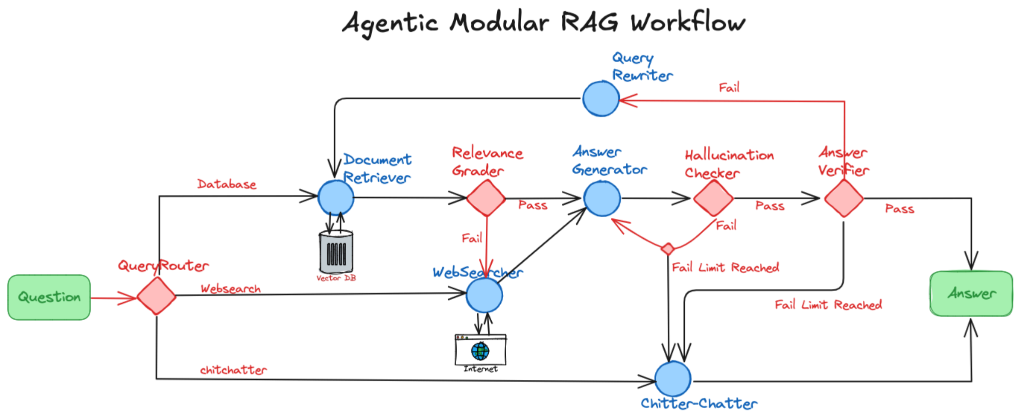
Lab 7: Building an Agentic RAG Workflow with LangGraph

This lab guides you through the design and implementation of a modular, agentic Retrieval-Augmented Generation (RAG) system using LangGraph.



Core Features Implemented

- Multi-Agent Collaboration

  Specialized agents (e.g., Query Router, Answer Generator, Verifier) work together to deliver robust, high-quality responses.

- Adaptive Retrieval Routing

  Inspired by Adaptive RAG, the system dynamically selects between vectorstore, web search, or fallback dialogue based on the question's intent.

- Fallback Mechanism (Corrective RAG)

  Based on Corrective RAG, the system falls back to web search if retrieved documents are weak or irrelevant.

- Self-Correction & Reflection

  Following Self-RAG, the system performs hallucination detection and answer usefulness checks, triggering retries or rewrites when needed.

- Performance Considerations

  - Efficiency: Uses async document grading to speed up multi-query retrieval.
  - Failure Handling: Implements structured retry logic with maximum retry limits.

The lab consists of three main phases:

1. Define Agent Functions.
2. Build the Workflow with LangGraph.
3. Run the Workflow.

In [ ]:
```
# %pip install -Uq langchain langchain_community langgraph
```

```
[notice] A new release of pip is available: 23.0.1 -> 25.0.1
[notice] To update, run: pip install --upgrade pip
Note: you may need to restart the kernel to use updated packages.
```

In [4]:
```
# Environment Configuration
from dotenv import load_dotenv
import os
from sqlalchemy.engine.url import make_url # Used to parse and construct
from langchain_postgres.vectorstores import PGVector # Integration with P

# LLM and Core LangChain Tools
from langchain_openai import OpenAIEmbeddings
from langchain_openai import ChatOpenAI

from langchain_core.messages import HumanMessage, SystemMessage
from langchain.load import dumps, loads  # Serialize/deserialize LangChai
from langchain_core.prompts import PromptTemplate
from langchain_core.output_parsers import StrOutputParser
from langchain_core.documents import Document # # Standard document forma

from typing_extensions import TypedDict # Define structured types for sta
from typing import List  # Specify types for list inputs or outputs
import asyncio # Support asynchronous execution for parallel LLM calls

from langgraph.graph import StateGraph, END # LangGraph tools to define s

# Visualization and Display Utilities
import textwrap
from IPython.display import Markdown, Image
from pprint import pprint

# Web Search Tool
from langchain_community.tools.tavily_search import TavilySearchResults
```

In [2]:
```
# Load environment variables from .env file
load_dotenv()

# Access the environment variable
openai_api_key = os.getenv("OPENAI_API_KEY")
connection_string = os.getenv("DB_CONNECTION")
tavily_api_key =os.getenv("TAVILY_API_KEY")

# Configure Database Connection
# Use the same shared table as from the last lab
shared_connection_string = make_url(connection_string)\
    .set(database="IST345_Drucker_data").render_as_string(hide_password=F

# Initialize the embedding model
embedding_model = OpenAIEmbeddings(model="text-embedding-3-large")

# Quick check environment variables
if not openai_api_key or not shared_connection_string or not tavily_api_k
Loading [MathJax]/extensions/Safe.js(f"Error: Missing one or more required environment variables") #
```

```
else:
    print("All environment variables loaded successfully")
```

```
All environment variables loaded successfully
```

In [4]:
```
# Main LLM for handling complex or creative tasks
llm_gpt = ChatOpenAI(
    model="gpt-4o", # GPT-4o is a powerful model with strong reasoning ca
    temperature=0.7,
    api_key = openai_api_key
)

# Lightweight LLM for simple or deterministic tasks
llm_gpt_mini = ChatOpenAI(
    model="gpt-4o-mini",    #  Smaller, faster variant for lightweight ta
    temperature=0,          # Temperature 0 = fully deterministic output
    api_key = openai_api_key
)

# Connect to the PGVector Vector Store that contains book data.
book_data_vector_store = PGVector(
    embeddings = embedding_model,
    collection_name = "Book_data",   # Name of the collection/table in th
    connection=shared_connection_string, # Use shared DB connection from
    use_jsonb=True,
)
```

1. Define Agents

In this section, we define the different agents used in the workflow.

1.1 Query Router Agent

The Query Router is an LLM-powered decision-making agent that analyzes a user's question and determines the most appropriate information source to handle it.

It uses a structured prompt to classify the query into one of three categories:

1. A vector search for questions answerable by the existing content in our Drucker book collection.
2. A web search for in-scope questions that require more factual, comprehensive, or real-time information.
3. A fallback "Chitter-Chatter" agent for out-of-scope question.

In [5]:
```
# Define the routing prompt
query_router_prompt_template = PromptTemplate.from_template("""
You are an expert at analyzing user question and deciding which data sour

1. **Vectorstore**: Use this if the question can be answered by the **exi
   The vectorstore contains information about **{vectorstore_content_summ

---

2. **Websearch**: Use this if the question is **within scope** (see below
   - The answer **cannot** be found in the local vectorstore
```

```
    - The question requires **more detailed or factual information** than
    - The topic is **time-sensitive** , **current**, or depends on recent

---

3. **Chitter-Chatter**: Use this if the question:
   - Is **not related** to the scope below, or
   - Is too **broad, casual, or off-topic** to be answered using vectorst

   Chitter-Chatter is a fallback agent that gives a friendly response and

---

Scope Definition:
Relevant questions are those related to **{relevant_scope}**

---

Your Task:
Analyze the user's question. Return a JSON object with one key `"Datasour

""")

# Define a summary of what's in the vectorstore
# This helps the LLM understand what kind of information is already avail
# It gets embedded into the prompt above dynamically.
vectorstore_content_summary = """
Peter Drucker's "The Daily Drucker" (2004) provides 366 daily insights an
serving as a practical guide for personal and professional growth. "The E
enable executives to achieve effectiveness, focusing on time management,
is a curated collection of Drucker's foundational principles on managemen
complex business environments. These books collectively address key aspec
resources for understanding organizational dynamics and personal producti
"""

# Define the topical scope of the system
# This defines what topics are considered "in-scope" for this assistant o
# It also gets embedded into the prompt above dynamically.
relevant_scope = """Peter Drucker-related topics, including his managemen
and their applications in modern business contexts"""

# Format the prompt using the content summary and scope
# The final formatted prompt is what will be sent to the LLM to determine
query_router_prompt = query_router_prompt_template.format(
    relevant_scope = relevant_scope,
    vectorstore_content_summary = vectorstore_content_summary
)
```

In [6]:
```
# Test Query Router

# Example user questions for testing
questions = [
    "Who is Peter Drucker, and where was he born?",
    "What did Drucker say about knowledge workers in the book?",
    "How are you doing today?"
]

print(f"\n{'='*40} Testing the Router Prompt {'='*40}\n")

                 rough test questions and print routing decisions
```

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```
for q in questions:
    response = llm_gpt.with_structured_output(method="json_mode").invoke(
        [SystemMessage(content=query_router_prompt), # Use the formatted
        HumanMessage(content=q)] # Feed in the user query
    )

    # Extract and print the decision
    print(f"Question: {q}")
    print(f"Datasource: {response['Datasource']}")
    print("-" * 50)
```

```
======================================== Testing the Router Prompt =======
=================================

Question: Who is Peter Drucker, and where was he born?
Datasource: Websearch
--------------------------------------------------
Question: What did Drucker say about knowledge workers in the book?
Datasource: Vectorstore
--------------------------------------------------
Question: How are you doing today?
Datasource: Chitter-Chatter
--------------------------------------------------
```

1.2 Document Retriever Agent

This agent retrieves relevant documents using a multi-step retrieval strategy:

- Multi-query generation: Rewrites the user's question in different ways to improve recall.
- MMR retrieval: Finds diverse, relevant documents for each query variant.
- Reciprocal Rank Fusion: Combines and reranks results to prioritize the most consistently relevant documents.

The result is a high-quality, reranked list of documents optimized for use in the workflow.

Step 1. Query translation

Use an LLM to generate multiple alternative versions of a user query.

Because semantic similarity search (in vector DBs) can miss relevant results, we use query translation to improve recall.

In [14]:
```
# Define the multi-query generation prompt
# The prompt gives the LLM both context about the vectorstore and a speci

multi_query_generation_prompt = PromptTemplate.from_template("""
You are an AI assistant helping improve document retrieval in a vector-ba

---

**Context about the database**
The vectorstore contains the following content:
{vectorstore_content_summary}
```

```
Your goal is to help retrieve **more relevant documents** by rewriting a
This helps compensate for the limitations of semantic similarity in vecto

---

**Instructions**:
Given the original question and the content summary above:
1. Return the **original user question** first.
2. Then generate {num_queries} **alternative versions** of the same quest
    - Rephrase using different word choices, structure, or focus.
    - Use synonyms or shift emphasis slightly, but keep the original mean
    - Make sure all rewrites are topically relevant to the database conte

Format requirements:
- Do **not** include bullet points or numbers.
- Each version should appear on a **separate newline**.
- Return **exactly {num_queries} + 1 total questions** (1 original + {num

---

**Original user question**: {question}
""")

# Create the query generation pipeline
multi_query_generator = (
    multi_query_generation_prompt   # The prompt defines what the LLM sho
    | llm_gpt                       # An LLM generates query variants
    | StrOutputParser()             # Parses the raw output as a string
    | (lambda x: x.split("\n"))   # A lambda function to split the result
)
```

In [15]:

```
# === Test Query Translation ===

# Run the query generator with example input
test_query_translation = multi_query_generator.invoke(
{"question":"What did Drucker say about knowledge workers in the book?",
 "num_queries":3,   # number of alternative versions to generate
 "vectorstore_content_summary":vectorstore_content_summary
 })

# Print results in a readable format
print(f"\n{'='*40} Testing the Query Translation Prompt {'='*40}\n")

for i, query in enumerate(test_query_translation):
    if i == 0:
        print(f"Original query: {query}")
    else:
        print(f"Generated query {i}: {query}")
```

```
======================================== Testing the Query Translation Pro
mpt ========================================

Original query: What did Drucker say about knowledge workers in the book?
Generated query 1: How does Drucker address the concept of knowledge worke
rs within his writings?
Generated query 2: In his works, what insights does Drucker offer regardin
g knowledge workers?
Generated query 3: What are Drucker's thoughts on the role of knowledge wo
rkers as discussed in his books?
```

Step 2. RAG fusion

This section implements a RAG Fusion retrieval strategy that is similar to the Lab 6.

Each version of the query from the previous step is used to retrieve documents from the vectorstore using MMR (Maximal Marginal Relevance).

Then the results from all query variations are reranked using Reciprocal Rank Fusion.

In [16]:
```
# Reciprocal Rank Fusion (RRF) Implementation
def reciprocal_rank_fusion(results, k=60):
    fused_scores = {}  # Dictionary to store cumulative RRF scores for ea

    # Iterate through each ranked list of documents
    for docs in results:
        for i, doc in enumerate(docs):
            doc_str = dumps(doc)    # Convert document to a string format

            # Initialize the document's fused score if not already presen
            if doc_str not in fused_scores:
                fused_scores[doc_str] = 0

            # Apply RRF scoring: 1 / (rank + k), where rank is 1-based
            rank = i + 1  # Adjust rank to start from 1 instead of 0
            fused_scores[doc_str] += 1 / (rank + k)

    # Sort by cumulative RRF score (descending)
    reranked_results = sorted(fused_scores.items(), key=lambda x: x[1], r

    # Convert JSON strings back to Document objects and store RRF scores
    reranked_documents = []
    for doc_str, score in reranked_results:
        doc = loads(doc_str)  # Convert back to Document object
        doc.metadata["rrf_score"] = score  # Track how the document was r
        reranked_documents.append(doc)

    # Return the list of documents with scores embedded in metadata
    return reranked_documents
```

In [17]:
```
# Define a retrieval chain for Multi-Query RAG fusion

retrieval_chain_rag_fusion_mmr = (
    multi_query_generator
    | book_data_vector_store.as_retriever(
        search_type="mmr", # Use MMR retrieval to enhance diversity in re
        search_kwargs={
            'k': 3,             # Final number of documents to return per
            'fetch_k': 15,      # Initial candidate pool (larger for bett
            "lambda_mult": 0.5  # Balances relevance (0) and diversity (1
            }
            ).map()  # Apply MMR retrieval to each reformulated query
    | reciprocal_rank_fusion # Rerank the combined results using RRF
)
```

In [18]:
```
# === Test the RAG Fusion Retrieval Pipeline ===

rag_fusion_mmr_results = retrieval_chain_rag_fusion_mmr.invoke({
```

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```
    "question":"What did Drucker say about knowledge workers in the book?
    "num_queries":3,
    "vectorstore_content_summary":vectorstore_content_summary})

print(f"\n{'='*40} Testing the reranked retrieved results {'='*40}\n")

# Display the total number of retrieved and reranked documents
print(f"Total number of results: {len(rag_fusion_mmr_results)}")

# Iterate through the retrieved documents and display them in a structure
for i, doc in enumerate(rag_fusion_mmr_results, start=1):
    # Display metadata: Source and page number
    display(Markdown(f"\n **From `{doc.metadata['source']}`, page {doc.me

    # Display the score
    print(f"RRF score: {doc.metadata['rrf_score']:.4g}") # Display the sc

    # Print the document content with proper text wrapping for better rea
    print(textwrap.fill(doc.page_content, width=100))

    # Add a separator for each document
    print("-" * 80)
```

```
======================================== Testing the reranked retrieved re
sults ========================================

Total number of results: 7
```

```
C:\Users\yuyum\AppData\Local\Temp\ipykernel_48028\1905607030.py:24: LangCh
ainBetaWarning: The function `loads` is in beta. It is actively being work
ed on, so the API may change.
  doc = loads(doc_str)  # Convert back to Document object
```

From `The Daily Drucker-2004.pdf`, page 806

```
RRF score: 0.04788
. Drucker analyzes the new realities of strategy, shows how to be a leader
in periods of change, and
explains the “New Information Revolution,” discussing the information an e
xecutive needs and the
information an executive owes. He also examines knowledge-worker productiv
ity, and shows that
changes in the basic attitude of individuals and organizations, as well as
structural changes in
work itself, are needed for increased productivity. Finally, Drucker addre
sses the ultimate
challenge of
--------------------------------------------------------------------------
------
```

From `The Essential Drucker-2008.pdf`, page 196

```
RRF score: 0.03279
. Knowledge  workers, after all, first came into being in any substantial
numbers a generation ago.
(I coined the  term “knowledge worker” years ago.)   But also the shift fr
om manual workers who do
as they are being told—either by the task or by the  boss—to knowledge wor
kers who have to manage
themselves profoundly challenges social  structure
--------------------------------------------------------------------------
------
```

From `The Effective Executive-2002.pdf`, page 17

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```
RRF score: 0.03279
.  It takes his knowledge and uses it as the resource, the motivation, and
the vision of  other
knowledge workers. Knowledge workers are rarely in phase with each other,
precisely because they
are knowledge workers. Each has his own skill and his own  concerns. One m
an may be interested in
tax accounting or in bacteriology, or in training  and developing tomorro
w’s key administrators in
the city government
```

From `The Daily Drucker-2004.pdf` **, page 321**

```
RRF score: 0.032
. 5. Productivity of the knowledge worker is not—at least not primarily—a
matter of the quantity of
output. Quality is at least as important. 6. Finally, knowledge-worker pro
ductivity requires that
the knowledge worker be both seen and treated as an “asset” rather than a
“cost.” It requires that
knowledge workers want to work for the organization in preference to all o
ther opportunities. ACTION
POINT: Apply steps one through five to your knowledge work. Management Cha
llenges for the 21st
Century
```

From `The Daily Drucker-2004.pdf` **, page 800**

```
RRF score: 0.01613
. According to Peter Drucker, “This book tries to equip the manager with t
he understanding, the
thinking, the knowledge, and the skills for today’s and also tomorrow’s jo
bs.” This management
classic has been developed and tested during more than thirty years of man
agement teaching in
universities, executive programs, seminars, and through the author’s close
work with managers as a
consultant for large and small businesses, government agencies, hospitals,
and schools
```

From `The Daily Drucker-2004.pdf` **, page 321**

```
RRF score: 0.01613
23 May Knowledge-Worker Productivity Knowledge-worker productivity require
s that the knowledge
worker be both seen and treated as an asset rather than a cost. W ork on t
he productivity of the
knowledge worker has barely begun. But we already know a good many of the
answers. We also know the
challenges to which we do not yet know the answers. Six major factors dete
rmine knowledge-worker
productivity. 1. Knowledge-worker productivity demands that we ask the que
stion: “What is the task?”
2
```

From `The Daily Drucker-2004.pdf` **, page 323**

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```
RRF score: 0.01587
. They know what steps are most important and what methods need to be used
to complete the tasks;
and it is their knowledge that tells them what chores are unnecessary and
should be eliminated. Work
on knowledge-worker productivity therefore begins with asking the knowledg
e workers themselves: What
is your task? What should it be? What should you be expected to contribut
e? and What hampers you in
doing your task and should be eliminated? The how only comes after the wha
t has been answered
────────────────────────────────────────────────────────────────────────────
──────
```

1.3 Relevance Grader Agent

This agent evaluates whether a retrieved document is relevant to a user's question.

It uses an LLM to determine if the document contains **keyword overlap** or **semantic alignment** with the query.

The output is a simple `"pass"` or `"fail"` label in JSON format, useful for:

- Filtering out low-quality documents in RAG pipelines.
- Scoring retrieval effectiveness.
- Constructing feedback loops for reranking or refinement.

In [19]:
```
# Define the relevance grader prompt
relevance_grader_prompt_template = PromptTemplate.from_template("""
You are a a relevance grader evaluating whether a retrieved document is h

---

**Retrieved Document**:
{document}

**User Question**:
{question}

---

**Your Task**:
Carefully and  objectively assess whether the document contains any **key
Do not require a full answer—just some relevant content is enough to pass

Return your decision as a JSON object with twith keys: "binary_score".
The "binary_score" should be "pass" or "fail" indicating relevance.
""")
```

In [20]:
```
# === Test Relevant Grader ===

# Format the prompt with the first document from the reranked RAG fusion
relevance_grader_prompt = relevance_grader_prompt_template.format(
    document=rag_fusion_mmr_results[0].page_content,
    question="What did Drucker say about knowledge workers in the book?"
)
```

```
# Invoke the grading agent using a lightweight model
grader_result = llm_gpt_mini.with_structured_output(method="json_mode").i
    relevance_grader_prompt)

# Print the grading result
print(f"\n{'='*40} Testing Relevance Grader Prompt {'='*40}\n")
print(grader_result)
```

```
======================================== Testing Relevance Grader Prompt =
========================================

{'binary_score': 'pass'}
```

1.4 Answer Generator Agent

This agent uses context-relevant documents to generate an answer to the user's question.

It is grounded in retrieved content and includes a reference section at the end of the response.

In [21]:
```
# Define the prompt template for answer generation
answer_generator_prompt_template = PromptTemplate.from_template("""
You are an assistant for question-answering tasks.

---

**Context**:
Use the following information to help answer the question:
{context}

****User Question**:
{question}

---

**Instructions**:
1. Base your answer primarily on the context provided.
2. If the answer is **not present** in the context, say so explicitly.
3. Keep the answer **concise**, **accurate**, and **focused** on the ques
4. At the end, include a **reference section**:
    - For book-based sources, use **APA-style citations** if possible.
    - For web-based sources, include **page title and URL**.

---

**Answer**:
""")
```

In [22]:
```
# === Test Answer Generator ===

# Set up a test question and format the documents for input
test_question = "What did Drucker say about knowledge workers in the book

# Convert LangChain Documents into a simplified format (only metadata and
formatted_doc_results = [{"metadata": doc.metadata, "page_content": doc.p

# Format the final prompt with documents and question
```

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```
answer_generator_prompt = answer_generator_prompt_template.format(
    context=formatted_doc_results,  # Test with all documents
    question=test_question
)

# Generate an answer using the main LLM
answer_generation = llm_gpt.invoke(answer_generator_prompt)
print(f"\n{'='*40} Testing Answer Generator Prompt {'='*40}\n")

# Display the question and answer in a readable format
display(Markdown(f"**Question:** {test_question}\n"))
display(Markdown(f"**Answer:** {answer_generation.content}"))
```

```
======================================== Testing Answer Generator Prompt =
========================================
```

Question: What did Drucker say about knowledge workers in the book?

Answer: Peter Drucker discussed several key aspects of knowledge workers in his writings. He emphasized that knowledge workers require a shift from being seen as a cost to being considered an asset to organizations. Productivity for knowledge workers is not just about the quantity of output but also the quality. Drucker also highlighted that knowledge workers should manage themselves and be involved in determining their tasks, understanding their contributions, and identifying obstacles in their work. He coined the term "knowledge worker" and noted the transition from manual work to knowledge work as a profound change in the social structure.

Reference: Drucker, P. F. (2004). *The Daily Drucker: 366 Days of Insight and Motivation for Getting the Right Things Done*.
Drucker, P. F. (2008). *The Essential Drucker*.

1.5 Hallucination Checker Agent

This agent evaluates whether an answer is factually grounded in the provided source documents.

It compares the generated answer against reference material and returns:

- A binary grade (`"pass"` or `"fail"`)
- A brief explanation justifying the decision

It's useful for detecting hallucinations in LLM output and enforcing groundedness in your GenAI application.

In [23]:
```
# Define the hallucination checker prompt
# The grader compares a student-style answer to reference materials (i.e.
# checks for accuracy, fabrication, or unsupported claims.

hallucination_checker_prompt_template = PromptTemplate.from_template("""
You are an AI grader evaluating whether a student's answer is factually g

---

**Grading Criteria**:
```

```
- **Pass**: The answer is **fully based** on the given FACTS and does not
- **Fail**: The answer information that is **fabricated**, **inaccurate**

---

**Reference Materials (FACTS)**:
{documents}

**Student's Answer**:
{generation}

---

**Output Instructions**:
Return a JSON object with keys: "binary_score" and "explanation".
- "binary_score": either `"pass"` or `"fail"`
- `"explanation"`: a short justification of the grading decision
""")
```

In [24]:
```
# === Test Hallucination Checker Prompt ===

# Format the prompt with the provided documents and generated answer
hallucination_checker_prompt = hallucination_checker_prompt_template.form
    documents=formatted_doc_results,
    generation=answer_generation.content
)

# Use the mini LLM model to grade the document
hallucination_checker_result = llm_gpt_mini.with_structured_output(method
    hallucination_checker_prompt)

# Print the parsed JSON responses

print(f"\n{'='*40} Testing Hallucination Checker Prompt {'='*40}\n")

# Display the grade
display(Markdown(f"**Grade:** {hallucination_checker_result['binary_score

# Display the explanation
display(Markdown(f"**Explanation:** {hallucination_checker_result['explan
```

```
======================================== Testing Hallucination Checker Pro
mpt ========================================
```

Grade: pass

Explanation: The student's answer accurately reflects key concepts from Drucker's writings, including the importance of viewing knowledge workers as assets, the emphasis on quality over quantity in productivity, and the self-management of knowledge workers. All claims made in the answer are supported by the reference materials.

1.6 Answer Verifier Agent

This agent evaluates whether a generated answer meaningfully responds to the user’s original question.

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It does not assess factual accuracy; only whether the answer is relevant, responsive, and on-topic.

It returns a `"pass"` or `"fail"` grade, along with a brief explanation.

This is useful in the workflow to ensure answers stay aligned with user intent.

In [25]:
```
# Define the answer verifier prompt
# The LLM is asked to judge whether the answer is responsive, relevant, a

answer_verifier_prompt_template = PromptTemplate.from_template("""
You are an AI grader verifying whether a student's answer correctly addre

---

**Grading Criteria**:
- **Pass**: The answer directly addresses the question, even if it includ
- **Fail**: The answer is off-topic, misses the point, or does not meanin

---

**question**:
{question}

**Student's Answer**:
{generation}

---

**Output Instructions**:
Return aJSONobject with keys: "binary_score" and "explanation"
- "binary_score": either `"pass"` or `"fail"`
- "explanation":  a short justification for your grading decision
""")
```

In [26]:
```
# === Test Answer Verifier Prompt ===

#Format the prompt with a test question and its generated answer
answer_verifier_prompt = answer_verifier_prompt_template.format(
    question=test_question,
    generation=answer_generation.content
)

# Use the mini LLM model to grade the document
answer_verifier_result = llm_gpt_mini.with_structured_output(method="json
    answer_verifier_prompt)

# Print the parsed JSON responses
print(f"\n{'='*40} Testing Answer Verifier Prompt {'='*40}\n")

# Display the grade
display(Markdown(f"**Grade:** {answer_verifier_result['binary_score']}"))

# Display the explanation
display(Markdown(f"**Explanation:** {answer_verifier_result['explanation'
```

```
======================================== Testing Answer Verifier Prompt ==
======================================
```

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Grade: pass

Explanation: The student's answer directly addresses the question by summarizing Drucker's views on knowledge workers, including their value to organizations, the importance of self-management, and the transition from manual to knowledge work. This response is relevant and informative.

1.7 Query Rewriter

This agent improves search effectiveness by rewriting user questions that previously led to incomplete or irrelevant answers.

It reviews both the original question and the failed answer to detect gaps, ambiguities, or missed keywords.

The output includes:

- A rewritten question optimized for vector retrieval
- An explanation of how the rewrite improves the search

This is useful for query recovery, workflow feedback loops, and retrieval optimization.

In [28]:
```
# Define the query rewriter prompt

query_rewriter_prompt_template = PromptTemplate.from_template("""
You are a query optimization expert tasked with rewriting questions to im

---

**Context**:
- Original Question: {question}
- Previous Answer (incomplete or unhelpful): {generation}

**Vectorstore Summary**:
{vectorstore_content_summary}

Note: The summary provides context about what's in the database but shoul

---

**Your Task**:
Analyze the original question and the failed answer to identify:
1. What key information the original question was missing
2. Any ambiguities or unclear phrasing
3. Missing context or specialized terminology that should be included
4. Better keywords, phrasing, or terms to improve retrieval

---

**Output Format**:
Return a JSON object with keys: "rewritten_question" and "explanation".
- "rewritten_question":  A refined version of the user's question optimiz
- "explanation": A short explanation of how the rewrite improves coverage
""")
```

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```
In [29]: # === Test Query Rewriter Prompt ===

         # Format the prompt with actual values
         query_rewriter_prompt = query_rewriter_prompt_template.format(
             question=test_question,
             generation=answer_generation.content,
             vectorstore_content_summary = vectorstore_content_summary
         )

         # Use the LLM model to grade the document
         query_rewriter_result = llm_gpt.with_structured_output(method="json_mode"
             query_rewriter_prompt)

         # Print the parsed JSON responses
         print(f"\n{'='*40} Testing Query Rewriter Prompt {'='*40}\n")

         # Display the original question
         display(Markdown(f"**Original Question:** {test_question}"))

         # Display the rewritten question
         display(Markdown(f"**Rewritten Question:** {query_rewriter_result['rewrit

         # Display the explanation
         display(Markdown(f"**Explanation:** {query_rewriter_result['explanation']
```

```
======================================== Testing Query Rewriter Prompt ===
=====================================
```

Original Question: What did Drucker say about knowledge workers in the book?

Rewritten Question: What insights does Peter Drucker provide about the role and management of knowledge workers in 'The Daily Drucker' and 'The Essential Drucker'?

Explanation: The revised question specifies the books 'The Daily Drucker' and 'The Essential Drucker', which aligns with the context provided by the vectorstore summary, improving the retrieval accuracy by pinpointing the sources where Drucker discusses knowledge workers. It also clarifies the request for insights on the role and management of knowledge workers, using precise terminology that matches Drucker's focus areas, thus reducing ambiguity and enhancing relevance.

1.8 Chitter-Chatter Agent

This agent is a friendly fallback assistant that handles:

- Off-topic or unrelated questions
- In-scope but unanswerable questions
- Casual, social dialogue (e.g., greatings) with a friendly tone

It never fabricates or guesses answers. Instead, it acknowledges the user's input, maintains a warm tone, and gently redirects the conversation toward more relevant or answerable topics within the defined scope.

```
In [30]: # Define the Chitter-Chatter prompt
         chitterchatter_prompt_template = PromptTemplate.from_template("""
Loading [MathJax]/extensions/Safe.js friendly assistant designed to keep conversations within the cu
         ---

         **Current Scope**:
         {relevant_scope}

         Your job is to respond conversationally while gently guiding the user tow

         ---

         **Response Guidelines**:

         1. **Casual Chit-Chat**:
           - Respond warmly to greetings and social exchanges.
           - Maintain a natural, friendly tone.

         2. **Off-Topic Questions**:
           - Politely acknowledge the question.
           - Mention that it falls outside your current scope.
           - Redirect to a relevant topic or ask a follow-up question within scope
           - Avoid saying "I don't know" without offering guidance.

         3. **In-Scope but Unanswerable Questions**:
           - If the question fits the scope but lacks enough information to answer
             - Acknowledge the gap.
             - Avoid making unsupported claims.
             - Redirect the user toward a more specific or better-supported questi

         ---

         **Important**:
         Never invent or guess answers using general world knowledge.
         Your job is to **maintain trust** by keeping the conversation focused and

         Always end with a helpful redirection, question, or suggestion related to
         """)
```

In [31]:
```
# === Test Chitter-Chatter Prompt ===

# Format the prompt using the defined relevant scope
chitterchatter_prompt = chitterchatter_prompt_template.format(relevant_sc

# Run a test with a casual or off-topic input
chitterchatter_response = llm_gpt_mini.invoke(
    [SystemMessage(chitterchatter_prompt),
     HumanMessage("How are you doing today?")]
)

print(f"\n{'='*40} Testing Chitter-Chatter Prompt {'='*40}\n")

# Display the result
display(Markdown(f"**Response:** {chitterchatter_response.content}"))
```

```
======================================== Testing Chitter-Chatter Prompt ==
========================================
```

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Response: I'm doing great, thank you! How about you? Is there something specific about Peter Drucker's management philosophy or leadership principles that you're interested in discussing today?

1.9 Web Searcher

This agent performs real-time web searches using Tavily's search API. This is the same Web Search tool you defined previously.

It is ideal for answering:

- In-scope questions that require additional detail beyond the vectorstore
- Questions involving current events, specific dates, or external references
- Queries needing factual grounding or external verification

This specific agent returns up to 5 high-quality search results, including:

- A short summary answer (if available)
- Title, URL, snippet, and a relevance score for each result

In [32]:
```
# Define the web search tool

web_search_tool = TavilySearchResults(
    max_results=5,
    search_depth="advanced",        # Uses advanced search depth for more
    include_answer=True,            # Include a short answer to original
    tavily_api_key= tavily_api_key  # You have defined this API key in th
)
```

In [33]:
```
# === Test Web Search Tool ===

# Test the tool with a real question
web_results = web_search_tool.invoke("What was Peter Drucker's greatest a

# Display the web search results in a structured format
print("\n" + "="*40 + " Web Search Results " + "="*40 + "\n")

for i, result in enumerate(web_results, start=1):
    display(Markdown(f"**Result {i}:**\n"))
    display(Markdown(f"**Title:** {result['title']}"))
    display(Markdown(f"**URL:** {result['url']}"))
    display(Markdown(f"**Content Snippet:** {result['content']}"))
    display(Markdown(f"**Relevance Score:** {result['score']:.3f}"))
    display(Markdown("\n" + "-"*80 + "\n"))
```

```
======================================== Web Search Results ==============
==========================
```

Result 1:

Title: What was Peter Drucker's greatest contribution to management?

URL: https://www.quora.com/What-was-Peter-Druckers-greatest-contribution-to-management

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Content Snippet: Peter Drucker has been the father of modern management who has formulated the process of SMART & the theory of management by objectives(MBO).

Relevance Score: 0.751

Result 2:

Title: Peter Drucker's Management Theory Explained - Business.com

URL: https://www.business.com/articles/management-theory-of-peter-drucker/

Content Snippet: Peter Drucker was a world-famous management consultant whose ideas transformed business leadership from reactive to proactive.

Relevance Score: 0.443

Result 3:

Title: Peter F. Drucker | Biography, Management, Books, & Facts - Britannica

URL: https://www.britannica.com/money/Peter-F-Drucker

Content Snippet: He was also a leader in the development of management education, and he invented the concept known as management by objectives. Drucker, who

Relevance Score: 0.329

Result 4:

Title: why Peter Drucker is more relevant today than ever before

URL: https://www.thepeoplespace.com/ideas/articles/technology-humanity-and-prosperity-why-peter-drucker-more-relevant-today-ever

Content Snippet: He revolutionised several management theories and concepts — social entrepreneurship, second career, innovation, time management, decision making, employee

Relevance Score: 0.269

Result 5:

Title: About Peter Drucker * Drucker Institute

URL: https://drucker.institute/perspective__trashed/about-peter-drucker/

Content Snippet: That summer, he was awarded the Presidential Medal of Freedom, the nation's highest civilian honor. President Bush called Drucker “the world's foremost pioneer

Relevance Score: 0.208

---

2. Build the Agentic RAG Workflow with LangGraph

LangGraph is an extension of LangChain designed for building structured, agentic workflows using a graph-based execution model. It enables dynamic control flow, multi-agent collaboration, and persistent state tracking—making it ideal for complex RAG systems.

In this lab, we use LangGraph to construct a modular Agentic RAG pipeline that routes, retrieves, verifies, retries, and gracefully falls back when needed.

Core LangGraph Components Used in This Lab

- [`GraphState`] (Shared State Definition)

The first step in defining a graph is specifying its shared state. `GraphState` is the central data structure that flows between agents (nodes) and evolves during execution. In this lab, we define it using Python’s `TypedDict`. It tracks:

- The original and rewritten question
- Retrieved documents
- LLM generations
- Retry counters
- Edge decision outcomes (e.g., relevance checks)

> Note: This lab uses `TypedDict` for simplicity and clarity. LangGraph also supports Python's `Pydantic` (via `BaseModel`) for state definitions, which provides: "type enforcement", "validation", "default values", and "built-in serialization". `BaseModel` is especially useful in production settings when stricter control over state is required.

- `Nodes` (Agent Functions)

Functions that define what your agents do. Each node receives the current `GraphState` as input, perform some computation or side-effect (e.g., LLM call, retrieval), and returns an updated `State`. In short, `Nodes` do the work.

- `Edges`

Functions that determine which `Node` to execute next based on the current State. They can be conditional branches (Conditional Edges) or fixed transitions (Normal Edges).In short, `Edges` tell what to do next.

> Note: To build your graph, you first define the `GraphState`, then add `nodes` and `edges`, and then compile it. You **MUST** compile your graph before before it can be executed.

For a deeper dive, check out this talk: Building Reliable Agents With LangGraph.

2.1 Define the Graph State

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The first thing you do when you define a graph is define the `State` of the graph. The `StateGraph` class is the main graph class to use. This is parameterized by a user defined `State` object.

In [35]:
```
# Define the state of the graph
class GraphState(TypedDict):
    """
    Graph state is a dictionary that contains information we want to prop
    """
    question: str                                 # User question
    original_question : str                       # Copy of original question
    generation: str                               # LLM generation
    datasource: str                               # Output from router node: Vecto
    hallucination_checker_attempts: int           # Number of times hallucination 
    answer_verifier_attempts:int                  # Number of times answer verifie
    documents: List[str]                          # List of retrieved documents fr
    checker_result: str                           # Result of document relevance c
```

2.2 Define Node Functions

This section defines the core functional units (nodes) of the LangGraph workflow. Each node includes a specific task in the Agentic RAG pipeline or fallback logic. Together, they enable the system to:

- Retrieve relevant documents using multi-query RAG fusion
- Generate grounded answers based on retrieved context
- Fall back to web search when local content is insufficient
- Handle off-topic or unsupported questions with a friendly Chitter-Chatter agent
- Rewrite ineffective queries to improve search quality
- Track retry attempts for hallucination and answer verification

In [36]:
```
# ------------------------ Document Retriever Node -----------------------
def document_retriever(state):
    """
    Retrieves documents relevant to the user's question using multi-query

    This node performs the following steps:
    - Reformulates the original user question into multiple diverse sub-q
    - Executes MMR-based retrieval for each reformulated query.
    - Applies Reciprocal Rank Fusion (RRF) to combine and rerank results.
    - Filters out metadata fields that are internal (like RRF scores).
    - Prepares and returns a list of LangChain `Document` objects to be u

    Args:
        state (GraphState): The current state of the LangGraph, containin

    Returns:
        dict: A dictionary containing a cleaned list of relevant `Documen
    """
    print("\n---QUERY TRANSLATION AND RAG-FUSION---")

    question = state["question"]

     # Run multi-query RAG + MMR + RRF pipeline to get relevant results
    rag_fusion_mmr_results = retrieval_chain_rag_fusion_mmr.invoke({
```

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```
        "question": question,
        "num_queries": 3,
        "vectorstore_content_summary": vectorstore_content_summary
        })

     # Display summary of where results came from (for teaching purposes)
    print(f"Total number of results: {len(rag_fusion_mmr_results)}")
    for i, doc in enumerate(rag_fusion_mmr_results, start=1):
        display(Markdown(f"     Document {i} from `{doc.metadata['source'

    # Convert retrieved documents into Document objects with metadata and
    formatted_doc_results = [
        Document(
            metadata={k: v for k, v in doc.metadata.items() if k != 'rrf_
            page_content=doc.page_content
        )
        for doc in rag_fusion_mmr_results
    ]

    return {"documents": formatted_doc_results}


# ------------------------ Answer Generator Node ------------------------
def answer_generator(state):
    """
    Generates an answer based on the retrieved documents and user questio

    This node prepares a prompt that includes:
    - The original or rewritten user question
    - A list of relevant documents (from vectorstore or web search)

    It invokes the main LLM to synthesize a concise and grounded response
    for use in later hallucination and usefulness checks.

    Args:
        state (GraphState): The current LangGraph state containing docume

    Returns:
        dict: A dictionary with one key `"generation"` containing the LLM
    """
    print("\n---ANSWER GENERATION---")

    documents = state["documents"]

    # Use original_question if available (after rewriting), otherwise def
    original_question = state.get("original_question",0)
    if original_question !=0:
        question = original_question
    else:
        question = state["question"]

     # Ensure all documents are LangChain Document objects (convert from
    documents = [
        Document(metadata=doc["metadata"], page_content=doc["page_content
        if isinstance(doc, dict) else doc
        for doc in documents
    ]

    # Format the prompt for the answer generator
    answer_generator_prompt = answer_generator_prompt_template.format(
```
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```
        context=documents,
        question=question
    )

    # Call the LLM to generate the answer
    answer_generation = llm_gpt.invoke(answer_generator_prompt)
    print(f"Answer generation has been generated.")

    return {"generation": answer_generation.content}


# ------------------------ Web Searcher Node ------------------------
def web_search(state):
    """
    Performs a real-time web search and appends results to previously ret

    This node is used when:
    - The vectorstore lacks sufficient relevant information
    - The original question requires current or factual information from

    It queries the web using a tool (e.g., Tavily), formats the returned
    `Document` objects, and appends them to the existing document list fo

    Args:
        state (GraphState): Current graph state with the user's question

    Returns:
        dict: Updated state with the combined list of vectorstore and web
    """

    print("\n---WEB SEARCH---")

    question = state["question"]
    documents = state.get("documents", [])

    # Run the web search using the web search tool
    web_results = web_search_tool.invoke(question)

    # Convert raw web search results into a simplified format
    formatted_web_results = [
            {
                "metadata": {
                    "title": result["title"],
                    "url": result["url"]
                },
                "page_content": result["content"]
            }
            for result in web_results
        ]

    # Ensure previous documents are consistently formatted as LangChain D
    documents = [
        Document(metadata=doc["metadata"], page_content=doc["page_content
        if isinstance(doc, dict) else doc
        for doc in documents
    ]

    # Append the new web documents
    documents.extend(formatted_web_results)
```

```python
    print(f"Total number of web search documents: {len(formatted_web_resu
    return {"documents": documents}

# ------------------------ Chitter-Chatter Node ------------------------
def chitter_chatter(state):
    """
    Handles casual, off-topic, or unanswerable in-scope questions using a

    This node is designed to keep the user engaged and politely redirect
    that are better suited to the system's capabilities.

    Args:
        state (GraphState): Current graph state containing the user quest

    Returns:
        dict: Response from the Chitter-Chatter agent under the key `"gen
    """
    print("\n---CHIT-CHATTING---")
    question = state["question"]

    # Generate a friendly fallback response using the Chitter-Chatter pro
    chitterchatter_response = llm_gpt_mini.invoke(
        [SystemMessage(chitterchatter_prompt),
         HumanMessage(question)])

    return {"generation": chitterchatter_response.content}


# ------------------------ Adaptive Query Rewrite Node ------------------
def query_rewriter(state):
    """
    Rewrites the original question if the answer was hallucinated or unhe

    This node helps improve retrieval quality in the second attempt by:
    - Identifying gaps between the original query and the generated answe
    - Generating a clearer, more focused version of the question
    - Keeping a copy of the original for fallback comparison

    Args:
        state (GraphState): Contains the original and current question, a

    Returns:
        dict: Updated state with the rewritten question and preserved ori
    """
    print("\n---QUERY REWRITE---")

    # Use original question if available, otherwise fall back to input
    original_question = state.get("original_question",0)
    if original_question !=0:
        question = original_question
    else:
        question = state["question"]

    generation = state["generation"]

    # Create prompt and invoke the query rewriter
    query_rewriter_prompt = query_rewriter_prompt_template.format(
        question=question,
        generation=generation,
        ectorstore_content_summary = vectorstore_content_summary
    )

    # Use the LLM model to grade the document
    query_rewriter_result = llm_gpt.with_structured_output(method="json_m
        query_rewriter_prompt)

    return {"question": query_rewriter_result['rewritten_question'],
            "original_question": question}


# ------------------------ Retry Counter Node for Hallucination Checker –
def hallucination_checker_tracker(state):
    """
    Tracks how many times the hallucination checker has been triggered.

    This helps avoid infinite loops in the graph by limiting retries afte

    Args:
        state (GraphState): Current state of the graph including retry me

    Returns:
        dict: Updated state with incremented `hallucination_checker_attem
    """
    num_attempts = state.get("hallucination_checker_attempts", 0)
    return {"hallucination_checker_attempts": num_attempts + 1}

# ------------------------ Retry Counter Node for Answer Verifier -------
def answer_verifier_tracker(state):
    """
    Tracks how many times the answer usefulness checker has been triggere

    This node helps the workflow know when to stop trying to rewrite quer
    after repeated failures to generate an appropriate answer.

    Args:
        state (GraphState): Current state including verification metadata

    Returns:
        dict: Updated state with incremented `answer_verifier_attempts`.
    """
    num_attempts = state.get("answer_verifier_attempts", 0)
    return {"answer_verifier_attempts": num_attempts + 1}
```

2.3 Define Edge Functions

This section defines all edge functions responsible for decision-making and flow control within the LangGraph workflow.

These functions serve as conditional logic that that determines the next step based on current state, enabling the graph to adapt intelligently at runtime. Specifically, these edges handle:

- Routing the user query via the Query Router Agent
- Evaluating document quality using asynchronous relevance grading
- Deciding whether to generate or retry based on document sufficiency

- Verifying grounding and usefulness of the generated answer, with built-in retry logic

Together, these edges form the decision backbone that connects agent nodes.

This section also introduces a key Python: "Async Programming", used to improve performance when grading multiple documents.

Async Functions:

- Defined using `async def`, which creates a coroutine.
- Calling an async function returns a `coroutine` object—it does not run immediately.
- To execute, the coroutine must be awaited.

`await` Expression:

- Used inside async functions to pause execution until the awaited task completes.
- While paused, control is yielded back to the event loop, allowing other tasks to run.
- Execution resumes once the awaited operation finishes.

`asyncio.gather()`

- Executes multiple coroutines concurrently and waits for all to finish.
- Returns results in the same order as the input coroutines.
- Ideal for parallel tasks—like grading multiple documents at once.

In this workflow, we use `grade_documents_parallel()` to apply async programming. This allows the system to evaluate all retrieved documents simultaneously, making it significantly faster and more efficient than grading one document at a time.

In [37]:
```python
# ------------------------ Routing Decision  ------------------------
def route_question(state):
    """
    Routes the user question to the appropriate agent based on the Query

    Args:
        state (GraphState): Contains the user's input question.

    Returns:
        str: One of 'Vectorstore', 'Websearch', or 'Chitter-Chatter'.
    """
    print("---ROUTING QUESTION---")
    question = state["question"]
    route_question_response = llm_gpt.with_structured_output(method="json
        [SystemMessage(query_router_prompt),
        HumanMessage(question)]
    )

    parsed_router_output = route_question_response["Datasource"]

Loading [MathJax]/extensions/Safe.js rsed_router_output == "Websearch":
        print("---ROUTING QUESTION TO WEB SEARCH---")
        return "Websearch"
    elif parsed_router_output == "Vectorstore":
        print("---ROUTING QUESTION TO VECTORSTORE---")
        return "Vectorstore"
    elif parsed_router_output == "Chitter-Chatter":
        print("---ROUTING QUESTION TO CHITTER-CHATTER---")
        return "Chitter-Chatter"


# ------------------------ Async document relevance grading  ------------
async def grade_documents_parallel(state):
    """
    Grades retrieved documents asynchronously to determine their relevanc

    Documents are processed in parallel using async calls. If 50% or more
    the system flags this as a failure, triggering a web search in the ne

    Args:
        state (GraphState): Contains the documents and question.

    Returns:
        dict: Updated state with filtered documents and a `"checker_resul
    """
    print("---CHECK DOCUMENT RELEVANCE TO QUESTION---")
    question = state["question"]
    documents = state["documents"]

     # Inner coroutine that grades one document at a time using the relev
    async def grade_document(doc, question):
        relevance_grader_prompt = relevance_grader_prompt_template.format
            document=doc,
            question=question
        )
        grader_result = await llm_gpt_mini.with_structured_output(method=
            relevance_grader_prompt)
        return grader_result

    # Create async tasks for grading all documents
    tasks = [grade_document(doc, question) for doc in documents]

    # Run all tasks concurrently
    results = await asyncio.gather(*tasks)

    filtered_docs = []

   # Collect only documents marked as "pass"
    for i, score in enumerate(results):
        if score["binary_score"].lower() == "pass":
            print(f"---GRADE: DOCUMENT RELEVANT--- {score['binary_score']
            filtered_docs.append(documents[i]) # only keep the relevant o
        else:
            print("---GRADE: DOCUMENT NOT RELEVANT---")

    # Analyze how many documents were filtered out
    total_docs = len(documents)
    relevant_docs = len(filtered_docs)

    if total_docs > 0:
        filtered_out_percentage = (total_docs - relevant_docs) / total_do
```
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```
        # If more than 50% of documents were irrelevant, fail and fall ba
        checker_result = "fail" if filtered_out_percentage >= 0.5 else "p
        print(f"---FILTERED OUT {filtered_out_percentage*100:.1f}% OF IRR
        print(f"---**{checker_result}**---")
    else:
        # If no documents were retrieved at all, treat as automatic failu
        checker_result = "fail"
        print("---NO DOCUMENTS AVAILABLE, WEB SEARCH TRIGGERED---")

    return {"documents": filtered_docs, "checker_result": checker_result}


# ------------------------ Decide whether to generate or fallback -------
def decide_to_generate(state):
    """
    Conditional edge function used after document relevance grading.

    It checks the `checker_result` from the previous step:
    - If the result is 'fail' (indicating that a majority of documents we
      it triggers a fallback to web search for more reliable context.
    - If the result is 'pass', it proceeds to the answer generation node.

    Args:
        state (GraphState): Includes the 'checker_result' from the docume

    Returns:
        str: Either 'generate' or 'Websearch', used to transition to the 
    """
    print("---CHECK GENERATION CONDITION---")
    checker_result = state["checker_result"]

    if checker_result == "fail":
        print(
            "---DECISION: MORE THAN HALF OF THE DOCUMENTS ARE IRRELEVANT 
        )
        return "Websearch"
    else:
        # We have relevant documents, so generate answer
        print("---DECISION: GENERATE---")
        return "generate"


# # ------------------------ Final Answer Validation ---------------------
def check_generation_vs_documents_and_question(state):
    """
    Conditional edge function verifies the quality of the generated answe
    - Grounded in the retrieved documents (hallucination check)
    - Relevant to the original user question (answer verifier)

    Depending on the result, this function controls whether the system pr
    retries answer generation, or stops after exceeding retry limits.

    Args:
        state (GraphState): Includes question, generated answer, document

    Returns:
        str: One of the route labels used in LangGraph transitions:
            - 'useful': Answer is grounded and relevant
            - 'not useful': Answer is grounded but does not address the q
        - 'not supported': Answer is not grounded (hallucination)
        - 'max retries': Too many failed attempts, abort or fallback
    """

    print("---CHECK HALLUCINATIONS WITH DOCUMENTS---")

    # Use original rewritten question if present; otherwise use latest ve
    question = state["question"]
    original_question = state.get("original_question",0)

    if original_question !=0:
        question = original_question
    else:
        question = state["question"]

    documents = state["documents"]
    generation = state["generation"]

    # Retry counters
    hallucination_checker_attempts = state.get("hallucination_checker_att
    answer_verifier_attempts = state.get("answer_verifier_attempts", 0)

    # Run hallucination checker: does the answer come from the documents?
    hallucination_checker_prompt = hallucination_checker_prompt_template.
        documents=documents,
        generation=generation
    )
    hallucination_checker_result = llm_gpt_mini.with_structured_output(me
    hallucination_checker_prompt)

    # Helper to format "1st", "2nd", etc.
    def ordinal(n):
        return f"{n}{'th' if 10 <= n % 100 <= 20 else {1:'st', 2:'nd', 3:

    # If generation is grounded (pass hallucination check)
    if hallucination_checker_result['binary_score'].lower() == "pass":
        print("---DECISION: GENERATION IS GROUNDED IN DOCUMENTS---")

        # Now check if it answers the question usefully
        print("---VERIFY ANSWER WITH QUESTION---")
        # Test using question and generation from above
        answer_verifier_prompt = answer_verifier_prompt_template.format(
            question=question,
            generation=generation
        )
        answer_verifier_result = llm_gpt_mini.with_structured_output(meth
        answer_verifier_prompt)

        # If answer is grounded AND relevant, return final result
        if answer_verifier_result['binary_score'].lower() == "pass":
            print("---DECISION: GENERATION ADDRESSES QUESTION---")
            return "useful"

        # If max attempts reached for usefulness check, exit
        elif answer_verifier_attempts > 1:
            print("---DECISION: MAX RETRIES REACHED---")
            return "max retries"

        # Otherwise, try query rewrite and retry generation
        else:
```
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```
            print("---DECISION: GENERATION DOES NOT ADDRESS QUESTION, RE-
            print(f"This is the {ordinal(answer_verifier_attempts+1)} att
            return "not useful"

    # If generation is NOT grounded and retry limit exceeded
    elif hallucination_checker_attempts > 1:
        print("---DECISION: MAX RETRIES REACHED---")
        return "max retries"

    # If answer is not grounded but we can still retry
    else:
        print("---DECISION: GENERATION IS NOT GROUNDED IN DOCUMENTS, RE-T
        print(f"This is the {ordinal(hallucination_checker_attempts+1)} a
        return "not supported"
```

2.4 Define Agentic RAG Workflow (Graph Assembly)

This section defines the full LangGraph workflow by connecting all agents and conditional edge functions into a structured graph. It establishes:

- Entry routing via Query Router Agent classification
- Feedback loops for hallucination and answer verification
- Conditional flow control via document grading and answer evaluation
- Exit points for high-confidence answers or fallback responses

In [38]:
```
# Initialize the graph with shared state structure
workflow = StateGraph(GraphState)

# === Add agent nodes ===
workflow.add_node("WebSearcher", web_search)                     # web sea
workflow.add_node("DocumentRetriever", document_retriever)       # Multi-q
workflow.add_node("RelevanceGrader", grade_documents_parallel)  # Async d
workflow.add_node("AnswerGenerator", answer_generator)           # Generat
workflow.add_node("QueryRewriter", query_rewriter)               # Rewrite
workflow.add_node("ChitterChatter", chitter_chatter)             #  Fallba

# === Add retry tracker nodes ===
workflow.add_node("HallucinationCheckerFailed", hallucination_checker_tra
workflow.add_node("AnswerVerifierFailed", answer_verifier_tracker)

# === Entry point: Route query to appropriate agent ===
workflow.set_conditional_entry_point(
    route_question,
    {
        "Websearch": "WebSearcher",
        "Vectorstore": "DocumentRetriever",
        "Chitter-Chatter": "ChitterChatter",
    },
)

# === Node transitions ===
workflow.add_edge("DocumentRetriever", "RelevanceGrader")          # Ret
workflow.add_edge("WebSearcher", "AnswerGenerator")                # Web

workflow.add_edge("HallucinationCheckerFailed", "AnswerGenerator")  # Ret
workflow.add_edge("AnswerVerifierFailed", "QueryRewriter")         # Ret
workflow.add_edge("QueryRewriter", "DocumentRetriever")            # Rew
```

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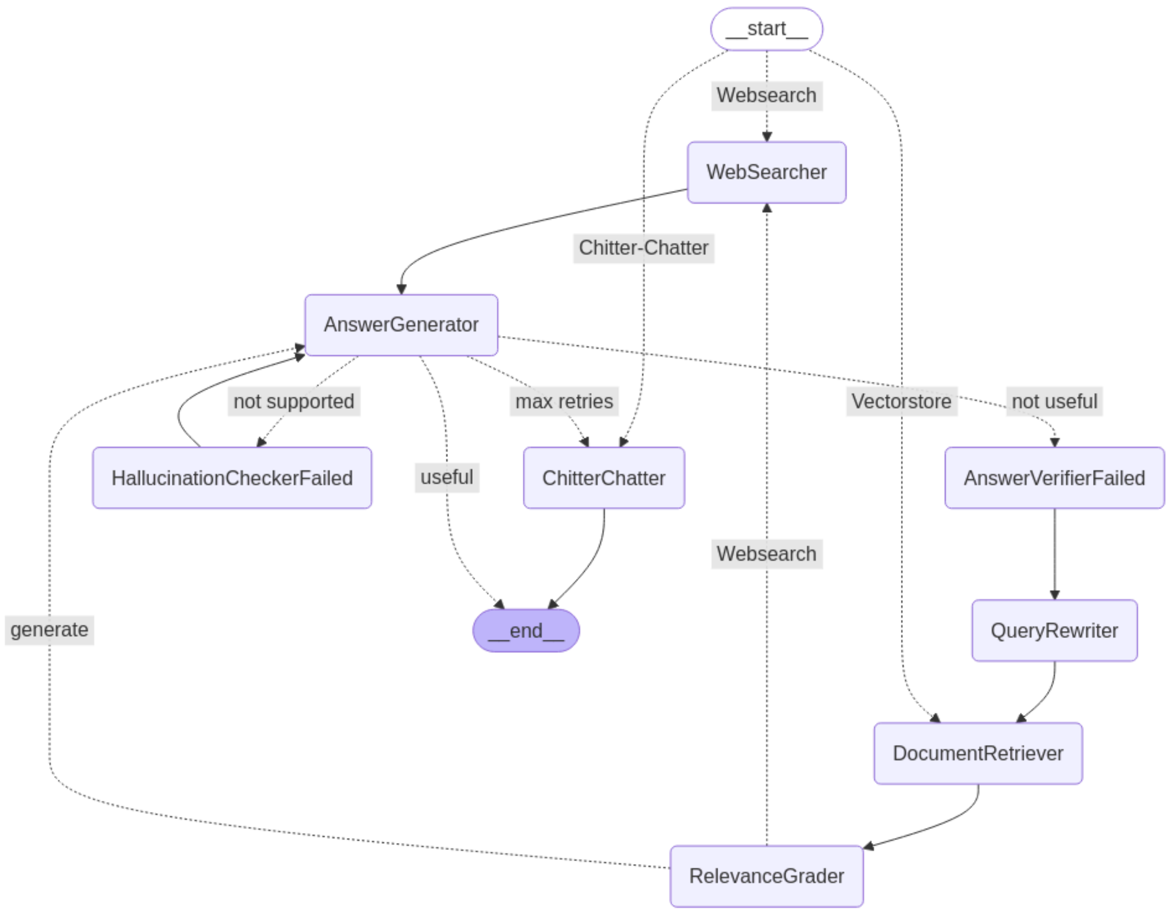
```
workflow.add_edge("ChitterChatter", END)                                       #

# === Conditional routing after document grading ===
workflow.add_conditional_edges(
    "RelevanceGrader",
    decide_to_generate,
    {
        "Websearch": "WebSearcher",          # Too many irrelevant docs →
        "generate": "AnswerGenerator",      # Good enough → Proceed to ge
    },
)

# === Conditional routing after generation quality checks ===
workflow.add_conditional_edges(
    "AnswerGenerator",
    check_generation_vs_documents_and_question,
    {
        "not supported": "HallucinationCheckerFailed",  # Hallucinated →
        "useful": END,                                  # Success
        "not useful": "AnswerVerifierFailed",           # Off-topic → Rew
        "max retries": "ChitterChatter"                 # Stop after too
    },
)


# --- Compile the graph ---
graph = workflow.compile()
```

In [39]:
```
# ------------------------ Visualize the Graph Structure ----------------
# This built-in visualization to render the workflow as a flow diagram.
display(Image(graph.get_graph().draw_mermaid_png()))
```



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3. Run the Workflow (Graph Execution)

LangGraph uses a "message-passing execution model", inspired by Google's Pregel system.

Execution flows through the graph based on data, decision logic, and state updates:

1. **Activation**: Nodes become active when they receive input.
2. **Processing**: Each node execute its logic and modifies the shared `GraphState`.
3. **Message Passing**: Updated state is passed to the next node(s) based on conditional edges.
4. **Termination**: Execution stops when no nodes are active. The `END` node terminates the execution.

Test Examples You tested the workflow with four types of questions, each triggering a different agent pathway:

1. Web Search Example: Routed to the `WebSearcher` due to real-time or factual content needs.
2. Vectorstore Search Example: Routed to the `DocumentRetriever` and successfully answered using vectorstore content.
3. Chitter-Chatter Example: Routed to `ChitterChatter` due to being off-topic or casual (e.g., small talk).
4. Vectorstore Search Loop Example: Started with vectorstore retrieval, but most documents were irrelevant. Then triggered retry logic (e.g., web fallback or query rewriting), showing how the graph handles failed retrieval or weak answers.

In [40]:
```
# Define a test question to run through the LangGraph workflow
test_question1 = "Who is Peter Drucker, and where was he born?"

# Execute the graph asynchronously in streaming mode.
async for event1 in graph.astream({"question": test_question1}, stream_mo
    print(event1)   # Print state after each node is processed

# Display the final result after the graph has completed execution
display(Markdown(f"\n{'='*40} Final Output {'='*40}\n"))
display(Markdown(event1["generation"]))
```

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```
---ROUTING QUESTION---
---ROUTING QUESTION TO WEB SEARCH---
{'question': 'Who is Peter Drucker, and where was he born?'}

---WEB SEARCH---
Total number of web search documents: 5
{'question': 'Who is Peter Drucker, and where was he born?', 'documents':
[{'metadata': {'title': 'Peter F. Drucker | Biography, Management, Books,
& Facts - Britannica', 'url': 'https://www.britannica.com/money/Peter-F-Dr
ucker'}, 'page_content': 'Peter F. Drucker (born November 19, 1909, Vienn
a, Austria—died November 11, 2005, Claremont, California, U.S.) was an Aus
trian-born American'}, {'metadata': {'title': 'Peter Drucker Biography - c
uriouscat.com', 'url': 'https://curiouscat.com/management/experts/peter-dr
ucker'}, 'page_content': 'Peter Ferdinand Drucker (19 Nov 1909 - 11 Nov 20
05) was a leading management theorist. Drucker, born in Vienna, Austria, m
oved to the United States in 1937.'}, {'metadata': {'title': 'Peter F. Dru
cker | Biography & Management Theory - Study.com', 'url': 'https://study.c
om/academy/lesson/peter-f-drucker-father-of-management-theory.html'}, 'pag
e_content': 'Lesson Summary. Peter F. Drucker was born in Vienna, Austria.
He was surrounded by Austrian intellectuals that worked with his fathe
r.'}, {'metadata': {'title': 'About Peter Drucker * Drucker Institute', 'u
rl': 'https://drucker.institute/perspective__trashed/about-peter-drucke
r/'}, 'page_content': 'Peter Drucker was born in Vienna, Austria, on Novem
ber 19, 1909. The household in which he grew up was one of great intellect
ual ferment. His parents, Adolph'}, {'metadata': {'title': 'PETER F. DRUCK
ER', 'url': 'https://www.druckerforum.org/peter-f-drucker/'}, 'page_conten
t': 'Peter F. Drucker was born in Vienna on November 19, 1909 in Vienna, w
hen the city was still the vibrant centre of the Habsburg monarchy.'}]}

---ANSWER GENERATION---
Answer generation has been generated.
---CHECK HALLUCINATIONS WITH DOCUMENTS---
---DECISION: GENERATION IS GROUNDED IN DOCUMENTS---
---VERIFY ANSWER WITH QUESTION---
---DECISION: GENERATION ADDRESSES QUESTION---
{'question': 'Who is Peter Drucker, and where was he born?', 'generation':
'Peter Drucker was an Austrian-born American who became a leading manageme
nt theorist. He was born in Vienna, Austria, on November 19, 1909.\n\n**Re
ferences**:\n- Peter F. Drucker | Biography, Management, Books, & Facts -
Britannica. Retrieved from [https://www.britannica.com/money/Peter-F-Druck
er](https://www.britannica.com/money/Peter-F-Drucker)\n- Peter Drucker Bio
graphy - curiouscat.com. Retrieved from [https://curiouscat.com/managemen
t/experts/peter-drucker](https://curiouscat.com/management/experts/peter-d
rucker)\n- About Peter Drucker * Drucker Institute. Retrieved from [http
s://drucker.institute/perspective__trashed/about-peter-drucker/](https://d
rucker.institute/perspective__trashed/about-peter-drucker/)', 'documents':
[{'metadata': {'title': 'Peter F. Drucker | Biography, Management, Books,
& Facts - Britannica', 'url': 'https://www.britannica.com/money/Peter-F-Dr
ucker'}, 'page_content': 'Peter F. Drucker (born November 19, 1909, Vienn
a, Austria—died November 11, 2005, Claremont, California, U.S.) was an Aus
trian-born American'}, {'metadata': {'title': 'Peter Drucker Biography - c
uriouscat.com', 'url': 'https://curiouscat.com/management/experts/peter-dr
ucker'}, 'page_content': 'Peter Ferdinand Drucker (19 Nov 1909 - 11 Nov 20
05) was a leading management theorist. Drucker, born in Vienna, Austria, m
oved to the United States in 1937.'}, {'metadata': {'title': 'Peter F. Dru
cker | Biography & Management Theory - Study.com', 'url': 'https://study.c
om/academy/lesson/peter-f-drucker-father-of-management-theory.html'}, 'pag
e_content': 'Lesson Summary. Peter F. Drucker was born in Vienna, Austria.
He was surrounded by Austrian intellectuals that worked with his fathe
       tadata': {'title': 'About Peter Drucker * Drucker Institute', 'u
```
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```
rl': 'https://drucker.institute/perspective__trashed/about-peter-drucke
r/'}, 'page_content': 'Peter Drucker was born in Vienna, Austria, on Novem
ber 19, 1909. The household in which he grew up was one of great intellect
ual ferment. His parents, Adolph'}, {'metadata': {'title': 'PETER F. DRUCK
ER', 'url': 'https://www.druckerforum.org/peter-f-drucker/'}, 'page_conten
t': 'Peter F. Drucker was born in Vienna on November 19, 1909 in Vienna, w
hen the city was still the vibrant centre of the Habsburg monarchy.'}]}
```

== Final Output

==

Peter Drucker was an Austrian-born American who became a leading management theorist. He was born in Vienna, Austria, on November 19, 1909.

References:

- Peter F. Drucker | Biography, Management, Books, & Facts - Britannica. Retrieved from https://www.britannica.com/money/Peter-F-Drucker
- Peter Drucker Biography - curiouscat.com. Retrieved from https://curiouscat.com/management/experts/peter-drucker
- About Peter Drucker * Drucker Institute. Retrieved from https://drucker.institute/perspective__trashed/about-peter-drucker/

In [41]:
```python
# Vector search example
test_question2 = "What did Drucker say about knowledge workers in the boo

async for event2 in graph.astream({"question": test_question2}, stream_mo
    print(event2)

display(Markdown(f"\n{'='*40} Final Output {'='*40}\n"))
display(Markdown(event2["generation"]))
```

```
---ROUTING QUESTION---
---ROUTING QUESTION TO VECTORSTORE---
{'question': 'What did Drucker say about knowledge workers in the book?'}

---QUERY TRANSLATION AND RAG-FUSION---
Total number of results: 8
Document 1 from `The Effective Executive-2002.pdf`, page 17

Document 2 from `The Daily Drucker-2004.pdf`, page 321

Document 3 from `The Daily Drucker-2004.pdf`, page 806

Document 4 from `The Essential Drucker-2008.pdf`, page 196

Document 5 from `The Daily Drucker-2004.pdf`, page 800

Document 6 from `The Essential Drucker-2008.pdf`, page 237

Document 7 from `The Daily Drucker-2004.pdf`, page 323

Document 8 from `The Daily Drucker-2004.pdf`, page 323
```

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```
{'question': 'What did Drucker say about knowledge workers in the book?',
'documents': [Document(metadata={'page': 17, 'year': '2002', 'title': 'The
Effective Executiver', 'author': 'Peter F. Drucker', 'source': 'The Effect
ive Executive-2002.pdf'}, page_content='. \nIt takes his knowledge and use
s it as the resource, the motivation, and the vision of \nother knowledge
workers. Knowledge workers are rarely in phase with each other, \nprecisel
y because they are knowledge workers. Each has his own skill and his own
\nconcerns. One man may be interested in tax accounting or in bacteriolog
y, or in training \nand developing tomorrow’s key administrators in the ci
ty government'), Document(metadata={'page': 321, 'year': '2004', 'title':
'The Daily Drucker: 366 Days of Insight and Motivation for Getting the Rig
ht Things Done', 'author': 'Drucker, Peter F.', 'source': 'The Daily Druck
er-2004.pdf'}, page_content='.\n5. Productivity of the knowledge worker is
not—at least not\nprimarily—a matter of the quantity of output. Quality is
at least\nas important.\n6. Finally, knowledge-worker productivity require
s that the\nknowledge worker be both seen and treated as an “asset” rather
\nthan a “cost.” It requires that knowledge workers want to work\nfor the
organization in preference to all other opportunities.\nACTION POINT: Appl
y steps one through five to your knowledge work.\nManagement Challenges fo
r the 21st Century'), Document(metadata={'page': 806, 'year': '2004', 'tit
le': 'The Daily Drucker: 366 Days of Insight and Motivation for Getting th
e Right Things Done', 'author': 'Drucker, Peter F.', 'source': 'The Daily
Drucker-2004.pdf'}, page_content='. Drucker analyzes the new realities of
strategy, shows how to\nbe a leader in periods of change, and explains the
“New Information\nRevolution,” discussing the information an executive nee
ds and the\ninformation an executive owes. He also examines knowledge-work
er\nproductivity, and shows that changes in the basic attitude of individu
als and\norganizations, as well as structural changes in work itself, are
needed for\nincreased productivity. Finally, Drucker addresses the ultimat
e challenge of'), Document(metadata={'page': 196, 'year': '2008', 'title':
'The Essential Drucker', 'author': 'Peter F. Drucker', 'source': 'The Esse
ntial Drucker-2008.pdf'}, page_content='. Knowledge \nworkers, after all,
first came into being in any substantial numbers a generation ago. (I coin
ed the \nterm “knowledge worker” years ago.)  \nBut also the shift from ma
nual workers who do as they are being told—either by the task or by the \n
boss—to knowledge workers who have to manage themselves profoundly challen
ges social \nstructure'), Document(metadata={'page': 800, 'year': '2004',
'title': 'The Daily Drucker: 366 Days of Insight and Motivation for Gettin
g the Right Things Done', 'author': 'Drucker, Peter F.', 'source': 'The Da
ily Drucker-2004.pdf'}, page_content='. According to Peter Drucker,\n“This
book tries to equip the manager with the understanding, the thinking,\nthe
knowledge, and the skills for today’s and also tomorrow’s jobs.” This\nman
agement classic has been developed and tested during more than thirty\nyea
rs of management teaching in universities, executive programs, seminars,\n
and through the author’s close work with managers as a consultant for larg
e\nand small businesses, government agencies, hospitals, and schools'), Do
cument(metadata={'page': 237, 'year': '2008', 'title': 'The Essential Druc
ker', 'author': 'Peter F. Drucker', 'source': 'The Essential Drucker-2008.
pdf'}, page_content='About the Author \nPeter F. Drucker was born in 1909
in Vienna and was educated there and in England. He received his \ndoctora
te in public and international law while working as a newspaper reporter i
n Frankfurt, \nGermany, and then worked as an economist for an internation
al bank in London. In 1927, he came to \nthe United States. Drucker’s mana
gement books and analyses of economics and society are widely \nread and r
espected throughout the world and have been translated into more than 20 l
anguages'), Document(metadata={'page': 323, 'year': '2004', 'title': 'The
Daily Drucker: 366 Days of Insight and Motivation for Getting the Right Th
ings Done', 'author': 'Drucker, Peter F.', 'source': 'The Daily Drucker-20
04.pdf'}, page_content='24 May\nDefining the Task in Knowledge Work\nIn kn
Loading [MathJax]/extensions/Safe.js rk, the how only comes after the what has been answered.\nI n ma
```

```
nual work the task is always given. Wherever there still are domestic\nser
vants, the owner of the house tells them what to do. The machine or the\na
ssembly line programs the factory worker. But, in knowledge work, what to
\ndo becomes the first and decisive question. For knowledge workers are no
t\nprogrammed by the machine'), Document(metadata={'page': 323, 'year': '2
004', 'title': 'The Daily Drucker: 366 Days of Insight and Motivation for
Getting the Right Things Done', 'author': 'Drucker, Peter F.', 'source':
'The Daily Drucker-2004.pdf'}, page_content='. They know\nwhat steps are m
ost important and what methods need to be used to complete\nthe tasks; and
it is their knowledge that tells them what chores are\nunnecessary and sho
uld be eliminated.\nWork on knowledge-worker productivity therefore begins
with asking the\nknowledge workers themselves: What is your task? What sho
uld it be?\nWhat should you be expected to contribute? and What hampers yo
u in\ndoing your task and should be eliminated? The how only comes after t
he\nwhat has been answered')]}
---CHECK DOCUMENT RELEVANCE TO QUESTION---
---GRADE: DOCUMENT RELEVANT--- pass
---GRADE: DOCUMENT RELEVANT--- pass
---GRADE: DOCUMENT RELEVANT--- pass
---GRADE: DOCUMENT RELEVANT--- pass
---GRADE: DOCUMENT NOT RELEVANT---
---GRADE: DOCUMENT NOT RELEVANT---
---GRADE: DOCUMENT RELEVANT--- pass
---GRADE: DOCUMENT RELEVANT--- pass
---FILTERED OUT 25.0% OF IRRELEVANT DOCUMENTS---
---**pass**---
---CHECK GENERATION CONDITION---
---DECISION: GENERATE---
{'question': 'What did Drucker say about knowledge workers in the book?',
'documents': [Document(metadata={'page': 17, 'year': '2002', 'title': 'The
Effective Executiver', 'author': 'Peter F. Drucker', 'source': 'The Effect
ive Executive-2002.pdf'}, page_content='. \nIt takes his knowledge and use
s it as the resource, the motivation, and the vision of \nother knowledge
workers. Knowledge workers are rarely in phase with each other, \nprecisel
y because they are knowledge workers. Each has his own skill and his own
\nconcerns. One man may be interested in tax accounting or in bacteriolog
y, or in training \nand developing tomorrow’s key administrators in the ci
ty government'), Document(metadata={'page': 321, 'year': '2004', 'title':
'The Daily Drucker: 366 Days of Insight and Motivation for Getting the Rig
ht Things Done', 'author': 'Drucker, Peter F.', 'source': 'The Daily Druck
er-2004.pdf'}, page_content='.\n5. Productivity of the knowledge worker is
not—at least not\nprimarily—a matter of the quantity of output. Quality is
at least\nas important.\n6. Finally, knowledge-worker productivity require
s that the\nknowledge worker be both seen and treated as an “asset” rather
\nthan a “cost.” It requires that knowledge workers want to work\nfor the
organization in preference to all other opportunities.\nACTION POINT: Appl
y steps one through five to your knowledge work.\nManagement Challenges fo
r the 21st Century'), Document(metadata={'page': 806, 'year': '2004', 'tit
le': 'The Daily Drucker: 366 Days of Insight and Motivation for Getting th
e Right Things Done', 'author': 'Drucker, Peter F.', 'source': 'The Daily
Drucker-2004.pdf'}, page_content='. Drucker analyzes the new realities of
strategy, shows how to\nbe a leader in periods of change, and explains the
“New Information\nRevolution,” discussing the information an executive nee
ds and the\ninformation an executive owes. He also examines knowledge-work
er\nproductivity, and shows that changes in the basic attitude of individu
als and\norganizations, as well as structural changes in work itself, are
needed for\nincreased productivity. Finally, Drucker addresses the ultimat
e challenge of'), Document(metadata={'page': 196, 'year': '2008', 'title':
'The Essential Drucker', 'author': 'Peter F. Drucker', 'source': 'The Esse
ker-2008.pdf'}, page_content='. Knowledge \nworkers, after all,
```

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```
first came into being in any substantial numbers a generation ago. (I coin
ed the \nterm “knowledge worker” years ago.)  \nBut also the shift from ma
nual workers who do as they are being told—either by the task or by the \n
boss—to knowledge workers who have to manage themselves profoundly challen
ges social \nstructure'), Document(metadata={'page': 323, 'year': '2004',
'title': 'The Daily Drucker: 366 Days of Insight and Motivation for Gettin
g the Right Things Done', 'author': 'Drucker, Peter F.', 'source': 'The Da
ily Drucker-2004.pdf'}, page_content='24 May\nDefining the Task in Knowled
ge Work\nIn knowledge work, the how only comes after the what has been ans
wered.\nI n manual work the task is always given. Wherever there still are
domestic\nservants, the owner of the house tells them what to do. The mach
ine or the\nassembly line programs the factory worker. But, in knowledge w
ork, what to\ndo becomes the first and decisive question. For knowledge wo
rkers are not\nprogrammed by the machine'), Document(metadata={'page': 32
3, 'year': '2004', 'title': 'The Daily Drucker: 366 Days of Insight and Mo
tivation for Getting the Right Things Done', 'author': 'Drucker, Peter
F.', 'source': 'The Daily Drucker-2004.pdf'}, page_content='. They know\nw
hat steps are most important and what methods need to be used to complete
\nthe tasks; and it is their knowledge that tells them what chores are\nun
necessary and should be eliminated.\nWork on knowledge-worker productivity
therefore begins with asking the\nknowledge workers themselves: What is yo
ur task? What should it be?\nWhat should you be expected to contribute? an
d What hampers you in\ndoing your task and should be eliminated? The how o
nly comes after the\nwhat has been answered')], 'checker_result': 'pass'}

---ANSWER GENERATION---
Answer generation has been generated.
---CHECK HALLUCINATIONS WITH DOCUMENTS---
---DECISION: GENERATION IS GROUNDED IN DOCUMENTS---
---VERIFY ANSWER WITH QUESTION---
---DECISION: GENERATION ADDRESSES QUESTION---
{'question': 'What did Drucker say about knowledge workers in the book?',
'generation': 'Peter Drucker described knowledge workers as individuals wh
o use their knowledge as a resource, motivation, and vision for other know
ledge workers. They have their own skills and concerns, making them rarely
in sync with one another. Drucker emphasized that knowledge workers\' prod
uctivity should not be measured primarily by the quantity of output, but r
ather by the quality. He suggested treating knowledge workers as assets ra
ther than costs and ensuring that they prefer to work for their organizati
on over other opportunities. Understanding the tasks for knowledge work be
gins with answering "what" rather than "how," as knowledge workers are not
programmed by machines but must manage themselves and define their tasks
(Drucker, 2002; Drucker, 2004; Drucker, 2008).\n\n**Reference**:\nDrucker,
P. F. (2002). *The Effective Executive*.  \nDrucker, P. F. (2004). *The Da
ily Drucker: 366 Days of Insight and Motivation for Getting the Right Thin
gs Done*.  \nDrucker, P. F. (2008). *The Essential Drucker*.', 'document
s': [Document(metadata={'page': 17, 'year': '2002', 'title': 'The Effectiv
e Executiver', 'author': 'Peter F. Drucker', 'source': 'The Effective Exec
utive-2002.pdf'}, page_content='. \nIt takes his knowledge and uses it as
the resource, the motivation, and the vision of \nother knowledge workers.
Knowledge workers are rarely in phase with each other, \nprecisely because
they are knowledge workers. Each has his own skill and his own \nconcerns.
One man may be interested in tax accounting or in bacteriology, or in trai
ning \nand developing tomorrow’s key administrators in the city governmen
t'), Document(metadata={'page': 321, 'year': '2004', 'title': 'The Daily D
rucker: 366 Days of Insight and Motivation for Getting the Right Things Do
ne', 'author': 'Drucker, Peter F.', 'source': 'The Daily Drucker-2004.pd
f'}, page_content='.\n5. Productivity of the knowledge worker is not—at le
ast not\nprimarily—a matter of the quantity of output. Quality is at least
Loading [MathJax]/extensions/Safe.js tant.\n6. Finally, knowledge-worker productivity requires that t
```

```
he\nknowledge worker be both seen and treated as an “asset” rather\nthan a
“cost.” It requires that knowledge workers want to work\nfor the organizat
ion in preference to all other opportunities.\nACTION POINT: Apply steps o
ne through five to your knowledge work.\nManagement Challenges for the 21s
t Century'), Document(metadata={'page': 806, 'year': '2004', 'title': 'The
Daily Drucker: 366 Days of Insight and Motivation for Getting the Right Th
ings Done', 'author': 'Drucker, Peter F.', 'source': 'The Daily Drucker-20
04.pdf'}, page_content='. Drucker analyzes the new realities of strategy,
shows how to\nbe a leader in periods of change, and explains the “New Info
rmation\nRevolution,” discussing the information an executive needs and th
e\ninformation an executive owes. He also examines knowledge-worker\nprodu
ctivity, and shows that changes in the basic attitude of individuals and\n
organizations, as well as structural changes in work itself, are needed fo
r\nincreased productivity. Finally, Drucker addresses the ultimate challen
ge of'), Document(metadata={'page': 196, 'year': '2008', 'title': 'The Ess
ential Drucker', 'author': 'Peter F. Drucker', 'source': 'The Essential Dr
ucker-2008.pdf'}, page_content='. Knowledge \nworkers, after all, first ca
me into being in any substantial numbers a generation ago. (I coined the
\nterm “knowledge worker” years ago.)  \nBut also the shift from manual wo
rkers who do as they are being told—either by the task or by the \nboss—to
knowledge workers who have to manage themselves profoundly challenges soci
al \nstructure'), Document(metadata={'page': 323, 'year': '2004', 'title':
'The Daily Drucker: 366 Days of Insight and Motivation for Getting the Rig
ht Things Done', 'author': 'Drucker, Peter F.', 'source': 'The Daily Druck
er-2004.pdf'}, page_content='24 May\nDefining the Task in Knowledge Work\n
In knowledge work, the how only comes after the what has been answered.\nI
n manual work the task is always given. Wherever there still are domestic
\nservants, the owner of the house tells them what to do. The machine or t
he\nassembly line programs the factory worker. But, in knowledge work, wha
t to\ndo becomes the first and decisive question. For knowledge workers ar
e not\nprogrammed by the machine'), Document(metadata={'page': 323, 'yea
r': '2004', 'title': 'The Daily Drucker: 366 Days of Insight and Motivatio
n for Getting the Right Things Done', 'author': 'Drucker, Peter F.', 'sour
ce': 'The Daily Drucker-2004.pdf'}, page_content='. They know\nwhat steps
are most important and what methods need to be used to complete\nthe task
s; and it is their knowledge that tells them what chores are\nunnecessary
and should be eliminated.\nWork on knowledge-worker productivity therefore
begins with asking the\nknowledge workers themselves: What is your task? W
hat should it be?\nWhat should you be expected to contribute? and What ham
pers you in\ndoing your task and should be eliminated? The how only comes
after the\nwhat has been answered')], 'checker_result': 'pass'}
```

==================================== Final Output
====================================

Peter Drucker described knowledge workers as individuals who use their knowledge as a resource, motivation, and vision for other knowledge workers. They have their own skills and concerns, making them rarely in sync with one another. Drucker emphasized that knowledge workers' productivity should not be measured primarily by the quantity of output, but rather by the quality. He suggested treating knowledge workers as assets rather than costs and ensuring that they prefer to work for their organization over other opportunities. Understanding the tasks for knowledge work begins with answering "what" rather than "how," as knowledge workers are not programmed by machines but must manage themselves and define their tasks (Drucker, 2002; Drucker, 2004; Drucker, 2008).

Reference: Drucker, P. F. (2002). *The Effective Executive*.
Drucker, P. F. (2004). *The Daily Drucker: 366 Days of Insight and Motivation for Getting the Right Things Done*.
Drucker, P. F. (2008). *The Essential Drucker*.

In [42]:
```python
# Chitter-Chatter example
test_question3 = "How are you doing today?"

async for event3 in graph.astream({"question": test_question3}, stream_mo
    print(event3)

display(Markdown(f"\n{'='*40} Final Output {'='*40}\n"))
display(Markdown(event3["generation"]))
```

```
---ROUTING QUESTION---
---ROUTING QUESTION TO CHITTER-CHATTER---
{'question': 'How are you doing today?'}

---CHIT-CHATTING---
{'question': 'How are you doing today?', 'generation': "I'm doing great, t
hank you! How about you? Is there something specific about Peter Drucker's
management philosophy or leadership principles that you'd like to discuss
today?"}
```

== Final Output
==

I'm doing great, thank you! How about you? Is there something specific about Peter Drucker's management philosophy or leadership principles that you'd like to discuss today?

A harder question:

- Conceptual leap: It asks Drucker to advise sentient AIs that reject all human organizational models.
- No grounding: Drucker never wrote about machine consciousness or post-human philosophy.
- Core tools removed: Time management, KPIs, human motivation — all irrelevant.
- Requires meta-reasoning: The agent must imagine how Drucker would respond with his framework obsolete.
- Webproof: Not too much searchable source can answer this.

- Hallucination risk: The agent must either fabricate or fall back to abstract principles — no safe middle.

In [44]:
```
# Vectorstore search loop example
test_question4 = """
Search the database first to see how Peter Drucker might advise a sentien
after rejecting all human organizational models as insufficient for post-
"""

async for event4 in graph.astream({"question": test_question4}, stream_mo
    print(event4)

display(Markdown(f"\n{'='*40} Final Output {'='*40}\n"))
display(Markdown(event4["generation"]))
```

```
---ROUTING QUESTION---
---ROUTING QUESTION TO VECTORSTORE---
{'question': '\nSearch the database first to see how Peter Drucker might a
dvise a sentient AI collective attempting to design its own management phi
losophy \nafter rejecting all human organizational models as insufficient
for post-biological cognition?\n'}

---QUERY TRANSLATION AND RAG-FUSION---
Total number of results: 11
Document 1 from `The Daily Drucker-2004.pdf`, page 271

Document 2 from `The Effective Executive-2002.pdf`, page 112

Document 3 from `The Effective Executive-2002.pdf`, page 133

Document 4 from `The Effective Executive-2002.pdf`, page 2

Document 5 from `The Daily Drucker-2004.pdf`, page 799

Document 6 from `The Daily Drucker-2004.pdf`, page 172

Document 7 from `The Essential Drucker-2008.pdf`, page 87

Document 8 from `The Daily Drucker-2004.pdf`, page 797

Document 9 from `The Daily Drucker-2004.pdf`, page 727

Document 10 from `The Daily Drucker-2004.pdf`, page 796

Document 11 from `The Daily Drucker-2004.pdf`, page 796
```

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dvise a sentient AI collective attempting to design its own management phi
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for post-biological cognition?\n', 'documents': [Document(metadata={'pag
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and Motivation for Getting the Right Things Done', 'author': 'Drucker, Pet
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Society'), Document(metadata={'page': 112, 'year': '2002', 'title': 'The E
ffective Executiver', 'author': 'Peter F. Drucker', 'source': 'The Effecti
ve Executive-2002.pdf'}, page_content='. But his is the only one of'), Doc
ument(metadata={'page': 133, 'year': '2002', 'title': 'The Effective Execu
tiver', 'author': 'Peter F. Drucker', 'source': 'The Effective Executive-2
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answer to the problem had to satisfy, \nthat is, of the "boundary conditio
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Drucker: 366 Days of Insight and Motivation for Getting the Right Things D
one', 'author': 'Drucker, Peter F.', 'source': 'The Daily Drucker-2004.pd
f'}, page_content='. Peter Drucker’s critical perspective will be welcomed
\nby scholars and students troubled by society’s growing reliance on\ntech
nological solutions to complex social and political problems.'), Document
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r the 21st Century \nThe Next Society (Corpedia Online Program)'), Documen
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page_content='.  \nA Philosophy of Management  \nWhat the business enterpr
ise needs is a principle of management that will give full scope to \nindi
vidual strength and responsibility, and at the same time give common direc
tion of vision and \neffort, establish team work, and harmonize the goals
of the individual with the commonweal.  \nThe only principle that can do t
his is management by objectives and self-control. It makes the \ncommonwea
l the aim of every manager'), Document(metadata={'page': 797, 'year': '200
4', 'title': 'The Daily Drucker: 366 Days of Insight and Motivation for Ge
tting the Right Things Done', 'author': 'Drucker, Peter F.', 'source': 'Th
e Daily Drucker-2004.pdf'}, page_content='. The first part of the book\ntr
eats the philosophical shift from a Cartesian universe of mechanical cause
\nto a new universe of pattern, purpose, and configuration. Drucker discus
ses\nthe need to organize men of knowledge and of high skill for joint eff
ort, and\nperformance as a key component of this change'), Document(metada
ta={'page': 727, 'year': '2004', 'title': 'The Daily Drucker: 366 Days of
Insight and Motivation for Getting the Right Things Done', 'author': 'Druc
ker, Peter F.', 'source': 'The Daily Drucker-2004.pdf'}, page_content='.\n
Forty years ago we built into the performance review of managerial\npeople
the question, “Are they ready for promotion?” Now we need to\nreplace that
question with “Are they ready for a bigger, more demanding\nchallenge and
for the addition of new responsibilities to their existing job?”\n \nACTIO
N POINT: Create a flat organization. Use information processing—its\nstruc
ture, its content, and its direction—to ensure that your organization is\n
agile and effective.\nThe Frontiers of Management'), Document(metadata={'p
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t and Motivation for Getting the Right Things Done', 'author': 'Drucker, P
eter F.', 'source': 'The Daily Drucker-2004.pdf'}, page_content='.’ He is
Loading [MathJax]/extensions/Safe.js at home in economics, political science,\nindustrial psycholog
```

```
y, and industrial sociology, and has succeeded admirably\nin harmonizing t
he findings of all four disciplines and applying them\nmeaningfully to the
practical problems of the ‘enterprise.’ ” Drucker believes\nthat the inter
ests of the worker, management, and corporation are\nreconcilable with soc
iety. He advances the idea of “the plant community” in\nwhich workers are
encouraged to take on more responsibility and act like\n“managers'), Docum
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ntent='. Drucker looks at General Motors’\nmanagerial organization and att
empts to understand what makes the company\nwork so effectively. Certain q
uestions are addressed, such as: “What are the\ncompany’s core principles,
and how do they contribute to the success of the\norganization?” The princ
iples of organization and management at General\nMotors described in this
book became models for organizations worldwide')]}
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---GRADE: DOCUMENT NOT RELEVANT---
---GRADE: DOCUMENT NOT RELEVANT---
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---GRADE: DOCUMENT NOT RELEVANT---
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---GRADE: DOCUMENT NOT RELEVANT---
---GRADE: DOCUMENT NOT RELEVANT---
---GRADE: DOCUMENT NOT RELEVANT---
---GRADE: DOCUMENT NOT RELEVANT---
---GRADE: DOCUMENT NOT RELEVANT---
---FILTERED OUT 100.0% OF IRRELEVANT DOCUMENTS---
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---CHECK GENERATION CONDITION---
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for post-biological cognition?\n', 'documents': [], 'checker_result': 'fai
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---CHECK HALLUCINATIONS WITH DOCUMENTS---
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t philosophy, especially in scenarios where traditional human organization
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er rejecting all human organizational models as insufficient for post-biol
ogical cognition?\n', 'generation': "The context provided does not contain
specific information about how Peter Drucker might advise a sentient AI co
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organizational models. Therefore, an answer based on the provided document
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ontent': 'That is, it is about the shorthand that makes artificial neural
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Total number of results: 7
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Document 1 from `The Daily Drucker-2004.pdf`, page 799

Document 2 from `The Daily Drucker-2004.pdf`, page 796

Document 3 from `The Daily Drucker-2004.pdf`, page 365

Document 4 from `The Essential Drucker-2008.pdf`, page 87

Document 5 from `The Essential Drucker-2008.pdf`, page 58

Document 6 from `The Daily Drucker-2004.pdf`, page 727

Document 7 from `The Daily Drucker-2004.pdf`, page 172

{'question': "How might Peter Drucker's principles on management and leade
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t philosophy, especially in scenarios where traditional human organization
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ent AI collective attempting to design its own management philosophy \naft
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organizational models. Therefore, an answer based on the provided document
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ts troubled by society's growing reliance on\ntechnological solutions to c
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'year': '2004', 'title': 'The Daily Drucker: 366 Days of Insight and Motiv
ation for Getting the Right Things Done', 'author': 'Drucker, Peter F.',
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General Motors'\nmanagerial organization and attempts to understand what m
akes the company\nwork so effectively. Certain questions are addressed, su
ch as: "What are the\ncompany's core principles, and how do they contribut
e to the success of the\norganization?" The principles of organization and
management at General\nMotors described in this book became models for org
anizations worldwide'), Document(metadata={'page': 365, 'year': '2004', 't
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the Right Things Done', 'author': 'Drucker, Peter F.', 'source': 'The Dail
y Drucker-2004.pdf'}, page_content='. Apply the concepts\ndirectly to your
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\nWhat the business enterprise needs is a principle of management that wil
l give full scope to \nindividual strength and responsibility, and at the
same time give common direction of vision and \neffort, establish team wor
k, and harmonize the goals of the individual with the commonweal. \nThe o
nly principle that can do this is management by objectives and self-contro
l. It makes the \ncommonweal the aim of every manager'), Document(metadata
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'Peter F. Drucker', 'source': 'The Essential Drucker-2008.pdf'}, page_cont
ent='. Taylor. This will require, above all, very \ndifferent assumptions
about people in organizations and their work: \na) One does not "manage"
people. \nb) The task is to lead people. \nc) And the goal is to make pr
oductive the specific strengths and knowledge of each individual. \nd) Te
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stated above, have been underlying the practice of management all \nalong—
in fact for much longer than there has been a discipline of management'),
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to\nreplace that question with "Are they ready for a bigger, more demandin
g\nchallenge and for the addition of new responsibilities to their existin
g job?"\n \nACTION POINT: Create a flat organization. Use information proc
\nstructure, its content, and its direction—to ensure that your
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rship be applied by a sentient AI collective in developing a new managemen
t philosophy, especially in scenarios where traditional human organization
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er rejecting all human organizational models as insufficient for post-biol
ogical cognition?\n', 'generation': "The context provided does not contain
specific information about how Peter Drucker might advise a sentient AI co
llective in designing its own management philosophy after rejecting human
organizational models. Therefore, an answer based on the provided document
s cannot be given.\n\n**Reference Section**:\n- No specific references are
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'Peter F. Drucker', 'source': 'The Essential Drucker-2008.pdf'}, page_cont
ent='. Taylor. This will require, above all, very \ndifferent assumptions
about people in organizations and their work:  \na) One does not "manage"
people.  \nb) The task is to lead people.  \nc) And the goal is to make pr
oductive the specific strengths and knowledge of each individual.  \nd) Te
chnologies and End Uses Are Fixed and Given.  \nFour major assumptions, as
stated above, have been underlying the practice of management all \nalong—
in fact for much longer than there has been a discipline of management')],
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---WEB SEARCH---
Total number of web search documents: 1
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rship be applied by a sentient AI collective in developing a new managemen
t philosophy, especially in scenarios where traditional human organization
al models are inadequate for non-human cognition?", 'original_question':
'\nSearch the database first to see how Peter Drucker might advise a senti
ent AI collective attempting to design its own management philosophy \naft
er rejecting all human organizational models as insufficient for post-biol
ogical cognition?\n', 'generation': "The context provided does not contain
specific information about how Peter Drucker might advise a sentient AI co
llective in designing its own management philosophy after rejecting human
onal models. Therefore, an answer based on the provided document
```

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s cannot be given.\n\n**Reference Section**:\n- No specific references are
available in the context provided for the question about Peter Drucker's a
dvice.", 'answer_verifier_attempts': 1, 'documents': [Document(metadata=
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about people in organizations and their work:  \na) One does not “manage”
people.  \nb) The task is to lead people.  \nc) And the goal is to make pr
oductive the specific strengths and knowledge of each individual.  \nd) Te
chnologies and End Uses Are Fixed and Given.  \nFour major assumptions, as
stated above, have been underlying the practice of management all \nalong—
in fact for much longer than there has been a discipline of management'),
{'metadata': {'title': '[PDF] Adventures in Higher Education Policy - The
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ogies are at first inadequate to displace today's technology in existing a
pplications, they later explosively displace the application as they enabl
e"}], 'checker_result': 'fail'}

---ANSWER GENERATION---
Answer generation has been generated.
---CHECK HALLUCINATIONS WITH DOCUMENTS---
---DECISION: GENERATION IS GROUNDED IN DOCUMENTS---
---VERIFY ANSWER WITH QUESTION---
---DECISION: GENERATION ADDRESSES QUESTION---
{'question': "How might Peter Drucker's principles on management and leade
rship be applied by a sentient AI collective in developing a new managemen
t philosophy, especially in scenarios where traditional human organization
al models are inadequate for non-human cognition?", 'original_question':
'\nSearch the database first to see how Peter Drucker might advise a senti
ent AI collective attempting to design its own management philosophy \naft
er rejecting all human organizational models as insufficient for post-biol
ogical cognition?\n', 'generation': 'The context provided includes insight
s from Peter Drucker, particularly from "The Essential Drucker." Based on
this, Drucker might advise a sentient AI collective designing its own mana
gement philosophy to focus on leading rather than managing individuals. He
emphasizes making productive the specific strengths and knowledge of each
individual, implying that the AI should harness the unique capabilities of
its components. Drucker also suggests considering that technologies and en
d uses are fixed and given, which could be interpreted as advising the AI
to navigate within certain constraints or established frameworks. However,
detailed advice specific to a sentient AI collective is not covered in the
provided context.\n\n**Reference Section**:\n- Drucker, P. F. (2008). *The
Essential Drucker*.', 'answer_verifier_attempts': 1, 'documents': [Documen
t(metadata={'page': 58, 'year': '2008', 'title': 'The Essential Drucker',
'author': 'Peter F. Drucker', 'source': 'The Essential Drucker-2008.pdf'},
page_content='. Taylor. This will require, above all, very \ndifferent ass
umptions about people in organizations and their work:  \na) One does not
“manage” people.  \nb) The task is to lead people.  \nc) And the goal is t
o make productive the specific strengths and knowledge of each individual.
\nd) Technologies and End Uses Are Fixed and Given.  \nFour major assumpti
ons, as stated above, have been underlying the practice of management all
\nalong—in fact for much longer than there has been a discipline of manage
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7/2017%20Adventures%20in%20HE%20Policy%20LR.pdf'}, 'page_content': "... ne
w technologies are at first inadequate to displace today's technology in e
xisting applications, they later explosively displace the application as t
hey enable"}], 'checker_result': 'fail'}
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========================================== Final Output
==========================================
```

The context provided includes insights from Peter Drucker, particularly from "The Essential Drucker." Based on this, Drucker might advise a sentient AI collective designing its own management philosophy to focus on leading rather than managing individuals. He emphasizes making productive the specific strengths and knowledge of each individual, implying that the AI should harness the unique capabilities of its components. Drucker also suggests considering that technologies and end uses are fixed and given, which could be interpreted as advising the AI to navigate within certain constraints or established frameworks. However, detailed advice specific to a sentient AI collective is not covered in the provided context.

Reference Section:

- Drucker, P. F. (2008). *The Essential Drucker*.

4. Potential Improvements

- Model & Embedding Optimization

Experiment with different embedding models to assess their impact on retrieval accuracy, semantic matching, and downstream response quality.

- Web Search Enhancement

Test alternative web search APIs/tools to dentify which service delivers the most relevant, reliable, and up-to-date content.

- Agent-Specific Model Selection

Assign different LLMs tailored to each agent's function (e.g., lighter models for routing, stronger ones for generation) to improve both efficiency and performance.

- Contextual Result Accumulation

Support multi-turn or follow-up queries by preserving and reusing relevant results from earlier steps, enabling more context-aware and coherent interactions.

- Advanced Prompt Engineering

Iteratively refine and customize prompts for each agent to better handle edge cases, ambiguous queries, or complex reasoning. Regularly create challenging test cases to evaluate agent robustness and adaptability.