SCRIPT-SAGE: An AI Chatbot that Helps You Learn Programming

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Abstract: This study presents SCRIPT-SAGE, an AI enhanced chatbot aimed at improving programming education, primirarily in C language. SCRIPT-SAGE provides an engaging and interactive learning experience by combining key features: a chatbot copilot for instant guidance, an integrated code editor for real-time practice, and quizzes to assess and reinforce understanding. The platform aims to simplify complex programming concepts, promote computational thinking, and support systematic learning through well-structured modules. By bridging the gap between theoretical knowledge and hands-on coding, SCRIPT-SAGE empowers learners to develop confidence and proficiency in programming in a user-friendly and accessible environment.

1 INTRODUCTION

The emergence of AI has profoundly altered technological interactions, with chatbots being a prominent advancement in this domain. Chatbots have contributed to a wide range of industries, offering efficient, automated solutions for tasks that once required human intervention. From customer service to healthcare, e-commerce to finance, chatbots have made processes faster, more accessible, and user-friendly.

Chatbots are now being used in various domains:

- Customer Support: Automating responses to frequently asked questions and troubleshooting issues in real-time.
- Healthcare: Assisting patients with symptom checks, scheduling appointments, and providing health-related information.
- E-commerce: Enhancing shopping experiences by recommending products, guiding customers through purchasing, and handling order queries.
- Banking and Finance: Facilitating transactions, helping users track expenses, and offering financial advice.

Nevertheless, one of the most consequential advancements attributed to chatbots resides within the domain of education, where they are fundamentally transforming the educational experience. From a sociocultural standpoint, chatbots seem to augment students' social presence by promoting emotional, transparent, and cohesive discourse (Pérez et al., 2020). Chatbots possess the capacity to provide uniform information to learners in real-time, incorporating critical elements such as evaluation standards, submission deadlines, and the geographical sites of suggested materials (Cunningham-Nelson et al., 2019). From pedagogical perspective, unlike traditional methods that rely on static resources and limited availability of teachers, chatbots provide flexibility in use, and are inexhaustibly available. Chatbots demonstrate the capacity to reiterate material multiple times, thereby supporting repetitive learning practices. Moreover, chatbots that integrate both textual and speech-based functionalities offer valuable assistance to students in developing comprehensive reading, writing, and listening skills (Roos, 2018). From a technical standpoint, the advent of transformer architecture has profoundly transformed the domain through the implementation of attention mechanisms. These mechanisms facilitate large language models (LLMs) in discerning contextual relationships within sentences and throughout paragraphs, thus significantly enhancing their efficacy in tasks including translation, summarization, and question-answering. (Abedi et al., 2023).

This paper provides a comprehensive overview of the SCRIPT-SAGE project, detailing its system architecture, core functionalities, and the rationale behind its design choices. We explore how SCRIPT-SAGE's intuitive user interface, progress tracking capabilities,

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and AI-powered interactions come together to create a holistic learning environment. By examining the intended outcomes and potential impact of SCRIPT-SAGE, we aim to demonstrate its significance in the field of computer science education and its potential to make programming more accessible to a wider audience. SCRIPT-SAGE, an AI-powered application, leverages these advancements by integrating a built-in chatbot specifically designed to help users learn the C programming language. Through interactive conversations, SCRIPT-SAGE guides learners through complex C programming concepts, offering real-time code feedback, debugging support, and simplified explanations to ensure that even beginners can navigate the intricacies of the language.

2 LITERATURE SURVEY

2.1 A Brief History of Chatbots

A literature review on current chatbot technologies by (Caldarini et al., 2022) outlines the various types of chatbots, including the Rule Based chatbots developed in the primary stages, and the most recenlty used Deep Learning (DL) based chatbots, the databases used to train the chatbots, the evaluation metrics used for each type of chatbot, and their applications in education and research. Techincal details, history, and general architecture of chatbots are highlighted in (Adamopoulou and Moussiades, 2020). Following are the outline points of a generalized chatbot architecture:

1. User interface component
2. User message analysis component - A spell-checker sentiment analysis and machine translation (multilingual chatbots).
3. Dialog management component - Data handling, error handling, and ambiguity handling.

2.2 Chatbots in Different Domains

The growing trend in healthcare chatbot development addresses the increasing demand for convenient, at-home medical advice for common ailments like colds, headaches, and abdominal pain. Research indicates that 60% of doctor visits are for minor conditions, 80% of which can be treated with simple home remedies, often without needing professional medical intervention. While existing healthcare chatbots can provide general advice through frequently asked questions (FAQs), they lack the ability to offer the nuanced, natural interaction expected in a human-doctor consultation. (Gumusel, 2024) The banking and finance sectors have rapidly embraced voice assistants and chatbots to offer more responsive and efficient customer service. In order to improve customer interactions, a recent study created a web-based chatbot for online banking that makes use of artificial intelligence (AI) capabilities, including natural language understanding (NLU). This chatbot enables users to seamlessly access personal banking information within the platform, improving the overall banking experience. (Doherty and Curran, 2019) Chatbot technology, often referred to as virtual assistants, has gained significant prominence in the hospitality industry.The viewpoints of users are not well understood, despite the fact that user perspectives have been thoroughly examined. A study that addressed this knowledge gap examined the use of chatbots in the hotel business using semi-structured interviews with professionals in the field. The results emphasise the main advantages chatbots offer the hotel sector, such as enhanced visitor experiences and more efficient operations (Buhalis and Cheng, 2020).

2.3 Chatbots in Education

The benefits of chatbots in the educational system are discussed by (Adamopoulou and Moussiades, 2020), noting that the learning support chatbots can preserve information by replaying previous lessons for students who miss them. The use of personal data by conversational chatbots is covered in (Caldarini et al., 2022). A security issue arises when chatbots use user data and even ”learn” from it. Along with how the backend manages user data on the server, the paper also discusses security concerns related to data transfers to the chatbot’s server. Some security-related topics discussed in the paper include:

- **Authentication and authorization** - Malicious chat-bots operating on crossplatforms, hazards of sharing data on the internet.
- **End-to-End Encryption** - Usage of https protocol and public-key encryption is encourages.
- **Self-destructing messages** - Messages containing sensitive PII (Personally identifiable information) are automatically erased after a set period of time.

2.4 Computational Thinking in Educational Landscape

1. The article (Papadakis, 2022), highlights the need for developing appropriate applications. Compu-

tational Thinking is one of the fundamental skill of 21st century. Despite the abundance of available apps, researchers have identified a critical need for developmentally appropriate applications specifically designed to promote CT concepts and coding skills in young learners.

2. The literature (Lye and Koh, 2014) emphasizes three key dimensions of CT: computational concepts, practices, and perspectives. This review underscores the need for more targeted research in K-12 settings and highlights the importance of developing comprehensive instructional strategies to effectively integrate CT across various educational contexts.
3. The literature (Fagerlund et al., 2021) reveals a significant challenge in defining clear educational objectives for CT at the primary level, with curricula across various countries focusing on related but distinct areas such as computer science, computing, programming, or digital literacy. This lack of specificity extends to the concrete operationalization of CT teaching, learning, and assessment methods, even when using popular programming environments like Scratch.

2.5 Pedagogical Approaches: Chatbot Case Study

1. A comprehensive study (Kim and Ko, 2017) analyzing 30 diverse and widely-used online coding tutorials against dimensions derived from learning sciences and education literature reveals both strengths and weaknesses in their approach. The research indicates that most tutorials share commonalities in content coverage and employ a bottom-up organizational structure, providing goal-directed practice opportunities with immediate feedback. (Labadze et al., 2023) However, the study highlights critical shortcomings, notably the lack of personalization to learners' prior coding knowledge and insufficient guidance on knowledge transfer and application.
2. The literature (Bers, 2019) highlights a significant gap in pedagogical approaches specifically tailored for teaching computer science to young children. Traditional STEM-based instructional methods, originally designed for older students, are often inadequate for early childhood education. (Peteranetz et al., 2018) Researchers have come up with creative solutions to this problem, like ”Coding as Another Language” (CAL), which views coding as a new symbolic representation system for expressive and communicative purposes. This method, which is based on principles of language and literacy education, stresses play, exploration, socialization, and creativity while acknowledging the distinct developmental phases of young children. The literature also introduces the concept of six coding stages or learning trajectories that children progress through when exposed to CAL curriculum. Case studies utilizing tools like the KIBO robot and ScratchJr app have been conducted to characterize these stages and demonstrate the practical application of CAL instructional practices.
3. Study in (Scott et al., 2007) have identified several key issues that contribute to student demotivation, including difficulties with programming language syntax and semantics, underdeveloped problem-solving and program design skills, and the complexity of development environments. (Popat and Starkey, 2019) In response to these challenges, researchers have explored various approaches to support novice programmers. One such innovative approach involves the use of interactive, visual problem-solving tools. This paper contributes to this body of research by proposing an interactive flowchart-based tool that not only aids in visual problem-solving but also generates syntactically correct program code. The literature emphasizes the importance of visual representations in enhancing student understanding, and this tool builds on that principle by providing animation features and establishing a clear connection between visual solutions and code representations.

3 PROPOSED METHODOLOGY

To address the challenges of teaching programming through chatbots, we propose SCRIPT-SAGE, an AI-driven chatbot designed to facilitate coding education. SCRIPT-SAGE offers an integrated platform where students can engage in interactive coding lessons, receive real-time feedback, and improve their coding skills in a supportive environment. By leveraging AI, SCRIPT-SAGE aims to enhance the learning experience by providing personalized assistance, answering questions, and guiding learners through programming concepts and practical exercises.

3.1 System Architecture

SCRIPT-SAGE is structured to provide comprehensive experience to the users. Layered architecture in

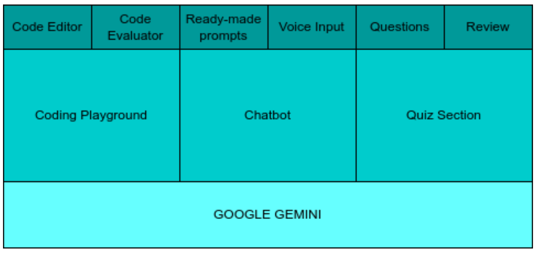


Figure 1: Script-Sage: Layered Architecture.

Figure 1 pans out the components of the system: Coding Playgound, Chatbot, and Quiz Section. User directly interacts with the top layer consisting of Code Editor, Code Evaluator, Prompts, Inputs, Questions and Reviews. All of the components interact with the core LLM - Gemini by Google. The details of the interaction are shown in Figure 2. Each data point generated by user is passed through LLM to convert the metric data into natural language. This approach condenses the data and provides user the compact information. User directly interacts with Code Engine, Quiz Engine and Chatbot Engine which interacts with respective utility engines which, in-turn interacts with Gemini LLM. The approach allows only required information to flow into the LLM, get the information from LLM and send it back to the user.

3.2 Technical Aspects

The underlying system mechanism of SCRIPT-SAGE includes a transformer based chatbot that works based on attention mechanism. (Vaswani, 2017)

- **Self Attention Mechanism**: An essential part of transformer models is the Self-Attention Mechanism. It is essential for comprehending the connections between words in a sentence, which enables the model to successfully capture contextual meanings. In a sentence, each word's meaning can depend on other words in the sentence. Self-attention calculates how much each word should pay attention to every other word, helping the model understand their contextual relationships. The mechanism computes scores that indicate the importance of each word in relation to the current word being processed. These scores help the model focus on the relevant words while generating a response.
- **Multiple layers of Attention**: Transformers can recognise the relationships between words in a sentence regardless of where they are in the sentence thanks to layered layers of self-attention processes. Each layer refines the understanding of word connections, allowing the model to interpret complex dependencies in language. This layered approach helps the model build a more detailed representation of the input text. Unlike older architectures like Recurrent Neural Networks (RNNs) or Long Short-Term Memory (LSTM) networks, which process words sequentially, transformers handle all tokens (words or subwords) in parallel. This parallelism greatly improves the speed of computation, making transformers much more efficient and suitable for processing large datasets. It enables the model to better manage long-range dependencies.
- **Cross Attention Mechanism**: The Cross-Attention Mechanism in multimodal models allows the model to process and relate information from different data types (modalities), such as text, images, audio, and video, to create a unified understanding of the data. Cross-attention links information from one data type to another, allowing the model to interpret the relationships between them. For example, when processing an image with a caption, the model can relate specific words to particular parts of the image.

Pseudocode for Attention based mechanisms:

```
1. Tokenization: Convert the input text into tokens.
2. Embedding: Map tokens to vectors using an embedding matrix.
3. For each token in the sequence:
   (a) Apply Self-Attention mechanism:
       i. Calculate Query, Key, and Value matrices.
       ii. Compute attention scores.
       iii. Generate a weighted representation of the tokens.
   (b) Apply Feed-Forward Neural Network to process the attended output.
   (c) Add Residual Connection and Layer Normalization.
4. Repeat step 4 for each layer in the transformer (stacked layers).
5. Generate the output token probabilities using a Softmax function.
6. Use Beam Search or Sampling to generate the most probable response.
7. Convert tokens back to human-readable text.
8. Output: Return the generated response to the user.
```

Query, Key, Value: These matrices are derived from the input tokens and help in computing the attention scores.

Attention Calculation: This step determines which words in the sentence should be focused on more heavily to generate the response.

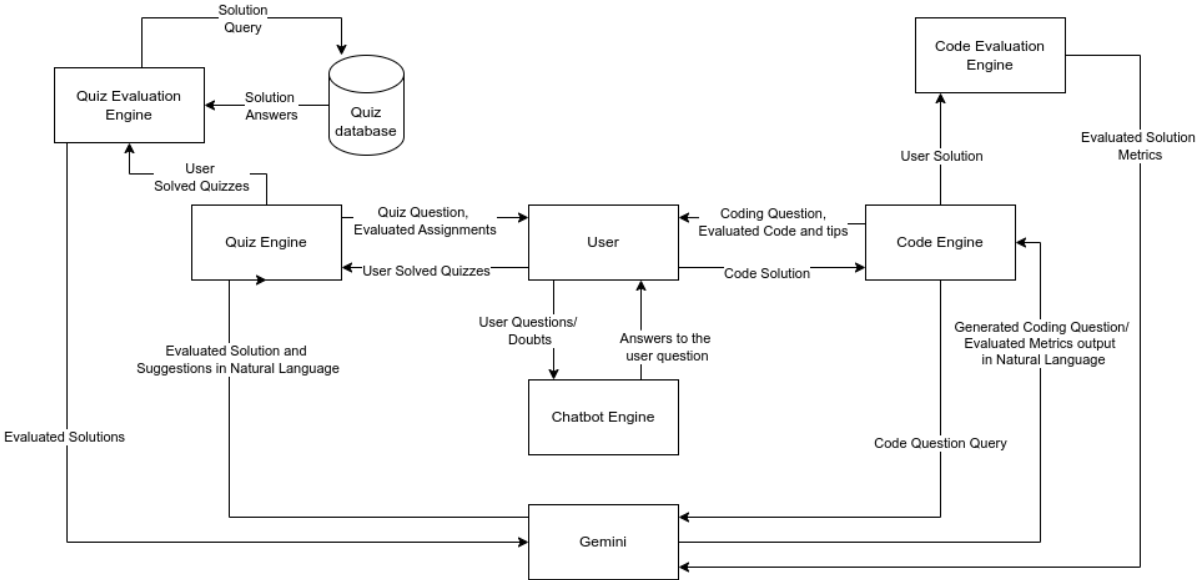


Figure 2: Script-Sage: Working Flow Diagram (DFD).

Softmax Function: Converts raw scores into probabilities to select the best token for the response.

Feed-Forward Neural Network: Applies transformations to the attended output for deeper processing.

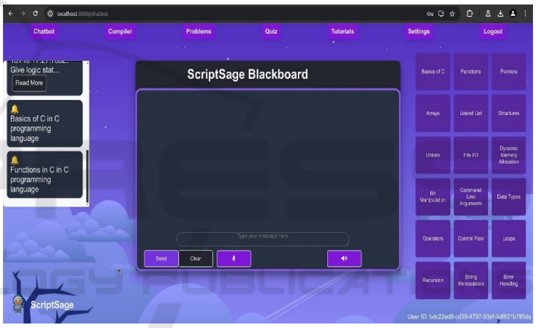
Beam Search/Sampling: Used to generate a coherent response by choosing the best possible sequence of words.

3.3 UI and Features

Script Sage is designed as an intelligent and interactive platform aimed at teaching programming languages, specifically focusing on C. Its architecture revolves around integrating AI-driven chatbot functionalities, real-time coding environments, and user progress tracking to create a seamless learning experience. (Tlili et al., 2023)

3.3.1 UI

1. The core of SCRIPT-SAGE in Figure 3, is Google Gemini 1.5 pro latest, which is tuned to answer user queries related to coding. The chatbot is trained on a large corpus of programming knowledge. By providing clear explanations and step-by-step guidance, it enhances the learning process for both beginners and intermediate users.
2. SCRIPT-SAGE integrates a real-time code editor as shown in 4 that supports C programming. This editor allows users to write and run code directly within the chatbot interface, offering immediate feedback on syntax and logic errors. It also includes features like syntax highlighting and error detection, which enhance the learning experience by providing useful insights into the coding process.



Give logic stat...

🔔 Basics of C in C programming language

🔔 Functions in C in C programming language

User ID: bdc22ed9-cd39-4797-93ef-5df831b785da

Figure 3: Script-Sage: Home.

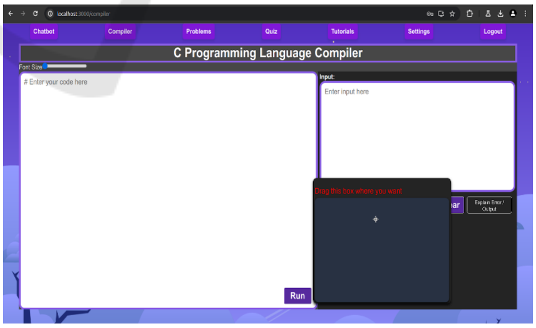


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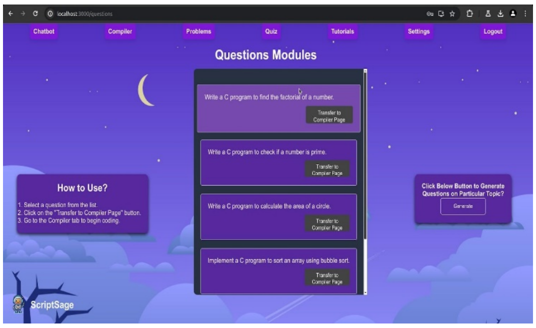
Figure 4: Script-Sage: Code Editor.

3. SCRIPT-SAGE includes interactive quizzes that evaluate the user's grasp of programming concepts. The learning module is adaptive, which



Questions Modules

Write a C program to find the factorial of a number.

Write a C program to check if a number is prime.

Write a C program to calculate the area of a circle.

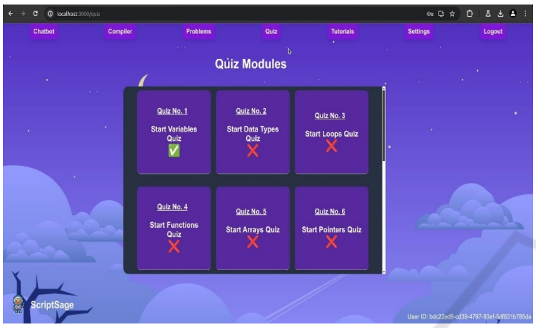
Implement a C program to sort an array using bubble sort.

How to Use?

1. Select a question from the list.
2. Click on the "Transfer to Compiler Page" button.
3. Go to the Compiler tab to begin coding.

Click Below Button to Generate Questions on Particular Topic?

Figure 5: Script-Sage: Question Generator.



Quiz Modules

User ID: bdc22ed9-cd39-4797-93ef-5df831b785da

Figure 6: Script-Sage: Quiz.

means that it presents content tailored to the user's skill level and progress. As users complete the quizzes (Figure 5), the system generates feedback, helping them focus on areas that need improvement.

4. A key feature of SCRIPT-SAGE is its ability to track user progress over time. The system records the modules completed, quiz scores , and coding exercises, allowing users to monitor their improvement. This data can also be used to personalize future learning materials.

3.3.2 Features

Key components of the system include the following:

1. The core of Script Sage is a generative AI chatbot that helps users learn programming by answering questions, explaining code, and debugging problems. The chatbot leverages a large dataset of programming-related content, enabling it to offer context-aware responses based on the user's queries.

2. The system integrates a code editor within the interface where users can write and execute C programming code. This editor provides immediate feedback on syntax errors, logic issues, and performance, making the learning process more practical and hands-on.

3. A dynamic learning module that adapts to the user's knowledge level, providing interactive quizzes to assess and reinforce their understanding of programming concepts. Based on performance, the module adjusts the difficulty of subsequent questions and provides detailed feedback.

4. Script Sage tracks user activities, including quiz scores, completed modules, and coding time spent. This data is analyzed to create personalized learning paths, ensuring that users focus on areas that require improvement while encouraging continuous engagement.

5. The system incorporates elements of casual conversation designed to support the mental well-being of the user. These include reminders to take breaks during long coding sessions and motivational feedback to encourage consistent learning without causing burnout.

6. The NLP component of Script Sage is crucial for understanding user input and delivering appropriate responses. The model is fine-tuned for programming education, ensuring that the chatbot can handle queries related to:

(a) Syntax explanation and logic-building.

(b) Debugging and error handling.

(c) Programming best practices.

The chatbot can interpret user intent, regardless of the query's complexity, and provide personalized assistance. Over time, the model can be improved using user data to enhance response accuracy and engagement.

4 COMPARATIVE ANALYSIS

4.1 Detailed Insights

- **Zendesk's Answer Bot (Customer Service)**:
  - **Functionality**: Focuses on automating customer service interactions by providing instant answers to frequently asked questions.
  - **Strengths**: Significantly reduces response times, enhancing customer satisfaction.
- **Woe-bot (Healthcare)**:
  - **Functionality**: Offers mental health support using cognitive behavioral therapy techniques.
  - **Strengths**: Provides accessible emotional support in a friendly manner.
- **Duolingo (Education)**:

Table 1: Domains and their corresponding chatbot functionalities. The final sentence of a caption should end with a period.

Domain	Chatbot	Functionality
Programming	Script Sage	C programming queries, code snippets, debugging assistance.
Customer Service	Zendesk's Answer Bot	Automates responses to customer queries.
Healthcare	Woebot	Mental health support and CBT techniques.
Education	Duolingo	Language learning through interactive conversations.
Finance	Cleo	Personal finance management and budgeting advice.
Entertainment	AI Dungeon	Interactive storytelling and creative writing.

  - **Functionality**: Engages users in language learning through games and quizzes.
  - **Strengths**: Its gamified approach keeps users motivated and enhances language retention.

- **Cleo (Finance)**:
  - **Functionality**: Acts as a personal finance assistant, offering insights on spending and budgeting.
  - **Strengths**: Provides users with a clear picture of their financial health.
- **AI Dungeon (Entertainment)**:
  - **Functionality**: Allows users to create and navigate through interactive storytelling adventures.
  - **Strengths**: The open-ended nature of interactions fosters creativity.
- **SCRIPT-SAGE**:
  - **Specialization**: Designed specifically for C programming, it excels in providing targeted support for coding-related queries.
  - **Strengths**: Offers deep insights into C language features, including memory management and data structures.

5 CONCLUSION

The SCRIPT-SAGE project exemplifies how modern technology, particularly AI, can be used to create a dynamic and engaging learning environment. Using generative AI to power its conversational chatbot, SCRIPT-SAGE provides contextually relevant personalized support to learners. The integration of a real-time code editor, quizzes, and user progress tracking ensures that users receive immediate feedback and can monitor their learning journey effectively.

The technology stack, consisting of React JS for the frontend and AWS cloud services for deployment, enables scalability, performance, and a seamless user experience. The use of CI/CD pipelines ensures that updates to chatbot and learning modules are deployed efficiently, maintaining the quality and availability of the application.

In future phases, the deployment of SCRIPT-SAGE in the cloud will allow continuous improvements in system performance, scalability, and user interaction, laying the groundwork for a long-lasting and impactful tool in the world of programming education.

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