# Coursework and GenAI: A Practical Guide for Students

# Understand Module

## What is “Generative AI”?

Generative Artificial Intelligence (GenAI) refers to algorithms that create digital content. This can include:

* Text
* Images
* Videos
* Audio
* Molecular structures

GenAI models learn patterns by analyzing large sets of examples to generate new content based on a user's descriptive prompt or instruction. Understanding how these powerful tools work can help you use them effectively to simplify and accelerate everyday tasks.  Examples you may be familiar with include grammar checkers, music recommendations, customer support chatbots, or agents such as Microsoft Copilot or ChatGPT for question responses or content creation.

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| What is a Large Language Model?   Large Language Models (LLMs) are a type of GenAI that learn patterns from vast amounts of text data. They are enormous in terms of both computing power and the amount of training data used.   The main job of an LLM is to predict which words are likely to appear next in a given phrase or sentence. At a basic level, this involves recognizing grammatical correctness, like preferring "the dog slept" over "the dog green." However, modern LLMs consider larger contexts, helping them produce more accurate and nuanced responses. | Picture 1505100301, Picture, Picture |
| How do LLMs generate text?   When generating text, an LLM evaluates the likelihood of each possible next word. For example, if the model generates the phrase "the cow jumped over the..." it then determines the probability of each word in its vocabulary coming next.  This process is repeated word-by-word until it predicts the segment is finished. Because each word is selected independently and with some randomness, slightly different outputs may occur each time. | Picture 1966622116, Picture, Picture |

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| Do LLMs “plan” responses?  Despite generating coherent responses, LLMs do not actually plan or have intentions. They predict each word based solely on probability, which means:   * The same prompt can lead to different responses. * Long responses might lose earlier details, as the model can only consider a limited context. * They can't perform tasks requiring strategic planning, like playing chess effectively, because there's no forward-thinking involved. |

Hallucination and truthfulness

You might have heard that LLMs sometimes "hallucinate," producing information that sounds true but isn't. This happens because the words are predicted based on likelihood, not facts.

For tasks like programming, there's usually one correct option, so the model performs well. For regular language, many similar-sounding words can work, making truthfulness less clear.  For example, consider these sentences:

* "King Charles was born in 1944."
* "King Charles was born in 1949."
* "King Charles was born in 1945."

All of these sound equally correct grammatically, but none are true, since he was actually born in 1948! Because LLMs focus on grammar and likelihood rather than factual accuracy, they can easily choose incorrect but plausible answers across all disciplines. Other examples include fabricated references or statistics, fake quotes or incorrect formulas that look “right,” but are false information generated by the tools. In general, LLMs are good at *sounding right*, even when they are making things up!

Once an incorrect word or fact is chosen, the model can't go back to correct it, which can propagate to cause further inaccuracies.

## Practice activity – Explore Varied responses from chatbots

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| Complete the sentence...   To investigate how chatbots vary their responses based on the predictability of a sentence, follow these steps:   1. **Create Sentence Prompts**:    * Think of a few sentence prompts that have:      + **A very likely next word** (e.g., “The sun rises in the \_\_\_.”)      + **A wide range of possible next words** (e.g., “The artist looked at the canvas and \_\_\_.”) 2. **Input Sentences into Chatbots**:    * Use chatbots like Microsoft Copilot, Claude or ChatGPT to complete each sentence. *"I’m testing how predictable the next word is. Please complete this sentence: The sun rises in the..."* 3. **Repeat and Compare**:    * Repeat this process multiple times with the same sentence to observe if you get different results.    * Try using different GenAI tools if available.    * Compare the consistency of the completions across your examples.     Reflect on the results. Do the variations surprise you? |

Training Data in Large Language Models

Large Language Models (LLMs), like ChatGPT or Google's Gemini, learn by analyzing huge amounts of text data from various sources. While developers generally do not share the details of their underlying training data, understanding more about these sources helps explain why LLMs produce certain responses.

## Types of Training Data

Data is collected from publicly accessible websites by automated web crawlers providing diverse content:

* Internet
* Books and literature
* Wikipedia and knowledge bases
* Programming code
* Images

**Examples:**

* **Internet**: Models like ChatGPT use text from publicly available web pages gathered by web crawlers. This provides diverse content but includes inaccuracies, biased information, and otherwise harmful or outdated content which models will learn from. In addition, many have criticized the lack of permission involved in scraping websites, while proponents argue that this practice has been employed for years to power tools like Google Search.
* **Books and literature**: LLMs use collections of books, both public domain and proprietary. Book data offers richer linguistic capabilities as these sources provide better represent well-edited, thoughtful language but has sparked controversy over use of copyrighted texts without permission.
* **Wikipedia and knowledge bases**: These platforms provide structured, factually dense, and regularly updated content, helping models develop a baseline of factual accuracy on an extensive range of topics, from detailed biographies to scientific concepts. While valuable for including information about general world knowledge, although they don’t prevent hallucination or learning inaccurate or false information from less reliable sources.
* **Programming code**: Because modern LLMs are increasingly used to assist with programming tasks, they draw on open-source code from platforms like GitHub, enabling code generation and improving grammatical accuracy.
* **Images:** Images may be drawn from available web pages gathered by web crawlers or from databases available to the public, which may have copyright implications.

## Encoded Bias

LLMs learn from real-world data, absorbing biases from their sources. Internet text often contains stereotypes or biased perspectives, which models unintentionally reproduce. For example, frequent negative portrayals of a group in training data can lead to the model repeating these biases. Recognizing and mitigating these biases is crucial. Developers and researchers are continually working on strategies to:

* Curate data more carefully.
* Use bias detection tools.
* Implement techniques to reduce biased outputs.

Still, it's important to remember current LLMs contain biases that could impact their responses and take responsibility for potential issues in content generated through your chatbot interactions.

Public vs. Licensed Data

Although data may be publicly accessible, it does not always mean developers have clear permission to use it. This issue has sparked significant ethical and legal debates regarding ownership and licence arrangements.

* **Public data** is easy to access for training LLMs but may lead to escalation of issues around permission and copyright.
* **Licensed data** is well-edited, fact-checked, reliable, and ensures authors receive compensation.

For additional guidance visit [University of Toronto Libraries: GenAI and Copyright Considerations](https://onesearch.library.utoronto.ca/copyright/generative-ai-tools-and-copyright-considerations)

## User Interactions

Models like ChatGPT also learn from actual user interactions (prompts, corrections, follow-ups), enabling them to adapt and better handle real-world tasks. However, it's important to be cautious, as user-submitted data, including your original work, could potentially reappear in future responses.

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| Your Data in LLMs  When you use services like ChatGPT, your interactions can be used to help train and improve the model. This means your shared information, like personal details or assignments, or private information, might shape future responses. For example, if you submit your own essay or original work, the model might generate similar text in the future, potentially sharing your ideas and text with others.  To keep your data safe and maintain privacy:    * Think twice before sharing sensitive or personal details. * Avoid inputting private information like your full name, student ID, passwords, or confidential research data. * Always check how a service handles your data to make informed decisions.   Remember, being cautious about what you share online helps protect your privacy and ensures responsible use of technology.  For additional guidance visit the University of Toronto [Information Security Guidelines on use of GenAI](https://security.utoronto.ca/governance/guidelines/use-ai-intelligently/). |

## How Data is Used

During training, LLMs repeatedly see text sequences and attempt to predict the next word based on the context. The model has billions, or even trillions of internal parameters that are adjusted each time the prediction differs from the actual next word. Over time, the model gradually becomes more adept at correctly predicting the next word based on language structure, grammar and more.

This training process helps to explain why these models can provide coherent and contextually relevant responses. However, they don’t “understand” language the way we do – they simply predict words based on highly complex patterns in the data. This is also why models can generate plausible but incorrect information, as their predictions are based on statistical modelling rather than a sense of truth or understanding or generation of new knowledge in a topic or discipline.

# GenAI Chatbots: Advancing techniques at scale

## Energy resources and sustainability

Generative AI (GenAI) is a powerful tool that requires significant energy resources to operate, particularly due to the high computational demands of training and running large models. This energy consumption can contribute to increased carbon emissions and environmental impact. However, there are sustainability initiatives that can help mitigate these effects. For instance, optimizing energy efficiency in data centers, using renewable energy sources, and improving the algorithms using methods described below may reduce computational load. While responsible development practices, such as focusing on energy-efficient model training and deployment may lessen the environmental footprint, this remains a significant concern as the use of AI-enabled tools increases.

## Increasing efficiency and efficacy

As people worry more about how sustainable Generative AI tools are, developers are working on making them more efficient. One way they do this is by **cleaning up the data** before training the AI. Raw text from the internet often has repeated phrases, low-quality content, personal information, and mixed languages. By removing these, the AI can learn better and faster. This process helps reduce the amount of computing power needed.

Another method is called **Retrieval-Augmented Generation (RAG).** Since AI models are trained on fixed data and can't access new information on their own, they might give wrong answers about recent events. RAG helps by letting the AI look up information from sources like Wikipedia or news articles before answering. This makes the AI's responses more accurate and up-to-date without needing constant retraining.

Additionally, **Chain-of-Thought reasoning (CoT)** helps AI handle complex problems by breaking them down into smaller steps and explaining each one clearly. This makes the answers more accurate and easier to understand, especially for tasks involving logic, math, or puzzles.

By using these techniques, developers can create AI systems that are more efficient, accurate, and better suited for real-world use.

**If you are interested in a more detailed explanation, review the topics below to learn more about advanced methods:**

## Retrieval-Augmented Generation

All LLMs are trained on fixed datasets based on pre-processed content to support efficient training from clean structured text. This can involve removing repeated or low-quality content, personally identifiable names, etc. However, as they can't automatically access information beyond their training data, LLMs may omit or produce incorrect facts about recent events. Developers have implemented a strategy called Retrieval-Augmented Generation (RAG) that addresses this by allowing tools to access external knowledge sources using the following process:

1. **Retrieve:** When a user asks a question, the system first searches a reference database (e.g., Wikipedia, articles, web results) for relevant information.
2. **Augment:** The retrieved information is provided as context to the LLM.
3. **Generate:** The LLM then produces a more accurate and informed response based on this additional context.

For example, asking an LLM trained only up to 2021, "Who won the FIFA World Cup in 2022?" would normally result in a guess or incorrect response. However, a RAG-enhanced system would first retrieve updated information, enabling the model to provide the correct answer along with relevant sources. RAG processing implemented by developers of GenAI agents makes the outputs of LLMs more reliable and up-to-date, significantly reducing inaccuracies.  Retrieval-Augmented Generation (RAG) can also significantly improve efficiency and reduce compute time load in Generative AI applications.

## Chain-of-Thought reasoning

Chain-of-Thought reasoning (CoT) prompts LLMs to break down complex problems into smaller, step-by-step reasoning tasks before providing a final answer. Many newer models, like ChatGPT and Gemini, now explicitly support or are trained to use this technique.

Instead of immediately giving an answer, the model first explains its reasoning clearly.

This approach helps:

* Improve accuracy on tasks involving logic, math, or puzzles.
* Make answers more understandable and transparent by showing the reasoning process.

For example, instead of quickly answering a tricky math question, the model first describes each calculation step-by-step, making mistakes less likely. Researchers found CoT reasoning significantly enhances performance on tasks requiring careful thought, such as logical reasoning and math problems.

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| Explore and reflect  To explore how LLMs have a fixed “knowledge cutoff” and how this affects their ability to answer questions about recent events, follow these steps:   1. Ask a chatbot such as Microsoft Copilot or ChatGPT about a recent event, such as a sports tournament, political development, tech launch, or news story from the past 6–12 months. 2. Try multiple variations of the question to test what the model knows (and what it admits not knowing!) 3. Finally, ask the model directly: “What is your training data cutoff?” or “When does your knowledge end?” to compare with what you observe.   *Example prompts:*  *Who won the 2024 Olympic men’s 100m final?*  *Can you tell me what happened at COP29?*  *What are the most recent updates about Apple’s Vision Pro?*  Reflect on the results. Does the model give a date for its knowledge cutoff? Does this match what you observed in its answers?  How does the model handle uncertainty or unknown information — does it make a guess, hedge, or clearly say it doesn’t know? |

## Three Takeaways

1. Large Language Models work by learning patterns in existing data (e.g. books, web pages) and using them to predict the most likely sequence of words.
2. LLMs can produce plausible but incorrect information (hallucination) and may unintentionally reproduce biases from their training data.
3. Using LLMs involves risks such as data privacy concerns, where user interactions can be used to improve models but may inadvertently share sensitive information.

## References

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[**AI Demystified: Introduction to Large Language Models** Links to an external site.](https://uit.stanford.edu/service/techtraining/ai-demystified/llm) (Stanford University)

[**Learning with GenAI** Links to an external site.](https://genai.ubc.ca/guidance/teaching-learning-guidelines/learning-with-genai) (University of British Columbia)

[**Prompt Engineering Best Practices** Links to an external site.](https://help.openai.com/en/articles/10032626-prompt-engineering-best-practices-for-chatgpt) (OpenAI)

## Acknowledgements

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