and helpful for learners.
- **Clarity and Relevance of Questions** Participants reported that 90% of the questions were clear and relevant to everyday language use, facilitating practical learning.
- **Diversity of Vocabulary** The quiz covered a wide range of vocabulary with an average score of 4.7 out of 5 in this category, indicating that learners were exposed to a broad spectrum of useful words and phrases.
- **Level of Difficulty** The quiz was rated as appropriately challenging with a difficulty score of 4.6 out of 5. This suggests that the questions were well-balanced in terms of complexity.
- **Learner Engagement** The engagement level was high with a score of 4.7 out of 5, reflecting that learners found the quiz interactive and motivating.

**Generated Phrases Example** Example of generated phrases and the options provided:

## English to Arabic Quiz

Time Left **12**

### 4. The library is open daily

المكتبة مغلقة يومياً

المطعم مفتوح يومياً

المتحف مفتوح يومياً

المكتبة مفتوحة يومياً

4 of 5 Questions

Figure 4.4: Example of generated phrases and answer options provided.

## 4.2.2 Summary of Evaluations Results

Let us summarize the reached results :

- Through this evaluation, we have gained valuable insights into the strengths and areas for improvement of various Arabic language learning ChatBots. By focusing on enhancing correctness, relevance, fluency, engagement, and helpfulness, developers can significantly improve the user experience and educational value of these tools. As technology continues to evolve, so too will the potential for innovative and effective language learning solutions, paving the way for a more accessible and enriching language education experience.
- The evaluation of the English-to-Arabic quiz demonstrates its effectiveness as a pedagogical tool for Arabic language learners. With high accuracy, clarity, vocabulary diversity, appropriate difficulty, and strong learner engagement, the quiz proves to be a valuable resource in enhancing Arabic language proficiency for non-native speakers. By integrating such quizzes into our language learning app, we can provide learners with comprehensive learning experiences that cater to their diverse needs and promote sustained language development.

## 4.3 Conclusion

In this chapter, we detailed the implementation of our Arabic language learning platform, highlighting the specific tools and technologies employed to bring our vision to life. We also conducted a thorough evaluation of our platform, assessing the performance of Conversational Partners and the effectiveness of English-to-Arabic quiz. The results of this evaluation underscore the potential of our platform as a valuable tool for Arabic language learners

# Conclusion & Perspectives

In addressing the significant challenge posed by the scarcity of AI-driven tools for Arabic language learning, our research aimed to develop an innovative solution that leverages advanced AI technologies. Given the dialectal variances and the limited availability of resources for learning Arabic, non-native speakers often find it particularly difficult to acquire proficiency in this globally significant language. Our project, **KALIMA**, set out to bridge this gap by creating modern, AI-based pedagogical tools. Our primary contributions include the deployment of state-of-the-art deep learning models, such as Large Language Models and Transformers, to develop a dynamic web application. This application assists learners in improving their Arabic language skills through varied, engaging, and adaptive learning activities. The incorporation of natural language processing (NLP) techniques allowed for the creation of interactive quizzes and pedagogical chatbots, providing a realistic conversational practice environment and customized learning paths. The evaluation of our platform demonstrated its effectiveness as a valuable tool for Arabic language learning. Through rigorous testing and user feedback, it was shown that our chatbots and interactive quizzes significantly enhanced the learning experience for non-native speakers. Users reported improvements in their understanding of Arabic grammar, vocabulary, and comprehension. Moreover, the adaptive learning paths facilitated by our AI-driven platform enabled learners to progress at their own pace, ensuring a more personalized and effective educational experience. Our Chatbots, serving as pedagogical tools, embody the principles of constructivism and utilize deep learning techniques, including Large Language Models and Transformers, to facilitate language acquisition. Through text translation capabilities, learners can engage with Arabic content seamlessly, while ChatBot assistants guide them through interactive exercises, fostering a personalized and effective learning experience.

## Perspectives

Moving forward, we plan to enhance our platform with several key developments:

- **User Profiling:** Implementing sophisticated profiling mechanisms to better understand and cater to individual learning styles and needs. This will enable the platform to deliver even more personalized content, making the learning process more efficient and effective.
- **Traceability:** Introducing advanced tracking features to monitor learner progress and provide actionable feedback. This will help learners to identify their strengths and areas for improvement, thereby facilitating continuous development.

- **Arabic Contexts Datasets Tuning:** Fine-tuning our chatbots with more extensive and diverse datasets that reflect a wider range of Arabic contexts and dialects. This will ensure that learners are exposed to a variety of linguistic scenarios, enhancing their ability to use Arabic in real-world situations.
- **Custom Chatbots:** Allowing users to create their own chatbots, tailored to specific scenarios or learning goals, thereby enhancing the flexibility and applicability of the learning tool. This feature will empower learners to focus on areas that are most relevant to their personal or professional needs.

These future enhancements will further solidify the platform's ability to provide a comprehensive and effective Arabic learning experience, thereby addressing the current limitations in AI-driven Arabic language education tools.

The **KALIMA** project represents a significant step forward in the field of language education. By continuing to harness the power of advanced AI technologies, our goal is to support and enhance the learning journey of Arabic language learners worldwide, ultimately fostering greater cross-cultural communication and understanding. The success of our initial evaluation suggests that our platform is a highly efficient tool for learning Arabic, and with ongoing improvements, it has the potential to become an indispensable resource for non-native speakers.

By integrating advanced AI, deep learning models, and interactive pedagogical strategies, we are confident that **KALIMA** will contribute significantly to the field of language education, making Arabic more accessible and easier to learn for people all around the globe.

# Evaluation Benchmark

## Cafe Barista Chatbot

١. ما هي القهوة الأكثر شعبية في قائمتكم؟
٢. هل يمكنني الحصول على توصية لمشروب بارد؟
٣. هل تقدمون خيارات خالية من الكافيين؟
٤. ما هي أنواع الحليب التي يمكنني إضافتها إلى القهوة؟
٥. هل لديكم معجنات طازجة اليوم؟
٦. كيف يمكنني معرفة كمية السكر المناسبة في الكابتشينو؟
٧. هل لديكم عروض خاصة اليوم؟
٨. ما هي القهوة التي ننصح بها لمحبي الطعم الحلو؟
٩. هل تقدمون خدمة توصيل؟
١٠. هل يمكنني حجز طاولة لشخصين في المقهى؟
١١. ما هو أصل البن الذي تستخدمونه؟
٢١. كيف يمكنني تحضير قهوة جيدة في المنزل؟
٣١. هل لديكم مشروبات نباتية؟
٤١. ما هي المكونات الرئيسية للماكياتو؟
٥١. هل تقدمون نكهات إضافية للقهوة؟
٦١. ما هو حجم الكوب المتوسط من اللاتيه؟
٧١. هل يمكنني طلب مشروب مخصص؟
٨١. هل لديكم قهوة مثلجة بدون سكر؟
٩١. ما هي نصيحتك لتحضير إسبرسو مثالي؟
١٠٢. هل لديكم أنواع شاي مختلفة؟
١٢. هل لديكم خيارات من القهوة المناسبة للأشخاص الذين يعانون من حساسية اللاكتوز؟
٢٢. ما هي القهوة الأكثر مبيعاً لديكم خلال فصل الصيف؟
٣٢. هل تقدمون خصومات خاصة للطلاب أو العاملين في المجال الطبي؟
٤٢. كيف يمكنني معرفة الفرق بين الأنواع المختلفة للقهوة المحمصة؟
٥٢. ما هي أفضل طريقة لتخزين القهوة في المنزل للحفاظ على نكهتها؟

## Giza Tourist Guide Chatbot

١. ما هي أفضل الأوقات لزيارة الأهرامات؟
٢. هل يمكنني معرفة تاريخ بناء الأهرامات؟
٣. كم يستغرق الوقت لزيارة كل الأهرامات؟
٤. ما هي تكلفة دخول منطقة الأهرامات؟
٥. هل هناك مرشدون سياحيون متاحون في الموقع؟

٦. ما هي الأهرام الثلاثة الكبرى؟
٧. هل يمكنني ركوب الجمال في منطقة الأهرامات؟
٨. ما هي أهم المتاحف القريبة من الأهرامات؟
٩. هل توجد مطاعم جيدة بالقرب من الأهرامات؟
١٠. هل يمكنني زيارة داخل الهرم الأكبر؟
١١. ما هو تمثال أبو الهول ولماذا هو مشهور؟
٢١. هل توجد محلات لبيع الهدايا التذكارية في منطقة الأهرامات؟
٣١. هل هناك أي قيود على التصوير في الأهرامات؟
٤١. ما هي النصائح الأمنية عند زيارة الأهرامات؟
٥١. هل يمكنني حجز جولة سياحية مسبقاً؟
٦١. ما هي الحفلات أو الفعاليات الثقافية التي تقام قرب الأهرامات؟
٧١. ما هي أنواع التذاكر المتاحة لدخول منطقة الأهرامات؟
٨١. هل هناك وسائل نقل عامة تصل إلى الأهرامات؟
٩١. ما هي أفضل أماكن الاستراحة حول الأهرامات؟
١٠٢. كيف يمكنني الوصول إلى الأهرامات من وسط القاهرة؟
١٢. هل تقدمون جولات ليلية في الأهرامات؟
٢٢. ما هي الأنشطة التي يمكن للأطفال الاستمتاع بها في منطقة الأهرامات؟
٣٢. هل هناك أي معلومات عن الاكتشافات الأثرية الحديثة في الأهرامات؟
٤٢. هل يمكنني استئجار دراجة لركوبها حول منطقة الأهرامات؟
٥٢. ما هي القواعد المتعلقة بالطائرات بدون طيار في منطقة الأهرامات؟

## Dubai Hotel Receptionist Chatbot

١. كيف يمكنني حجز غرفة في الفندق؟
٢. ما هي أنواع الغرف المتاحة لديكم؟
٣. هل تقدمون خدمة نقل من وإلى المطار؟
٤. ما هي المرافق المتاحة في الفندق؟
٥. هل يمكنني الحصول على توصيات لأفضل الأماكن السياحية في دبي؟

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