In [1]:
```
pip install pymupdf pdfplumber
```

```
Requirement already satisfied: pymupdf in c:\users\rizwana\anaconda3\envs\finalproject\lib\site-packages (1.26.3)
Requirement already satisfied: pdfplumber in c:\users\rizwana\anaconda3\envs\finalproject\lib\site-packages (0.11.7)
Requirement already satisfied: pdfminer.six==20250506 in c:\users\rizwana\anaconda3\envs\finalproject\lib\site-packages (from pdfplumber) (20250506)
Requirement already satisfied: Pillow>=9.1 in c:\users\rizwana\anaconda3\envs\finalproject\lib\site-packages (from pdfplumber) (11.3.0)
Requirement already satisfied: pypdfium2>=4.18.0 in c:\users\rizwana\anaconda3\envs\finalproject\lib\site-packages (from pdfplumber) (4.30.0)
Requirement already satisfied: charset-normalizer>=2.0.0 in c:\users\rizwana\anaconda3\envs\finalproject\lib\site-packages (from pdfminer.six==20250506->pdfplumber) (3.4.3)
Requirement already satisfied: cryptography>=36.0.0 in c:\users\rizwana\anaconda3\envs\finalproject\lib\site-packages (from pdfminer.six==20250506->pdfplumber) (45.0.6)
Requirement already satisfied: cffi>=1.14 in c:\users\rizwana\anaconda3\envs\finalproject\lib\site-packages (from cryptography>=36.0.0->pdfminer.six==20250506->pdfplumber) (1.17.1)
Requirement already satisfied: pycparser in c:\users\rizwana\anaconda3\envs\finalproject\lib\site-packages (from cffi>=1.14->cryptography>=36.0.0->pdfminer.six==20250506->pdfplumber) (2.22)
Note: you may need to restart the kernel to use updated packages.
```

Data Preprocessing

Concatenate IGCSE data into single .csv

In [2]:
```python
import os, re, glob
import pandas as pd

import fitz  # pymupdf

def extract_text_pymupdf(pdf_path: str) -> str:
    text_parts = []
    with fitz.open(pdf_path) as doc:
        for page in doc:
            text_parts.append(page.get_text("text"))
    return "\n".join(text_parts).strip()


ROOT = r"C:\Users\Rizwana\Desktop\studyoclock project"

subjects = ["biology", "chemistry", "business", "ict"]
rows = []

for subj in subjects:
    folder = os.path.join(ROOT, subj)
    for pdf in glob.glob(os.path.join(folder, "*.pdf")):
        topic_name = os.path.splitext(os.path.basename(pdf))[0]
        raw_text = extract_text_pymupdf(pdf)
        rows.append({
            "subject": subj,
            "topic_name": topic_name,
            "raw_text": raw_text
        })

raw_df = pd.DataFrame(rows)
raw_df = raw_df.dropna(subset=["raw_text"])
raw_df = raw_df[raw_df["raw_text"].str.strip().astype(bool)]
```

```python
raw_df.to_csv("raw_notes_from_pdfs.csv", index=False)
print("Built raw_notes_from_pdfs.csv with", len(raw_df), "rows")
raw_df.head()
```

```
Built raw_notes_from_pdfs.csv with 75 rows
```

Out[2]:

	subject	topic_name	raw_text
0	biology	Unit 1 Characteristics and Classification of L...	Unit 1 Characteristics and Classification of L...
1	biology	Unit 10 Diseases and Immunity	Diseases and Immunity \nDisease \n• Pathogens ...
2	biology	Unit 11 Gas Exchange in Humans	Gas Exchange in Humans \nThe Gas Exchange Syst...
3	biology	Unit 12 Respiration	Respiration \nAerobic respiration \n• All ce...
4	biology	Unit 13 Excretion	Excretion \n \n• Excretion is the removal from...

Verification that data is sensible

In [4]:

```python
raw_df.tail()
```

Out[4]:

	subject	topic_name	raw_text
70	ict	4. Networks and the effects of using them	Networks and the effects of using them \n• A ...
71	ict	5. The effects of using ICT	The Effects of Using ICT \nThe effects of ICT...
72	ict	6. ICT Applications	ICT Applications \nCommunication applications ...
73	ict	7. Systems Analysis and Design	Systems Analysis and Design \n• It is a method...
74	ict	8.Safety and Security	Safety and Security \nPhysical Safety \nHealt...

Assignment of Difficulty Tags

In [5]:

```python
import re
import pandas as pd
from transformers import pipeline, AutoTokenizer
from textstat import flesch_kincaid_grade, flesch_reading_ease
from tqdm import tqdm

df = pd.read_csv("raw_notes_from_pdfs.csv")

required = {"subject", "topic_name", "raw_text"}
if not required.issubset(df.columns):
    raise ValueError(f"CSV must contain {required}")

df = df.dropna(subset=["raw_text"]).copy()
df["word_count"] = df["raw_text"].apply(lambda x: len(str(x).split()))

tqdm.pandas()

model_name = "sshleifer/distilbart-cnn-12-6"
tokenizer = AutoTokenizer.from_pretrained(model_name)
summarizer = pipeline("summarization", model=model_name, tokenizer=tokenizer, framework=

def chunk_by_tokens(text, tokenizer, max_tokens=1024):
    sentences = re.split(r'(?<=[.!?]) +', str(text))
    chunks, cur = [], ""
    for s in sentences:
        cand = (cur + " " + s).strip()
        if len(tokenizer.encode(cand)) < max_tokens:
            cur = cand
```

```python
        else:
            if cur: chunks.append(cur)
            cur = s
    if cur: chunks.append(cur)
    return chunks

def summarize_text(text):
    parts = chunk_by_tokens(text, tokenizer)
    outs = [summarizer(p, max_length=1000, min_length=40, truncation=True)[0]["summary_t
    return " ".join(outs)

if "summary_text" not in df.columns:
    df["summary_text"] = df["raw_text"].progress_apply(summarize_text)

def assign_difficulty(summary: str) -> str:
    grade = flesch_kincaid_grade(summary)
    ease  = flesch_reading_ease(summary)
    if grade <= 6 and ease >= 60:
        return "Easy"
    elif grade <= 10 and ease >= 40:
        return "Medium"
    else:
        return "Hard"

df["difficulty_level"] = df["summary_text"].apply(assign_difficulty)

df.to_csv("processed_notes.csv", index=False)
print("Saved processed_notes.csv with columns:", list(df.columns))
df.head()
```

```
Device set to use cpu
  0%|                                    | 0/75 [00:00<?, ?it/s]Token indices sequence length
is longer than the specified maximum sequence length for this model (2263 > 1024). Runni
ng this sequence through the model will result in indexing errors
Your max_length is set to 1000, but your input_length is only 345. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=172)
Your max_length is set to 1000, but your input_length is only 219. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=109)
  3%|███▍                          | 2/75 [00:18<11:20,  9.33s/it]Your max_length is set to 10
00, but your input_length is only 592. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=296)
Your max_length is set to 1000, but your input_length is only 909. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=454)
Your max_length is set to 1000, but your input_length is only 493. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=246)
  4%|████▋                         | 3/75 [01:00<27:15, 22.72s/it]Your max_length is set to 10
00, but your input_length is only 694. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=347)
Your max_length is set to 1000, but your input_length is only 872. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=436)
  7%|███████▋                      | 5/75 [01:31<20:49, 17.85s/it]Your max_length is set to 10
00, but your input_length is only 805. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=402)
```

```
Your max_length is set to 1000, but your input_length is only 98. Since this is a summar
ization task, where outputs shorter than the input are typically wanted, you might consi
der decreasing max_length manually, e.g. summarizer('...', max_length=49)
  8%|█████████
                              | 6/75 [01:56<23:12, 20.18s/it]Your max_length is set to 10
00, but your input_length is only 713. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=356)
Your max_length is set to 1000, but your input_length is only 826. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=413)
  9%|██████████
                              | 7/75 [02:37<30:37, 27.02s/it]Your max_length is set to 10
00, but your input_length is only 35. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=17)
Your max_length is set to 1000, but your input_length is only 26. Since this is a summar
ization task, where outputs shorter than the input are typically wanted, you might consi
der decreasing max_length manually, e.g. summarizer('...', max_length=13)
 11%|████████████
                              | 8/75 [03:05<30:37, 27.43s/it]Your max_length is set to 10
00, but your input_length is only 268. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=134)
Your max_length is set to 1000, but your input_length is only 932. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=466)
Your max_length is set to 1000, but your input_length is only 71. Since this is a summar
ization task, where outputs shorter than the input are typically wanted, you might consi
der decreasing max_length manually, e.g. summarizer('...', max_length=35)
Your max_length is set to 1000, but your input_length is only 869. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=434)
Your max_length is set to 1000, but your input_length is only 471. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=235)
Your max_length is set to 1000, but your input_length is only 743. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=371)
Your max_length is set to 1000, but your input_length is only 824. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=412)
Your max_length is set to 1000, but your input_length is only 776. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=388)
 12%|█████████████
                              | 9/75 [04:41<53:25, 48.56s/it]Your max_length is set to 10
00, but your input_length is only 965. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=482)
Your max_length is set to 1000, but your input_length is only 696. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=348)
Your max_length is set to 1000, but your input_length is only 636. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=318)
 13%|███████████████
                             | 10/75 [05:09<45:39, 42.15s/it]Your max_length is set to 10
00, but your input_length is only 168. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=84)
Your max_length is set to 1000, but your input_length is only 447. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=223)
 15%|████████████████
                             | 11/75 [05:28<37:40, 35.32s/it]Your max_length is set to 10
```

```
00, but your input_length is only 854. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=427)
 16%|█████████████████
                           | 12/75 [05:59<35:39, 33.97s/it]Your max_length is set to 100
0, but your input_length is only 469. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=234)
Your max_length is set to 1000, but your input_length is only 847. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=423)
 17%|███████████████████
                           | 13/75 [06:15<29:25, 28.47s/it]Your max_length is set to 100
0, but your input_length is only 140. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=70)
Your max_length is set to 1000, but your input_length is only 996. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=498)
Your max_length is set to 1000, but your input_length is only 164. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=82)
 19%|████████████████████
                           | 14/75 [06:44<29:05, 28.62s/it]Your max_length is set to 100
0, but your input_length is only 788. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=394)
Your max_length is set to 1000, but your input_length is only 24. Since this is a summar
ization task, where outputs shorter than the input are typically wanted, you might consi
der decreasing max_length manually, e.g. summarizer('...', max_length=12)
Your max_length is set to 1000, but your input_length is only 382. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=191)
 20%|██████████████████████
                           | 15/75 [07:39<36:42, 36.71s/it]Your max_length is set to 100
0, but your input_length is only 827. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=413)
Your max_length is set to 1000, but your input_length is only 308. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=154)
 21%|███████████████████████
                            | 16/75 [07:53<29:15, 29.76s/it]Your max_length is set to 10
00, but your input_length is only 953. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=476)
 23%|█████████████████████████
                            | 17/75 [08:03<22:59, 23.78s/it]Your max_length is set to 10
00, but your input_length is only 619. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=309)
 24%|███████████████████████████
                            | 18/75 [08:11<18:13, 19.19s/it]Your max_length is set to 10
00, but your input_length is only 918. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=459)
Your max_length is set to 1000, but your input_length is only 257. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=128)
 25%|████████████████████████████
                            | 19/75 [08:32<18:16, 19.59s/it]Your max_length is set to 10
00, but your input_length is only 631. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=315)
Your max_length is set to 1000, but your input_length is only 842. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
```

```
ider decreasing max_length manually, e.g. summarizer('...', max_length=421)
Your max_length is set to 1000, but your input_length is only 692. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=346)
Your max_length is set to 1000, but your input_length is only 469. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=234)
Your max_length is set to 1000, but your input_length is only 808. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=404)
Your max_length is set to 1000, but your input_length is only 644. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=322)
 27%|██████████████████████████████
                               | 20/75 [09:31<28:46, 31.40s/it]Your max_length is set to 10
00, but your input_length is only 910. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=455)
Your max_length is set to 1000, but your input_length is only 709. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=354)
 28%|███████████████████████████████▌
                               | 21/75 [09:51<25:15, 28.06s/it]Your max_length is set to 10
00, but your input_length is only 367. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=183)
Your max_length is set to 1000, but your input_length is only 768. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=384)
Your max_length is set to 1000, but your input_length is only 829. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=414)
Your max_length is set to 1000, but your input_length is only 446. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=223)
 29%|█████████████████████████████████
                               | 22/75 [10:32<28:04, 31.79s/it]Your max_length is set to 10
00, but your input_length is only 579. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=289)
 31%|██████████████████████████████████▌
                               | 23/75 [10:47<23:11, 26.75s/it]Your max_length is set to 10
00, but your input_length is only 767. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=383)
Your max_length is set to 1000, but your input_length is only 950. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=475)
Your max_length is set to 1000, but your input_length is only 883. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=441)
Your max_length is set to 1000, but your input_length is only 412. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=206)
 32%|████████████████████████████████████
                               | 24/75 [11:17<23:46, 27.97s/it]Your max_length is set to 10
00, but your input_length is only 966. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=483)
 33%|█████████████████████████████████████▌
                               | 25/75 [11:37<21:11, 25.43s/it]Your max_length is set to 10
00, but your input_length is only 648. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=324)
Your max_length is set to 1000, but your input_length is only 504. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=252)
```

```
ider decreasing max_length manually, e.g. summarizer('...', max_length=252)
 35%|██████████████████████████████████████
                              | 26/75 [11:56<19:11, 23.50s/it]Your max_length is set to 10
00, but your input_length is only 963. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=481)
Your max_length is set to 1000, but your input_length is only 81. Since this is a summar
ization task, where outputs shorter than the input are typically wanted, you might consi
der decreasing max_length manually, e.g. summarizer('...', max_length=40)
 36%|████████████████████████████████████████
                             | 27/75 [12:11<16:45, 20.94s/it]Your max_length is set to 100
0, but your input_length is only 995. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=497)
Your max_length is set to 1000, but your input_length is only 285. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=142)
 37%|█████████████████████████████████████████
                             | 28/75 [12:35<17:06, 21.84s/it]Your max_length is set to 100
0, but your input_length is only 954. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=477)
Your max_length is set to 1000, but your input_length is only 966. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=483)
Your max_length is set to 1000, but your input_length is only 90. Since this is a summar
ization task, where outputs shorter than the input are typically wanted, you might consi
der decreasing max_length manually, e.g. summarizer('...', max_length=45)
 39%|███████████████████████████████████████████
                             | 29/75 [13:28<24:03, 31.37s/it]Your max_length is set to 100
0, but your input_length is only 874. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=437)
Your max_length is set to 1000, but your input_length is only 905. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=452)
Your max_length is set to 1000, but your input_length is only 594. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=297)
 40%|████████████████████████████████████████████
                             | 30/75 [13:56<22:38, 30.19s/it]Your max_length is set to 100
0, but your input_length is only 609. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=304)
 41%|█████████████████████████████████████████████▋
                              | 31/75 [14:13<19:17, 26.31s/it]Your max_length is set to 10
00, but your input_length is only 747. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=373)
Your max_length is set to 1000, but your input_length is only 491. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=245)
Your max_length is set to 1000, but your input_length is only 868. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=434)
Your max_length is set to 1000, but your input_length is only 663. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=331)
 43%|███████████████████████████████████████████████▌
                              | 32/75 [14:46<20:13, 28.22s/it]Your max_length is set to 10
00, but your input_length is only 866. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=433)
Your max_length is set to 1000, but your input_length is only 444. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=222)
```

```
 44%|████████████████████████████████████████████████▍
                                | 33/75 [15:03<17:24, 24.87s/it]Your max_length is set to 10
00, but your input_length is only 875. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=437)
 45%|█████████████████████████████████████████████████▉
                                | 34/75 [15:13<13:52, 20.31s/it]Your max_length is set to 10
00, but your input_length is only 342. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=171)
 47%|███████████████████████████████████████████████████▍
                                | 35/75 [15:40<14:52, 22.31s/it]Your max_length is set to 10
00, but your input_length is only 197. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=98)
 48%|████████████████████████████████████████████████████▊
                                | 36/75 [15:56<13:22, 20.58s/it]Your max_length is set to 10
00, but your input_length is only 987. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=493)
Your max_length is set to 1000, but your input_length is only 553. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=276)
 49%|██████████████████████████████████████████████████████▎
                                | 37/75 [16:46<18:40, 29.50s/it]Your max_length is set to 10
00, but your input_length is only 636. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=318)
Your max_length is set to 1000, but your input_length is only 915. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=457)
Your max_length is set to 1000, but your input_length is only 334. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=167)
 51%|███████████████████████████████████████████████████████▋
                                | 38/75 [17:07<16:32, 26.82s/it]Your max_length is set to 10
00, but your input_length is only 116. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=58)
Your max_length is set to 1000, but your input_length is only 699. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=349)
 52%|█████████████████████████████████████████████████████████▏
                                | 39/75 [17:27<14:51, 24.77s/it]Your max_length is set to 10
00, but your input_length is only 805. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=402)
 53%|██████████████████████████████████████████████████████████▋
                                | 40/75 [17:35<11:33, 19.81s/it]Your max_length is set to 10
00, but your input_length is only 579. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=289)
 55%|████████████████████████████████████████████████████████████
                                | 41/75 [17:42<08:58, 15.84s/it]Your max_length is set to 10
00, but your input_length is only 182. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=91)
 56%|█████████████████████████████████████████████████████████████▌
                               | 42/75 [17:58<08:50, 16.07s/it]Your max_length is set to 100
0, but your input_length is only 974. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=487)
Your max_length is set to 1000, but your input_length is only 89. Since this is a summar
ization task, where outputs shorter than the input are typically wanted, you might consi
der decreasing max_length manually, e.g. summarizer('...', max_length=44)
 57%|███████████████████████████████████████████████████████████████
```

```
                                        | 43/75 [18:10<07:55, 14.87s/it]Your max_length is set to 100
0, but your input_length is only 195. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=97)
 59%|████████████████████████████████████████████████████████████████
                                        | 44/75 [18:25<07:41, 14.89s/it]Your max_length is set to 100
0, but your input_length is only 321. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=160)
 60%|██████████████████████████████████████████████████████████████████
                                        | 45/75 [18:43<07:52, 15.73s/it]Your max_length is set to 100
0, but your input_length is only 915. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=457)
Your max_length is set to 1000, but your input_length is only 905. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=452)
 61%|███████████████████████████████████████████████████████████████████
                                         | 46/75 [19:03<08:11, 16.94s/it]Your max_length is set to 10
00, but your input_length is only 918. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=459)
Your max_length is set to 1000, but your input_length is only 499. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=249)
 63%|█████████████████████████████████████████████████████████████████████
                                         | 47/75 [19:17<07:34, 16.22s/it]Your max_length is set to 10
00, but your input_length is only 702. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=351)
 64%|██████████████████████████████████████████████████████████████████████
                                         | 48/75 [19:28<06:32, 14.53s/it]Your max_length is set to 10
00, but your input_length is only 980. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=490)
Your max_length is set to 1000, but your input_length is only 801. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=400)
Your max_length is set to 1000, but your input_length is only 787. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=393)
 65%|████████████████████████████████████████████████████████████████████████
                                         | 49/75 [20:06<09:20, 21.57s/it]Your max_length is set to 10
00, but your input_length is only 945. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=472)
Your max_length is set to 1000, but your input_length is only 475. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=237)
 67%|█████████████████████████████████████████████████████████████████████████
                                         | 50/75 [20:21<08:08, 19.55s/it]Your max_length is set to 10
00, but your input_length is only 915. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=457)
Your max_length is set to 1000, but your input_length is only 141. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=70)
 68%|███████████████████████████████████████████████████████████████████████████
                                         | 51/75 [20:37<07:24, 18.54s/it]Your max_length is set to 10
00, but your input_length is only 186. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=93)
 69%|████████████████████████████████████████████████████████████████████████████
                                         | 52/75 [20:43<05:40, 14.82s/it]Your max_length is set to 10
00, but your input_length is only 475. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
```

```
nually, e.g. summarizer('...', max_length=237)
 71%|██████████████████████████████████████████████████████████████████████████████
                              | 53/75 [20:50<04:31, 12.35s/it]Your max_length is set to 10
00, but your input_length is only 932. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=466)
Your max_length is set to 1000, but your input_length is only 301. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=150)
 72%|███████████████████████████████████████████████████████████████████████████████
                              | 54/75 [21:16<05:45, 16.43s/it]Your max_length is set to 10
00, but your input_length is only 732. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=366)
 73%|█████████████████████████████████████████████████████████████████████████████████
                              | 55/75 [21:34<05:37, 16.87s/it]Your max_length is set to 10
00, but your input_length is only 909. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=454)
Your max_length is set to 1000, but your input_length is only 132. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=66)
 75%|██████████████████████████████████████████████████████████████████████████████████
▏                              | 56/75 [21:47<05:01, 15.88s/it]Your max_length is set to 1
000, but your input_length is only 950. Since this is a summarization task, where output
s shorter than the input are typically wanted, you might consider decreasing max_length
manually, e.g. summarizer('...', max_length=475)
Your max_length is set to 1000, but your input_length is only 551. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=275)
 76%|████████████████████████████████████████████████████████████████████████████████████
▌                             | 57/75 [22:05<04:58, 16.60s/it]Your max_length is set to 100
0, but your input_length is only 913. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=456)
Your max_length is set to 1000, but your input_length is only 695. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=347)
 77%|████████████████████████████████████████████████████████████████████████████████████
██                            | 58/75 [22:24<04:52, 17.19s/it]Your max_length is set to 100
0, but your input_length is only 689. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=344)
 79%|████████████████████████████████████████████████████████████████████████████████████
███▍                          | 59/75 [22:56<05:47, 21.69s/it]Your max_length is set to 100
0, but your input_length is only 772. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=386)
Your max_length is set to 1000, but your input_length is only 561. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=280)
 80%|████████████████████████████████████████████████████████████████████████████████████
█████                         | 60/75 [23:12<04:58, 19.87s/it]Your max_length is set to 100
0, but your input_length is only 827. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=413)
Your max_length is set to 1000, but your input_length is only 215. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=107)
 81%|████████████████████████████████████████████████████████████████████████████████████
██████▋                        | 61/75 [23:27<04:18, 18.49s/it]Your max_length is set to 10
00, but your input_length is only 925. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=462)
 83%|████████████████████████████████████████████████████████████████████████████████████
████████▍                      | 62/75 [23:37<03:26, 15.92s/it]Your max_length is set to 10
```

```
00, but your input_length is only 884. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=442)
Your max_length is set to 1000, but your input_length is only 664. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=332)
 84%|██████████████████████████████████████████████████████████████████████████████████
█████████                      | 63/75 [23:52<03:06, 15.54s/it]Your max_length is set to 10
00, but your input_length is only 392. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=196)
 85%|██████████████████████████████████████████████████████████████████████████████████
███████████                    | 64/75 [23:57<02:16, 12.36s/it]Your max_length is set to 10
00, but your input_length is only 941. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=470)
Your max_length is set to 1000, but your input_length is only 97. Since this is a summar
ization task, where outputs shorter than the input are typically wanted, you might consi
der decreasing max_length manually, e.g. summarizer('...', max_length=48)
 87%|██████████████████████████████████████████████████████████████████████████████████
████████████                   | 65/75 [24:12<02:11, 13.18s/it]Your max_length is set to 10
00, but your input_length is only 963. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=481)
Your max_length is set to 1000, but your input_length is only 521. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=260)
 88%|██████████████████████████████████████████████████████████████████████████████████
██████████████                 | 66/75 [24:29<02:09, 14.35s/it]Your max_length is set to 10
00, but your input_length is only 932. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=466)
Your max_length is set to 1000, but your input_length is only 900. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=450)
 89%|██████████████████████████████████████████████████████████████████████████████████
███████████████                | 67/75 [24:46<02:01, 15.15s/it]Your max_length is set to 10
00, but your input_length is only 808. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=404)
Your max_length is set to 1000, but your input_length is only 572. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=286)
 91%|██████████████████████████████████████████████████████████████████████████████████
█████████████████              | 68/75 [25:00<01:43, 14.80s/it]Your max_length is set to 10
00, but your input_length is only 992. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=496)
Your max_length is set to 1000, but your input_length is only 381. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=190)
 92%|██████████████████████████████████████████████████████████████████████████████████
██████████████████             | 69/75 [25:27<01:50, 18.41s/it]Your max_length is set to 10
00, but your input_length is only 864. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=432)
 93%|██████████████████████████████████████████████████████████████████████████████████
████████████████████           | 70/75 [26:30<02:40, 32.03s/it]Your max_length is set to 10
00, but your input_length is only 955. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=477)
Your max_length is set to 1000, but your input_length is only 171. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=85)
 95%|██████████████████████████████████████████████████████████████████████████████████
█████████████████████          | 71/75 [26:54<01:58, 29.55s/it]Your max_length is set to 10
```

```
00, but your input_length is only 838. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=419)
Your max_length is set to 1000, but your input_length is only 978. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=489)
Your max_length is set to 1000, but your input_length is only 993. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=496)
Your max_length is set to 1000, but your input_length is only 987. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=493)
Your max_length is set to 1000, but your input_length is only 959. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=479)
Your max_length is set to 1000, but your input_length is only 724. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=362)
 96%|████████████████████████████████████████████████████████████████████████████████████
███████████████████████     | 72/75 [28:00<02:00, 40.31s/it]Your max_length is set to 100
0, but your input_length is only 852. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=426)
 97%|████████████████████████████████████████████████████████████████████████████████████
████████████████████████   | 73/75 [28:07<01:00, 30.49s/it]Your max_length is set to 100
0, but your input_length is only 980. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=490)
Your max_length is set to 1000, but your input_length is only 863. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=431)
Your max_length is set to 1000, but your input_length is only 698. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=349)
Your max_length is set to 1000, but your input_length is only 991. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=495)
Your max_length is set to 1000, but your input_length is only 868. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=434)
Your max_length is set to 1000, but your input_length is only 298. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=149)
 99%|████████████████████████████████████████████████████████████████████████████████████
██████████████████████████ | 74/75 [30:02<00:55, 55.74s/it]Your max_length is set to 100
0, but your input_length is only 697. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=348)
Your max_length is set to 1000, but your input_length is only 978. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=489)
Your max_length is set to 1000, but your input_length is only 572. Since this is a summa
rization task, where outputs shorter than the input are typically wanted, you might cons
ider decreasing max_length manually, e.g. summarizer('...', max_length=286)
100%|████████████████████████████████████████████████████████████████████████████████████
███████████████████████████| 75/75 [30:38<00:00, 49.84s/it]Your max_length is set to 100
0, but your input_length is only 986. Since this is a summarization task, where outputs
shorter than the input are typically wanted, you might consider decreasing max_length ma
nually, e.g. summarizer('...', max_length=493)
100%|████████████████████████████████████████████████████████████████████████████████████
███████████████████████████| 75/75 [30:55<00:00, 24.73s/it]
Saved processed_notes.csv with columns: ['subject', 'topic_name', 'raw_text', 'word_coun
t', 'summary_text', 'difficulty_level']
```

Out[5]:

subject	topic_name	raw_text	word_count	summary_text	difficulty_level

	subject	topic_name	raw_text	word_count	summary_text	difficulty_level
0	biology	Unit 1 Characteristics and Classification of L...	Unit 1 Characteristics and Classification of L...	1458	Living organisms are classified into 5 groups...	Medium
1	biology	Unit 10 Diseases and Immunity	Diseases and Immunity \nDisease \n• Pathogens ...	2059	Pathogens are organisms that cause diseases (...	Medium
2	biology	Unit 11 Gas Exchange in Humans	Gas Exchange in Humans \nThe Gas Exchange Syst...	937	The lungs are spongy organs found inside the ...	Hard
3	biology	Unit 12 Respiration	Respiration \nAerobic respiration \n• All ce...	589	All cells need energy provided by burning glu...	Hard
4	biology	Unit 13 Excretion	Excretion \n \n• Excretion is the removal from...	1274	Excretion is the removal from the body of the...	Hard

In [6]:
```
df.tail()
```

Out[6]:

	subject	topic_name	raw_text	word_count	summary_text	difficulty_level
70	ict	4. Networks and the effects of using them	Networks and the effects of using them \n• A ...	3787	A computer network is developed by linking co...	Hard
71	ict	5. The effects of using ICT	The Effects of Using ICT \nThe effects of ICT...	540	Robots have replaced human workers in many ar...	Medium
72	ict	6. ICT Applications	ICT Applications \nCommunication applications ...	6582	Paper based communication used to inform peop...	Medium
73	ict	7. Systems Analysis and Design	Systems Analysis and Design \n• It is a method...	2172	Systems Analysis and Design is a method used ...	Hard
74	ict	8.Safety and Security	Safety and Security \nPhysical Safety \nHealt...	1280	Health and safety regulations advise that all...	Hard

Content Based Filtering

In [9]:
```
import os
from typing import List, Dict
import numpy as np
import pandas as pd
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.metrics.pairwise import cosine_similarity, linear_kernel

class ContentRecommender:
    def __init__(self, processed_csv: str = "processed_notes.csv",
                 tfidf_kwargs: Dict = None):
        if not os.path.exists(processed_csv):
            raise FileNotFoundError(f"{processed_csv} not found")
        self.df = pd.read_csv(processed_csv)

        required = {"subject", "topic_name", "summary_text"}
        if not required.issubset(self.df.columns):
            raise ValueError(f"CSV must contain {required}")
```

```python
        self.tfidf_kwargs = tfidf_kwargs or dict(
            stop_words="english", max_df=0.95, min_df=1, ngram_range=(1,2)
        )

        self.models = {}
        for subject, sub in self.df.groupby("subject"):
            sub = sub.reset_index(drop=True).copy()
            tfidf = TfidfVectorizer(**self.tfidf_kwargs)
            X = tfidf.fit_transform(sub["summary_text"])
            sim = cosine_similarity(X, X)
            index_by_topic = pd.Series(sub.index, index=sub["topic_name"]).drop_duplicat
            self.models[subject] = dict(df=sub, tfidf=tfidf, X=X, sim=sim,
                                        index_by_topic=index_by_topic)

    def _m(self, subject: str):
        if subject not in self.models:
            raise ValueError(f"No data for subject '{subject}'")
        return self.models[subject]

    def find_topic(self, subject: str, pattern: str, top: int = 5) -> pd.DataFrame:
        m = self._m(subject)
        mask = m["df"]["topic_name"].str.contains(pattern, case=False, na=False)
        return m["df"][mask].head(top)[["topic_name"]]

    def recommend_like(self, subject: str, topic_name: str, k: int = 5) -> pd.DataFrame:
        m = self._m(subject)
        if topic_name not in m["index_by_topic"]:
            raise ValueError(f"Topic '{topic_name}' not found in {subject}.")
        idx = m["index_by_topic"][topic_name]
        sims = list(enumerate(m["sim"][idx]))
        sims = sorted(sims, key=lambda x: x[1], reverse=True)[1:k+1]
        out = m["df"].iloc[[i for i,_ in sims]].copy()
        out["similarity"] = [s for _, s in sims]
        cols = ["topic_name", "similarity"]
        if "difficulty_level" in out.columns: cols.append("difficulty_level")
        return out[cols]

    def recommend_query(self, subject: str, query: str, k: int = 5) -> pd.DataFrame:
        m = self._m(subject)
        q_vec = m["tfidf"].transform([query])
        sims = linear_kernel(q_vec, m["X"]).ravel()
        top = sims.argsort()[::-1][:k]
        out = m["df"].iloc[top].copy()
        out["similarity"] = sims[top]
        cols = ["topic_name", "similarity"]
        if "difficulty_level" in out.columns: cols.append("difficulty_level")
        return out[cols]

    def recommend_from_profile(self, subject: str, liked_topics: List[str], k: int = 5)
        m = self._m(subject)
        sub = m["df"]
        mask = sub["topic_name"].isin(liked_topics)
        idxs = np.where(mask.values)[0]
        if len(idxs) == 0:
            raise ValueError("None of the liked topics are in this subject.")
        # mean() returns a numpy.matrix; convert to 2D ndarray
        centroid = np.asarray(m["X"][idxs].mean(axis=0)).reshape(1, -1)
        sims = linear_kernel(centroid, m["X"]).ravel()
        # exclude liked topics
        candidates = ~mask.values
        cand_idx = np.where(candidates)[0]
        ranked = cand_idx[np.argsort(-sims[cand_idx])[:k]]
        out = sub.iloc[ranked].copy()
        out["similarity"] = sims[ranked]
```

```python
        cols = ["topic_name", "similarity"]
        if "difficulty_level" in out.columns: cols.append("difficulty_level")
        return out[cols]




if __name__ == "__main__":
    rec = ContentRecommender(processed_csv="processed_notes.csv")


    def show(title, df):
        print(f"\n=== {title} ===")
        try:
            print(df.to_string(index=False))
        except Exception:
            print(df)

    #Locate exact topic names
    show("Find Biology topics containing 'Respiration'", rec.find_topic("biology", "Resp
    show("Find Chemistry topics containing 'Speed of Reaction'", rec.find_topic("chemist
    show("Find Business topics containing 'Market Research'", rec.find_topic("business",
    show("Find ICT topics containing 'Applications'", rec.find_topic("ict", "Application

    # 1) Item to Item
    # biology: "Unit 12 Respiration"
    try:
        show("Biology: more like 'Unit 12 Respiration'",
             rec.recommend_like("biology", "Unit 12 Respiration", k=5))
    except Exception as e:
        print("Biology example error:", e)

    # chemistry: "Unit 8 Speed of Reaction"
    try:
        show("Chemistry: more like 'Unit 8 Speed of Reaction'",
             rec.recommend_like("chemistry", "Unit 8 Speed of Reaction", k=5))
    except Exception as e:
        print("Chemistry example error:", e)

    # business: "Chapter 11-Market Research"
    try:
        show("Business: more like 'Chapter 11-Market Research'",
             rec.recommend_like("business", "Chapter 11-Market Research", k=5))
    except Exception as e:
        print("Business example error:", e)

    # 2) Query to Items
    show("ICT: query → 'computer networks and topologies'",
          rec.recommend_query("ict", "computer networks and topologies", k=5))

    show("Chemistry: query → 'stoichiometry mole calculations'",
          rec.recommend_query("chemistry", "stoichiometry mole calculations", k=5))

    # 3) Profile  to Items
    bio_liked = ["Unit 5 Enzymes", "Unit 8 Plant Transport"]
    try:
        show(f"Biology: profile from liked topics {bio_liked}",
             rec.recommend_from_profile("biology", bio_liked, k=5))
    except Exception as e:
        print("Biology profile example error:", e)

    chem_liked = ["Unit 13 Metals and Reactivity", "Unit 14 Metal Extraction"]
    try:
        show(f"Chemistry: profile from liked topics {chem_liked}",
             rec.recommend_from_profile("chemistry", chem_liked, k=5))
```

```python
    except Exception as e:
        print("Chemistry profile example error:", e)
```

```
=== Find Biology topics containing 'Respiration' ===
         topic_name
Unit 12 Respiration

=== Find Chemistry topics containing 'Speed of Reaction' ===
              topic_name
Unit 8 Speed of Reaction

=== Find Business topics containing 'Market Research' ===
                topic_name
Chapter 11-Market Research

=== Find ICT topics containing 'Applications' ===
         topic_name
6. ICT Applications

=== Biology: more like 'Unit 12 Respiration' ===
                             topic_name  similarity difficulty_level
                 Unit 6 Plant Nutrition    0.056429             Hard
                         Unit 5 Enzymes    0.046207             Hard
Unit 19 Organisms and their environment    0.038062             Hard
    Unit 3 Movement in and out of cells    0.033983           Medium
                Unit 7 Animal Nutrition    0.031785             Hard

=== Chemistry: more like 'Unit 8 Speed of Reaction' ===
                   topic_name  similarity difficulty_level
    Unit 9 Chemical Reactions    0.187213             Hard
Unit 16 The Chemical Industry    0.094836           Medium
   Unit 12 The Periodic Table    0.047639           Medium
      Unit 7 Chemical Changes    0.046958           Medium
             Unit 19 Polymers    0.046695           Medium

=== Business: more like 'Chapter 11-Market Research' ===
                                 topic_name  similarity difficulty_level
              Chapter 14-The Marketing Mix    0.081381             Hard
             Chapter 13- The Marketing Mix    0.075236           Medium
              Chapter 12-The Marketing Mix    0.071678           Medium
      Chapter 2- Classification of Business    0.071258             Hard
Chapter 17-Production of Goods and Services    0.031832             Hard

=== ICT: query → 'computer networks and topologies' ===
                                 topic_name  similarity difficulty_level
  4. Networks and the effects of using them    0.089699             Hard
                        6. ICT Applications    0.059133           Medium
1. Types and Components of Computer Systems    0.058302             Hard
                      8.Safety and Security    0.055853             Hard
                2. Input and Output Devices    0.013644           Medium

=== Chemistry: query → 'stoichiometry mole calculations' ===
                          topic_name  similarity difficulty_level
           Unit 9 Chemical Reactions         0.0             Hard
            Unit 8 Speed of Reaction         0.0             Hard
             Unit 10 Acids and Bases         0.0           Medium
Unit 11 Making and identifying salts         0.0           Medium
          Unit 12 The Periodic Table         0.0           Medium

=== Biology: profile from liked topics ['Unit 5 Enzymes', 'Unit 8 Plant Transport'] ===
                                                   topic_name  similarity difficulty_lev
el
                          Unit 3 Movement in and out of cells    0.083940           Medi
um
Unit 1 Characteristics and Classification of Living Organisms    0.065948           Medi
um
```

```
                                         Unit 2 Cells    0.033076           Medi
um
                           Unit 19 Organisms and their environment    0.030573            Ha
rd
                                         Unit 15 Drugs    0.028465           Medi
um

=== Chemistry: profile from liked topics ['Unit 13 Metals and Reactivity', 'Unit 14 Meta
l Extraction'] ===
                                  topic_name  similarity difficulty_level
                        Unit 15 Air and Water    0.105418           Medium
                 Unit 6 Electrcity and Chemistry    0.079165             Hard
            Unit 11 Making and identifying salts    0.066035           Medium
                  Unit 3 Structure and Bonding    0.059454             Hard
Unit 17 Organic chemistry and petrochemicals    0.057497             Hard
```

In [10]:

```python
import os
from typing import List, Dict
import numpy as np
import pandas as pd
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.metrics.pairwise import cosine_similarity, linear_kernel


class ContentRecommender:
    def __init__(self, processed_csv: str = "processed_notes.csv",
                 tfidf_kwargs: Dict = None):
        if not os.path.exists(processed_csv):
            raise FileNotFoundError(f"{processed_csv} not found")
        self.df = pd.read_csv(processed_csv)

        required = {"subject", "topic_name", "summary_text"}
        if not required.issubset(self.df.columns):
            raise ValueError(f"CSV must contain {required}")

        # keep rare terms; add bigrams; scale tf; allow long docs
        self.tfidf_kwargs = tfidf_kwargs or dict(
            stop_words="english",
            max_df=0.95,
            min_df=1,
            ngram_range=(1, 2),
            sublinear_tf=True
        )

        self.models = {}
        for subject, sub in self.df.groupby("subject"):
            sub = sub.reset_index(drop=True).copy()

            #combine title and summary for stronger signals
            sub["text_for_tfidf"] = (
                sub["topic_name"].fillna("") + " " + sub["summary_text"].fillna("")
            )

            tfidf = TfidfVectorizer(**self.tfidf_kwargs)
            X = tfidf.fit_transform(sub["text_for_tfidf"])
            sim = cosine_similarity(X, X)
            index_by_topic = pd.Series(sub.index, index=sub["topic_name"]).drop_duplicat

            self.models[subject] = dict(
                df=sub, tfidf=tfidf, X=X, sim=sim, index_by_topic=index_by_topic
            )

    def _m(self, subject: str):
        if subject not in self.models:
            raise ValueError(f"No data for subject '{subject}'")
```

```python
        return self.models[subject]

    def find_topic(self, subject: str, pattern: str, top: int = 5) -> pd.DataFrame:
        """Case-insensitive partial match over topic_name."""
        m = self._m(subject)
        mask = m["df"]["topic_name"].str.contains(pattern, case=False, na=False)
        return m["df"][mask].head(top)[["topic_name"]]

    #Item to Item
    def recommend_like(self, subject: str, topic_name: str, k: int = 5) -> pd.DataFrame:
        m = self._m(subject)
        if topic_name not in m["index_by_topic"]:
            raise ValueError(
                f"Topic '{topic_name}' not found in {subject}. "
                f"Try rec.find_topic('{subject}', '<part of title>')."
            )
        idx = m["index_by_topic"][topic_name]
        sims = list(enumerate(m["sim"][idx]))
        sims = sorted(sims, key=lambda x: x[1], reverse=True)[1:k+1]
        out = m["df"].iloc[[i for i, _ in sims]].copy()
        out["similarity"] = [s for _, s in sims]
        cols = ["topic_name", "similarity"]
        if "difficulty_level" in out.columns:
            cols.append("difficulty_level")
        return out[cols]

    #Query to Item
    def recommend_query(self, subject: str, query: str, k: int = 5) -> pd.DataFrame:
        m = self._m(subject)
        q_vec = m["tfidf"].transform([query])
        sims = linear_kernel(q_vec, m["X"]).ravel()
        top = sims.argsort()[::-1][:k]
        out = m["df"].iloc[top].copy()
        out["similarity"] = sims[top]
        cols = ["topic_name", "similarity"]
        if "difficulty_level" in out.columns:
            cols.append("difficulty_level")
        return out[cols]

    #Liked Topics to Items
    def recommend_from_profile(self, subject: str, liked_topics: List[str], k: int = 5)
        m = self._m(subject)
        sub = m["df"]
        mask = sub["topic_name"].isin(liked_topics)
        idxs = np.where(mask.values)[0]
        if len(idxs) == 0:
            raise ValueError("None of the liked topics are in this subject.")
        # convert to ndarray row vector to avoid np.matrix issues
        centroid = np.asarray(m["X"][idxs].mean(axis=0)).reshape(1, -1)
        sims = linear_kernel(centroid, m["X"]).ravel()
        # exclude liked topics
        candidates = ~mask.values
        cand_idx = np.where(candidates)[0]
        ranked = cand_idx[np.argsort(-sims[cand_idx])[:k]]
        out = sub.iloc[ranked].copy()
        out["similarity"] = sims[ranked]
        cols = ["topic_name", "similarity"]
        if "difficulty_level" in out.columns:
            cols.append("difficulty_level")
        return out[cols]


#Verification
if __name__ == "__main__":
    rec = ContentRecommender(processed_csv="processed_notes.csv")
```

```
    def show(title, df):
        print(f"\n=== {title} ===")
        try:
            print(df.to_string(index=False))
        except Exception:
            print(df)

    #Helpers to confirm exact titles present
    show("Find Biology topics containing 'Respiration'", rec.find_topic("biology", "Resp
    show("Find Chemistry topics containing 'Speed of Reaction'", rec.find_topic("chemist
    show("Find Business topics containing 'Market Research'", rec.find_topic("business",
    show("Find ICT topics containing 'Applications'", rec.find_topic("ict", "Application

    #Item to Item
    try:
        show("Biology: more like 'Unit 12 Respiration'",
             rec.recommend_like("biology", "Unit 12 Respiration", k=5))
    except Exception as e:
        print("Biology example error:", e)

    try:
        show("Chemistry: more like 'Unit 8 Speed of Reaction'",
             rec.recommend_like("chemistry", "Unit 8 Speed of Reaction", k=5))
    except Exception as e:
        print("Chemistry example error:", e)

    try:
        show("Business: more like 'Chapter 11-Market Research'",
             rec.recommend_like("business", "Chapter 11-Market Research", k=5))
    except Exception as e:
        print("Business example error:", e)

    #Query to Items
    show("ICT: query → 'computer networks and topologies'",
         rec.recommend_query("ict", "computer networks topologies data transmission", k=

    chem_query = "stoichiometry mole calculations reacting masses molar mass empirical f
    show("Chemistry: query → 'stoichiometry ...'",
         rec.recommend_query("chemistry", chem_query, k=5))

    #Profile to Items
    bio_liked = ["Unit 5 Enzymes", "Unit 8 Plant Transport"]
    try:
        show(f"Biology: profile from liked topics {bio_liked}",
             rec.recommend_from_profile("biology", bio_liked, k=5))
    except Exception as e:
        print("Biology profile example error:", e)

    chem_liked = ["Unit 13 Metals and Reactivity", "Unit 14 Metal Extraction"]
    try:
        show(f"Chemistry: profile from liked topics {chem_liked}",
             rec.recommend_from_profile("chemistry", chem_liked, k=5))
    except Exception as e:
        print("Chemistry profile example error:", e)
```

```
=== Find Biology topics containing 'Respiration' ===
         topic_name
Unit 12 Respiration

=== Find Chemistry topics containing 'Speed of Reaction' ===
              topic_name
Unit 8 Speed of Reaction

=== Find Business topics containing 'Market Research' ===
                topic_name
Chapter 11-Market Research
```

```
=== Find ICT topics containing 'Applications' ===
         topic_name
6. ICT Applications

=== Biology: more like 'Unit 12 Respiration' ===
                             topic_name  similarity difficulty_level
                 Unit 6 Plant Nutrition    0.056465             Hard
                         Unit 5 Enzymes    0.037409             Hard
    Unit 3 Movement in and out of cells    0.035064           Medium
                           Unit 2 Cells    0.024262           Medium
Unit 19 Organisms and their environment    0.023323             Hard

=== Chemistry: more like 'Unit 8 Speed of Reaction' ===
                       topic_name  similarity difficulty_level
        Unit 9 Chemical Reactions    0.120159             Hard
Unit 1 Particles and Purification    0.057249             Hard
    Unit 16 The Chemical Industry    0.054509           Medium
          Unit 7 Chemical Changes    0.049372           Medium
       Unit 12 The Periodic Table    0.038646           Medium

=== Business: more like 'Chapter 11-Market Research' ===
                                         topic_name  similarity difficulty_level
                          Chapter 14-The Marketing Mix    0.088040             Hard
                 Chapter 2- Classification of Business    0.069118             Hard
                         Chapter 13- The Marketing Mix    0.055396           Medium
                          Chapter 12-The Marketing Mix    0.038188           Medium
Chapter 26-Government economic objectives and policies    0.034162           Medium

=== ICT: query → 'computer networks and topologies' ===
                                 topic_name  similarity difficulty_level
  4. Networks and the effects of using them    0.117060             Hard
1. Types and Components of Computer Systems    0.057340             Hard
                        6. ICT Applications    0.046885           Medium
                      8.Safety and Security    0.043486             Hard
               2. Input and Output Devices    0.035215           Medium

=== Chemistry: query → 'stoichiometry ...' ===
                           topic_name  similarity difficulty_level
   Unit 1 Particles and Purification    0.088777             Hard
            Unit 8 Speed of Reaction    0.079808             Hard
             Unit 10 Acids and Bases    0.000000           Medium
Unit 11 Making and identifying salts    0.000000           Medium
          Unit 12 The Periodic Table    0.000000           Medium

=== Biology: profile from liked topics ['Unit 5 Enzymes', 'Unit 8 Plant Transport'] ===
                                                   topic_name  similarity difficulty_lev
el
                          Unit 3 Movement in and out of cells    0.072408           Medi
um
Unit 1 Characteristics and Classification of Living Organisms    0.058643           Medi
um
                                                 Unit 2 Cells    0.032526           Medi
um
                                       Unit 6 Plant Nutrition    0.029948             Ha
rd
                      Unit 19 Organisms and their environment    0.029076             Ha
rd

=== Chemistry: profile from liked topics ['Unit 13 Metals and Reactivity', 'Unit 14 Meta
l Extraction'] ===
                              topic_name  similarity difficulty_level
                   Unit 15 Air and Water    0.072337           Medium
         Unit 6 Electrcity and Chemistry    0.069945             Hard
    Unit 11 Making and identifying salts    0.053230           Medium
```

```
                Unit 3 Structure and Bonding    0.046227             Hard
Unit 17 Organic chemistry and petrochemicals    0.040450             Hard
```

Collaborative Filtering

In [11]:
```
import os
import numpy as np
import pandas as pd
from typing import Optional
from sklearn.metrics.pairwise import cosine_similarity

#load in synthetic data
if not os.path.exists("processed_notes.csv"):
    raise FileNotFoundError("processed_notes.csv not found.")

topics = pd.read_csv("processed_notes.csv")
req = {"subject", "topic_name"}
if not req.issubset(topics.columns):
    raise ValueError(f"processed_notes.csv must contain {req}")

#Clean duplicates
topics = topics.dropna(subset=["subject", "topic_name"]).drop_duplicates(subset=["subjec

#Synthetic interactions generator
rng = np.random.default_rng(7)

subjects = topics["subject"].unique().tolist()


N_USERS = 60

rows = []
for user in range(1, N_USERS + 1):
    #Each user has a primary subject bias
    main_subj = rng.choice(subjects)
    # number of interactions this user makes
    n_interactions = rng.integers(8, 16)   # 8-15 interactions

    #choose subjects with a higher prob on the main subject
    subj_choices = rng.choice(
        subjects,
        size=n_interactions,
        p=[0.55 if s == main_subj else (0.45/(len(subjects)-1)) for s in subjects]
    )

    for subj in subj_choices:
        pool = topics[topics["subject"] == subj]["topic_name"].values
        if len(pool) == 0:
            continue
        topic = rng.choice(pool)

        #rating pattern: biased a bit higher for the main subject
        base = 0.6 if subj == main_subj else 0.4
        # skew ratings to 3-5 range mostly
        prob_1 = 0.02 * (1-base)
        prob_2 = 0.08 * (1-base)
        prob_3 = 0.30 + 0.10*base
        prob_4 = 0.35 + 0.15*base
        prob_5 = 1.0 - (prob_1 + prob_2 + prob_3 + prob_4)
        rating = rng.choice([1,2,3,4,5], p=[prob_1, prob_2, prob_3, prob_4, prob_5])

        rows.append((user, subj, topic, int(rating)))
```

```
interactions = pd.DataFrame(rows, columns=["user_id", "subject", "topic_name", "rating"]
interactions.to_csv(r"C:\Users\Rizwana\Desktop\studyoclock project\Sample_Interactions_D
print(f"Saved interactions.csv with {len(interactions)} rows and {interactions['user_id'


#Collaborative Filtering helpers (User-User and Item-Item)

def _pivot_by_subject(interactions_df: pd.DataFrame, subject: str) -> pd.DataFrame:
    """User-Item matrix for a single subject."""
    sub = interactions_df[interactions_df["subject"] == subject].copy()
    if sub.empty:
        raise ValueError(f"No interactions for subject='{subject}'")
    pivot = sub.pivot_table(index="user_id", columns="topic_name", values="rating")
    return pivot

def user_user_recommend(
    interactions_df: pd.DataFrame,
    subject: str,
    user_id: int,
    top_n: int = 5
) -> pd.DataFrame:
    """
    Recommend topics for user_id in a subject using User-User CF.
    Cosine similarity over users; aggregate neighbors' ratings.
    Returns: DataFrame[topic_name, score]
    """
    pivot = _pivot_by_subject(interactions_df, subject)
    if user_id not in pivot.index:
        raise ValueError(f"user_id {user_id} has no interactions in subject '{subject}'"

    #similarities between users
    sim = cosine_similarity(pivot.fillna(0))
    sim_df = pd.DataFrame(sim, index=pivot.index, columns=pivot.index)

    #candidate topics = not rated by user yet
    user_rated = set(interactions_df[(interactions_df["user_id"] == user_id) &
                                     (interactions_df["subject"] == subject)]["topic_nam
    rec_scores = {}

    #weight neighbors' ratings by similarity
    neighbors = sim_df[user_id].sort_values(ascending=False).drop(user_id)
    for other_id, s in neighbors.items():
        other_row = pivot.loc[other_id]
        for topic, r in other_row.dropna().items():
            if topic in user_rated:
                continue
            rec_scores[topic] = rec_scores.get(topic, 0.0) + s * r

    if not rec_scores:
        return pd.DataFrame(columns=["topic_name","score"])

    ranked = sorted(rec_scores.items(), key=lambda x: x[1], reverse=True)[:top_n]
    return pd.DataFrame(ranked, columns=["topic_name","score"])


def item_item_recommend(
    interactions_df: pd.DataFrame,
    subject: str,
    topic_name: str,
    top_n: int = 5
) -> pd.DataFrame:
    """
    Recommend similar topics (Item-Item CF) inside a subject using cosine
    similarity of item rating vectors.
    Returns: DataFrame[topic_name, similarity]
    """
```

```
    pivot = _pivot_by_subject(interactions_df, subject)
    if topic_name not in pivot.columns:
        raise ValueError(f"Topic '{topic_name}' has no ratings in subject '{subject}'")

    sim = cosine_similarity(pivot.T.fillna(0))
    sim_df = pd.DataFrame(sim, index=pivot.columns, columns=pivot.columns)

    sims = sim_df[topic_name].sort_values(ascending=False).drop(topic_name).head(top_n)
    return pd.DataFrame({"topic_name": sims.index, "similarity": sims.values})

#biology and chemistry example for verification

print("\n--- Example: User-User CF (biology) ---")
try:
    u_example = interactions[interactions["subject"]=="biology"]["user_id"].iloc[0]
    print("user_id:", u_example)
    print(user_user_recommend(interactions, "biology", user_id=u_example, top_n=5))
except Exception as e:
    print("User-User example error:", e)

print("\n--- Example: Item-Item CF (chemistry) ---")
try:
    # pick a chemistry topic that appears in interactions
    chem_topic = interactions[interactions["subject"]=="chemistry"]["topic_name"].iloc[0
    print("topic:", chem_topic)
    print(item_item_recommend(interactions, "chemistry", topic_name=chem_topic, top_n=5)
except Exception as e:
    print("Item-Item example error:", e)
```

```
Saved interactions.csv with 648 rows and 60 users.

--- Example: User-User CF (biology) ---
user_id: 1
                               topic_name     score
0         Unit 18 Variation and selection  8.365624
1                     Unit 12 Respiration  7.030872
2  Unit 21 Human Influences on Ecosystems  4.468643
3                          Unit 5 Enzymes  3.555991
4                     Unit 17 Inheritance  2.451482

--- Example: Item-Item CF (chemistry) ---
topic: Unit 6 Electrcity and Chemistry
                                     topic_name  similarity
0      Unit 18 The Variety of Organic Chemicals    0.341972
1  Unit 17 Organic chemistry and petrochemicals    0.222744
2              Unit 1 Particles and Purification    0.216192
3                  Unit 16 The Chemical Industry    0.197579
4                  Unit 13 Metals and Reactivity    0.165256
```

Traing the BiLSTM

Training each subject individually

In [2]:
```
#biology

import os, pickle, random
from typing import List, Tuple, Dict
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split

import torch
import torch.nn as nn
```

```
from torch.utils.data import Dataset, DataLoader

#configuration
SEED = 42
random.seed(SEED); np.random.seed(SEED); torch.manual_seed(SEED)

CSV_PATH     = r"C:\Users\Rizwana\Desktop\studyoclock project\Sample_Interactions_Data.c
SUBJECT      = "biology"
MODELS_DIR   = "models"
DEVICE       = "cpu"

MIN_SEQ_LEN  = 4
MAX_HIST_LEN = 50
BATCH_SIZE   = 64
EPOCHS       = 8
LR           = 1e-3
TOPK         = 5

#utilities
def load_interactions(path: str) -> pd.DataFrame:
    if not os.path.exists(path): raise FileNotFoundError(path)
    df = pd.read_csv(path)
    need = {"user_id","subject","topic_name","rating"}
    if not need.issubset(df.columns): raise ValueError(f"{path} must contain {need}")
    if "timestamp" not in df.columns:
        df = df.copy()
        df["timestamp"] = df.groupby(["user_id","subject"]).cumcount()
    return df

def build_vocab_sequences(df_subj: pd.DataFrame) -> Tuple[Dict[str,int], Dict[int,str],
    df_subj = df_subj.sort_values(["user_id","timestamp"])
    topics = df_subj["topic_name"].unique().tolist()
    topic2id = {t:i+1 for i,t in enumerate(topics)}  # 0=PAD
    id2topic = {i:t for t,i in topic2id.items()}
    sequences = []
    for uid, g in df_subj.groupby("user_id"):
        seq = [topic2id[t] for t in g["topic_name"].tolist()]
        if len(seq) >= MIN_SEQ_LEN:
            sequences.append((uid, seq))
    return topic2id, id2topic, sequences

def make_next_pairs(sequences: List[Tuple[int,List[int]]]):
    X, y = [], []
    for _, seq in sequences:
        for t in range(1, len(seq)):
            hist = seq[max(0, t - MAX_HIST_LEN):t]
            if hist:
                X.append(hist); y.append(seq[t])
    return X, y

def pad_batch(seqs: List[List[int]], pad_id=0):
    L = max(len(s) for s in seqs)
    arr = np.zeros((len(seqs), L), dtype=np.int64)
    lens = np.array([len(s) for s in seqs], dtype=np.int64)
    for i,s in enumerate(seqs): arr[i,:len(s)] = s
    x = torch.tensor(arr); lengths = torch.tensor(lens)
    mask = (x != pad_id).float()
    return x, lengths, mask

class NextDataset(Dataset):
    def __init__(self, X, y): self.X, self.y = X, y
    def __len__(self): return len(self.X)
    def __getitem__(self, i): return self.X[i], self.y[i]

def collate_fn(batch, pad_id=0):
    seqs, targets = zip(*batch)
```

```
    x, lengths, mask = pad_batch(seqs, pad_id)
    y = torch.tensor(targets, dtype=torch.long)
    return x, lengths, mask, y

#model building
class AdditiveAttention(nn.Module):
    def __init__(self, hidden_dim):
        super().__init__()
        self.W = nn.Linear(hidden_dim, hidden_dim)
        self.v = nn.Linear(hidden_dim, 1, bias=False)
    def forward(self, H, mask):
        scores = self.v(torch.tanh(self.W(H))).squeeze(-1)    # (B,T)
        scores = scores.masked_fill(mask == 0, -1e9)
        alpha  = torch.softmax(scores, dim=-1)                # (B,T)
        ctx    = torch.bmm(alpha.unsqueeze(1), H).squeeze(1) # (B,H)
        return ctx, alpha

class BiLSTMAttnRec(nn.Module):
    def __init__(self, num_items, emb_dim=64, hidden_dim=128, pad_id=0):
        super().__init__()
        self.emb  = nn.Embedding(num_items+1, emb_dim, padding_idx=pad_id)
        self.lstm = nn.LSTM(emb_dim, hidden_dim//2, batch_first=True, bidirectional=True
        self.attn = AdditiveAttention(hidden_dim)
        self.drop = nn.Dropout(0.2)
        self.out  = nn.Linear(hidden_dim, num_items+1)
    def forward(self, x, lengths, mask):
        E = self.emb(x)               # (B,T,E)
        H, _ = self.lstm(E)           # (B,T,H)
        ctx, _ = self.attn(H, mask)   # (B,H)
        z = self.drop(ctx)
        logits = self.out(z)          # (B,V)
        return logits

#train and save
def train_biology():
    df = load_interactions(CSV_PATH)
    bio = df[df["subject"] == SUBJECT].copy()
    if bio.empty: raise ValueError("No biology rows in interactions.csv")
    if bio["user_id"].nunique() < 5:
        print("[biology] Few users detected; training anyway.")

    topic2id, id2topic, sequences = build_vocab_sequences(bio)
    if not sequences:
        raise ValueError("No biology sequences with length ≥ MIN_SEQ_LEN")

    X, y = make_next_pairs(sequences)
    Xtr, Xva, ytr, yva = train_test_split(X, y, test_size=0.2, random_state=SEED, shuffl
    train_loader = DataLoader(NextDataset(Xtr, ytr), batch_size=BATCH_SIZE, shuffle=True
    val_loader   = DataLoader(NextDataset(Xva, yva), batch_size=BATCH_SIZE, shuffle=Fals

    model  = BiLSTMAttnRec(num_items=len(topic2id)).to(DEVICE)
    crit   = nn.CrossEntropyLoss(ignore_index=0)
    opt    = torch.optim.AdamW(model.parameters(), lr=LR)

    for ep in range(1, EPOCHS+1):
        model.train(); tloss=0
        for x,l,m,yb in train_loader:
            x,l,m,yb = x.to(DEVICE), l.to(DEVICE), m.to(DEVICE), yb.to(DEVICE)
            logits = model(x,l,m)
            loss = crit(logits, yb)
            opt.zero_grad(); loss.backward()
            nn.utils.clip_grad_norm_(model.parameters(), 1.0)
            opt.step()
            tloss += loss.item()*x.size(0)

        #         model.eval(); vloss=0
```

```
        with torch.no_grad():
            for x,l,m,yb in val_loader:
                x,l,m,yb = x.to(DEVICE), l.to(DEVICE), m.to(DEVICE), yb.to(DEVICE)
                vloss += crit(model(x,l,m), yb).item()*x.size(0)
        print(f"[biology] Epoch {ep:02d}  train_loss={tloss/len(Xtr):.4f}  val_loss={vlo

    os.makedirs(MODELS_DIR, exist_ok=True)
    torch.save(model.state_dict(), os.path.join(MODELS_DIR, "bilstm_biology.pt"))
    with open(os.path.join(MODELS_DIR, "topic2id_biology.pkl"), "wb") as f: pickle.dump(
    with open(os.path.join(MODELS_DIR, "id2topic_biology.pkl"), "wb") as f: pickle.dump(
    print("[biology] Saved model + vocab to models/")


    example_hist = list(topic2id.keys())[:3]
    recs = recommend_next("biology", example_hist, already_seen=example_hist, top_n=TOPK
    print("\nDemo history:", example_hist)
    print("Top-N next topics:", recs)

#Inference
def load_biology_model():
    t2i_p = os.path.join(MODELS_DIR, "topic2id_biology.pkl")
    i2t_p = os.path.join(MODELS_DIR, "id2topic_biology.pkl")
    m_p   = os.path.join(MODELS_DIR, "bilstm_biology.pt")
    if not (os.path.exists(t2i_p) and os.path.exists(i2t_p) and os.path.exists(m_p)):
        raise FileNotFoundError("Train biology first to create model + mappings in model
    with open(t2i_p, "rb") as f: topic2id = pickle.load(f)
    with open(i2t_p, "rb") as f: id2topic = pickle.load(f)
    model = BiLSTMAttnRec(num_items=len(topic2id)).to(DEVICE)
    model.load_state_dict(torch.load(m_p, map_location=DEVICE))
    model.eval()
    return model, topic2id, id2topic

def recommend_next(subject: str, history_topics: List[str], already_seen: List[str] = No
    assert subject == "biology", "This script is biology-only."
    model, topic2id, id2topic = load_biology_model()
    ids = [topic2id[t] for t in history_topics if t in topic2id]
    if not ids: return []
    x = torch.tensor([ids], dtype=torch.long).to(DEVICE)
    lengths = torch.tensor([len(ids)], dtype=torch.long).to(DEVICE)
    mask = (x != 0).float()
    with torch.no_grad():
        logits = model(x, lengths, mask)
        probs = torch.softmax(logits, dim=-1).squeeze(0).cpu().numpy()
    seen = set(already_seen or [])
    cands = [(tid,p) for tid,p in enumerate(probs) if tid!=0 and id2topic.get(tid) not i
    cands.sort(key=lambda x: x[1], reverse=True)
    return [(id2topic[tid], float(p)) for tid,p in cands[:top_n]]


if __name__ == "__main__":
    train_biology()
```

```
[biology] Epoch 01  train_loss=3.0865  val_loss=3.0691
[biology] Epoch 02  train_loss=3.0623  val_loss=3.0731
[biology] Epoch 03  train_loss=3.0476  val_loss=3.0756
[biology] Epoch 04  train_loss=3.0311  val_loss=3.0777
[biology] Epoch 05  train_loss=3.0125  val_loss=3.0791
[biology] Epoch 06  train_loss=2.9944  val_loss=3.0786
[biology] Epoch 07  train_loss=2.9861  val_loss=3.0767
[biology] Epoch 08  train_loss=2.9712  val_loss=3.0756
[biology] Saved model + vocab to models/

Demo history: ['Unit 13 Excretion', 'Unit 3 Movement in and out of cells', 'Unit 21 Huma
n Influences on Ecosystems']
Top-N next topics: [('Unit 18 Variation and selection', 0.0549352653324604), ('Unit 12 R
espiration', 0.050515495240688324), ('Unit 6 Plant Nutrition', 0.05047224089503288), ('U
```

nit 10 Diseases and Immunity', 0.05010153353214264), ('Unit 8 Plant Transport', 0.047745
74562907219)]

In [4]:

```
#chemistry

import os, pickle, random
from typing import List, Tuple, Dict
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split

import torch
import torch.nn as nn
from torch.utils.data import Dataset, DataLoader

#configuration
SEED = 42
random.seed(SEED); np.random.seed(SEED); torch.manual_seed(SEED)

CSV_PATH     = r"C:\Users\Rizwana\Desktop\studyoclock project\Sample_Interactions_Data.c
SUBJECT      = "chemistry"
MODELS_DIR   = "models"
DEVICE       = "cpu"

MIN_SEQ_LEN  = 4
MAX_HIST_LEN = 50
BATCH_SIZE   = 64
EPOCHS       = 8
LR           = 1e-3
TOPK         = 5

#utilities
def load_interactions(path: str) -> pd.DataFrame:
    if not os.path.exists(path): raise FileNotFoundError(path)
    df = pd.read_csv(path)
    need = {"user_id","subject","topic_name","rating"}
    if not need.issubset(df.columns): raise ValueError(f"{path} must contain {need}")
    if "timestamp" not in df.columns:
        df = df.copy()
        df["timestamp"] = df.groupby(["user_id","subject"]).cumcount()
    return df

def build_vocab_sequences(df_subj: pd.DataFrame) -> Tuple[Dict[str,int], Dict[int,str],
    df_subj = df_subj.sort_values(["user_id","timestamp"])
    topics = df_subj["topic_name"].unique().tolist()
    topic2id = {t:i+1 for i,t in enumerate(topics)}  # 0=PAD
    id2topic = {i:t for t,i in topic2id.items()}
    sequences = []
    for uid, g in df_subj.groupby("user_id"):
        seq = [topic2id[t] for t in g["topic_name"].tolist()]
        if len(seq) >= MIN_SEQ_LEN:
            sequences.append((uid, seq))
    return topic2id, id2topic, sequences

def make_next_pairs(sequences: List[Tuple[int,List[int]]]):
    X, y = [], []
    for _, seq in sequences:
        for t in range(1, len(seq)):
            hist = seq[max(0, t - MAX_HIST_LEN):t]
            if hist:
                X.append(hist); y.append(seq[t])
    return X, y

def pad_batch(seqs: List[List[int]], pad_id=0):
    L = max(len(s) for s in seqs)
```

```
    arr = np.zeros((len(seqs), L), dtype=np.int64)
    lens = np.array([len(s) for s in seqs], dtype=np.int64)
    for i,s in enumerate(seqs): arr[i,:len(s)] = s
    x = torch.tensor(arr); lengths = torch.tensor(lens)
    mask = (x != pad_id).float()
    return x, lengths, mask

class NextDataset(Dataset):
    def __init__(self, X, y): self.X, self.y = X, y
    def __len__(self): return len(self.X)
    def __getitem__(self, i): return self.X[i], self.y[i]

def collate_fn(batch, pad_id=0):
    seqs, targets = zip(*batch)
    x, lengths, mask = pad_batch(seqs, pad_id)
    y = torch.tensor(targets, dtype=torch.long)
    return x, lengths, mask, y

#model building
class AdditiveAttention(nn.Module):
    def __init__(self, hidden_dim):
        super().__init__()
        self.W = nn.Linear(hidden_dim, hidden_dim)
        self.v = nn.Linear(hidden_dim, 1, bias=False)
    def forward(self, H, mask):
        scores = self.v(torch.tanh(self.W(H))).squeeze(-1)    # (B,T)
        scores = scores.masked_fill(mask == 0, -1e9)
        alpha  = torch.softmax(scores, dim=-1)                # (B,T)
        ctx    = torch.bmm(alpha.unsqueeze(1), H).squeeze(1) # (B,H)
        return ctx, alpha

class BiLSTMAttnRec(nn.Module):
    def __init__(self, num_items, emb_dim=64, hidden_dim=128, pad_id=0):
        super().__init__()
        self.emb  = nn.Embedding(num_items+1, emb_dim, padding_idx=pad_id)
        self.lstm = nn.LSTM(emb_dim, hidden_dim//2, batch_first=True, bidirectional=True
        self.attn = AdditiveAttention(hidden_dim)
        self.drop = nn.Dropout(0.2)
        self.out  = nn.Linear(hidden_dim, num_items+1)
    def forward(self, x, lengths, mask):
        E = self.emb(x)                 # (B,T,E)
        H, _ = self.lstm(E)             # (B,T,H)
        ctx, _ = self.attn(H, mask)     # (B,H)
        z = self.drop(ctx)
        logits = self.out(z)           # (B,V)
        return logits

#train and save
def train_chemistry():
    df = load_interactions(CSV_PATH)
    chem = df[df["subject"] == SUBJECT].copy()
    if chem.empty: raise ValueError("No chemistry rows in interactions.csv")
    if chem["user_id"].nunique() < 5:
        print("[chemistry] Few users detected; training anyway.")

    topic2id, id2topic, sequences = build_vocab_sequences(chem)
    if not sequences:
        raise ValueError("No chemistry sequences with length ≥ MIN_SEQ_LEN")

    X, y = make_next_pairs(sequences)
    Xtr, Xva, ytr, yva = train_test_split(X, y, test_size=0.2, random_state=SEED, shuffl
    train_loader = DataLoader(NextDataset(Xtr, ytr), batch_size=BATCH_SIZE, shuffle=True
    val_loader   = DataLoader(NextDataset(Xva, yva), batch_size=BATCH_SIZE, shuffle=Fals

    model = BiLSTMAttnRec(num_items=len(topic2id)).to(DEVICE)
    crit  = nn.CrossEntropyLoss(ignore_index=0)
```

```
    opt   = torch.optim.AdamW(model.parameters(), lr=LR)

    for ep in range(1, EPOCHS+1):
        model.train(); tloss=0
        for x,l,m,yb in train_loader:
            x,l,m,yb = x.to(DEVICE), l.to(DEVICE), m.to(DEVICE), yb.to(DEVICE)
            logits = model(x,l,m)
            loss = crit(logits, yb)
            opt.zero_grad(); loss.backward()
            nn.utils.clip_grad_norm_(model.parameters(), 1.0)
            opt.step()
            tloss += loss.item()*x.size(0)


        model.eval(); vloss=0
        with torch.no_grad():
            for x,l,m,yb in val_loader:
                x,l,m,yb = x.to(DEVICE), l.to(DEVICE), m.to(DEVICE), yb.to(DEVICE)
                vloss += crit(model(x,l,m), yb).item()*x.size(0)
        print(f"[chemistry] Epoch {ep:02d}  train_loss={tloss/len(Xtr):.4f}  val_loss={v

    os.makedirs(MODELS_DIR, exist_ok=True)
    torch.save(model.state_dict(), os.path.join(MODELS_DIR, "bilstm_chemistry.pt"))
    with open(os.path.join(MODELS_DIR, "topic2id_chemistry.pkl"), "wb") as f: pickle.dum
    with open(os.path.join(MODELS_DIR, "id2topic_chemistry.pkl"), "wb") as f: pickle.dum
    print("[chemistry] Saved model + vocab to models/")

    # demo: ranked list for a short history
    example_hist = list(topic2id.keys())[:3]
    recs = recommend_next("chemistry", example_hist, already_seen=example_hist, top_n=TO
    print("\nDemo history:", example_hist)
    print("Top-N next topics:", recs)

#Inference
def load_chemistry_model():
    t2i_p = os.path.join(MODELS_DIR, "topic2id_chemistry.pkl")
    i2t_p = os.path.join(MODELS_DIR, "id2topic_chemistry.pkl")
    m_p   = os.path.join(MODELS_DIR, "bilstm_chemistry.pt")
    if not (os.path.exists(t2i_p) and os.path.exists(i2t_p) and os.path.exists(m_p)):
        raise FileNotFoundError("Train chemistry first to create model + mappings in mod
    with open(t2i_p, "rb") as f: topic2id = pickle.load(f)
    with open(i2t_p, "rb") as f: id2topic = pickle.load(f)
    model = BiLSTMAttnRec(num_items=len(topic2id)).to(DEVICE)
    model.load_state_dict(torch.load(m_p, map_location=DEVICE))
    model.eval()
    return model, topic2id, id2topic

def recommend_next(subject: str, history_topics: List[str], already_seen: List[str] = No
    assert subject == "chemistry", "This script is chemistry-only."
    model, topic2id, id2topic = load_chemistry_model()
    ids = [topic2id[t] for t in history_topics if t in topic2id]
    if not ids: return []
    x = torch.tensor([ids], dtype=torch.long).to(DEVICE)
    lengths = torch.tensor([len(ids)], dtype=torch.long).to(DEVICE)
    mask = (x != 0).float()
    with torch.no_grad():
        logits = model(x, lengths, mask)
        probs = torch.softmax(logits, dim=-1).squeeze(0).cpu().numpy()
    seen = set(already_seen or [])
    cands = [(tid,p) for tid,p in enumerate(probs) if tid!=0 and id2topic.get(tid) not i
    cands.sort(key=lambda x: x[1], reverse=True)
    return [(id2topic[tid], float(p)) for tid,p in cands[:top_n]]


if __name__ == "__main__":
    train_chemistry()
```

```
[chemistry] Epoch 01  train_loss=2.9427  val_loss=2.9507
[chemistry] Epoch 02  train_loss=2.9181  val_loss=2.9569
[chemistry] Epoch 03  train_loss=2.9006  val_loss=2.9634
[chemistry] Epoch 04  train_loss=2.8904  val_loss=2.9700
[chemistry] Epoch 05  train_loss=2.8596  val_loss=2.9767
[chemistry] Epoch 06  train_loss=2.8368  val_loss=2.9838
[chemistry] Epoch 07  train_loss=2.8109  val_loss=2.9911
[chemistry] Epoch 08  train_loss=2.8015  val_loss=2.9987
[chemistry] Saved model + vocab to models/

Demo history: ['Unit 6 Electrcity and Chemistry', 'Unit 16 The Chemical Industry', 'Unit
18 The Variety of Organic Chemicals']
Top-N next topics: [('Unit 15 Air and Water', 0.06551077961921692), ('Unit 12 The Period
ic Table', 0.06037665903568268), ('Unit 3 Structure and Bonding', 0.0581340491771698),
('Unit 14 Metal Extraction', 0.05558158829808235), ('Unit 9 Chemical Reactions', 0.05486
50324344635)]
```

In [5]:

```
#business studies
import os, pickle, random
from typing import List, Tuple, Dict
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split

import torch
import torch.nn as nn
from torch.utils.data import Dataset, DataLoader

#configurations
SEED = 42
random.seed(SEED); np.random.seed(SEED); torch.manual_seed(SEED)

CSV_PATH     = r"C:\Users\Rizwana\Desktop\studyoclock project\Sample_Interactions_Data.c
SUBJECT      = "business"
MODELS_DIR   = "models"
DEVICE       = "cpu"

MIN_SEQ_LEN  = 4
MAX_HIST_LEN = 50
BATCH_SIZE   = 64
EPOCHS       = 8
LR           = 1e-3
TOPK         = 5

#utilities
def load_interactions(path: str) -> pd.DataFrame:
    if not os.path.exists(path): raise FileNotFoundError(path)
    df = pd.read_csv(path)
    need = {"user_id","subject","topic_name","rating"}
    if not need.issubset(df.columns): raise ValueError(f"{path} must contain {need}")
    if "timestamp" not in df.columns:
        df = df.copy()
        df["timestamp"] = df.groupby(["user_id","subject"]).cumcount()
    return df

def build_vocab_sequences(df_subj: pd.DataFrame) -> Tuple[Dict[str,int], Dict[int,str],
    df_subj = df_subj.sort_values(["user_id","timestamp"])
    topics = df_subj["topic_name"].unique().tolist()
    topic2id = {t:i+1 for i,t in enumerate(topics)}   # 0=PAD
    id2topic = {i:t for t,i in topic2id.items()}
    sequences = []
    for uid, g in df_subj.groupby("user_id"):
        seq = [topic2id[t] for t in g["topic_name"].tolist()]
        if len(seq) >= MIN_SEQ_LEN:
            sequences.append((uid, seq))
```

```python
    return topic2id, id2topic, sequences

def make_next_pairs(sequences: List[Tuple[int,List[int]]]):
    X, y = [], []
    for _, seq in sequences:
        for t in range(1, len(seq)):
            hist = seq[max(0, t - MAX_HIST_LEN):t]
            if hist:
                X.append(hist); y.append(seq[t])
    return X, y

def pad_batch(seqs: List[List[int]], pad_id=0):
    L = max(len(s) for s in seqs)
    arr = np.zeros((len(seqs), L), dtype=np.int64)
    lens = np.array([len(s) for s in seqs], dtype=np.int64)
    for i,s in enumerate(seqs): arr[i,:len(s)] = s
    x = torch.tensor(arr); lengths = torch.tensor(lens)
    mask = (x != pad_id).float()
    return x, lengths, mask

class NextDataset(Dataset):
    def __init__(self, X, y): self.X, self.y = X, y
    def __len__(self): return len(self.X)
    def __getitem__(self, i): return self.X[i], self.y[i]

def collate_fn(batch, pad_id=0):
    seqs, targets = zip(*batch)
    x, lengths, mask = pad_batch(seqs, pad_id)
    y = torch.tensor(targets, dtype=torch.long)
    return x, lengths, mask, y

#model building
class AdditiveAttention(nn.Module):
    def __init__(self, hidden_dim):
        super().__init__()
        self.W = nn.Linear(hidden_dim, hidden_dim)
        self.v = nn.Linear(hidden_dim, 1, bias=False)
    def forward(self, H, mask):
        scores = self.v(torch.tanh(self.W(H))).squeeze(-1)    # (B,T)
        scores = scores.masked_fill(mask == 0, -1e9)
        alpha  = torch.softmax(scores, dim=-1)                # (B,T)
        ctx    = torch.bmm(alpha.unsqueeze(1), H).squeeze(1)  # (B,H)
        return ctx, alpha

class BiLSTMAttnRec(nn.Module):
    def __init__(self, num_items, emb_dim=64, hidden_dim=128, pad_id=0):
        super().__init__()
        self.emb  = nn.Embedding(num_items+1, emb_dim, padding_idx=pad_id)
        self.lstm = nn.LSTM(emb_dim, hidden_dim//2, batch_first=True, bidirectional=True
        self.attn = AdditiveAttention(hidden_dim)
        self.drop = nn.Dropout(0.2)
        self.out  = nn.Linear(hidden_dim, num_items+1)
    def forward(self, x, lengths, mask):
        E = self.emb(x)                 # (B,T,E)
        H, _ = self.lstm(E)             # (B,T,H)
        ctx, _ = self.attn(H, mask)     # (B,H)
        z = self.drop(ctx)
        logits = self.out(z)            # (B,V)
        return logits

#train and save
def train_business():
    df = load_interactions(CSV_PATH)
    bus = df[df["subject"] == SUBJECT].copy()
    if bus.empty: raise ValueError("No business rows in interactions.csv")
    if bus["user_id"].nunique() < 5:
```

```python
        print("[business] Few users detected; training anyway.")

    topic2id, id2topic, sequences = build_vocab_sequences(bus)
    if not sequences:
        raise ValueError("No business sequences with length ≥ MIN_SEQ_LEN")

    X, y = make_next_pairs(sequences)
    Xtr, Xva, ytr, yva = train_test_split(X, y, test_size=0.2, random_state=SEED, shuffl
    train_loader = DataLoader(NextDataset(Xtr, ytr), batch_size=BATCH_SIZE, shuffle=True
    val_loader   = DataLoader(NextDataset(Xva, yva), batch_size=BATCH_SIZE, shuffle=Fals

    model = BiLSTMAttnRec(num_items=len(topic2id)).to(DEVICE)
    crit  = nn.CrossEntropyLoss(ignore_index=0)
    opt   = torch.optim.AdamW(model.parameters(), lr=LR)

    for ep in range(1, EPOCHS+1):
        model.train(); tloss=0
        for x,l,m,yb in train_loader:
            x,l,m,yb = x.to(DEVICE), l.to(DEVICE), m.to(DEVICE), yb.to(DEVICE)
            logits = model(x,l,m)
            loss = crit(logits, yb)
            opt.zero_grad(); loss.backward()
            nn.utils.clip_grad_norm_(model.parameters(), 1.0)
            opt.step()
            tloss += loss.item()*x.size(0)


        model.eval(); vloss=0
        with torch.no_grad():
            for x,l,m,yb in val_loader:
                x,l,m,yb = x.to(DEVICE), l.to(DEVICE), m.to(DEVICE), yb.to(DEVICE)
                vloss += crit(model(x,l,m), yb).item()*x.size(0)
        print(f"[business] Epoch {ep:02d}  train_loss={tloss/len(Xtr):.4f}  val_loss={vl

    os.makedirs(MODELS_DIR, exist_ok=True)
    torch.save(model.state_dict(), os.path.join(MODELS_DIR, "bilstm_business.pt"))
    with open(os.path.join(MODELS_DIR, "topic2id_business.pkl"), "wb") as f: pickle.dump
    with open(os.path.join(MODELS_DIR, "id2topic_business.pkl"), "wb") as f: pickle.dump
    print("[business] Saved model + vocab to models/")


    example_hist = list(topic2id.keys())[:3]
    recs = recommend_next("business", example_hist, already_seen=example_hist, top_n=TOP
    print("\nDemo history:", example_hist)
    print("Top-N next topics:", recs)

#Inference
def load_business_model():
    t2i_p = os.path.join(MODELS_DIR, "topic2id_business.pkl")
    i2t_p = os.path.join(MODELS_DIR, "id2topic_business.pkl")
    m_p   = os.path.join(MODELS_DIR, "bilstm_business.pt")
    if not (os.path.exists(t2i_p) and os.path.exists(i2t_p) and os.path.exists(m_p)):
        raise FileNotFoundError("Train business first to create model + mappings in mode
    with open(t2i_p, "rb") as f: topic2id = pickle.load(f)
    with open(i2t_p, "rb") as f: id2topic = pickle.load(f)
    model = BiLSTMAttnRec(num_items=len(topic2id)).to(DEVICE)
    model.load_state_dict(torch.load(m_p, map_location=DEVICE))
    model.eval()
    return model, topic2id, id2topic

def recommend_next(subject: str, history_topics: List[str], already_seen: List[str] = No
    assert subject == "business", "This script is business-only."
    model, topic2id, id2topic = load_business_model()
    ids = [topic2id[t] for t in history_topics if t in topic2id]
    if not ids: return []
    x = torch.tensor([ids], dtype=torch.long).to(DEVICE)
```

```python
    lengths = torch.tensor([len(ids)], dtype=torch.long).to(DEVICE)
    mask = (x != 0).float()
    with torch.no_grad():
        logits = model(x, lengths, mask)
        probs = torch.softmax(logits, dim=-1).squeeze(0).cpu().numpy()
    seen = set(already_seen or [])
    cands = [(tid,p) for tid,p in enumerate(probs) if tid!=0 and id2topic.get(tid) not i
    cands.sort(key=lambda x: x[1], reverse=True)
    return [(id2topic[tid], float(p)) for tid,p in cands[:top_n]]


if __name__ == "__main__":
    train_business()
```

```
[business] Epoch 01  train_loss=3.3960  val_loss=3.3538
[business] Epoch 02  train_loss=3.3726  val_loss=3.3577
[business] Epoch 03  train_loss=3.3504  val_loss=3.3614
[business] Epoch 04  train_loss=3.3354  val_loss=3.3630
[business] Epoch 05  train_loss=3.3080  val_loss=3.3633
[business] Epoch 06  train_loss=3.2957  val_loss=3.3629
[business] Epoch 07  train_loss=3.2826  val_loss=3.3611
[business] Epoch 08  train_loss=3.2716  val_loss=3.3599
[business] Saved model + vocab to models/

Demo history: ['Chapter 4- Types of Business Organisation', 'Chapter 21-Business Finance
-Needs and Sources', 'Chapter 9- Internal and External Communication']
Top-N next topics: [('Chapter 15-The Marketing Mix', 0.04480503872036934), ('Chapter 2-
Classification of Business', 0.04317012429237366), ('Chapter 7-Organisation and mangemen
t', 0.03879755362868309), ('Chapter 5- Business Objectives and Stakeholder objectives',
0.03878293186426163), ('Chapter 26-Government economic objectives and policies', 0.03672
325611114502)]
```

In [6]:

```python
#ict

import os, pickle, random
from typing import List, Tuple, Dict
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split

import torch
import torch.nn as nn
from torch.utils.data import Dataset, DataLoader

#configuration
SEED = 42
random.seed(SEED); np.random.seed(SEED); torch.manual_seed(SEED)

CSV_PATH     = r"C:\Users\Rizwana\Desktop\studyoclock project\Sample_Interactions_Data.c
SUBJECT      = "ict"
MODELS_DIR   = "models"
DEVICE       = "cpu"

MIN_SEQ_LEN  = 4
MAX_HIST_LEN = 50
BATCH_SIZE   = 64
EPOCHS       = 8
LR           = 1e-3
TOPK         = 5

#utilities
def load_interactions(path: str) -> pd.DataFrame:
    if not os.path.exists(path): raise FileNotFoundError(path)
    df = pd.read_csv(path)
    need = {"user_id","subject","topic_name","rating"}
    if not need.issubset(df.columns): raise ValueError(f"{path} must contain {need}")
```

```python
    if "timestamp" not in df.columns:
        df = df.copy()
        df["timestamp"] = df.groupby(["user_id","subject"]).cumcount()
    return df

def build_vocab_sequences(df_subj: pd.DataFrame) -> Tuple[Dict[str,int], Dict[int,str],
    df_subj = df_subj.sort_values(["user_id","timestamp"])
    topics = df_subj["topic_name"].unique().tolist()
    topic2id = {t:i+1 for i,t in enumerate(topics)}   # 0=PAD
    id2topic = {i:t for t,i in topic2id.items()}
    sequences = []
    for uid, g in df_subj.groupby("user_id"):
        seq = [topic2id[t] for t in g["topic_name"].tolist()]
        if len(seq) >= MIN_SEQ_LEN:
            sequences.append((uid, seq))
    return topic2id, id2topic, sequences

def make_next_pairs(sequences: List[Tuple[int,List[int]]]):
    X, y = [], []
    for _, seq in sequences:
        for t in range(1, len(seq)):
            hist = seq[max(0, t - MAX_HIST_LEN):t]
            if hist:
                X.append(hist); y.append(seq[t])
    return X, y

def pad_batch(seqs: List[List[int]], pad_id=0):
    L = max(len(s) for s in seqs)
    arr = np.zeros((len(seqs), L), dtype=np.int64)
    lens = np.array([len(s) for s in seqs], dtype=np.int64)
    for i,s in enumerate(seqs): arr[i,:len(s)] = s
    x = torch.tensor(arr); lengths = torch.tensor(lens)
    mask = (x != pad_id).float()
    return x, lengths, mask

class NextDataset(Dataset):
    def __init__(self, X, y): self.X, self.y = X, y
    def __len__(self): return len(self.X)
    def __getitem__(self, i): return self.X[i], self.y[i]

def collate_fn(batch, pad_id=0):
    seqs, targets = zip(*batch)
    x, lengths, mask = pad_batch(seqs, pad_id)
    y = torch.tensor(targets, dtype=torch.long)
    return x, lengths, mask, y

#model building
class AdditiveAttention(nn.Module):
    def __init__(self, hidden_dim):
        super().__init__()
        self.W = nn.Linear(hidden_dim, hidden_dim)
        self.v = nn.Linear(hidden_dim, 1, bias=False)
    def forward(self, H, mask):
        scores = self.v(torch.tanh(self.W(H))).squeeze(-1)    # (B,T)
        scores = scores.masked_fill(mask == 0, -1e9)
        alpha  = torch.softmax(scores, dim=-1)                # (B,T)
        ctx    = torch.bmm(alpha.unsqueeze(1), H).squeeze(1) # (B,H)
        return ctx, alpha

class BiLSTMAttnRec(nn.Module):
    def __init__(self, num_items, emb_dim=64, hidden_dim=128, pad_id=0):
        super().__init__()
        self.emb  = nn.Embedding(num_items+1, emb_dim, padding_idx=pad_id)
        self.lstm = nn.LSTM(emb_dim, hidden_dim//2, batch_first=True, bidirectional=True
        self.attn = AdditiveAttention(hidden_dim)
        self.drop = nn.Dropout(0.2)
```

```
        self.out   = nn.Linear(hidden_dim, num_items+1)
    def forward(self, x, lengths, mask):
        E = self.emb(x)                  # (B,T,E)
        H, _ = self.lstm(E)              # (B,T,H)
        ctx, _ = self.attn(H, mask)      # (B,H)
        z = self.drop(ctx)
        logits = self.out(z)             # (B,V)
        return logits

#train and save
def train_ict():
    df = load_interactions(CSV_PATH)
    ict = df[df["subject"] == SUBJECT].copy()
    if ict.empty: raise ValueError("No ICT rows in interactions.csv")
    if ict["user_id"].nunique() < 5:
        print("[ict] Few users detected; training anyway.")

    topic2id, id2topic, sequences = build_vocab_sequences(ict)
    if not sequences:
        raise ValueError("No ICT sequences with length ≥ MIN_SEQ_LEN")

    X, y = make_next_pairs(sequences)
    Xtr, Xva, ytr, yva = train_test_split(X, y, test_size=0.2, random_state=SEED, shuffl
    train_loader = DataLoader(NextDataset(Xtr, ytr), batch_size=BATCH_SIZE, shuffle=True
    val_loader   = DataLoader(NextDataset(Xva, yva), batch_size=BATCH_SIZE, shuffle=Fals

    model = BiLSTMAttnRec(num_items=len(topic2id)).to(DEVICE)
    crit  = nn.CrossEntropyLoss(ignore_index=0)
    opt   = torch.optim.AdamW(model.parameters(), lr=LR)

    for ep in range(1, EPOCHS+1):
        model.train(); tloss=0
        for x,l,m,yb in train_loader:
            x,l,m,yb = x.to(DEVICE), l.to(DEVICE), m.to(DEVICE), yb.to(DEVICE)
            logits = model(x,l,m)
            loss = crit(logits, yb)
            opt.zero_grad(); loss.backward()
            nn.utils.clip_grad_norm_(model.parameters(), 1.0)
            opt.step()
            tloss += loss.item()*x.size(0)


        model.eval(); vloss=0
        with torch.no_grad():
            for x,l,m,yb in val_loader:
                x,l,m,yb = x.to(DEVICE), l.to(DEVICE), m.to(DEVICE), yb.to(DEVICE)
                vloss += crit(model(x,l,m), yb).item()*x.size(0)
        print(f"[ict] Epoch {ep:02d}  train_loss={tloss/len(Xtr):.4f}  val_loss={vloss/l

    os.makedirs(MODELS_DIR, exist_ok=True)
    torch.save(model.state_dict(), os.path.join(MODELS_DIR, "bilstm_ict.pt"))
    with open(os.path.join(MODELS_DIR, "topic2id_ict.pkl"), "wb") as f: pickle.dump(topi
    with open(os.path.join(MODELS_DIR, "id2topic_ict.pkl"), "wb") as f: pickle.dump(id2t
    print("[ict] Saved model + vocab to models/")


    example_hist = list(topic2id.keys())[:3]
    recs = recommend_next("ict", example_hist, already_seen=example_hist, top_n=TOPK)
    print("\nDemo history:", example_hist)
    print("Top-N next topics:", recs)

#Ineference
def load_ict_model():
    t2i_p = os.path.join(MODELS_DIR, "topic2id_ict.pkl")
    i2t_p = os.path.join(MODELS_DIR, "id2topic_ict.pkl")
    m_p   = os.path.join(MODELS_DIR, "bilstm_ict.pt")
```

```python
    if not (os.path.exists(t2i_p) and os.path.exists(i2t_p) and os.path.exists(m_p)):
        raise FileNotFoundError("Train ICT first to create model + mappings in models/")
    with open(t2i_p, "rb") as f: topic2id = pickle.load(f)
    with open(i2t_p, "rb") as f: id2topic = pickle.load(f)
    model = BiLSTMAttnRec(num_items=len(topic2id)).to(DEVICE)
    model.load_state_dict(torch.load(m_p, map_location=DEVICE))
    model.eval()
    return model, topic2id, id2topic

def recommend_next(subject: str, history_topics: List[str], already_seen: List[str] = No
    assert subject == "ict", "This script is ICT-only."
    model, topic2id, id2topic = load_ict_model()
    ids = [topic2id[t] for t in history_topics if t in topic2id]
    if not ids: return []
    x = torch.tensor([ids], dtype=torch.long).to(DEVICE)
    lengths = torch.tensor([len(ids)], dtype=torch.long).to(DEVICE)
    mask = (x != 0).float()
    with torch.no_grad():
        logits = model(x, lengths, mask)
        probs = torch.softmax(logits, dim=-1).squeeze(0).cpu().numpy()
    seen = set(already_seen or [])
    cands = [(tid,p) for tid,p in enumerate(probs) if tid!=0 and id2topic.get(tid) not i
    cands.sort(key=lambda x: x[1], reverse=True)
    return [(id2topic[tid], float(p)) for tid,p in cands[:top_n]]


if __name__ == "__main__":
    train_ict()
```

```
[ict] Epoch 01  train_loss=2.1836  val_loss=2.1953
[ict] Epoch 02  train_loss=2.1590  val_loss=2.1948
[ict] Epoch 03  train_loss=2.1363  val_loss=2.1947
[ict] Epoch 04  train_loss=2.1200  val_loss=2.1927
[ict] Epoch 05  train_loss=2.1047  val_loss=2.1904
[ict] Epoch 06  train_loss=2.0796  val_loss=2.1885
[ict] Epoch 07  train_loss=2.0659  val_loss=2.1870
[ict] Epoch 08  train_loss=2.0447  val_loss=2.1867
[ict] Saved model + vocab to models/

Demo history: ['4. Networks and the effects of using them', '5. The effects of using IC
T', '1. Types and Components of Computer Systems']
Top-N next topics: [('8.Safety and Security', 0.12913718819618225), ('3. Storage Devices
and Media', 0.1258760243654251), ('7. Systems Analysis and Design', 0.1099312976002693
2), ('2. Input and Output Devices', 0.10689781606197357), ('6. ICT Applications', 0.1059
8456859588623)]
```

In [5]:

```python
import pandas as pd
import numpy as np
from sklearn.metrics.pairwise import cosine_similarity

PATH = r"C:\Users\Rizwana\Desktop\studyoclock project\interactions_real.csv"

df = pd.read_csv(PATH)

#verification of data
for subj in ["biology","chemistry","business","ict"]:
    sub = df[df.subject==subj]
    users = sub["user_id"].nunique()
    avg_per_user = sub.groupby("user_id").size().mean()
    print(f"{subj:10s} users={users:3d}  avg_interactions/user={avg_per_user:.1f}")

#per-user holdout
def per_user_holdout(df_subj: pd.DataFrame):
    train_rows = []
    test_truth = {}
    for uid, g in df_subj.groupby("user_id"):
```

```python
        if len(g) < 2:
            continue
        g = g.sort_values("timestamp")
        n_test = max(1, int(0.3*len(g)))
        test_part = g.tail(n_test)
        train_part = g.iloc[:-n_test]
        if train_part.empty:
            continue
        train_rows.append(train_part)
        test_truth[uid] = set(test_part["topic_name"].tolist())
    train_df = pd.concat(train_rows, ignore_index=True) if train_rows else pd.DataFrame(
    return train_df, test_truth

#self-contained user-user CF (evaluation)
def user_user_recommend_eval(train_df: pd.DataFrame, subject: str, user_id, top_n=5):
    sub = train_df[train_df["subject"]==subject].copy()
    if sub.empty:
        return []
    #user-item matrix
    users = sub["user_id"].unique().tolist()
    items = sub["topic_name"].unique().tolist()
    ui = pd.pivot_table(sub, index="user_id", columns="topic_name", values="rating")
    ui = ui.reindex(index=users, columns=items)
    if user_id not in ui.index:
        return []
    sim = cosine_similarity(ui.fillna(0))
    sim = pd.DataFrame(sim, index=ui.index, columns=ui.index)

    # weighted scores
    scores = sim.loc[user_id].values @ ui.fillna(0).values
    scores = pd.Series(scores, index=ui.columns)

    # remove already-seen
    seen = set(sub[sub["user_id"]==user_id]["topic_name"])
    scores.loc[list(seen)] = -np.inf

    ranked = scores.sort_values(ascending=False)
    return ranked.index[:top_n].tolist()

def precision_recall_at_k(pred_items, true_items, k):
    if not pred_items:
        return 0.0, 0.0
    pred_k = pred_items[:k]
    hits = len(set(pred_k) & true_items)
    return hits/float(k), hits/float(len(true_items))

#evaluate with the fallback recommender
def evaluate_cf_fallback(df: pd.DataFrame, subjects, k=5):
    rows = []
    for subj in subjects:
        sub = df[df["subject"]==subj].copy()
        if sub.empty:
            print(f"[{subj}] no rows; skip")
            continue
        train_df, test_truth = per_user_holdout(sub)
        if train_df.empty or not test_truth:
            print(f"[{subj}] holdout produced 0 users; skip")
            continue
        p_list, r_list = [], []
        for uid, truth in test_truth.items():
            recs = user_user_recommend_eval(train_df, subj, uid, top_n=k)
            p, r = precision_recall_at_k(recs, truth, k)
            p_list.append(p); r_list.append(r)
        if p_list:
            rows.append({
                "subject": subj,
```

```
                f"precision@{k}": float(np.mean(p_list)),
                f"recall@{k}": float(np.mean(r_list)),
                "users_eval": int(len(p_list))
            })
        else:
            print(f"[{subj}] recommender returned empty for all users.")
    return pd.DataFrame(rows)

report = evaluate_cf_fallback(df, ["biology","chemistry","business","ict"], k=5)
print("\nCF fallback evaluation:")
print(report if not report.empty else "No evaluable users (unexpected).")
```

```
biology    users=  0  avg_interactions/user=nan
chemistry  users=  0  avg_interactions/user=nan
business   users=  0  avg_interactions/user=nan
ict        users=  0  avg_interactions/user=nan
[biology] no rows; skip
[chemistry] no rows; skip
[business] no rows; skip
[ict] no rows; skip

CF fallback evaluation:
No evaluable users (unexpected).
```

Hybrid Recommender (BiLSTM)

In [6]:

```
import os
import pickle
from typing import List, Optional, Dict, Tuple
import numpy as np
import pandas as pd

#Content
class ContentEmbedRecommender:
    """
    Semantic content recommender using sentence-transformer embeddings.
    Falls back to TF-IDF if sentence-transformers isn't available.
    """
    def __init__(self, processed_csv: str, model_name: str = "sentence-transformers/all-
        self.df = pd.read_csv(processed_csv)
        need = {"subject","topic_name","summary_text"}
        if not need.issubset(self.df.columns):
            raise ValueError(f"{processed_csv} must contain {need}")
        self.df["text_for_embed"] = (
            self.df["topic_name"].fillna("") + " | " + self.df["summary_text"].fillna(""
        )
        self.model_name = model_name
        self._fit()

    def _fit(self):
        try:
            from sentence_transformers import SentenceTransformer
            from sklearn.preprocessing import normalize
            self.encoder = SentenceTransformer(self.model_name)
            embs = self.encoder.encode(self.df["text_for_embed"].tolist(), normalize_emb
            self.embs = embs.astype(np.float32)  # (N, d), already L2-normalized
            self.backend = "sbert"
        except Exception:
            #Fallback: TF-IDF
            from sklearn.feature_extraction.text import TfidfVectorizer
            from sklearn.preprocessing import normalize
            self.vectorizer = TfidfVectorizer(min_df=2, max_df=0.9, ngram_range=(1,2))
            X = self.vectorizer.fit_transform(self.df["text_for_embed"].tolist())
            self.embs = normalize(X).astype(np.float32)
```

```python
            self.backend = "tfidf"

    def _cosine_topk(self, vec, mask_idx, k):

        if hasattr(self.embs, "dot"):
            sims = self.embs.dot(vec.T).toarray().ravel()
        else:
            sims = self.embs @ vec.ravel()
        if mask_idx is not None:
            sims[mask_idx] = -np.inf
        order = np.argpartition(-sims, range(min(k, len(sims))))[:k]
        order = order[np.argsort(-sims[order])]
        return order, sims

    def _encode_text(self, text: str):
        if self.backend == "sbert":
            v = self.encoder.encode([text], normalize_embeddings=True)
            return v.astype(np.float32)
        else:
            v = self.vectorizer.transform([text])
            from sklearn.preprocessing import normalize
            return normalize(v).astype(np.float32)

    def _mask_subject(self, subject: str):
        return np.where(self.df["subject"].values != subject)[0]

    def recommend_like(self, subject: str, topic_name: str, top_n=5) -> pd.DataFrame:
        if topic_name not in set(self.df.loc[self.df["subject"]==subject, "topic_name"])
            raise ValueError(f"'{topic_name}' not found in subject='{subject}'")
        idx = self.df.index[(self.df["subject"]==subject) & (self.df["topic_name"]==topi
        vec = self.embs[idx:idx+1] if self.backend=="sbert" else self.embs[idx:idx+1]
        mask_idx = np.where(self.df.index.values == idx)[0]
        order, sims = self._cosine_topk(vec, mask_idx, top_n+1)
        order = [i for i in order if i != idx][:top_n]
        out = self.df.loc[order, ["subject","topic_name","difficulty_level"]].copy()
        out["score_content"] = sims[order]
        return out.reset_index(drop=True)

    def recommend_query(self, subject: str, query: str, top_n=5) -> pd.DataFrame:
        vec = self._encode_text(query)
        mask = self._mask_subject(subject)
        order, sims = self._cosine_topk(vec, mask, top_n)
        out = self.df.loc[order, ["subject","topic_name","difficulty_level"]].copy()
        out["score_content"] = sims[order]
        return out.reset_index(drop=True)

    def recommend_from_profile(self, subject: str, liked_topics: List[str], top_n=5) -> 
        #Average embeddings of liked topics
        rows = self.df[(self.df["subject"]==subject) & (self.df["topic_name"].isin(liked
        if rows.empty:
            raise ValueError("None of the liked topics found in this subject.")
        idxs = rows.index.values
        if hasattr(self.embs, "mean"):
            vec = np.mean(self.embs[idxs], axis=0, keepdims=True)
            vec = vec / (np.linalg.norm(vec) + 1e-8)
        else:
            vec = self.embs[idxs].mean(axis=0)
            from sklearn.preprocessing import normalize
            vec = normalize(vec)
        mask_idx = self._mask_subject(subject)

        mask_idx = np.unique(np.concatenate([mask_idx, np.array([np.where(self.df.index.
        order, sims = self._cosine_topk(vec, mask_idx, top_n)
        out = self.df.loc[order, ["subject","topic_name","difficulty_level"]].copy()
        out["score_content"] = sims[order]
        return out.reset_index(drop=True)
```

```python
#Collaborative Filtering (User-User)
class UserUserCF:
    """
    Simple cosine User-User CF. Designed to run on a per-subject train slice.
    """
    def __init__(self, interactions_csv: str):
        self.full = pd.read_csv(interactions_csv)
        need = {"user_id","subject","topic_name","rating"}
        if not need.issubset(self.full.columns):
            raise ValueError(f"{interactions_csv} must contain {need}")

    def _pivot(self, df_subj: pd.DataFrame):
        users = df_subj["user_id"].unique().tolist()
        items = df_subj["topic_name"].unique().tolist()
        ui = pd.pivot_table(df_subj, index="user_id", columns="topic_name", values="rati
        ui = ui.reindex(index=users, columns=items)
        return ui

    def recommend(self, subject: str, user_id, top_n=5) -> pd.DataFrame:
        from sklearn.metrics.pairwise import cosine_similarity
        df_subj = self.full[self.full["subject"]==subject].copy()
        if df_subj.empty:
            return pd.DataFrame(columns=["topic_name","score_cf"])
        ui = self._pivot(df_subj)
        if user_id not in ui.index:
            return pd.DataFrame(columns=["topic_name","score_cf"])
        sim = cosine_similarity(ui.fillna(0))
        sim = pd.DataFrame(sim, index=ui.index, columns=ui.index)
        scores = sim.loc[user_id].values @ ui.fillna(0).values
        scores = pd.Series(scores, index=ui.columns)

        seen = set(df_subj[df_subj["user_id"]==user_id]["topic_name"])
        if seen:
            scores.loc[list(seen)] = -np.inf
        ranked = scores.sort_values(ascending=False)
        top_items = ranked.head(top_n)
        return pd.DataFrame({"topic_name": top_items.index, "score_cf": top_items.values


#BiLSTM loader
class BiLSTMNextTopic:
    """
    Thin loader/inferencer for your saved BiLSTM models (optional).
    If assets aren't found, calls return empty DataFrames.
    """
    def __init__(self, models_dir="models", device="cpu"):
        self.models_dir = models_dir
        self.device = device
        self._cache = {}

    def _paths(self, subject):
        return (
            os.path.join(self.models_dir, f"bilstm_{subject}.pt"),
            os.path.join(self.models_dir, f"topic2id_{subject}.pkl"),
            os.path.join(self.models_dir, f"id2topic_{subject}.pkl"),
        )

    def _load(self, subject):
        if subject in self._cache:
            return self._cache[subject]
        m_p, t2i_p, i2t_p = self._paths(subject)
        if not (os.path.exists(m_p) and os.path.exists(t2i_p) and os.path.exists(i2t_p))
            self._cache[subject] = None
            return None
```

```python
        import torch
        import torch.nn as nn

        class AdditiveAttention(nn.Module):
            def __init__(self, hidden_dim):
                super().__init__()
                self.W = nn.Linear(hidden_dim, hidden_dim)
                self.v = nn.Linear(hidden_dim, 1, bias=False)
            def forward(self, H, mask):
                scores = self.v(torch.tanh(self.W(H))).squeeze(-1)
                scores = scores.masked_fill(mask==0, -1e9)
                alpha = torch.softmax(scores, dim=-1)
                ctx = torch.bmm(alpha.unsqueeze(1), H).squeeze(1)
                return ctx

        class BiLSTMAttnRec(nn.Module):
            def __init__(self, num_items, emb_dim=64, hidden_dim=128, pad_id=0):
                super().__init__()
                self.emb  = nn.Embedding(num_items+1, emb_dim, padding_idx=pad_id)
                self.lstm = nn.LSTM(emb_dim, hidden_dim//2, batch_first=True, bidirectio
                self.attn = AdditiveAttention(hidden_dim)
                self.out  = nn.Linear(hidden_dim, num_items+1)
            def forward(self, x, mask):
                E = self.emb(x)
                H, _ = self.lstm(E)
                ctx = self.attn(H, mask)
                logits = self.out(ctx)
                return logits

        with open(t2i_p, "rb") as f: topic2id = pickle.load(f)
        with open(i2t_p, "rb") as f: id2topic = pickle.load(f)
        num_items = len(topic2id)

        model = BiLSTMAttnRec(num_items=num_items)
        import torch
        model.load_state_dict(torch.load(m_p, map_location=self.device))
        model.eval()
        self._cache[subject] = (model, topic2id, id2topic)
        return self._cache[subject]

    def recommend(self, subject: str, history: List[str], already_seen: Optional[List[st
        pack = self._load(subject)
        if pack is None:
            return pd.DataFrame(columns=["topic_name","score_seq"])
        import torch
        model, topic2id, id2topic = pack
        ids = [topic2id[t] for t in history if t in topic2id]
        if not ids:
            return pd.DataFrame(columns=["topic_name","score_seq"])
        x = torch.tensor([ids], dtype=torch.long)
        mask = (x != 0).float()
        with torch.no_grad():
            logits = model(x, mask)
            probs = torch.softmax(logits, dim=-1).squeeze(0).numpy()
        seen = set(already_seen or [])
        items = []
        for tid, p in enumerate(probs):
            if tid == 0:    # pad
                continue
            name = id2topic.get(tid)
            if name and name not in seen:
                items.append((name, float(p)))
        items.sort(key=lambda z: z[1], reverse=True)
        items = items[:top_n]
        if not items:
            return pd.DataFrame(columns=["topic_name","score_seq"])
```

```python
        return pd.DataFrame(items, columns=["topic_name","score_seq"])


#Hybrid ranker
class HybridRecommender:
    """
    Blend Content, CF, and Sequence scores (min-max normalized per list) and rank.
    Weights default to a recall-friendly profile: content 0.4, CF 0.3, seq 0.3.
    """
    def __init__(self, processed_csv: str, interactions_csv: str, models_dir="models"):
        self.content = ContentEmbedRecommender(processed_csv)
        self.cf = UserUserCF(interactions_csv)
        self.seq = BiLSTMNextTopic(models_dir=models_dir)

    @staticmethod
    def _normalize(series: pd.Series) -> pd.Series:
        if series.empty:
            return series
        vmin, vmax = float(series.min()), float(series.max())
        if not np.isfinite(vmin) or not np.isfinite(vmax) or vmax <= vmin:
            return pd.Series(np.zeros(len(series)), index=series.index)
        return (series - vmin) / (vmax - vmin)

    def _blend(self, frames: List[pd.DataFrame], weights: Dict[str,float], k=10) -> pd.D
        # Outer-join on topic_name and fill NaNs with 0
        if not frames:
            return pd.DataFrame(columns=["topic_name","score"])
        df = frames[0]
        for f in frames[1:]:
            df = df.merge(f, on=["topic_name"], how="outer")
        # normalize individual score columns
        for col in ["score_content","score_cf","score_seq"]:
            if col in df.columns:
                df[col] = df[col].fillna(0.0)
                df[col] = self._normalize(df[col])
            else:
                df[col] = 0.0
        score = (
            weights.get("content",0.0)*df["score_content"]
            + weights.get("cf",0.0)*df["score_cf"]
            + weights.get("seq",0.0)*df["score_seq"]
        )
        df["score"] = score
        df = df.sort_values("score", ascending=False)
        return df[["topic_name","score","score_content","score_cf","score_seq"]].head(k)

    # Public APIs
    def recommend_like(self, subject: str, topic_name: str, user_id=None, history: Optio
                       weights={"content":0.4,"cf":0.3,"seq":0.3}, k=10) -> pd.DataFrame
        frames = []
        frames.append(self.content.recommend_like(subject, topic_name, top_n=k)[["topic_
        if user_id is not None:
            frames.append(self.cf.recommend(subject, user_id, top_n=k)[["topic_name","sc
        if history:
            frames.append(self.seq.recommend(subject, history, already_seen=[topic_name]
        return self._blend([f for f in frames if not f.empty], weights, k)

    def recommend_query(self, subject: str, query: str, user_id=None, history: Optional[
                        weights={"content":0.5,"cf":0.25,"seq":0.25}, k=10) -> pd.DataFr
        frames = []
        frames.append(self.content.recommend_query(subject, query, top_n=k)[["topic_name
        if user_id is not None:
            frames.append(self.cf.recommend(subject, user_id, top_n=k)[["topic_name","sc
        if history:
            frames.append(self.seq.recommend(subject, history, already_seen=history, top
        return self._blend([f for f in frames if not f.empty], weights, k)
```

```python
    def recommend_from_profile(self, subject: str, liked_topics: List[str], user_id=None
                               weights={"content":0.4,"cf":0.3,"seq":0.3}, k=10) -> pd.D
        frames = []
        frames.append(self.content.recommend_from_profile(subject, liked_topics, top_n=k
        if user_id is not None:
            frames.append(self.cf.recommend(subject, user_id, top_n=k)[["topic_name","sc
        if history:
            frames.append(self.seq.recommend(subject, history, already_seen=liked_topics
        return self._blend([f for f in frames if not f.empty], weights, k)


#Evaluation
if __name__ == "__main__":
    PROCESSED = "processed_notes.csv"
    INTERACTIONS = r"C:\Users\Rizwana\Downloads\interactions2.csv"

    if not (os.path.exists(PROCESSED) and os.path.exists(INTERACTIONS)):
        raise SystemExit("Place processed_notes.csv and interactions*.csv next to this s

    rec = HybridRecommender(PROCESSED, INTERACTIONS)

    #Example 1: Biology
    print("\n=== Hybrid: 'like' a Biology topic (user_3) ===")
    out1 = rec.recommend_like(
        subject="biology",
        topic_name="Unit 5 Enzymes",
        user_id="user_3",
        history=["Unit 2 Cells", "Unit 12 Respiration"],
        k=8
    )
    print(out1)

    # Example 2:Chemistry
    print("\n=== Hybrid: query 'rates of reaction' (Chemistry, user_10) ===")
    out2 = rec.recommend_query(
        subject="chemistry",
        query="rates of reaction, collision theory, catalysts",
        user_id="user_10",
        history=["Unit 12 Periodic Table", "Unit 3 Structure and Bonding"],
        k=8
    )
    print(out2)
```

```
=== Hybrid: 'like' a Biology topic (user_3) ===
                       topic_name     score  score_content  score_cf  score_seq
0      Unit 9 Chemical Reactions  0.400000       1.000000       0.0   0.000000
1       Unit 8 Speed of Reaction  0.346783       0.866958       0.0   0.000000
2  Unit 10 Diseases and Immunity  0.300000       0.000000       0.0   1.000000
3              Unit 13 Excretion  0.290038       0.000000       0.0   0.966793
4         Unit 6 Plant Nutrition  0.287960       0.000000       0.0   0.959865
5         Unit 8 Plant Transport  0.285170       0.000000       0.0   0.950566
6            Unit 17 Inheritance  0.281574       0.000000       0.0   0.938581
7    Unit 4 Biological Molecules  0.281152       0.000000       0.0   0.937174

=== Hybrid: query 'rates of reaction' (Chemistry, user_10) ===
                           topic_name     score  score_content  score_cf  \
0            Unit 8 Speed of Reaction  0.500000       1.000000       0.0
1      Unit 16 The Chemical Industry  0.372615       0.245230       0.0
2           Unit 9 Chemical Reactions  0.336670       0.284830       0.0
3         Unit 12 The Periodic Table  0.226644       0.082268       0.0
4           Unit 14 Metal Extraction  0.212034       0.000000       0.0
5              Unit 15 Air and Water  0.208325       0.000000       0.0
6  Unit 1 Particles and Purification  0.205907       0.000000       0.0
```

```
7            Unit 10 Acids and Bases   0.202813        0.000000       0.0

   score_seq
0   0.000000
1   1.000000
2   0.777022
3   0.742041
4   0.848135
5   0.833299
6   0.823626
7   0.811252
```

Establishing the Baseline

In [1]:

```python
import numpy as np
import pandas as pd
from difflib import get_close_matches

def _closest_topic(df: pd.DataFrame, subject: str, topic_name: str, cutoff: float = 0.55
    pool = df.loc[df["subject"] == subject, "topic_name"].astype(str).unique().tolist()
    match = get_close_matches(str(topic_name), pool, n=1, cutoff=cutoff)
    return match[0] if match else None

def _normalize_vec(vec):

    try:
        v = np.asarray(vec).astype(np.float32)
        if v.ndim == 1:
            v = v[None, :]
        norm = np.linalg.norm(v) + 1e-8
        return (v / norm).astype(np.float32)
    except Exception:

        return vec

def patched_recommend_from_profile(self, subject: str, liked_topics, top_n: int = 8) ->
    """
    Robust version:
      - Accepts messy liked_topics (exact or fuzzy).
      - Works with SBERT (dense) and TF-IDF (sparse) embeddings.
      - Falls back to query if nothing matches.
    """
    liked_topics = list(liked_topics or [])
    subdf = self.df[self.df["subject"] == subject]

    #Build a valid list of liked topics (exact or fuzzy)
    valid = []
    for t in liked_topics:
        if (subdf["topic_name"] == t).any():
            valid.append(t)
        else:
            m = _closest_topic(self.df, subject, t, cutoff=0.55)
            if m:
                print(f"[content] liked '{t}' → matched '{m}'")
                valid.append(m)

    #Unique while preserving order
    seen = set()
    valid = [x for x in valid if not (x in seen or seen.add(x))]

    if not valid:
        print("[content] No liked topics matched; using query fallback.")
        return self.recommend_query(subject, " ".join(liked_topics), top_n=top_n)
```

```python
    #Indices of the valid liked topics
    idxs = subdf.index[subdf["topic_name"].isin(valid)].values
    if len(idxs) == 0:
        print("[content] Matched liked topics not found in embeddings; using query fallb
        return self.recommend_query(subject, " ".join(liked_topics), top_n=top_n)

    #Dense vs Sparse average embedding (safe)
    if getattr(self, "backend", "") == "sbert":
        # Dense numpy array: (N,d) → mean (1,d)
        vec = np.mean(self.embs[idxs], axis=0, keepdims=True).astype(np.float32)
        vec = _normalize_vec(vec)
    else:
        #Sparse matrix: use scipy sparse .mean(axis=0), then convert to dense row
        from sklearn.preprocessing import normalize
        vec = self.embs[idxs].mean(axis=0)          # 1 x V (sparse)
        vec = normalize(vec)                        # L2 normalize sparse
        vec = np.asarray(vec.todense(), dtype=np.float32)  # (1,V) as dense row

    #Ban liked items themselves
    banned_idx = self.df.index[self.df["topic_name"].isin(valid)].values

    #Retrieve top-k by cosine similarity
    order, sims = self._cosine_topk(vec, banned_idx, top_n + len(valid))

    #Filter out liked items (in case any slipped through) and take top_n
    order = [i for i in order if self.df.iloc[i]["topic_name"] not in valid][:top_n]

    out = self.df.loc[order, ["subject","topic_name","difficulty_level"]].copy()
    out["score_content"] = sims[order]
    return out.reset_index(drop=True)


try:
    ContentEmbedRecommender.recommend_from_profile = patched_recommend_from_profile
    print("Patched ContentEmbedRecommender.recommend_from_profile successfully.")
except NameError:
    print("ContentEmbedRecommender class not found in this kernel. "
          "Run the cell that defines the class first, then re-run this patch.")
```

```
ContentEmbedRecommender class not found in this kernel. Run the cell that defines the cl
ass first, then re-run this patch.
```

In [7]:

```python
import os
import math
import random
import argparse
import pickle
from typing import List, Dict, Tuple

import numpy as np
import pandas as pd

import torch
import torch.nn as nn
from torch.utils.data import Dataset, DataLoader



SEED = 42
random.seed(SEED); np.random.seed(SEED); torch.manual_seed(SEED)
if torch.cuda.is_available():
    torch.cuda.manual_seed_all(SEED)
    torch.backends.cudnn.deterministic = True
    torch.backends.cudnn.benchmark = False

DEVICE = "cuda" if torch.cuda.is_available() else "cpu"
```

```python
#utilities
def load_subject_sequences(interactions_csv: str, subject: str) -> Dict[str, List[str]]:
    """Load user → ordered topic sequences for a subject from interactions CSV."""
    df = pd.read_csv(interactions_csv)
    need = {"user_id","subject","topic_name","timestamp"}
    if not need.issubset(df.columns):
        raise ValueError(f"{interactions_csv} must contain columns: {need}")
    sub = df[df["subject"].str.lower() == subject.lower()].copy()
    if sub.empty:
        raise ValueError(f"No rows for subject='{subject}' in {interactions_csv}")
    sub = sub.sort_values(["user_id","timestamp"])
    sessions: Dict[str, List[str]] = {}
    for uid, g in sub.groupby("user_id"):
        seq = g["topic_name"].tolist()
        if len(seq) >= 3:   # need at least 3 to learn transitions robustly
            sessions[uid] = seq
    if not sessions:
        raise ValueError(f"No users with >=3 interactions for subject='{subject}'.")
    return sessions

def build_vocab(sessions: Dict[str, List[str]]) -> Tuple[Dict[str,int], Dict[int,str]]:
    """Create topic ↔ id mapping (0 reserved for PAD)."""
    topics = sorted({t for seq in sessions.values() for t in seq})
    topic2id = {t:i+1 for i,t in enumerate(topics)}  # 1..V
    id2topic = {i+1:t for i,t in enumerate(topics)}
    return topic2id, id2topic

def make_examples(sessions: Dict[str, List[str]], topic2id: Dict[str,int], seq_len: int)
    """Sliding-window next-item examples: history → next_topic."""
    X, y = [], []
    for seq in sessions.values():
        ids = [topic2id[t] for t in seq if t in topic2id]
        for i in range(1, len(ids)):
            hist = ids[max(0, i - seq_len):i]
            target = ids[i]
            if len(hist) == 0:  # require at least 1 item in history
                continue
            X.append(hist); y.append(target)
    return X, y

def pad_left(seqs: List[List[int]], pad_id=0, max_len=None):
    """Left-pad sequences to max_len; mask=1 for real tokens, 0 for pad."""
    if max_len is None:
        max_len = max(len(s) for s in seqs)
    X = np.zeros((len(seqs), max_len), dtype=np.int64)
    M = np.zeros((len(seqs), max_len), dtype=np.float32)
    for i, s in enumerate(seqs):
        s = s[-max_len:]            # truncate long histories
        X[i, -len(s):] = np.array(s, dtype=np.int64)
        M[i, -len(s):] = 1.0
    return torch.from_numpy(X), torch.from_numpy(M)

class NextTopicDataset(Dataset):
    def __init__(self, X_hist: List[List[int]], y_next: List[int], seq_len: int, pad_id:
        self.X, self.mask = pad_left(X_hist, pad_id=pad_id, max_len=seq_len)
        self.y = torch.tensor(y_next, dtype=torch.long)
    def __len__(self): return len(self.y)
    def __getitem__(self, idx): return self.X[idx], self.mask[idx], self.y[idx]

def split_users(sessions: Dict[str, List[str]], val_frac=0.2):
    """User-level split to avoid leakage; returns two dicts like sessions."""
    users = list(sessions.keys())
    random.shuffle(users)
    n_val = max(1, int(len(users) * val_frac))
    val_users = set(users[:n_val])
```

```python
    train = {u:s for u,s in sessions.items() if u not in val_users}
    val   = {u:s for u,s in sessions.items() if u in val_users}
    return train, val

#Model
class AdditiveAttention(nn.Module):
    def __init__(self, hidden_dim):
        super().__init__()
        self.W = nn.Linear(hidden_dim, hidden_dim)
        self.v = nn.Linear(hidden_dim, 1, bias=False)
    def forward(self, H, mask):
        # H: (B,T,H), mask: (B,T)
        scores = self.v(torch.tanh(self.W(H))).squeeze(-1)   # (B,T)
        scores = scores.masked_fill(mask == 0, -1e9)
        alpha = torch.softmax(scores, dim=-1)                # (B,T)
        ctx = torch.bmm(alpha.unsqueeze(1), H).squeeze(1)    # (B,H)
        return ctx

class BiLSTMAttnRec(nn.Module):
    def __init__(self, num_items, emb_dim=64, hidden_dim=128, pad_id=0, dropout=0.2):
        super().__init__()
        self.emb  = nn.Embedding(num_items+1, emb_dim, padding_idx=pad_id)
        self.lstm = nn.LSTM(emb_dim, hidden_dim//2, batch_first=True, bidirectional=True
        self.drop = nn.Dropout(dropout)
        self.attn = AdditiveAttention(hidden_dim)
        self.out  = nn.Linear(hidden_dim, num_items+1)
    def forward(self, x, mask):
        E = self.emb(x)                        # (B,T,E)
        H, _ = self.lstm(E)                    # (B,T,H)
        H = self.drop(H)
        ctx = self.attn(H, mask)               # (B,H)
        logits = self.out(ctx)                 # (B, V+1)
        return logits

#Train/Eval
@torch.no_grad()
def evaluate(model, loader, device, topk=(5,10)):
    model.eval()
    total = 0
    hits = {k:0 for k in topk}
    for X, M, y in loader:
        X, M, y = X.to(device), M.to(device), y.to(device)
        logits = model(X, M)                   # (B,V)
        probs = torch.softmax(logits, dim=-1)
        for k in topk:
            topk_ids = torch.topk(probs, k=k, dim=-1).indices   # (B,k)
            hits[k] += (topk_ids == y.view(-1,1)).any(dim=1).sum().item()
        total += y.size(0)
    return {f"recall@{k}": (hits[k] / max(total,1)) for k in topk}

def train_subject(
    interactions: str,
    subject: str,
    save_dir: str = "models",
    seq_len: int = 10,
    batch_size: int = 128,
    epochs: int = 12,
    lr: float = 1e-3,
    weight_decay: float = 0.0,
    dropout: float = 0.2,
    hidden_dim: int = 128,
    emb_dim: int = 64,
    val_frac: float = 0.2,
    patience: int = 4,
    clip_norm: float = 1.0,
):
```

```python
    os.makedirs(save_dir, exist_ok=True)

    # 1)Build sequences
    sessions = load_subject_sequences(interactions, subject)
    topic2id, id2topic = build_vocab(sessions)
    num_items = len(topic2id)
    print(f"[{subject}] users={len(sessions)}  vocab_size={num_items}")

    # 2)Split by user to avoid leakage
    train_sess, val_sess = split_users(sessions, val_frac=val_frac)

    # 3)Create sliding-window examples
    Xtr, ytr = make_examples(train_sess, topic2id, seq_len)
    Xva, yva = make_examples(val_sess,   topic2id, seq_len)
    if len(Xtr) == 0 or len(Xva) == 0:
        raise RuntimeError("Not enough examples after split; increase data density or re

    # 4)Datasets/DataLoaders
    train_ds = NextTopicDataset(Xtr, ytr, seq_len)
    val_ds   = NextTopicDataset(Xva, yva, seq_len)
    train_loader = DataLoader(train_ds, batch_size=batch_size, shuffle=True,  drop_last=
    val_loader   = DataLoader(val_ds,   batch_size=batch_size, shuffle=False, drop_last=

    # 5)Model/optim/loss
    model = BiLSTMAttnRec(num_items=num_items, emb_dim=emb_dim, hidden_dim=hidden_dim, d
    opt   = torch.optim.AdamW(model.parameters(), lr=lr, weight_decay=weight_decay)
    crit  = nn.CrossEntropyLoss()

    # 6)Training loop with early stopping on recall@5
    best_val = -1.0
    bad = 0
    save_path = os.path.join(save_dir, f"bilstm_{subject}.pt")
    t2i_path  = os.path.join(save_dir, f"topic2id_{subject}.pkl")
    i2t_path  = os.path.join(save_dir, f"id2topic_{subject}.pkl")

    print(f"[{subject}] Training on {DEVICE} ...")
    for epoch in range(1, epochs+1):
        model.train()
        total_loss = 0.0
        for X, M, y in train_loader:
            X, M, y = X.to(DEVICE), M.to(DEVICE), y.to(DEVICE)
            opt.zero_grad()
            logits = model(X, M)
            loss = crit(logits, y)
            loss.backward()
            nn.utils.clip_grad_norm_(model.parameters(), clip_norm)
            opt.step()
            total_loss += loss.item() * y.size(0)

        train_loss = total_loss / len(train_ds)
        val_metrics = evaluate(model, val_loader, DEVICE, topk=(5,10))
        score = val_metrics["recall@5"]

        print(f"[{subject}] Epoch {epoch:02d}  loss={train_loss:.4f}   "
              f"val@5={val_metrics['recall@5']:.3f}  val@10={val_metrics['recall@10']:.3

        if score > best_val:
            best_val, bad = score, 0
            torch.save(model.state_dict(), save_path)
            with open(t2i_path, "wb") as f: pickle.dump(topic2id, f)
            with open(i2t_path, "wb") as f: pickle.dump(id2topic, f)
        else:
            bad += 1
            if bad >= patience:
                print(f"[{subject}] Early stopping.")
                break
```

```python
    print(f"[{subject}] Best val recall@5 = {best_val:.3f}")
    print(f"[{subject}] Saved model/vocabs to: {save_dir}")

    # 7) demo on a random val history
    if len(val_sess) > 0:
        any_user = next(iter(val_sess))
        hist = val_sess[any_user][-seq_len:]
        print(f"[{subject}] Demo history ({any_user}): {hist}")

        #Reload best
        model.load_state_dict(torch.load(save_path, map_location=DEVICE))
        model.eval()
        ids = [topic2id[t] for t in hist if t in topic2id]
        X = torch.tensor([([0]*(seq_len-len(ids))) + ids[-seq_len:]], dtype=torch.long).
        M = (X != 0).float()
        with torch.no_grad():
            probs = torch.softmax(model(X, M), dim=-1).squeeze(0).cpu().numpy()
        top_idx = np.argsort(probs)[::-1][:8]
        top_names = [id2topic[i] for i in top_idx if i in id2topic][:8]
        print(f"[{subject}] Top-8 next topics: {top_names}")

#CLI
def parse_args():
    ap = argparse.ArgumentParser(description="Train BiLSTM+Attention next-topic model pe
    ap.add_argument("--interactions", type=str, required=True,
                    help="Path to interactions CSV (requires columns: user_id, subject,
    ap.add_argument("--subject", type=str, required=True, choices=["biology","chemistry"
    ap.add_argument("--save_dir", type=str, default="models")
    ap.add_argument("--seq_len", type=int, default=10)
    ap.add_argument("--batch_size", type=int, default=128)
    ap.add_argument("--epochs", type=int, default=12)
    ap.add_argument("--lr", type=float, default=1e-3)
    ap.add_argument("--weight_decay", type=float, default=0.0)
    ap.add_argument("--dropout", type=float, default=0.2)
    ap.add_argument("--hidden_dim", type=int, default=128)
    ap.add_argument("--emb_dim", type=int, default=64)
    ap.add_argument("--val_frac", type=float, default=0.2)
    ap.add_argument("--patience", type=int, default=4)
    return ap.parse_args()

if __name__ == "__main__":
    args = parse_args()
    train_subject(
        interactions=args.interactions,
        subject=args.subject,
        save_dir=args.save_dir,
        seq_len=args.seq_len,
        batch_size=args.batch_size,
        epochs=args.epochs,
        lr=args.lr,
        weight_decay=args.weight_decay,
        dropout=args.dropout,
        hidden_dim=args.hidden_dim,
        emb_dim=args.emb_dim,
        val_frac=args.val_frac,
        patience=args.patience,
    )
```

```
usage: ipykernel_launcher.py [-h] --interactions INTERACTIONS --subject {biology,chemist
ry,business,ict} [--save_dir SAVE_DIR] [--seq_len SEQ_LEN]
                             [--batch_size BATCH_SIZE] [--epochs EPOCHS] [--lr LR] [--we
ight_decay WEIGHT_DECAY] [--dropout DROPOUT]
                             [--hidden_dim HIDDEN_DIM] [--emb_dim EMB_DIM] [--val_frac V
AL_FRAC] [--patience PATIENCE]
```

```
ipykernel_launcher.py: error: the following arguments are required: --interactions, --su
bject
An exception has occurred, use %tb to see the full traceback.

SystemExit: 2

C:\Users\Rizwana\anaconda3\envs\finalproject\lib\site-packages\IPython\core\interactives
hell.py:3587: UserWarning: To exit: use 'exit', 'quit', or Ctrl-D.
  warn("To exit: use 'exit', 'quit', or Ctrl-D.", stacklevel=1)
```

In [10]:

```
# Baseline embedding model per subject (fixed)



import os
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
import torch
import torch.nn as nn
import torch.optim as optim

INTERACTIONS = r"C:\Users\Rizwana\Downloads\interactions2.csv"
SAVE_DIR = "trained_models"
os.makedirs(SAVE_DIR, exist_ok=True)

#Load & sanity
df = pd.read_csv(INTERACTIONS)
required = {"user_id","subject","topic_name"}
missing = required - set(df.columns)
if missing:
    raise ValueError(f"CSV is missing columns: {missing}")

#Optional rating; if absent, assume implicit positive = 1
if "rating" not in df.columns:
    df["rating"] = 1.0

# Normalize subject labels
df["subject"] = df["subject"].str.lower().str.strip()

#Make indices (NO item_id column in csv; we derive from topic_name ----------
df["user_idx"] = df["user_id"].astype("category").cat.codes
df["item_key"] = df["topic_name"].astype(str).str.strip()       #
df["item_idx"] = df["item_key"].astype("category").cat.codes

num_users_total = int(df["user_idx"].nunique())
num_items_total = int(df["item_idx"].nunique())
print(f"Users (global): {num_users_total} | Items (global): {num_items_total}")
print("Subjects:", sorted(df["subject"].unique()))

# Label (binary for BCE)
# If rating is numeric, treat >0 as positive; otherwise cast to float
df["label"] = (df["rating"].astype(float) > 0).astype(np.float32)

#4) Simple embedding model
class TinyRec(nn.Module):
    def __init__(self, num_users, num_items, emb_dim=64):
        super().__init__()
        self.user_emb = nn.Embedding(num_users, emb_dim)
        self.item_emb = nn.Embedding(num_items, emb_dim)
        self.out = nn.Linear(emb_dim * 2, 1)
        self.sigmoid = nn.Sigmoid()
    def forward(self, u_idx, i_idx):
        u = self.user_emb(u_idx)       # (B, d)
        i = self.item_emb(i_idx)       # (B, d)
        x = torch.cat([u, i], dim=1)   # (B, 2d)
```

```
        logit = self.out(x)            # (B, 1)
        return self.sigmoid(logit).squeeze(1)

def train_subject(df_subj, subject, epochs=6, batch_size=256, lr=1e-3):
    if len(df_subj) < 50:
        print(f"  Skipping {subject}: too few rows ({len(df_subj)}).")
        return

    #Random split (quick baseline)
    train_df, test_df = train_test_split(df_subj, test_size=0.2, random_state=42)

    #Tensors
    tr_users = torch.tensor(train_df["user_idx"].values, dtype=torch.long)
    tr_items = torch.tensor(train_df["item_idx"].values, dtype=torch.long)
    tr_y     = torch.tensor(train_df["label"].values,    dtype=torch.float32)

    te_users = torch.tensor(test_df["user_idx"].values, dtype=torch.long)
    te_items = torch.tensor(test_df["item_idx"].values, dtype=torch.long)
    te_y     = test_df["label"].values.astype(np.float32)

    model = TinyRec(num_users_total, num_items_total, emb_dim=64)
    opt = optim.Adam(model.parameters(), lr=lr)
    crit = nn.BCELoss()

    #Simple mini-batching
    def batches(U, I, Y, bs):
        n = len(Y)
        for s in range(0, n, bs):
            e = min(s+bs, n)
            yield U[s:e], I[s:e], Y[s:e]

    for ep in range(1, epochs+1):
        model.train()
        total_loss = 0.0
        for U, I, Y in batches(tr_users, tr_items, tr_y, batch_size):
            opt.zero_grad()
            pred = model(U, I)
            loss = crit(pred, Y)
            loss.backward()
            opt.step()
            total_loss += float(loss.item()) * len(Y)
        avg_loss = total_loss / len(tr_y)
        print(f"[{subject}] epoch {ep:02d}  loss={avg_loss:.4f}")

    #Save
    save_path = os.path.join(SAVE_DIR, f"{subject}_tinyrec.pth")
    torch.save(model.state_dict(), save_path)
    print(f" saved {save_path}")

    # Quick accuracy on test split
    model.eval()
    with torch.no_grad():
        pred = model(te_users, te_items).cpu().numpy()
    acc = ( (pred >= 0.5).astype(np.float32) == te_y ).mean()
    print(f"[{subject}] test accuracy: {acc:.3f}")

#Train per subject
for subj, df_sub in df.groupby("subject"):
    print(f"\n=== Training baseline for subject: {subj} ===")
    train_subject(df_sub, subj, epochs=6, batch_size=256, lr=1e-3)

print("\n Baseline finished. Models stored in:", SAVE_DIR)
```

```
Users (global): 40 | Items (global): 40
Subjects: ['biology', 'business', 'chemistry', 'ict']
```

```
=== Training baseline for subject: biology ===
[biology] epoch 01  loss=0.7961
[biology] epoch 02  loss=0.7800
[biology] epoch 03  loss=0.7641
[biology] epoch 04  loss=0.7485
[biology] epoch 05  loss=0.7332
[biology] epoch 06  loss=0.7181
 saved trained_models\biology_tinyrec.pth
[biology] test accuracy: 0.481

=== Training baseline for subject: business ===
[business] epoch 01  loss=0.7671
[business] epoch 02  loss=0.7505
[business] epoch 03  loss=0.7341
[business] epoch 04  loss=0.7180
[business] epoch 05  loss=0.7022
[business] epoch 06  loss=0.6867
 saved trained_models\business_tinyrec.pth
[business] test accuracy: 0.706

=== Training baseline for subject: chemistry ===
[chemistry] epoch 01  loss=0.8832
[chemistry] epoch 02  loss=0.8657
[chemistry] epoch 03  loss=0.8485
[chemistry] epoch 04  loss=0.8316
[chemistry] epoch 05  loss=0.8150
[chemistry] epoch 06  loss=0.7986
 saved trained_models\chemistry_tinyrec.pth
[chemistry] test accuracy: 0.481

=== Training baseline for subject: ict ===
[ict] epoch 01  loss=0.6427
[ict] epoch 02  loss=0.6286
[ict] epoch 03  loss=0.6148
[ict] epoch 04  loss=0.6012
[ict] epoch 05  loss=0.5879
[ict] epoch 06  loss=0.5748
 saved trained_models\ict_tinyrec.pth
[ict] test accuracy: 0.852

 Baseline finished. Models stored in: trained_models
```

In [2]:

```
#Baseline embedding model per subject (metrics + more epochs)


import os
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.metrics import precision_score, recall_score, f1_score, roc_auc_score, mean
import torch
import torch.nn as nn
import torch.optim as optim

INTERACTIONS = r"C:\Users\Rizwana\Downloads\interactions2.csv"
SAVE_DIR = "trained_models"
EPOCHS = 20
BATCH_SIZE = 256
LR = 1e-3
EMB_DIM = 64
os.makedirs(SAVE_DIR, exist_ok=True)

#Load & sanity
df = pd.read_csv(INTERACTIONS)
required = {"user_id","subject","topic_name"}
```

```python
missing = required - set(df.columns)
if missing:
    raise ValueError(f"CSV is missing columns: {missing}")

#Optional rating
if "rating" not in df.columns:
    df["rating"] = 1.0

#Normalize subject labels
df["subject"] = df["subject"].str.lower().str.strip()

#Indices from columns
df["user_idx"] = df["user_id"].astype("category").cat.codes
df["item_key"] = df["topic_name"].astype(str).str.strip()
df["item_idx"] = df["item_key"].astype("category").cat.codes

num_users_total = int(df["user_idx"].nunique())
num_items_total = int(df["item_idx"].nunique())
print(f"Users (global): {num_users_total} | Items (global): {num_items_total}")
print("Subjects:", sorted(df["subject"].unique()))

#Label (binary)

df["label"] = (df["rating"].astype(float) > 0).astype(np.float32)

#Tiny embedding model
class TinyRec(nn.Module):
    def __init__(self, num_users, num_items, emb_dim=64):
        super().__init__()
        self.user_emb = nn.Embedding(num_users, emb_dim)
        self.item_emb = nn.Embedding(num_items, emb_dim)
        self.out = nn.Linear(emb_dim * 2, 1)
        self.sigmoid = nn.Sigmoid()
    def forward(self, u_idx, i_idx):
        u = self.user_emb(u_idx)      # (B, d)
        i = self.item_emb(i_idx)      # (B, d)
        x = torch.cat([u, i], dim=1)  # (B, 2d)
        logit = self.out(x)           # (B, 1)
        return self.sigmoid(logit).squeeze(1)

def train_subject(df_subj, subject, epochs=EPOCHS, batch_size=BATCH_SIZE, lr=LR):
    if len(df_subj) < 50:
        print(f"  Skipping {subject}: too few rows ({len(df_subj)}).")
        return

    # User-stratified split (keeps users in both sets if possible; ok for baseline)
    train_df, test_df = train_test_split(df_subj, test_size=0.2, random_state=42)

    tr_users = torch.tensor(train_df["user_idx"].values, dtype=torch.long)
    tr_items = torch.tensor(train_df["item_idx"].values, dtype=torch.long)
    tr_y     = torch.tensor(train_df["label"].values,    dtype=torch.float32)

    te_users = torch.tensor(test_df["user_idx"].values, dtype=torch.long)
    te_items = torch.tensor(test_df["item_idx"].values, dtype=torch.long)
    te_y_np  = test_df["label"].values.astype(np.float32)

    model = TinyRec(num_users_total, num_items_total, emb_dim=EMB_DIM)
    opt = optim.Adam(model.parameters(), lr=lr)
    crit = nn.BCELoss()

    def batches(U, I, Y, bs):
        n = len(Y)
        for s in range(0, n, bs):
            e = min(s+bs, n)
            yield U[s:e], I[s:e], Y[s:e]
```

```python
    print(f"\n=== Training baseline for subject: {subject} ===")
    for ep in range(1, epochs+1):
        model.train()
        total_loss = 0.0
        for U, I, Y in batches(tr_users, tr_items, tr_y, batch_size):
            opt.zero_grad()
            pred = model(U, I)
            loss = crit(pred, Y)
            loss.backward()
            opt.step()
            total_loss += float(loss.item()) * len(Y)
        avg_loss = total_loss / len(tr_y)
        if ep % 2 == 0 or ep == 1 or ep == epochs:
            print(f"[{subject}] epoch {ep:02d}  loss={avg_loss:.4f}")

    #Save
    save_path = os.path.join(SAVE_DIR, f"{subject}_tinyrec.pth")
    torch.save(model.state_dict(), save_path)
    print(f" saved {save_path}")

    #Evaluation
    model.eval()
    with torch.no_grad():
        te_pred = model(te_users, te_items).cpu().numpy()
    te_pred_label = (te_pred >= 0.5).astype(np.float32)

    # Metrics
    acc  = accuracy_score(te_y_np, te_pred_label)
    prec = precision_score(te_y_np, te_pred_label, zero_division=0)
    rec  = recall_score(te_y_np, te_pred_label,  zero_division=0)
    f1   = f1_score(te_y_np, te_pred_label,      zero_division=0)
    try:
        auc  = roc_auc_score(te_y_np, te_pred)
    except ValueError:
        auc  = float("nan")
    rmse = np.sqrt(mean_squared_error(te_y_np, te_pred))

    print(f"[{subject}] ACC={acc:.3f}  PREC={prec:.3f}  REC={rec:.3f}  F1={f1:.3f}  AUC=


    return {
        "subject": subject,
        "acc": acc, "precision": prec, "recall": rec, "f1": f1, "auc": auc, "rmse": rmse
    }

#Train & evaluate per subject
all_metrics = []
for subj, df_sub in df.groupby("subject"):
    m = train_subject(df_sub, subj)
    if m: all_metrics.append(m)

print("\n=== Summary ===")
if all_metrics:
    summary = pd.DataFrame(all_metrics).set_index("subject")
    display(summary)
else:
    print("No subjects trained.")
```

```
Users (global): 40 | Items (global): 40
Subjects: ['biology', 'business', 'chemistry', 'ict']

=== Training baseline for subject: biology ===
[biology] epoch 01  loss=0.8069
[biology] epoch 02  loss=0.7895
[biology] epoch 04  loss=0.7556
[biology] epoch 06  loss=0.7229
```

```
[biology] epoch 08  loss=0.6913
[biology] epoch 10  loss=0.6608
[biology] epoch 12  loss=0.6315
[biology] epoch 14  loss=0.6033
[biology] epoch 16  loss=0.5763
[biology] epoch 18  loss=0.5503
[biology] epoch 20  loss=0.5255
 saved trained_models\biology_tinyrec.pth
[biology] ACC=0.788  PREC=1.000  REC=0.788  F1=0.882  AUC=nan  RMSE=0.424

=== Training baseline for subject: business ===
[business] epoch 01  loss=0.7387
[business] epoch 02  loss=0.7205
[business] epoch 04  loss=0.6853
[business] epoch 06  loss=0.6514
[business] epoch 08  loss=0.6189
[business] epoch 10  loss=0.5880
[business] epoch 12  loss=0.5584
[business] epoch 14  loss=0.5303
[business] epoch 16  loss=0.5037
[business] epoch 18  loss=0.4783
[business] epoch 20  loss=0.4544
 saved trained_models\business_tinyrec.pth
[business] ACC=0.784  PREC=1.000  REC=0.784  F1=0.879  AUC=nan  RMSE=0.411

=== Training baseline for subject: chemistry ===
[chemistry] epoch 01  loss=0.7452
[chemistry] epoch 02  loss=0.7297
[chemistry] epoch 04  loss=0.6995
[chemistry] epoch 06  loss=0.6702
[chemistry] epoch 08  loss=0.6420
[chemistry] epoch 10  loss=0.6147
[chemistry] epoch 12  loss=0.5883
[chemistry] epoch 14  loss=0.5630
[chemistry] epoch 16  loss=0.5387
[chemistry] epoch 18  loss=0.5153
[chemistry] epoch 20  loss=0.4928
 saved trained_models\chemistry_tinyrec.pth
[chemistry] ACC=0.907  PREC=1.000  REC=0.907  F1=0.951  AUC=nan  RMSE=0.397

=== Training baseline for subject: ict ===
[ict] epoch 01  loss=0.7704
[ict] epoch 02  loss=0.7539
[ict] epoch 04  loss=0.7217
[ict] epoch 06  loss=0.6906
[ict] epoch 08  loss=0.6607
[ict] epoch 10  loss=0.6320
[ict] epoch 12  loss=0.6044
[ict] epoch 14  loss=0.5779
[ict] epoch 16  loss=0.5525
[ict] epoch 18  loss=0.5282
[ict] epoch 20  loss=0.5050
 saved trained_models\ict_tinyrec.pth
[ict] ACC=0.852  PREC=1.000  REC=0.852  F1=0.920  AUC=nan  RMSE=0.395

=== Summary ===
```

	acc	precision	recall	f1	auc	rmse
subject						
biology	0.788462	1.0	0.788462	0.881720	NaN	0.424377
business	0.784314	1.0	0.784314	0.879121	NaN	0.410583
chemistry	0.907407	1.0	0.907407	0.951456	NaN	0.397006

ict	0.851852	1.0	0.851852	0.920000	NaN	0.395435

In [6]:

```
#Baseline embedding model per subject


import os
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.metrics import (
    precision_score, recall_score, f1_score,
    roc_auc_score, mean_squared_error, accuracy_score
)
import torch
import torch.nn as nn
import torch.optim as optim

INTERACTIONS = r"C:\Users\Rizwana\Desktop\studyoclock project\interactions_real.csv"
SAVE_DIR = "trained_models"
EPOCHS = 20
BATCH_SIZE = 256
LR = 1e-3
EMB_DIM = 64
os.makedirs(SAVE_DIR, exist_ok=True)

#Loading and error handling
df = pd.read_csv(INTERACTIONS)
required = {"user_id","subject","topic_name"}
missing = required - set(df.columns)
if missing:
    raise ValueError(f"CSV is missing columns: {missing}")

if "rating" not in df.columns:
    df["rating"] = 1.0

df["subject"]  = df["subject"].str.lower().str.strip()
df["user_idx"] = df["user_id"].astype("category").cat.codes
df["item_key"] = df["topic_name"].astype(str).str.strip()
df["item_idx"] = df["item_key"].astype("category").cat.codes
df["label"]    = (df["rating"].astype(float) > 0).astype(np.float32)

num_users_total = int(df["user_idx"].nunique())
num_items_total = int(df["item_idx"].nunique())
print(f"Users={num_users_total}  Items={num_items_total}  Subjects={sorted(df['subject']

#Model
class TinyRec(nn.Module):
    def __init__(self, num_users, num_items, emb_dim=64):
        super().__init__()
        self.user_emb = nn.Embedding(num_users, emb_dim)
        self.item_emb = nn.Embedding(num_items, emb_dim)
        self.out = nn.Linear(emb_dim * 2, 1)
        self.sigmoid = nn.Sigmoid()
    def forward(self, u_idx, i_idx):
        u = self.user_emb(u_idx)
        i = self.item_emb(i_idx)
        x = torch.cat([u, i], dim=1)
        return self.sigmoid(self.out(x)).squeeze(1)

def train_subject(df_subj, subject, epochs=EPOCHS, batch_size=BATCH_SIZE, lr=LR):
    if len(df_subj) < 50:
        print(f"  Skipping {subject}: too few rows ({len(df_subj)}).")
        return
```

```
#Class distribution
y_all = df_subj["label"].values
pos = int((y_all == 1).sum()); neg = int((y_all == 0).sum())
print(f"\n=== {subject.upper()} ===  class dist -> pos={pos}  neg={neg}")

# Stratify only when both classes present
can_stratify = (pos > 0) and (neg > 0)
if can_stratify:
    train_df, test_df = train_test_split(
        df_subj, test_size=0.2, random_state=42, stratify=df_subj["label"]
    )
else:
    print("Only one class present. Using non-stratified split; AUC will be NaN.")
    train_df, test_df = train_test_split(df_subj, test_size=0.2, random_state=42)

tr_users = torch.tensor(train_df["user_idx"].values, dtype=torch.long)
tr_items = torch.tensor(train_df["item_idx"].values, dtype=torch.long)
tr_y     = torch.tensor(train_df["label"].values,    dtype=torch.float32)

te_users = torch.tensor(test_df["user_idx"].values, dtype=torch.long)
te_items = torch.tensor(test_df["item_idx"].values, dtype=torch.long)
te_y_np  = test_df["label"].values.astype(np.float32)

model = TinyRec(num_users_total, num_items_total, emb_dim=EMB_DIM)
opt = torch.optim.Adam(model.parameters(), lr=lr)
crit = nn.BCELoss()

def batches(U, I, Y, bs):
    n = len(Y)
    for s in range(0, n, bs):
        e = min(s+bs, n)
        yield U[s:e], I[s:e], Y[s:e]

for ep in range(1, epochs+1):
    model.train()
    total = 0.0
    for U, I, Y in batches(tr_users, tr_items, tr_y, batch_size):
        opt.zero_grad()
        pred = model(U, I)
        loss = crit(pred, Y)
        loss.backward()
        nn.utils.clip_grad_norm_(model.parameters(), 1.0)
        opt.step()
        total += float(loss.item()) * len(Y)
    if ep in {1,2,5,10,15,epochs}:
        print(f"[{subject}] epoch {ep:02d}  loss={total/len(tr_y):.4f}")

path = os.path.join(SAVE_DIR, f"{subject}_tinyrec.pth")
torch.save(model.state_dict(), path)
print(f" saved {path}")

#Evaluation
model.eval()
with torch.no_grad():
    te_prob = model(te_users, te_items).cpu().numpy()
te_pred = (te_prob >= 0.5).astype(np.float32)

acc  = accuracy_score(te_y_np, te_pred)
prec = precision_score(te_y_np, te_pred, zero_division=0)
rec  = recall_score(te_y_np, te_pred,  zero_division=0)
f1   = f1_score(te_y_np, te_pred,      zero_division=0)
# AUC safe
try:
    auc = roc_auc_score(te_y_np, te_prob) if can_stratify else float("nan")
except ValueError:
    auc = float("nan")
```

```python
    rmse = np.sqrt(mean_squared_error(te_y_np, te_prob))

    print(f"[{subject}] ACC={acc:.3f}  PREC={prec:.3f}  REC={rec:.3f}  F1={f1:.3f}  AUC=
    return {"subject":subject, "acc":acc, "precision":prec, "recall":rec, "f1":f1, "auc"

#Train/Eval per subject
all_metrics = []
for subj, df_sub in df.groupby("subject"):
    m = train_subject(df_sub, subj)
    if m: all_metrics.append(m)

print("\n=== Summary ===")
if all_metrics:
    display(pd.DataFrame(all_metrics).set_index("subject"))
else:
    print("No subjects trained.")
```

```
Users=20  Items=73  Subjects=['biology', 'business', 'chemistry', 'ict']

=== BIOLOGY ===  class dist -> pos=84  neg=0
Only one class present. Using non-stratified split; AUC will be NaN.
[biology] epoch 01  loss=0.7189
[biology] epoch 02  loss=0.7028
[biology] epoch 05  loss=0.6559
[biology] epoch 10  loss=0.5834
[biology] epoch 15  loss=0.5174
[biology] epoch 20  loss=0.4574
 saved trained_models\biology_tinyrec.pth
[biology] ACC=0.765  PREC=1.000  REC=0.765  F1=0.867  AUC=nan  RMSE=0.371

=== BUSINESS ===  class dist -> pos=108  neg=0
Only one class present. Using non-stratified split; AUC will be NaN.
[business] epoch 01  loss=0.7038
[business] epoch 02  loss=0.6901
[business] epoch 05  loss=0.6503
[business] epoch 10  loss=0.5878
[business] epoch 15  loss=0.5301
[business] epoch 20  loss=0.4767
 saved trained_models\business_tinyrec.pth
[business] ACC=0.773  PREC=1.000  REC=0.773  F1=0.872  AUC=nan  RMSE=0.440

=== CHEMISTRY ===  class dist -> pos=68  neg=0
Only one class present. Using non-stratified split; AUC will be NaN.
[chemistry] epoch 01  loss=0.6069
[chemistry] epoch 02  loss=0.5921
[chemistry] epoch 05  loss=0.5493
[chemistry] epoch 10  loss=0.4836
[chemistry] epoch 15  loss=0.4244
[chemistry] epoch 20  loss=0.3714
 saved trained_models\chemistry_tinyrec.pth
[chemistry] ACC=0.857  PREC=1.000  REC=0.857  F1=0.923  AUC=nan  RMSE=0.347
  Skipping ict: too few rows (40).

=== Summary ===
```

	acc	precision	recall	f1	auc	rmse
subject						
biology	0.764706	1.0	0.764706	0.866667	NaN	0.370679
business	0.772727	1.0	0.772727	0.871795	NaN	0.439777
chemistry	0.857143	1.0	0.857143	0.923077	NaN	0.346535

In [3]:

```python
import pandas as pd
```

```
from sklearn.model_selection import train_test_split
from sklearn.feature_extraction.text import TfidfVectorizer
import numpy as np
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Embedding, LSTM, Bidirectional, Dense, Dropout


df = pd.read_csv(r"C:\Users\Rizwana\Desktop\studyoclock project\interactions_real.csv")
print(df.head())


#Create features (X) and labels (y)


df["X"] = df["subject"] + " " + df["topic_name"]

#Use ratings as the label
df["y"] = df["rating"]

print(df[["X", "y"]].head())


#Convert text into numerical vectors (TF-IDF)

vectorizer = TfidfVectorizer(max_features=5000)  # limit to 5000 words
X = vectorizer.fit_transform(df["X"]).toarray()
y = df["y"].values


#Train/test split

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42


#Build a BiLSTM model

X_train_seq = np.expand_dims(X_train, axis=-1)
X_test_seq = np.expand_dims(X_test, axis=-1)

model = Sequential()
model.add(Bidirectional(LSTM(64, return_sequences=False), input_shape=(X_train_seq.shape
model.add(Dropout(0.3))
model.add(Dense(64, activation="relu"))
model.add(Dense(1, activation="linear"))  # regression (predict rating)

model.compile(optimizer="adam", loss="mse", metrics=["mae"])
model.summary()


#Train model

history = model.fit(
    X_train_seq, y_train,
    validation_data=(X_test_seq, y_test),
    epochs=5,
    batch_size=16
)


#Evaluate

loss, mae = model.evaluate(X_test_seq, y_test)
print(f"Test Loss: {loss}, Test MAE: {mae}")
```

```
  user_id   subject                                   topic_name   rating    timestamp
```

```
0  user_1       ICT          Unit 8 Safety and Security      4  1755302429
1  user_1  Business        Chapter 16 Marketing Strategy      3  1755269216
2  user_1  Business         Chapter 13 The Marketing Mix      1  1755422586
3  user_1   Biology  Unit 3 Movement in and out of cells      2  1755636804
4  user_1  Business         Chapter 23 Income Statements      4  1755710187
                                          X  y
0                ICT Unit 8 Safety and Security  4
1       Business Chapter 16 Marketing Strategy  3
2        Business Chapter 13 The Marketing Mix  1
3  Biology Unit 3 Movement in and out of cells  2
4        Business Chapter 23 Income Statements  4
```

```
C:\Users\Rizwana\anaconda3\envs\finalproject\lib\site-packages\keras\src\layers\rnn\bidirectional.py:107: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(**kwargs)
```

Model: "sequential"

Layer (type)	Output Shape	Param #
bidirectional (Bidirectional)	(None, 128)	33,792
dropout (Dropout)	(None, 128)	0
dense (Dense)	(None, 64)	8,256
dense_1 (Dense)	(None, 1)	65

Total params: 42,113 (164.50 KB)

Trainable params: 42,113 (164.50 KB)

Non-trainable params: 0 (0.00 B)

```
Epoch 1/5
15/15 ━━━━━━━━━━━━━━━━━━━━ 5s 82ms/step - loss: 8.8850 - mae: 2.6274 - val_loss: 2.2944 - val_mae: 1.3195
Epoch 2/5
15/15 ━━━━━━━━━━━━━━━━━━━━ 1s 37ms/step - loss: 2.8568 - mae: 1.3537 - val_loss: 1.9257 - val_mae: 1.1520
Epoch 3/5
15/15 ━━━━━━━━━━━━━━━━━━━━ 1s 40ms/step - loss: 2.1027 - mae: 1.2435 - val_loss: 1.9708 - val_mae: 1.2237
Epoch 4/5
15/15 ━━━━━━━━━━━━━━━━━━━━ 1s 39ms/step - loss: 2.0667 - mae: 1.2387 - val_loss: 1.7530 - val_mae: 1.1331
Epoch 5/5
15/15 ━━━━━━━━━━━━━━━━━━━━ 1s 37ms/step - loss: 1.9379 - mae: 1.2050 - val_loss: 1.9385 - val_mae: 1.2111
2/2 ━━━━━━━━━━━━━━━━━━━━ 0s 49ms/step - loss: 1.9385 - mae: 1.2111
Test Loss: 1.938524842262268, Test MAE: 1.2111347913742065
```

In [6]:

```python
import joblib

#save model in  .keras format
model.save("bilstm_model.keras")

#save TF-IDF vectorizer separately
joblib.dump(vectorizer, "tfidf_vectorizer.pkl")

print("Model and vectorizer saved successfully")
```

```
Model and vectorizer saved successfully!
```

In [7]:

```python
import tensorflow as tf
```

```
import joblib

#load model
model = tf.keras.models.load_model("bilstm_model.keras")

#load vectorizer
vectorizer = joblib.load("tfidf_vectorizer.pkl")

print("Model and vectorizer reloaded successfully")
```

```
Model and vectorizer reloaded successfully
C:\Users\Rizwana\anaconda3\envs\finalproject\lib\site-packages\keras\src\saving\saving_l
ib.py:797: UserWarning: Skipping variable loading for optimizer 'rmsprop', because it ha
s 12 variables whereas the saved optimizer has 22 variables.
  saveable.load_own_variables(weights_store.get(inner_path))
```

In [11]:

```
import numpy as np
import pandas as pd
import joblib
from tensorflow.keras.models import load_model

#Load model + vectorizer
model = load_model("bilstm_model.keras")
vectorizer = joblib.load("tfidf_vectorizer.pkl")

#Reload dataset
df = pd.read_csv(r"C:\Users\Rizwana\Desktop\studyoclock project\interactions_real.csv")
all_topics = df['topic_name'].unique()

def predict_for_user(model, user_id, all_topics, interactions, vectorizer, k=5):
    # Topics user has already interacted with
    seen_topics = interactions[interactions['user_id'] == user_id]['topic_name'].unique(
    candidate_topics = [t for t in all_topics if t not in seen_topics]

    preds = []
    for topic in candidate_topics:
        #Recreate "subject topic_name"
        subject = interactions[interactions['topic_name'] == topic]['subject'].values[0]
        text = subject + " " + topic

        #Vectorize
        X_vec = vectorizer.transform([text]).toarray()
        X_seq = np.expand_dims(X_vec, axis=-1)

        #Predict
        score = model.predict(X_seq, verbose=0)[0][0]
        preds.append((topic, score))

    # Return top-K
    results = pd.DataFrame(preds, columns=["topic_name", "predicted_score"])
    return results.sort_values("predicted_score", ascending=False).head(k)

#Example: Top-5 recs for user_1
top_k_for_user1 = predict_for_user(model, "user_1", all_topics, df, vectorizer, k=5)
print("Top-K Recommendations for user_1:")
print(top_k_for_user1)
```

```
Top-K Recommendations for user_1:
                          topic_name  predicted_score
31             Unit 15 Air and Water         3.267026
51  Unit 18 Variation and selection          3.255251
25                Unit 12 Respiration         3.246816
3                       Unit 15 Drugs         3.246668
4                   Unit 13 Excretion         3.246009
```

In [12]:

```
import numpy as np
```

```python
import pandas as pd


#Prediction function

def predict_for_user(model, user_id, all_topics, interactions, vectorizer, k=5):
    # Topics already seen by the user
    seen_topics = interactions[interactions['user_id'] == user_id]['topic_name'].unique(
    candidate_topics = [t for t in all_topics if t not in seen_topics]

    preds = []
    for topic in candidate_topics:
        #Combine subject + topic
        subject = interactions[interactions['topic_name'] == topic]['subject'].values[0]
        text = subject + " " + topic

        #Vectorize + reshape for LSTM
        X_vec = vectorizer.transform([text]).toarray()
        X_seq = np.expand_dims(X_vec, axis=-1)

        #Predict score
        score = model.predict(X_seq, verbose=0)[0][0]
        preds.append((topic, score))

    #Return top-K predictions
    results = pd.DataFrame(preds, columns=["topic_name", "predicted_score"])
    return results.sort_values("predicted_score", ascending=False).head(k)


#Generate Top-K for multiple users

unique_users = df["user_id"].unique()
print("Available Users:", unique_users)

#Pick first 5 users
sample_users = unique_users[:5]

all_topics = df['topic_name'].unique()

recommendations = {}  # store results for all users

for user in sample_users:
    top_k = predict_for_user(model, user, all_topics, df, vectorizer, k=5)
    recommendations[user] = top_k

    print(f"\nTop-5 Recommendations for {user}:")
    print(top_k)


#Combine into one DataFrame
all_recs = []
for user, recs in recommendations.items():
    temp = recs.copy()
    temp.insert(0, "user_id", user)
    all_recs.append(temp)

all_recs_df = pd.concat(all_recs, ignore_index=True)
all_recs_df.to_csv("user_recommendations.csv", index=False)
print("\nSaved recommendations for multiple users to user_recommendations.csv")
```

```
Available Users: ['user_1' 'user_2' 'user_3' 'user_4' 'user_5' 'user_6' 'user_7' 'user_
8'
 'user_9' 'user_10' 'user_11' 'user_12' 'user_13' 'user_14' 'user_15'
 'user_16' 'user_17' 'user_18' 'user_19' 'user_20']

Top-5 Recommendations for user_1:
```

```
                            topic_name  predicted_score
31             Unit 15 Air and Water         3.267026
51  Unit 18 Variation and selection         3.255251
25               Unit 12 Respiration         3.246816
3                      Unit 15 Drugs         3.246668
4                  Unit 13 Excretion         3.246009

Top-5 Recommendations for user_2:
                                     topic_name  predicted_score
31                        Unit 15 Air and Water         3.267026
51              Unit 18 Variation and selection         3.255251
25                          Unit 12 Respiration         3.246816
24  Unit 18 The Variety of Organic Chemicals         3.244677
22                    Unit 12 The Periodic Table         3.243503

Top-5 Recommendations for user_3:
                            topic_name  predicted_score
31             Unit 15 Air and Water         3.267026
51  Unit 18 Variation and selection         3.255251
25               Unit 12 Respiration         3.246816
16                     Unit 15 Drugs         3.246668
17                 Unit 13 Excretion         3.246009

Top-5 Recommendations for user_4:
                                topic_name  predicted_score
31                 Unit 15 Air and Water         3.267026
51       Unit 18 Variation and selection         3.255251
14                         Unit 15 Drugs         3.246668
15                     Unit 13 Excretion         3.246009
53  Chapter 25 Analysis of Accountants         3.241866

Top-5 Recommendations for user_5:
                                topic_name  predicted_score
51       Unit 18 Variation and selection         3.255251
31                   Unit 12 Respiration         3.246816
14                     Unit 13 Excretion         3.246009
29            Unit 12 The Periodic Table         3.243503
53  Chapter 25 Analysis of Accountants         3.241866

Saved recommendations for multiple users to user_recommendations.csv
```

In [17]:

```python
import pandas as pd
import numpy as np
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.metrics.pairwise import cosine_similarity

from surprise import SVD, Dataset, Reader
from surprise.model_selection import train_test_split
from surprise import accuracy


df = pd.read_csv(r"C:\Users\Rizwana\Desktop\studyoclock project\interactions_real.csv")


#Collaborative Filtering (SVD)

print("Collaborative Filtering (SVD) Evaluation")

#Encode IDs
df["user_id_encoded"] = df["user_id"].astype("category").cat.codes
df["topic_id_encoded"] = df["topic_name"].astype("category").cat.codes

# Surprise Dataset
reader = Reader(rating_scale=(1, 5))
data = Dataset.load_from_df(df[["user_id_encoded", "topic_id_encoded", "rating"]], reade
```

```python
#Train/test split
trainset, testset = train_test_split(data, test_size=0.2, random_state=42)

#Train model
algo = SVD()
algo.fit(trainset)

#Predict
predictions = algo.test(testset)

#Evaluate
print("RMSE:", accuracy.rmse(predictions))
print("MAE:", accuracy.mae(predictions))



#3. Content-Based (TF-IDF + Cosine)

print("Content-Based Similarity Analysis")

subject_similarity = {}
subject_tables = {}

for subject in df["subject"].unique():
    subj_df = df[df["subject"] == subject]

    # Use summary_text if available, else topic_name
    if "summary_text" in subj_df.columns:
        texts = subj_df["summary_text"].astype(str).tolist()
    else:
        texts = subj_df["topic_name"].astype(str).tolist()

    topics = subj_df["topic_name"].tolist()

    # Local vectorizer per subject
    vectorizer = TfidfVectorizer()
    tfidf_matrix = vectorizer.fit_transform(texts)

    # Cosine similarity
    sim_matrix = cosine_similarity(tfidf_matrix)

    # Store as DataFrame
    df_sim = pd.DataFrame(sim_matrix, index=topics, columns=topics)
    subject_similarity[subject] = sim_matrix
    subject_tables[subject] = df_sim

    print(f"\n--- Similarity Table for {subject.upper()} ---")
    print(df_sim.head())   # show only first few rows to avoid too much output

    # Save CSV
    filename = f"{subject}_similarity_matrix.csv"
    df_sim.to_csv(filename)
    print(f"Saved {filename}")
```

```
Collaborative Filtering (SVD) Evaluation
RMSE: 1.4161
RMSE: 1.416146255187813
MAE:  1.2351
MAE: 1.2350898227967984
Content-Based Similarity Analysis

--- Similarity Table for ICT ---
                                 Unit 8 Safety and Security  \
Unit 8 Safety and Security                         1.000000
Unit 2 Input and Output Devices                    0.151798
```

```
Unit 8 Safety and Security                          1.000000
Unit 5 The effects of using ICT                     0.044965
Unit 5 The effects of using ICT                     0.044965

                                  Unit 2 Input and Output Devices  \
Unit 8 Safety and Security                               0.151798
Unit 2 Input and Output Devices                          1.000000
Unit 8 Safety and Security                               0.151798
Unit 5 The effects of using ICT                          0.038578
Unit 5 The effects of using ICT                          0.038578

                                  Unit 8 Safety and Security  \
Unit 8 Safety and Security                          1.000000
Unit 2 Input and Output Devices                     0.151798
Unit 8 Safety and Security                          1.000000
Unit 5 The effects of using ICT                     0.044965
Unit 5 The effects of using ICT                     0.044965

                                  Unit 5 The effects of using ICT  \
Unit 8 Safety and Security                               0.044965
Unit 2 Input and Output Devices                          0.038578
Unit 8 Safety and Security                               0.044965
Unit 5 The effects of using ICT                          1.000000
Unit 5 The effects of using ICT                          1.000000

                                  Unit 5 The effects of using ICT  \
Unit 8 Safety and Security                               0.044965
Unit 2 Input and Output Devices                          0.038578
Unit 8 Safety and Security                               0.044965
Unit 5 The effects of using ICT                          1.000000
Unit 5 The effects of using ICT                          1.000000

                                  Unit 2 Input and Output Devices  \
Unit 8 Safety and Security                               0.151798
Unit 2 Input and Output Devices                          1.000000
Unit 8 Safety and Security                               0.151798
Unit 5 The effects of using ICT                          0.038578
Unit 5 The effects of using ICT                          0.038578

                                  Unit 7 Systems Analysis and Design  \
Unit 8 Safety and Security                                  0.135774
Unit 2 Input and Output Devices                             0.116487
Unit 8 Safety and Security                                  0.135774
Unit 5 The effects of using ICT                             0.034505
Unit 5 The effects of using ICT                             0.034505

                                  Unit 2 Input and Output Devices  \
Unit 8 Safety and Security                               0.151798
Unit 2 Input and Output Devices                          1.000000
Unit 8 Safety and Security                               0.151798
Unit 5 The effects of using ICT                          0.038578
Unit 5 The effects of using ICT                          0.038578

                                  Unit 7 Systems Analysis and Design  \
Unit 8 Safety and Security                                  0.135774
Unit 2 Input and Output Devices                             0.116487
Unit 8 Safety and Security                                  0.135774
Unit 5 The effects of using ICT                             0.034505
Unit 5 The effects of using ICT                             0.034505

                                  Unit 8 Safety and Security  ...  \
Unit 8 Safety and Security                          1.000000  ...
Unit 2 Input and Output Devices                     0.151798  ...
Unit 8 Safety and Security                          1.000000  ...
Unit 5 The effects of using ICT                     0.044965  ...
Unit 5 The effects of using ICT                     0.044965  ...
```

```
                                 Unit 7 Systems Analysis and Design  \
Unit 8 Safety and Security                                 0.135774
Unit 2 Input and Output Devices                            0.116487
Unit 8 Safety and Security                                 0.135774
Unit 5 The effects of using ICT                            0.034505
Unit 5 The effects of using ICT                            0.034505

                                 Unit 6 ICT Applications  \
Unit 8 Safety and Security                      0.064541
Unit 2 Input and Output Devices                 0.055373
Unit 8 Safety and Security                      0.064541
Unit 5 The effects of using ICT                 0.266438
Unit 5 The effects of using ICT                 0.266438

                                 Unit 7 Systems Analysis and Design  \
Unit 8 Safety and Security                                 0.135774
Unit 2 Input and Output Devices                            0.116487
Unit 8 Safety and Security                                 0.135774
Unit 5 The effects of using ICT                            0.034505
Unit 5 The effects of using ICT                            0.034505

                                 Unit 3 Storage Devices and Media  \
Unit 8 Safety and Security                               0.146816
Unit 2 Input and Output Devices                          0.325087
Unit 8 Safety and Security                               0.146816
Unit 5 The effects of using ICT                          0.037312
Unit 5 The effects of using ICT                          0.037312

                                 Unit 8 Safety and Security  \
Unit 8 Safety and Security                         1.000000
Unit 2 Input and Output Devices                    0.151798
Unit 8 Safety and Security                         1.000000
Unit 5 The effects of using ICT                    0.044965
Unit 5 The effects of using ICT                    0.044965

                                 Unit 6 ICT Applications  \
Unit 8 Safety and Security                      0.064541
Unit 2 Input and Output Devices                 0.055373
Unit 8 Safety and Security                      0.064541
Unit 5 The effects of using ICT                 0.266438
Unit 5 The effects of using ICT                 0.266438

                                 Unit 2 Input and Output Devices  \
Unit 8 Safety and Security                              0.151798
Unit 2 Input and Output Devices                         1.000000
Unit 8 Safety and Security                              0.151798
Unit 5 The effects of using ICT                         0.038578
Unit 5 The effects of using ICT                         0.038578

                                 Unit 3 Storage Devices and Media  \
Unit 8 Safety and Security                               0.146816
Unit 2 Input and Output Devices                          0.325087
Unit 8 Safety and Security                               0.146816
Unit 5 The effects of using ICT                          0.037312
Unit 5 The effects of using ICT                          0.037312

                                 Unit 8 Safety and Security  \
Unit 8 Safety and Security                         1.000000
Unit 2 Input and Output Devices                    0.151798
Unit 8 Safety and Security                         1.000000
Unit 5 The effects of using ICT                    0.044965
Unit 5 The effects of using ICT                    0.044965

                                 Unit 5 The effects of using ICT
Unit 8 Safety and Security                              0.044965
```

```
Unit 2 Input and Output Devices                          0.038578
Unit 8 Safety and Security                               0.044965
Unit 5 The effects of using ICT                          1.000000
Unit 5 The effects of using ICT                          1.000000

[5 rows x 40 columns]
Saved ICT_similarity_matrix.csv

--- Similarity Table for BUSINESS ---
                                                  Chapter 16 Marketing Strategy  \
Chapter 16 Marketing Strategy                                          1.000000
Chapter 13 The Marketing Mix                                           0.197224
Chapter 23 Income Statements                                           0.023768
Chapter 20 Location Decisions                                          0.019459
Chapter 21 Business Finance - Needs and Sources                        0.017816

                                                  Chapter 13 The Marketing Mix  \
Chapter 16 Marketing Strategy                                         0.197224
Chapter 13 The Marketing Mix                                          1.000000
Chapter 23 Income Statements                                          0.024814
Chapter 20 Location Decisions                                         0.020315
Chapter 21 Business Finance - Needs and Sources                       0.018600

                                                  Chapter 23 Income Statements  \
Chapter 16 Marketing Strategy                                         0.023768
Chapter 13 The Marketing Mix                                          0.024814
Chapter 23 Income Statements                                          1.000000
Chapter 20 Location Decisions                                         0.019002
Chapter 21 Business Finance - Needs and Sources                       0.017398

                                                  Chapter 20 Location Decisions  \
Chapter 16 Marketing Strategy                                          0.019459
Chapter 13 The Marketing Mix                                           0.020315
Chapter 23 Income Statements                                           0.019002
Chapter 20 Location Decisions                                          1.000000
Chapter 21 Business Finance - Needs and Sources                        0.014243

                                                  Chapter 21 Business Finance - Needs and
Sources  \
Chapter 16 Marketing Strategy
0.017816
Chapter 13 The Marketing Mix
0.018600
Chapter 23 Income Statements
0.017398
Chapter 20 Location Decisions
0.014243
Chapter 21 Business Finance - Needs and Sources
1.000000

                                                  Chapter 7 Organisation and management
\
Chapter 16 Marketing Strategy                                                  0.026311

Chapter 13 The Marketing Mix                                                   0.027468

Chapter 23 Income Statements                                                   0.025693

Chapter 20 Location Decisions                                                  0.021035

Chapter 21 Business Finance - Needs and Sources                                0.086080


                                                  Chapter 10 Marketing, Competition and t
he Customer  \
Chapter 16 Marketing Strategy
```

```
  0.140918
Chapter 13 The Marketing Mix
  0.279909
Chapter 23 Income Statements
  0.017730
Chapter 20 Location Decisions
  0.014515
Chapter 21 Business Finance - Needs and Sources
  0.059400

                                                  Chapter 24 Balance Sheets  \
Chapter 16 Marketing Strategy                                      0.023768
Chapter 13 The Marketing Mix                                       0.024814
Chapter 23 Income Statements                                       0.023210
Chapter 20 Location Decisions                                      0.019002
Chapter 21 Business Finance - Needs and Sources                    0.017398

                                                  Chapter 23 Income Statements  \
Chapter 16 Marketing Strategy                                         0.023768
Chapter 13 The Marketing Mix                                          0.024814
Chapter 23 Income Statements                                          1.000000
Chapter 20 Location Decisions                                         0.019002
Chapter 21 Business Finance - Needs and Sources                       0.017398

                                                  Chapter 8 Recruitment, Selection and Tr
aining  \
Chapter 16 Marketing Strategy                                                        0.
023625
Chapter 13 The Marketing Mix                                                         0.
024665
Chapter 23 Income Statements                                                         0.
023071
Chapter 20 Location Decisions                                                        0.
018888
Chapter 21 Business Finance - Needs and Sources                                      0.
077294

                                                  ...  \
Chapter 16 Marketing Strategy                     ...
Chapter 13 The Marketing Mix                      ...
Chapter 23 Income Statements                      ...
Chapter 20 Location Decisions                     ...
Chapter 21 Business Finance - Needs and Sources   ...

                                                  Chapter 10 Marketing, Competition and t
he Customer  \
Chapter 16 Marketing Strategy
  0.140918
Chapter 13 The Marketing Mix
  0.279909
Chapter 23 Income Statements
  0.017730
Chapter 20 Location Decisions
  0.014515
Chapter 21 Business Finance - Needs and Sources
  0.059400

                                                  Chapter 23 Income Statements  \
Chapter 16 Marketing Strategy                                         0.023768
Chapter 13 The Marketing Mix                                          0.024814
Chapter 23 Income Statements                                          1.000000
Chapter 20 Location Decisions                                         0.019002
Chapter 21 Business Finance - Needs and Sources                       0.017398

                                                  Chapter 22 Cash flow forecasting and wo
rking capital  \
```

```
Chapter 16 Marketing Strategy
  0.013629
Chapter 13 The Marketing Mix
  0.014229
Chapter 23 Income Statements
  0.013309
Chapter 20 Location Decisions
  0.010896
Chapter 21 Business Finance - Needs and Sources
  0.044590

                                                Chapter 17 Production of Goods and Serv
ices  \
Chapter 16 Marketing Strategy                                                      0.01
9604
Chapter 13 The Marketing Mix                                                       0.02
0466
Chapter 23 Income Statements                                                       0.01
9143
Chapter 20 Location Decisions                                                      0.01
5673
Chapter 21 Business Finance - Needs and Sources                                    0.06
4136

                                                Chapter 8 Recruitment, Selection and Tr
aining  \
Chapter 16 Marketing Strategy                                                        0.
023625
Chapter 13 The Marketing Mix                                                         0.
024665
Chapter 23 Income Statements                                                         0.
023071
Chapter 20 Location Decisions                                                        0.
018888
Chapter 21 Business Finance - Needs and Sources                                      0.
077294

                                                Chapter 17 Production of Goods and Serv
ices  \
Chapter 16 Marketing Strategy                                                      0.01
9604
Chapter 13 The Marketing Mix                                                       0.02
0466
Chapter 23 Income Statements                                                       0.01
9143
Chapter 20 Location Decisions                                                      0.01
5673
Chapter 21 Business Finance - Needs and Sources                                    0.06
4136

                                                Chapter 4 Types of Business Organisatio
n  \
Chapter 16 Marketing Strategy                                                   0.02235
7
Chapter 13 The Marketing Mix                                                    0.02334
1
Chapter 23 Income Statements                                                    0.02183
3
Chapter 20 Location Decisions                                                   0.01787
4
Chapter 21 Business Finance - Needs and Sources                                 0.10744
6

                                                Chapter 16 Marketing Strategy  \
Chapter 16 Marketing Strategy                                        1.000000
Chapter 13 The Marketing Mix                                         0.197224
```

```
Chapter 23 Income Statements                                              0.023768
Chapter 20 Location Decisions                                             0.019459
Chapter 21 Business Finance - Needs and Sources                           0.017816

                                                 Chapter 28 Business and the Internation
al Economy  \
Chapter 16 Marketing Strategy
  0.018305
Chapter 13 The Marketing Mix
  0.152989
Chapter 23 Income Statements
  0.017875
Chapter 20 Location Decisions
  0.014634
Chapter 21 Business Finance - Needs and Sources
  0.134458

                                                 Chapter 25 Analysis of Accountants
Chapter 16 Marketing Strategy                                                 0.021304
Chapter 13 The Marketing Mix                                                  0.022242
Chapter 23 Income Statements                                                  0.020804
Chapter 20 Location Decisions                                                 0.017032
Chapter 21 Business Finance - Needs and Sources                               0.015594

[5 rows x 108 columns]
Saved Business_similarity_matrix.csv

--- Similarity Table for BIOLOGY ---
                                     Unit 3 Movement in and out of cells  \
Unit 3 Movement in and out of cells                             1.000000
Unit 7 Animal Nutrition                                         0.021557
Unit 8 Plant Transport                                          0.026379
Unit 17 Inheritance                                             0.024619
Unit 2 Cells                                                    0.421808

                                     Unit 7 Animal Nutrition  \
Unit 3 Movement in and out of cells                 0.021557
Unit 7 Animal Nutrition                             1.000000
Unit 8 Plant Transport                              0.036859
Unit 17 Inheritance                                 0.034399
Unit 2 Cells                                        0.051105

                                     Unit 8 Plant Transport  \
Unit 3 Movement in and out of cells                0.026379
Unit 7 Animal Nutrition                            0.036859
Unit 8 Plant Transport                             1.000000
Unit 17 Inheritance                                0.042094
Unit 2 Cells                                       0.062537

                                     Unit 17 Inheritance  Unit 2 Cells  \
Unit 3 Movement in and out of cells             0.024619      0.421808
Unit 7 Animal Nutrition                         0.034399      0.051105
Unit 8 Plant Transport                          0.042094      0.062537
Unit 17 Inheritance                             1.000000      0.058365
Unit 2 Cells                                    0.058365      1.000000

                                     Unit 15 Drugs  Unit 13 Excretion  \
Unit 3 Movement in and out of cells       0.024619           0.024619
Unit 7 Animal Nutrition                   0.034399           0.034399
Unit 8 Plant Transport                    0.042094           0.042094
Unit 17 Inheritance                       0.039286           0.039286
Unit 2 Cells                              0.058365           0.058365

                                     Unit 8 Plant Transport  \
Unit 3 Movement in and out of cells                0.026379
Unit 7 Animal Nutrition                            0.036859
```

```
Unit 8 Plant Transport                              1.000000
Unit 17 Inheritance                                 0.042094
Unit 2 Cells                                        0.062537

                                    Unit 9 Transport in humans  \
Unit 3 Movement in and out of cells                   0.211623
Unit 7 Animal Nutrition                               0.031860
Unit 8 Plant Transport                                0.423397
Unit 17 Inheritance                                   0.036386
Unit 2 Cells                                          0.054056

                                    Unit 10 Diseases and Immunity  ...  \
Unit 3 Movement in and out of cells                      0.101728  ...
Unit 7 Animal Nutrition                                  0.026783  ...
Unit 8 Plant Transport                                   0.032775  ...
Unit 17 Inheritance                                      0.030588  ...
Unit 2 Cells                                             0.045443  ...

                                    Unit 4 Biological Molecules  \
Unit 3 Movement in and out of cells                    0.022532
Unit 7 Animal Nutrition                                0.031484
Unit 8 Plant Transport                                 0.038527
Unit 17 Inheritance                                    0.035956
Unit 2 Cells                                           0.053418

                                    Unit 14 Coordination and Response  \
Unit 3 Movement in and out of cells                          0.101728
Unit 7 Animal Nutrition                                      0.026783
Unit 8 Plant Transport                                       0.032775
Unit 17 Inheritance                                          0.030588
Unit 2 Cells                                                 0.045443

                                    Unit 17 Inheritance  Unit 15 Drugs  \
Unit 3 Movement in and out of cells            0.024619       0.024619
Unit 7 Animal Nutrition                        0.034399       0.034399
Unit 8 Plant Transport                         0.042094       0.042094
Unit 17 Inheritance                            1.000000       0.039286
Unit 2 Cells                                   0.058365       0.058365

                                    Unit 10 Diseases and Immunity  \
Unit 3 Movement in and out of cells                      0.101728
Unit 7 Animal Nutrition                                  0.026783
Unit 8 Plant Transport                                   0.032775
Unit 17 Inheritance                                      0.030588
Unit 2 Cells                                             0.045443

                                    Unit 10 Diseases and Immunity  \
Unit 3 Movement in and out of cells                      0.101728
Unit 7 Animal Nutrition                                  0.026783
Unit 8 Plant Transport                                   0.032775
Unit 17 Inheritance                                      0.030588
Unit 2 Cells                                             0.045443

                                    Unit 13 Excretion  \
Unit 3 Movement in and out of cells          0.024619
Unit 7 Animal Nutrition                      0.034399
Unit 8 Plant Transport                       0.042094
Unit 17 Inheritance                          0.039286
Unit 2 Cells                                 0.058365

                                    Unit 1 Characteristics and Classification of Living
Organisms  \
Unit 3 Movement in and out of cells                                              0.231778

Unit 7 Animal Nutrition                                                          0.019488
```

```
Unit 8 Plant Transport                                                       0.023848

Unit 17 Inheritance                                                          0.022256

Unit 2 Cells                                                                 0.033065


                                     Unit 14 Coordination and Response  \
Unit 3 Movement in and out of cells                               0.101728
Unit 7 Animal Nutrition                                           0.026783
Unit 8 Plant Transport                                            0.032775
Unit 17 Inheritance                                               0.030588
Unit 2 Cells                                                      0.045443

                                     Unit 16 Reproduction
Unit 3 Movement in and out of cells              0.021330
Unit 7 Animal Nutrition                          0.029804
Unit 8 Plant Transport                           0.036472
Unit 17 Inheritance                              0.034038
Unit 2 Cells                                     0.050569

[5 rows x 84 columns]
Saved Biology_similarity_matrix.csv

--- Similarity Table for CHEMISTRY ---
                                              Unit 17 Organic chemistry and petrochemica
ls  \
Unit 17 Organic chemistry and petrochemicals                                        1.0000
00
Unit 2 Atoms, Elements and Compounds                                                0.1018
29
Unit 11 Making and identifying salts                                                0.0937
11
Unit 20 Natural Polymers                                                            0.0246
57
Unit 9 Chemical Reactions                                                           0.0352
59

                                              Unit 2 Atoms, Elements and Compounds  \
Unit 17 Organic chemistry and petrochemicals                              0.101829
Unit 2 Atoms, Elements and Compounds                                      1.000000
Unit 11 Making and identifying salts                                      0.099106
Unit 20 Natural Polymers                                                  0.026077
Unit 9 Chemical Reactions                                                 0.037289

                                              Unit 11 Making and identifying salts  \
Unit 17 Organic chemistry and petrochemicals                              0.093711
Unit 2 Atoms, Elements and Compounds                                      0.099106
Unit 11 Making and identifying salts                                      1.000000
Unit 20 Natural Polymers                                                  0.023998
Unit 9 Chemical Reactions                                                 0.034316

                                              Unit 20 Natural Polymers  \
Unit 17 Organic chemistry and petrochemicals                  0.024657
Unit 2 Atoms, Elements and Compounds                          0.026077
Unit 11 Making and identifying salts                          0.023998
Unit 20 Natural Polymers                                      1.000000
Unit 9 Chemical Reactions                                     0.042951

                                              Unit 9 Chemical Reactions  \
Unit 17 Organic chemistry and petrochemicals                   0.035259
Unit 2 Atoms, Elements and Compounds                           0.037289
Unit 11 Making and identifying salts                           0.034316
Unit 20 Natural Polymers                                       0.042951
Unit 9 Chemical Reactions                                      1.000000
```

```
                                              Unit 1 Particles and Purification  \
Unit 17 Organic chemistry and petrochemicals                          0.126868
Unit 2 Atoms, Elements and Compounds                                  0.134172
Unit 11 Making and identifying salts                                  0.123476
Unit 20 Natural Polymers                                              0.032489
Unit 9 Chemical Reactions                                             0.046458

                                              Unit 14 Metal Extraction  \
Unit 17 Organic chemistry and petrochemicals                  0.022380
Unit 2 Atoms, Elements and Compounds                          0.023668
Unit 11 Making and identifying salts                          0.021781
Unit 20 Natural Polymers                                      0.027262
Unit 9 Chemical Reactions                                     0.038983

                                              Unit 17 Organic chemistry and petrochemica
ls  \
Unit 17 Organic chemistry and petrochemicals                                        1.0000
00
Unit 2 Atoms, Elements and Compounds                                                0.1018
29
Unit 11 Making and identifying salts                                                0.0937
11
Unit 20 Natural Polymers                                                            0.0246
57
Unit 9 Chemical Reactions                                                           0.0352
59

                                              Unit 9 Chemical Reactions  \
Unit 17 Organic chemistry and petrochemicals                   0.035259
Unit 2 Atoms, Elements and Compounds                           0.037289
Unit 11 Making and identifying salts                           0.034316
Unit 20 Natural Polymers                                       0.042951
Unit 9 Chemical Reactions                                      1.000000

                                              Unit 17 Organic chemistry and petrochemica
ls  \
Unit 17 Organic chemistry and petrochemicals                                        1.0000
00
Unit 2 Atoms, Elements and Compounds                                                0.1018
29
Unit 11 Making and identifying salts                                                0.0937
11
Unit 20 Natural Polymers                                                            0.0246
57
Unit 9 Chemical Reactions                                                           0.0352
59

                                              ...  Unit 14 Metal Extraction  \
Unit 17 Organic chemistry and petrochemicals  ...                  0.022380
Unit 2 Atoms, Elements and Compounds          ...                  0.023668
Unit 11 Making and identifying salts          ...                  0.021781
Unit 20 Natural Polymers                      ...                  0.027262
Unit 9 Chemical Reactions                     ...                  0.038983

                                              Unit 18 The Variety of Organic Chemicals
\
Unit 17 Organic chemistry and petrochemicals                                  0.169278

Unit 2 Atoms, Elements and Compounds                                          0.020919

Unit 11 Making and identifying salts                                          0.019251

Unit 20 Natural Polymers                                                      0.024095

Unit 9 Chemical Reactions                                                     0.034455
```

```
                                              Unit 14 Metal Extraction  \
Unit 17 Organic chemistry and petrochemicals                  0.022380
Unit 2 Atoms, Elements and Compounds                          0.023668
Unit 11 Making and identifying salts                          0.021781
Unit 20 Natural Polymers                                      0.027262
Unit 9 Chemical Reactions                                     0.038983

                                              Unit 11 Making and identifying salts  \
Unit 17 Organic chemistry and petrochemicals                              0.093711
Unit 2 Atoms, Elements and Compounds                                      0.099106
Unit 11 Making and identifying salts                                      1.000000
Unit 20 Natural Polymers                                                  0.023998
Unit 9 Chemical Reactions                                                 0.034316

                                              Unit 16 The Chemical Industry  \
Unit 17 Organic chemistry and petrochemicals                       0.024240
Unit 2 Atoms, Elements and Compounds                               0.025636
Unit 11 Making and identifying salts                               0.023592
Unit 20 Natural Polymers                                           0.029528
Unit 9 Chemical Reactions                                          0.298069

                                              Unit 8 Speed of Reaction  \
Unit 17 Organic chemistry and petrochemicals                  0.024105
Unit 2 Atoms, Elements and Compounds                          0.025493
Unit 11 Making and identifying salts                          0.023461
Unit 20 Natural Polymers                                      0.029364
Unit 9 Chemical Reactions                                     0.041990

                                              Unit 19 Polymers  \
Unit 17 Organic chemistry and petrochemicals          0.029840
Unit 2 Atoms, Elements and Compounds                  0.031558
Unit 11 Making and identifying salts                  0.029042
Unit 20 Natural Polymers                              0.348734
Unit 9 Chemical Reactions                             0.051979

                                              Unit 18 The Variety of Organic Chemicals
\
Unit 17 Organic chemistry and petrochemicals                                  0.169278

Unit 2 Atoms, Elements and Compounds                                          0.020919

Unit 11 Making and identifying salts                                          0.019251

Unit 20 Natural Polymers                                                      0.024095

Unit 9 Chemical Reactions                                                     0.034455


                                              Unit 17 Organic chemistry and petrochemica
ls  \
Unit 17 Organic chemistry and petrochemicals                                      1.0000
00
Unit 2 Atoms, Elements and Compounds                                              0.1018
29
Unit 11 Making and identifying salts                                              0.0937
11
Unit 20 Natural Polymers                                                          0.0246
57
Unit 9 Chemical Reactions                                                         0.0352
59

                                              Unit 2 Atoms, Elements and Compounds
Unit 17 Organic chemistry and petrochemicals                              0.101829
Unit 2 Atoms, Elements and Compounds                                      1.000000
Unit 11 Making and identifying salts                                      0.099106
```

```
Unit 20 Natural Polymers                                              0.026077
Unit 9 Chemical Reactions                                             0.037289

[5 rows x 68 columns]
Saved Chemistry_similarity_matrix.csv
```

In [15]:
```python
import pandas as pd
from surprise import SVD, Dataset, Reader
from surprise.model_selection import train_test_split
from surprise import accuracy


df = pd.read_csv(r"C:\Users\Rizwana\Desktop\studyoclock project\interactions_real.csv")

#Encoding
df["user_id_encoded"] = df["user_id"].astype("category").cat.codes
df["topic_id_encoded"] = df["topic_name"].astype("category").cat.codes

#Create mappings for easy lookup
topic_map = df.drop_duplicates("topic_id_encoded").set_index("topic_id_encoded")["topic_
user_map = df.drop_duplicates("user_id").set_index("user_id")["user_id_encoded"].to_dict

#Surprise Dataset
reader = Reader(rating_scale=(1, 5))
data = Dataset.load_from_df(df[["user_id_encoded", "topic_id_encoded", "rating"]], reade

#Train/test split
trainset, testset = train_test_split(data, test_size=0.2, random_state=42)

#Train SVD model
algo = SVD()
algo.fit(trainset)

#Evaluate
predictions = algo.test(testset)
print("RMSE:", accuracy.rmse(predictions))
print("MAE:", accuracy.mae(predictions))


#Recommendation function

def get_top_n_recommendations(user_id, n=5):
    user_inner_id = user_map[user_id]
    all_topic_ids = df["topic_id_encoded"].unique()
    interacted_items = df[df["user_id_encoded"] == user_inner_id]["topic_id_encoded"].to

    preds = []
    for item in all_topic_ids:
        if item not in interacted_items:
            # Pass string IDs to Surprise
            pred = algo.predict(str(user_inner_id), str(item))
            preds.append((item, pred.est))

    preds.sort(key=lambda x: x[1], reverse=True)
    return [(topic_map[item], score) for item, score in preds[:n]]


#Show recommendations

results = []
for user in ["user_1", "user_2", "user_3", "user_4", "user_5"]:
    print(f"\nTop-5 Recommendations for {user}:")
    recs = get_top_n_recommendations(user, n=5)
    for topic, score in recs:
        print(f"{topic:30}  {score:.4f}")
```

```python
        results.append({"user_id": user, "topic_name": topic, "predicted_score": score})


recs_df = pd.DataFrame(results)
recs_df.to_csv("svd_recommendations.csv", index=False)
print("Recommendations saved to svd_recommendations.csv")
```

```
RMSE: 1.3966
RMSE: 1.3966440109000955
MAE:  1.2131
MAE: 1.2131064141822392

Top-5 Recommendations for user_1:
Unit 17 Inheritance            2.9250
Unit 2 Cells                   2.9250
Chapter 10 Marketing, Competition and the Customer  2.9250
Unit 15 Drugs                  2.9250
Unit 13 Excretion              2.9250

Top-5 Recommendations for user_2:
Chapter 16 Marketing Strategy   2.9250
Chapter 13 The Marketing Mix    2.9250
Unit 3 Movement in and out of cells  2.9250
Chapter 20 Location Decisions   2.9250
Unit 17 Organic chemistry and petrochemicals  2.9250

Top-5 Recommendations for user_3:
Unit 8 Safety and Security      2.9250
Chapter 16 Marketing Strategy   2.9250
Unit 3 Movement in and out of cells  2.9250
Chapter 23 Income Statements    2.9250
Chapter 20 Location Decisions   2.9250

Top-5 Recommendations for user_4:
Unit 8 Safety and Security      2.9250
Chapter 16 Marketing Strategy   2.9250
Chapter 13 The Marketing Mix    2.9250
Unit 3 Movement in and out of cells  2.9250
Chapter 23 Income Statements    2.9250

Top-5 Recommendations for user_5:
Unit 8 Safety and Security      2.9250
Chapter 16 Marketing Strategy   2.9250
Unit 3 Movement in and out of cells  2.9250
Chapter 23 Income Statements    2.9250
Chapter 20 Location Decisions   2.9250
Recommendations saved to svd_recommendations.csv
```

In [22]:

```
pip install seaborn
```

```
Collecting seaborn
  Using cached seaborn-0.13.2-py3-none-any.whl.metadata (5.4 kB)
Requirement already satisfied: numpy!=1.24.0,>=1.20 in c:\users\rizwana\anaconda3\envs\f
inalproject\lib\site-packages (from seaborn) (1.24.3)
Requirement already satisfied: pandas>=1.2 in c:\users\rizwana\anaconda3\envs\finalproje
ct\lib\site-packages (from seaborn) (2.3.1)
Collecting matplotlib!=3.6.1,>=3.4 (from seaborn)
  Downloading matplotlib-3.10.5-cp310-cp310-win_amd64.whl.metadata (11 kB)
Collecting contourpy>=1.0.1 (from matplotlib!=3.6.1,>=3.4->seaborn)
  Downloading contourpy-1.3.2-cp310-cp310-win_amd64.whl.metadata (5.5 kB)
Collecting cycler>=0.10 (from matplotlib!=3.6.1,>=3.4->seaborn)
  Downloading cycler-0.12.1-py3-none-any.whl.metadata (3.8 kB)
Collecting fonttools>=4.22.0 (from matplotlib!=3.6.1,>=3.4->seaborn)
  Downloading fonttools-4.59.1-cp310-cp310-win_amd64.whl.metadata (111 kB)
Collecting kiwisolver>=1.3.1 (from matplotlib!=3.6.1,>=3.4->seaborn)
  Downloading kiwisolver-1.4.9-cp310-cp310-win_amd64.whl.metadata (6.4 kB)
```

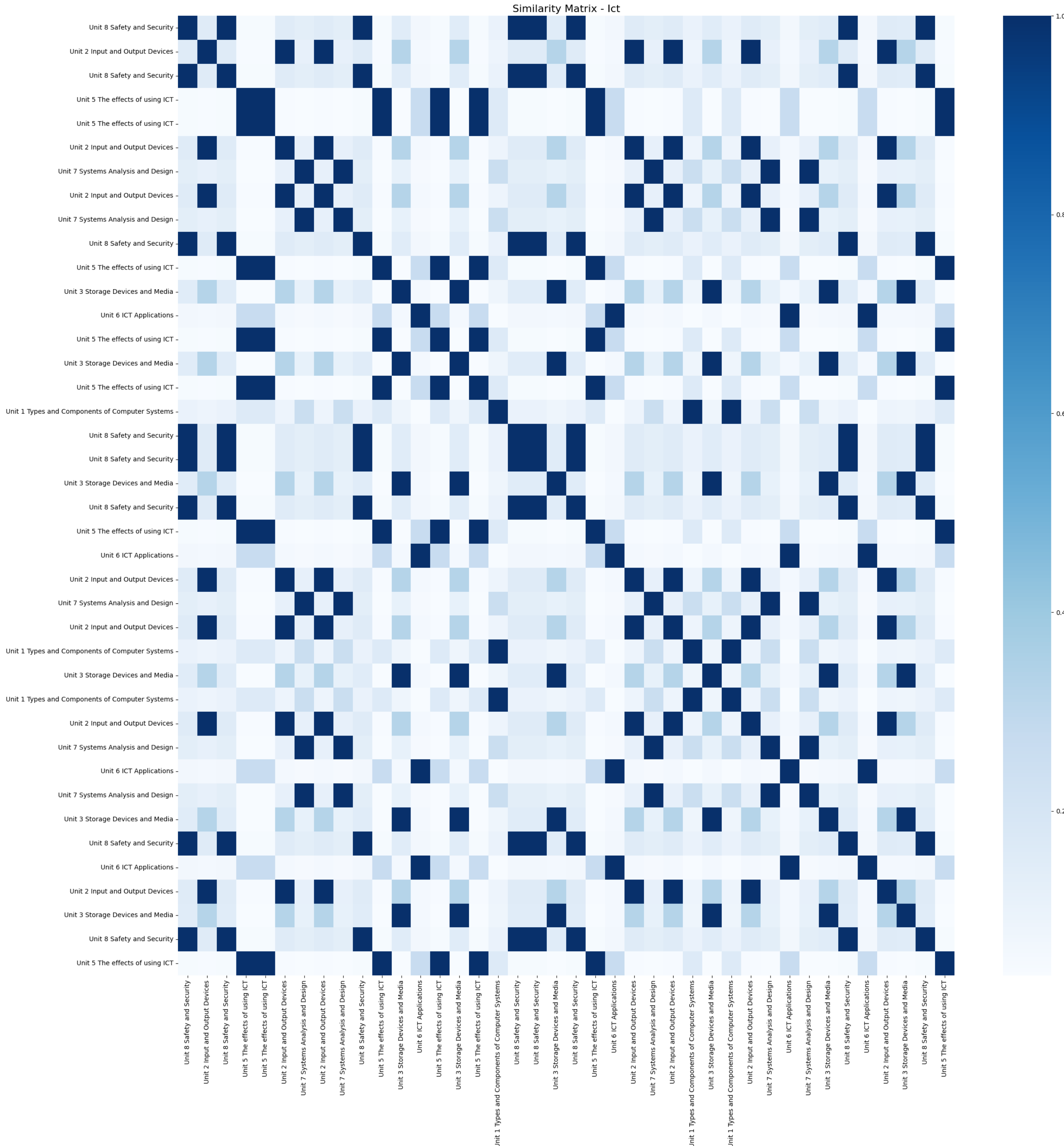
```
Requirement already satisfied: packaging>=20.0 in c:\users\rizwana\anaconda3\envs\finalp
roject\lib\site-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (25.0)
Requirement already satisfied: pillow>=8 in c:\users\rizwana\anaconda3\envs\finalproject
\lib\site-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (11.3.0)
Collecting pyparsing>=2.3.1 (from matplotlib!=3.6.1,>=3.4->seaborn)
  Downloading pyparsing-3.2.3-py3-none-any.whl.metadata (5.0 kB)
Requirement already satisfied: python-dateutil>=2.7 in c:\users\rizwana\anaconda3\envs\f
inalproject\lib\site-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in c:\users\rizwana\anaconda3\envs\finalproj
ect\lib\site-packages (from pandas>=1.2->seaborn) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in c:\users\rizwana\anaconda3\envs\finalpr
oject\lib\site-packages (from pandas>=1.2->seaborn) (2025.2)
Requirement already satisfied: six>=1.5 in c:\users\rizwana\anaconda3\envs\finalproject
\lib\site-packages (from python-dateutil>=2.7->matplotlib!=3.6.1,>=3.4->seaborn) (1.17.
0)
Using cached seaborn-0.13.2-py3-none-any.whl (294 kB)
Downloading matplotlib-3.10.5-cp310-cp310-win_amd64.whl (8.1 MB)
   ---------------------------------------- 0.0/8.1 MB ? eta -:--:--
   ---------------------------------------- 0.0/8.1 MB ? eta -:--:--
   - -------------------------------------- 0.3/8.1 MB ? eta -:--:--
   -- ------------------------------------- 0.5/8.1 MB 1.0 MB/s eta 0:00:08
   ----- ---------------------------------- 1.0/8.1 MB 1.6 MB/s eta 0:00:05
   --------- ------------------------------ 1.8/8.1 MB 2.2 MB/s eta 0:00:03
   ---------------- ----------------------- 3.4/8.1 MB 3.4 MB/s eta 0:00:02
   ------------------------ --------------- 5.0/8.1 MB 4.1 MB/s eta 0:00:01
   ------------------------ --------------- 5.0/8.1 MB 4.1 MB/s eta 0:00:01
   ------------------------ --------------- 5.0/8.1 MB 4.1 MB/s eta 0:00:01
   ------------------------- -------------- 5.2/8.1 MB 2.7 MB/s eta 0:00:02
   ------------------------------- -------- 6.3/8.1 MB 3.3 MB/s eta 0:00:01
   --------------------------------- ------ 6.8/8.1 MB 3.1 MB/s eta 0:00:01
   ------------------------------------ --- 7.3/8.1 MB 3.0 MB/s eta 0:00:01
   -------------------------------------- - 7.9/8.1 MB 2.9 MB/s eta 0:00:01
   ---------------------------------------- 8.1/8.1 MB 2.7 MB/s  0:00:03
Downloading contourpy-1.3.2-cp310-cp310-win_amd64.whl (221 kB)
Downloading cycler-0.12.1-py3-none-any.whl (8.3 kB)
Downloading fonttools-4.59.1-cp310-cp310-win_amd64.whl (2.3 MB)
   ---------------------------------------- 0.0/2.3 MB ? eta -:--:--
   ------------------ --------------------- 1.0/2.3 MB 12.5 MB/s eta 0:00:01
   ------------------ --------------------- 1.0/2.3 MB 12.5 MB/s eta 0:00:01
   ------------------ --------------------- 1.0/2.3 MB 12.5 MB/s eta 0:00:01
   ------------------ --------------------- 1.0/2.3 MB 12.5 MB/s eta 0:00:01
   ------------------ --------------------- 1.0/2.3 MB 12.5 MB/s eta 0:00:01
   ------------------ --------------------- 1.0/2.3 MB 12.5 MB/s eta 0:00:01
   ------------------ --------------------- 1.0/2.3 MB 12.5 MB/s eta 0:00:01
   ------------------ --------------------- 1.0/2.3 MB 12.5 MB/s eta 0:00:01
   ------------------ --------------------- 1.0/2.3 MB 12.5 MB/s eta 0:00:01
   ------------------ --------------------- 1.0/2.3 MB 12.5 MB/s eta 0:00:01
   ------------------ --------------------- 1.0/2.3 MB 12.5 MB/s eta 0:00:01
   ----------------------- ---------------- 1.3/2.3 MB 435.6 kB/s eta 0:00:03
   ----------------------- ---------------- 1.3/2.3 MB 435.6 kB/s eta 0:00:03
   --------------------------- ------------ 1.6/2.3 MB 448.6 kB/s eta 0:00:02
   --------------------------- ------------ 1.6/2.3 MB 448.6 kB/s eta 0:00:02
   --------------------------- ------------ 1.6/2.3 MB 448.6 kB/s eta 0:00:02
   -------------------------------- ------- 1.8/2.3 MB 457.5 kB/s eta 0:00:01
   -------------------------------- ------- 1.8/2.3 MB 457.5 kB/s eta 0:00:01
   ------------------------------------- -- 2.1/2.3 MB 466.0 kB/s eta 0:00:01
   ---------------------------------------- 2.3/2.3 MB 472.1 kB/s  0:00:04
Downloading kiwisolver-1.4.9-cp310-cp310-win_amd64.whl (73 kB)
Downloading pyparsing-3.2.3-py3-none-any.whl (111 kB)
Installing collected packages: pyparsing, kiwisolver, fonttools, cycler, contourpy, matp
lotlib, seaborn

   ---------------------------------------- 0/7 [pyparsing]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
```

```
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------- ---------------------------- 2/7 [fonttools]
   ----------------- ---------------------- 3/7 [cycler]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------- ----------- 5/7 [matplotlib]
   ---------------------------------- ----- 6/7 [seaborn]
   ---------------------------------- ----- 6/7 [seaborn]
   ---------------------------------------- 7/7 [seaborn]

Successfully installed contourpy-1.3.2 cycler-0.12.1 fonttools-4.59.1 kiwisolver-1.4.9 m
atplotlib-3.10.5 pyparsing-3.2.3 seaborn-0.13.2
Note: you may need to restart the kernel to use updated packages.
```

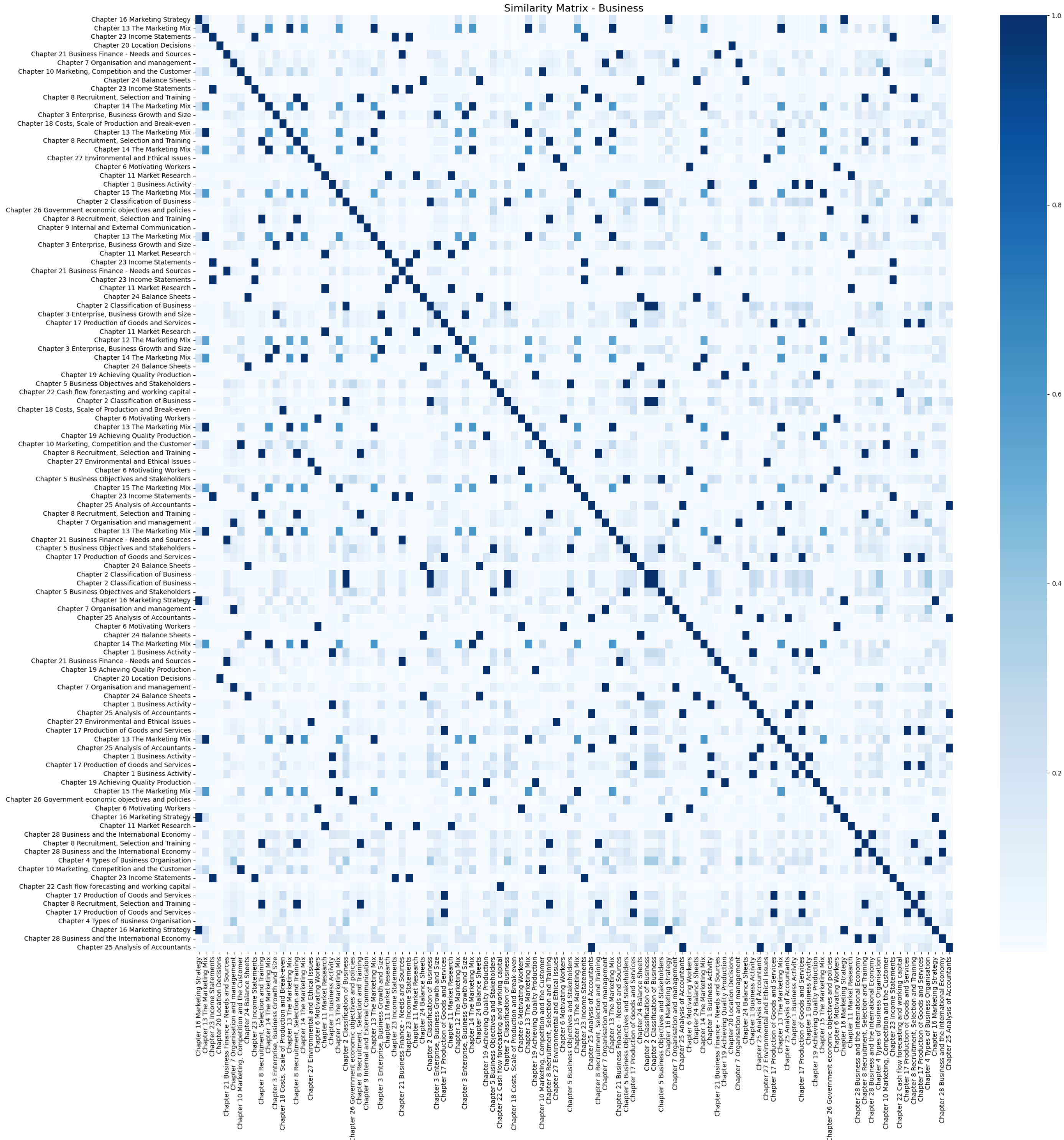
In [22]:

```python
import seaborn as sns
import matplotlib.pyplot as plt

# Function to plot similarity heatmap
def plot_similarity_matrix(subject, table):
    plt.figure(figsize=(25, 25))
    sns.heatmap(table, cmap="Blues", annot=False, cbar=True,
                xticklabels=True, yticklabels=True)
    plt.title(f"Similarity Matrix - {subject.capitalize()}", fontsize=16)
    plt.xticks(rotation=90)
    plt.yticks(rotation=0)
    plt.tight_layout()
    plt.show()

# Plot for all subjects
for subject, table in subject_tables.items():
    print(f"Plotting {subject} similarity matrix...")
    plot_similarity_matrix(subject, table)
```

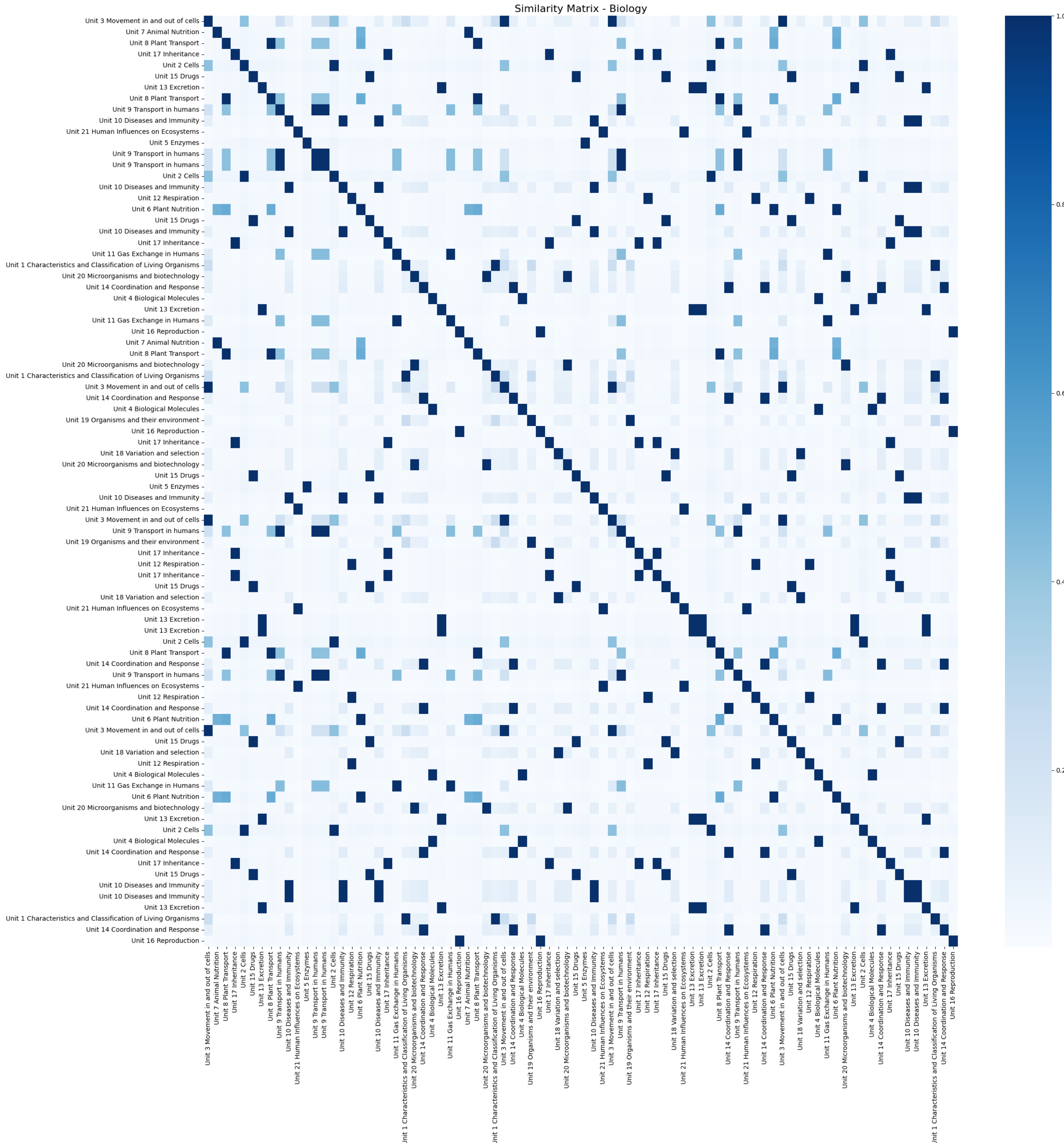
```
Plotting ICT similarity matrix...
```



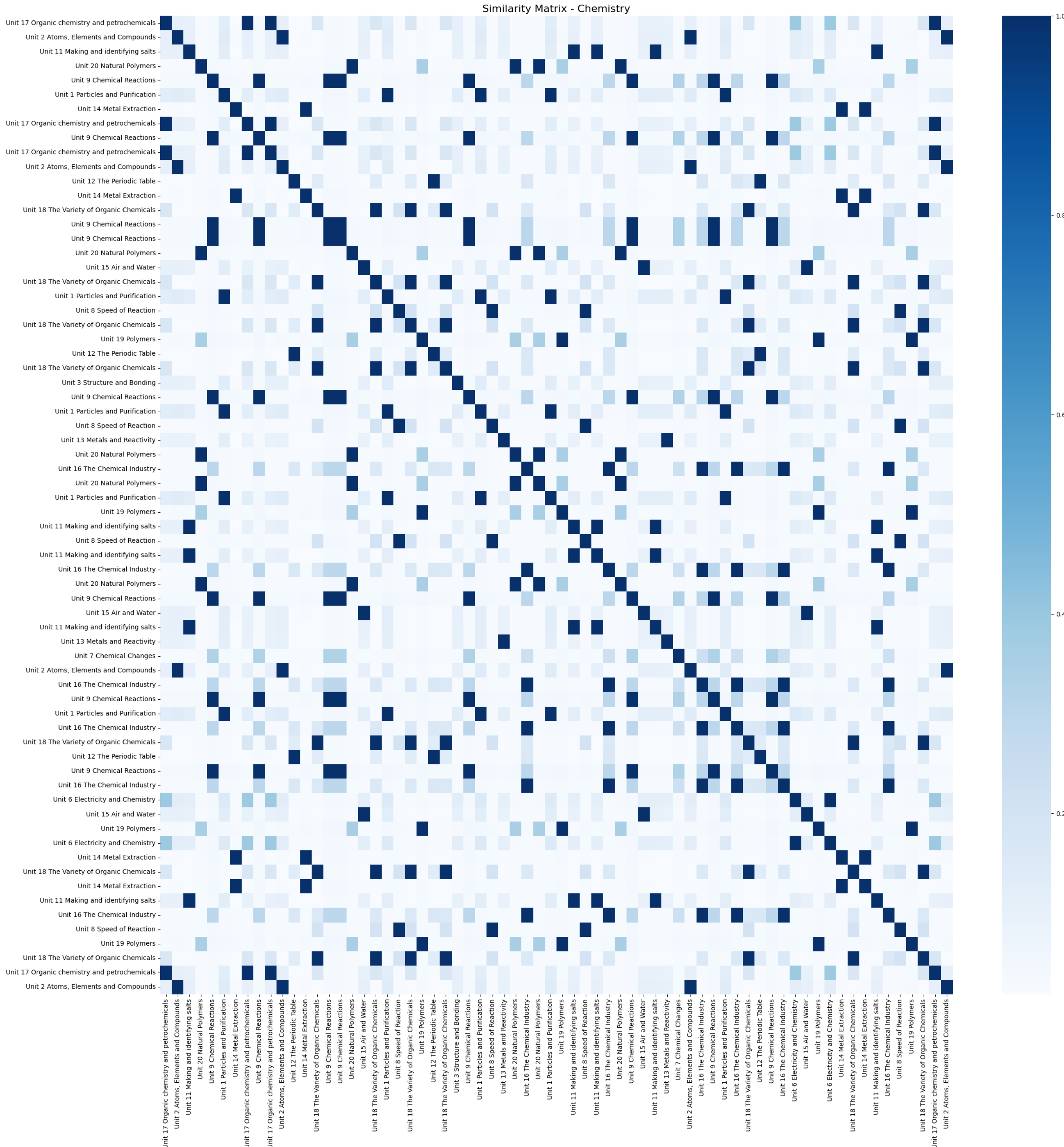
Plotting Business similarity matrix...



Plotting Biology similarity matrix...



Plotting Chemistry similarity matrix...




```
In [2]: import pandas as pd
        import numpy as np
        import matplotlib.pyplot as plt
        import seaborn as sns
        from surprise import SVD, Dataset, Reader, accuracy
        from surprise.model_selection import train_test_split, cross_validate
        from sklearn.metrics import precision_score, recall_score, ndcg_score
        import warnings
        warnings.filterwarnings('ignore')


        df = pd.read_csv(r"C:\Users\Rizwana\Desktop\studyoclock project\interactions_real.csv")

        #Encoding
        df["user_id_encoded"] = df["user_id"].astype("category").cat.codes
        df["topic_id_encoded"] = df["topic_name"].astype("category").cat.codes
```

```python
#Create mappings for easy lookup
topic_map = df.drop_duplicates("topic_id_encoded").set_index("topic_id_encoded")["topic_
user_map = df.drop_duplicates("user_id").set_index("user_id")["user_id_encoded"].to_dict

#Surprise Dataset
reader = Reader(rating_scale=(1, 5))
data = Dataset.load_from_df(df[["user_id_encoded", "topic_id_encoded", "rating"]], reade

#Train/test split
trainset, testset = train_test_split(data, test_size=0.2, random_state=42)

#Train SVD model
algo = SVD(random_state=42)
algo.fit(trainset)

#Evaluate
predictions = algo.test(testset)
rmse = accuracy.rmse(predictions)
mae = accuracy.mae(predictions)

print(" SVD MODEL EVALUATION")
print("=" * 50)
print(f"RMSE: {rmse:.4f}")
print(f"MAE: {mae:.4f}")

# 1. PREDICTION ERROR ANALYSIS
print("\n PREDICTION ERROR ANALYSIS")
print("=" * 50)

# Extract actual and predicted ratings
actual_ratings = [pred.r_ui for pred in predictions]
predicted_ratings = [pred.est for pred in predictions]
errors = [abs(pred.r_ui - pred.est) for pred in predictions]

print(f"Average prediction error: {np.mean(errors):.4f}")
print(f"Max prediction error: {np.max(errors):.4f}")
print(f"Min prediction error: {np.min(errors):.4f}")

# Visualization: Prediction vs Actual
plt.figure(figsize=(12, 10))

# Scatter plot of actual vs predicted
plt.subplot(2, 2, 1)
plt.scatter(actual_ratings, predicted_ratings, alpha=0.6, s=30)
plt.plot([1, 5], [1, 5], 'r--', alpha=0.8)  # Perfect prediction line
plt.xlabel('Actual Rating')
plt.ylabel('Predicted Rating')
plt.title('Actual vs Predicted Ratings')
plt.grid(True, alpha=0.3)

# Error distribution
plt.subplot(2, 2, 2)
plt.hist(errors, bins=30, alpha=0.7, color='orange', edgecolor='black')
plt.xlabel('Absolute Error')
plt.ylabel('Frequency')
plt.title('Distribution of Prediction Errors')
plt.grid(True, alpha=0.3)

# Error by rating value
error_by_rating = pd.DataFrame({
    'actual': actual_ratings,
    'error': errors
}).groupby('actual')['error'].mean()

plt.subplot(2, 2, 3)
error_by_rating.plot(kind='bar', color='skyblue', edgecolor='black')
```

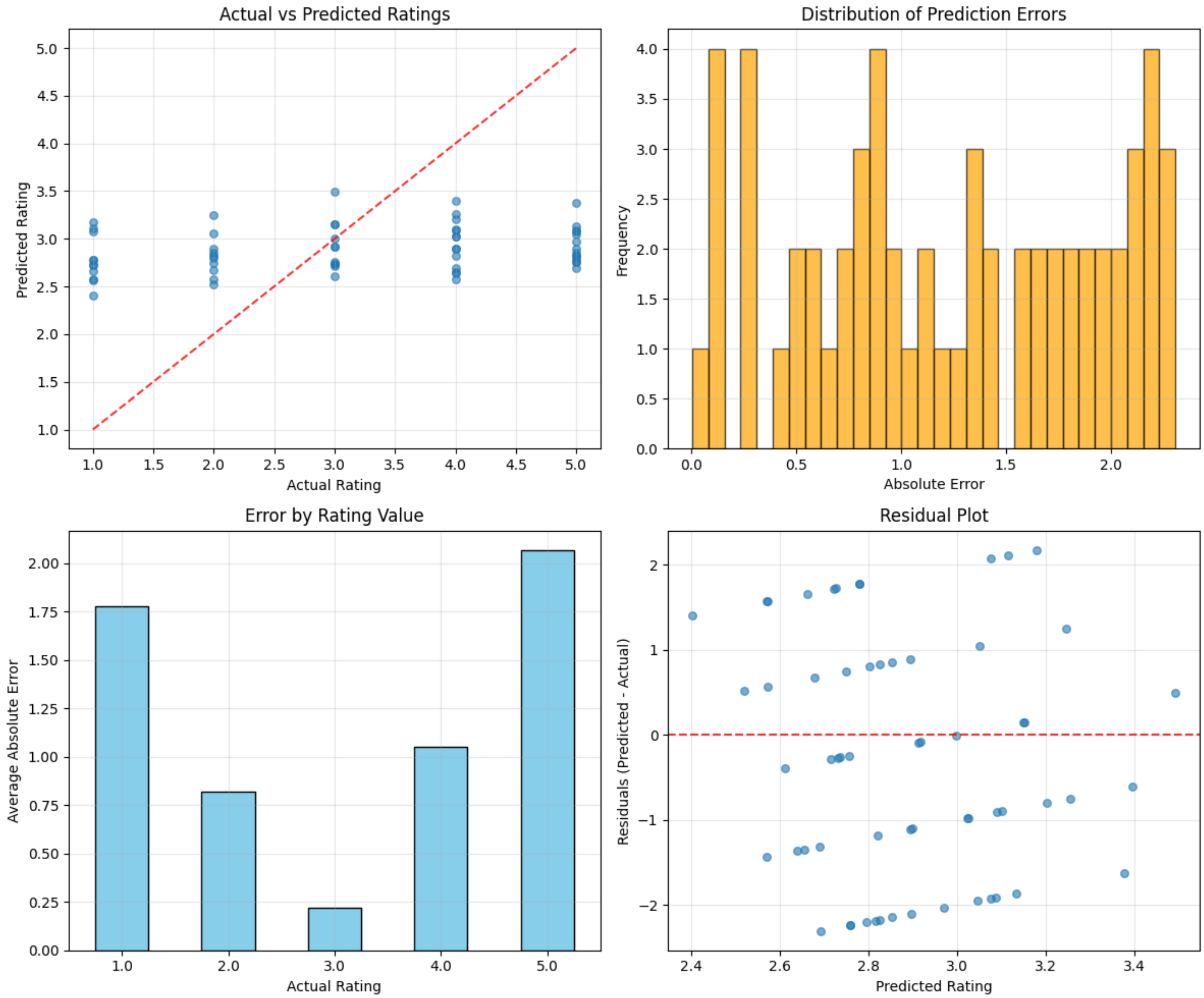
```python
plt.xlabel('Actual Rating')
plt.ylabel('Average Absolute Error')
plt.title('Error by Rating Value')
plt.xticks(rotation=0)
plt.grid(True, alpha=0.3)

# Residual plot
residuals = [pred.est - pred.r_ui for pred in predictions]
plt.subplot(2, 2, 4)
plt.scatter(predicted_ratings, residuals, alpha=0.6, s=30)
plt.axhline(y=0, color='r', linestyle='--', alpha=0.8)
plt.xlabel('Predicted Rating')
plt.ylabel('Residuals (Predicted - Actual)')
plt.title('Residual Plot')
plt.grid(True, alpha=0.3)

plt.tight_layout()
plt.savefig('svd_prediction_analysis.png', dpi=300, bbox_inches='tight')
plt.show()

# 2. CROSS-VALIDATION FOR ROBUST EVALUATION
print("\n CROSS-VALIDATION RESULTS")
print("=" * 50)

cv_results = cross_validate(algo, data, measures=['RMSE', 'MAE'], cv=5, verbose=False)

print("Cross-validation RMSE scores:", [f"{score:.4f}" for score in cv_results['test_rms
print("Cross-validation MAE scores:", [f"{score:.4f}" for score in cv_results['test_mae'
print(f"Mean RMSE: {np.mean(cv_results['test_rmse']):.4f} (±{np.std(cv_results['test_rms
print(f"Mean MAE: {np.mean(cv_results['test_mae']):.4f} (±{np.std(cv_results['test_mae']

# 3. TOP-N RECOMMENDATION EVALUATION
print("\n TOP-N RECOMMENDATION EVALUATION")
print("=" * 50)

# Create binary relevance (rating >= 4 is relevant)
df['relevant'] = (df['rating'] >= 4).astype(int)

# Recommendation function with relevance
def get_top_n_recommendations_with_relevance(user_id, n=5):
    user_inner_id = user_map[user_id]
    all_topic_ids = df["topic_id_encoded"].unique()
    interacted_items = df[df["user_id_encoded"] == user_inner_id]["topic_id_encoded"].to

    preds = []
    for item in all_topic_ids:
        if item not in interacted_items:
            pred = algo.predict(str(user_inner_id), str(item))
            preds.append((item, pred.est))

    preds.sort(key=lambda x: x[1], reverse=True)

    # Get relevance information
    recommendations = []
    for item, score in preds[:n]:
        topic_name = topic_map[item]
        # Check if this topic would be relevant (has high rating from other users)
        avg_rating = df[df['topic_id_encoded'] == item]['rating'].mean()
        relevant = 1 if avg_rating >= 4 else 0
        recommendations.append({
            'topic_name': topic_name,
            'predicted_score': score,
            'relevance': relevant
        })

    return recommendations
```

```python
# Evaluate precision and recall for top-N recommendations
def evaluate_top_n(precision_at=5):
    precisions = []
    recalls = []

    test_users = df['user_id'].unique()[:20]  # Evaluate on first 20 users for efficienc

    for user in test_users:
        recs = get_top_n_recommendations_with_relevance(user, n=precision_at)
        relevant_recs = sum(1 for rec in recs if rec['relevance'] == 1)

        precision = relevant_recs / precision_at
        # For recall, we need the total number of relevant items for this user
        user_relevant_items = len(df[(df['user_id'] == user) & (df['relevant'] == 1)])
        recall = relevant_recs / user_relevant_items if user_relevant_items > 0 else 0

        precisions.append(precision)
        recalls.append(recall)

    return np.mean(precisions), np.mean(recalls)

precision, recall = evaluate_top_n(5)
print(f"Precision@5: {precision:.4f}")
print(f"Recall@5: {recall:.4f}")

# 4. USER AND ITEM ANALYSIS
print("\n USER AND ITEM ANALYSIS")
print("=" * 50)

# User activity analysis
user_activity = df.groupby('user_id_encoded').agg({
    'rating': 'count',
    'rating': 'mean'
}).rename(columns={'rating': 'avg_rating'})
user_activity['interaction_count'] = df.groupby('user_id_encoded').size()

# Topic popularity analysis
topic_popularity = df.groupby('topic_id_encoded').agg({
    'rating': 'count',
    'rating': 'mean'
}).rename(columns={'rating': 'avg_rating'})
topic_popularity['interaction_count'] = df.groupby('topic_id_encoded').size()

print("User activity statistics:")
print(user_activity.describe().round(3))
print("\nTopic popularity statistics:")
print(topic_popularity.describe().round(3))

# Visualization: User and item analysis
plt.figure(figsize=(15, 10))

# User interaction distribution
plt.subplot(2, 3, 1)
plt.hist(user_activity['interaction_count'], bins=30, alpha=0.7, color='lightblue', edge
plt.xlabel('Number of Interactions per User')
plt.ylabel('Frequency')
plt.title('User Interaction Distribution')
plt.grid(True, alpha=0.3)

# Topic interaction distribution
plt.subplot(2, 3, 2)
plt.hist(topic_popularity['interaction_count'], bins=30, alpha=0.7, color='lightgreen',
plt.xlabel('Number of Interactions per Topic')
plt.ylabel('Frequency')
plt.title('Topic Interaction Distribution')
```

```python
plt.grid(True, alpha=0.3)

# Rating distribution
plt.subplot(2, 3, 3)
rating_counts = df['rating'].value_counts().sort_index()
plt.bar(rating_counts.index, rating_counts.values, alpha=0.7, color='salmon', edgecolor=
plt.xlabel('Rating')
plt.ylabel('Count')
plt.title('Rating Distribution')
plt.xticks(range(1, 6))
plt.grid(True, alpha=0.3)

# User rating distribution
plt.subplot(2, 3, 4)
plt.hist(user_activity['avg_rating'], bins=20, alpha=0.7, color='gold', edgecolor='black
plt.xlabel('Average User Rating')
plt.ylabel('Frequency')
plt.title('User Rating Behavior')
plt.grid(True, alpha=0.3)

# Topic rating distribution
plt.subplot(2, 3, 5)
plt.hist(topic_popularity['avg_rating'], bins=20, alpha=0.7, color='purple', edgecolor='
plt.xlabel('Average Topic Rating')
plt.ylabel('Frequency')
plt.title('Topic Rating Quality')
plt.grid(True, alpha=0.3)

# Cold start problem analysis
user_interaction_counts = df.groupby('user_id_encoded').size()
cold_users = sum(user_interaction_counts < 5)  # Users with few interactions
cold_topics = sum(topic_popularity['interaction_count'] < 5)  # Topics with few interact

plt.subplot(2, 3, 6)
categories = ['Cold Users (<5 interactions)', 'Cold Topics (<5 interactions)']
values = [cold_users, cold_topics]
plt.bar(categories, values, alpha=0.7, color=['orange', 'red'], edgecolor='black')
plt.ylabel('Count')
plt.title('Cold Start Problem Analysis')
plt.xticks(rotation=45, ha='right')
plt.grid(True, alpha=0.3)

plt.tight_layout()
plt.savefig('svd_user_item_analysis.png', dpi=300, bbox_inches='tight')
plt.show()

# 5. RECOMMENDATION DIVERSITY ANALYSIS
print("\ RECOMMENDATION DIVERSITY ANALYSIS")
print("=" * 50)

# Analyze how diverse recommendations are across users
all_recommendations = []
test_users = df['user_id'].unique()[:30]

for user in test_users:
    recs = get_top_n_recommendations(user, n=5)
    for topic, score in recs:
        all_recommendations.append(topic)

# Calculate recommendation frequency
rec_frequency = pd.Series(all_recommendations).value_counts()
print("Top 10 most frequently recommended topics:")
print(rec_frequency.head(10))

print(f"\nRecommendation diversity: {len(rec_frequency)} unique topics recommended")
print(f"Gini coefficient of recommendation distribution: {1 - sum((rec_frequency / rec_f
```

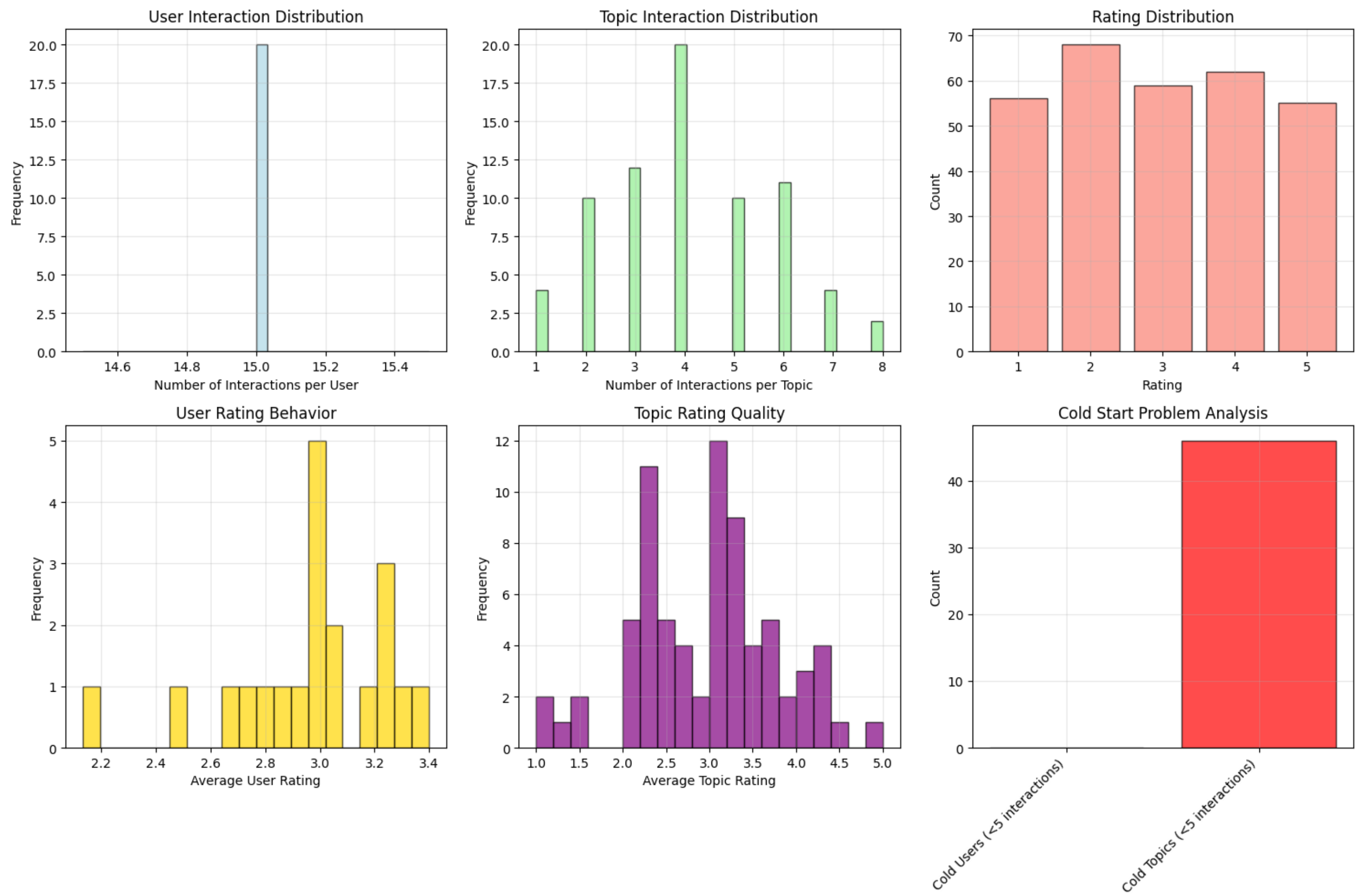
```python
# 6. SAVE COMPREHENSIVE EVALUATION RESULTS
evaluation_results = {
    'rmse': rmse,
    'mae': mae,
    'precision_at_5': precision,
    'recall_at_5': recall,
    'avg_prediction_error': np.mean(errors),
    'cv_mean_rmse': np.mean(cv_results['test_rmse']),
    'cv_mean_mae': np.mean(cv_results['test_mae']),
    'cold_users': cold_users,
    'cold_topics': cold_topics,
    'recommendation_diversity': len(rec_frequency),
    'avg_user_interactions': user_activity['interaction_count'].mean(),
    'avg_topic_interactions': topic_popularity['interaction_count'].mean()
}

results_df = pd.DataFrame(list(evaluation_results.items()), columns=['metric', 'value'])
results_df.to_csv('svd_evaluation_metrics.csv', index=False)

print("\COMPREHENSIVE EVALUATION COMPLETED!")
print("=" * 50)
print("Evaluation metrics saved to 'svd_evaluation_metrics.csv'")
print("Visualizations saved as PNG files")
print("\ SUMMARY:")
for metric, value in evaluation_results.items():
    if isinstance(value, float):
        print(f"{metric:.<25}: {value:.4f}")
    else:
        print(f"{metric:.<25}: {value}")

# 7. GENERATE SAMPLE RECOMMENDATIONS FOR DEMONSTRATION
print(" SAMPLE RECOMMENDATIONS")
print("=" * 50)

sample_users = ["user_1", "user_2", "user_3", "user_4", "user_5"]
results = []

for user in sample_users:
    print(f"\nTop-5 Recommendations for {user}:")
    recs = get_top_n_recommendations(user, n=5)
    for topic, score in recs:
        print(f"  {topic:35}  {score:.4f}")
        results.append({"user_id": user, "topic_name": topic, "predicted_score": score})

recs_df = pd.DataFrame(results)
recs_df.to_csv("svd_recommendations.csv", index=False)
print(" Recommendations saved to 'svd_recommendations.csv'")
```

```
RMSE: 1.4136
MAE:  1.2309
 SVD MODEL EVALUATION
==================================================
RMSE: 1.4136
MAE: 1.2309

 PREDICTION ERROR ANALYSIS
==================================================
Average prediction error: 1.2309
Max prediction error: 2.3092
Min prediction error: 0.0022
```




```
 CROSS-VALIDATION RESULTS
==================================================
Cross-validation RMSE scores: ['1.5240', '1.2743', '1.4741', '1.4845', '1.3133']
Cross-validation MAE scores: ['1.2974', '1.0991', '1.3067', '1.2839', '1.1215']
Mean RMSE: 1.4140 (±0.1004)
Mean MAE: 1.2217 (±0.0916)

 TOP-N RECOMMENDATION EVALUATION
==================================================
Precision@5: 0.1400
Recall@5: 0.1427

 USER AND ITEM ANALYSIS
==================================================
User activity statistics:
       avg_rating  interaction_count
count      20.000               20.0
mean        2.973               15.0
std         0.308                0.0
min         2.133               15.0
25%         2.850               15.0
50%         3.000               15.0
75%         3.217               15.0
max         3.400               15.0

Topic popularity statistics:
       avg_rating  interaction_count
count      73.000             73.000
mean        2.945              4.110
```

```
std        0.818       1.704
min        1.000       1.000
25%        2.400       3.000
50%        3.000       4.000
75%        3.500       5.000
max        5.000       8.000
```




```
\ RECOMMENDATION DIVERSITY ANALYSIS
==================================================
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
Cell In[2], line 271
    268 test_users = df['user_id'].unique()[:30]
    270 for user in test_users:
--> 271     recs = get_top_n_recommendations(user, n=5)
    272     for topic, score in recs:
    273         all_recommendations.append(topic)

NameError: name 'get_top_n_recommendations' is not defined
```

Hybrid Recommender without BiLSTM

In [26]:

```
import pandas as pd
import numpy as np
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.metrics.pairwise import cosine_similarity

df = pd.read_csv(r"C:\Users\Rizwana\Desktop\studyoclock project\interactions_real.csv")

#Build TF-IDF similarity (per subject)
tfidf = TfidfVectorizer(stop_words="english")

subject_sim_matrices = {}
for subject in df["subject"].unique():
    subject_topics = df[df["subject"] == subject]["topic_name"].unique()
```

```python
    tfidf_matrix = tfidf.fit_transform(subject_topics)
    cosine_sim = cosine_similarity(tfidf_matrix)
    subject_sim_matrices[subject] = {
        "topics": subject_topics,
        "matrix": cosine_sim
    }

#Hybrid Recommendation Function
def hybrid_recommend(user_id, topic_name, top_k=5, alpha=0.5, beta=0.5):
    # Identify the subject of the selected topic
    if topic_name not in df["topic_name"].values:
        return f"Topic '{topic_name}' not found!"

    subject = df[df["topic_name"] == topic_name]["subject"].iloc[0]
    sim_data = subject_sim_matrices[subject]
    topics = sim_data["topics"]
    cosine_sim = sim_data["matrix"]

    # Content similarity
    idx = np.where(topics == topic_name)[0][0]
    cos_sim = cosine_sim[idx]

    content_scores = pd.DataFrame({
        "topic_name": topics,
        "content_score": cos_sim
    })

    #Collaborative Filtering
    cf_scores = []
    for t in topics:
        pred = df[(df["user_id"] == user_id) & (df["topic_name"] == t)]["rating"].mean()
        if np.isnan(pred):
            pred = df[df["topic_name"] == t]["rating"].mean()
        cf_scores.append(pred)
    content_scores["cf_score"] = cf_scores

    # Hybrid score
    content_scores["hybrid_score"] = (
        alpha * content_scores["content_score"] +
        beta * content_scores["cf_score"]
    )

    #Rank and return
    recs = content_scores.sort_values(by="hybrid_score", ascending=False).head(top_k)
    return subject, recs[["topic_name", "content_score", "cf_score", "hybrid_score"]]

print("=== Biology Example ===")
subject, recs = hybrid_recommend("user_5", "Unit 12 Respiration", top_k=5)
print(f"Subject: {subject}")
print(recs.to_string(index=False, float_format="%.3f"))
print()  # Empty line for spacing

print("=== Chemistry Example ===")
subject, recs = hybrid_recommend("user_7", "Unit 12 The Periodic Table", top_k=5)
print(f"Subject: {subject}")
print(recs.to_string(index=False, float_format="%.3f"))
```

```
=== Biology Example ===
Subject: Biology
                              topic_name  content_score  cf_score  hybrid_score
                     Unit 12 Respiration          1.000     4.250         2.625
                 Unit 7 Animal Nutrition          0.044     5.000         2.522
Unit 20 Microorganisms and biotechnology          0.034     4.250         2.142
                  Unit 6 Plant Nutrition          0.047     4.000         2.023
                     Unit 17 Inheritance          0.042     4.000         2.021
```

```
=== Chemistry Example ===
Subject: Chemistry
                      topic_name  content_score  cf_score  hybrid_score
       Unit 7 Chemical Changes          0.042     4.000         2.021
 Unit 3 Structure and Bonding           0.038     4.000         2.019
Unit 16 The Chemical Industry           0.034     3.833         1.934
      Unit 14 Metal Extraction          0.032     3.750         1.891
      Unit 20 Natural Polymers          0.033     3.400         1.716
```

In [28]:

```python
import pandas as pd
import numpy as np
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.metrics.pairwise import cosine_similarity

# Load the data
df = pd.read_csv(r"C:\Users\Rizwana\Desktop\studyoclock project\interactions_real.csv")

# Build TF-IDF similarity (per subject)
tfidf = TfidfVectorizer(stop_words="english")

subject_sim_matrices = {}
for subject in df["subject"].unique():
    subject_topics = df[df["subject"] == subject]["topic_name"].unique()
    tfidf_matrix = tfidf.fit_transform(subject_topics)
    cosine_sim = cosine_similarity(tfidf_matrix)
    subject_sim_matrices[subject] = {
        "topics": subject_topics,
        "matrix": cosine_sim
    }

# Hybrid Recommendation Function
def hybrid_recommend(user_id, topic_name, top_k=5, alpha=0.5, beta=0.5):
    # Identify the subject of the selected topic
    if topic_name not in df["topic_name"].values:
        raise ValueError(f"Topic '{topic_name}' not found!")

    subject = df[df["topic_name"] == topic_name]["subject"].iloc[0]
    sim_data = subject_sim_matrices[subject]
    topics = sim_data["topics"]
    cosine_sim = sim_data["matrix"]

    # Content similarity
    idx = np.where(topics == topic_name)[0][0]
    cos_sim = cosine_sim[idx]

    content_scores = pd.DataFrame({
        "topic_name": topics,
        "content_score": cos_sim
    })

    # Collaborative Filtering
    cf_scores = []
    for t in topics:
        pred = df[(df["user_id"] == user_id) & (df["topic_name"] == t)]["rating"].mean()
        if np.isnan(pred):
            pred = df[df["topic_name"] == t]["rating"].mean()
        cf_scores.append(pred)
    content_scores["cf_score"] = cf_scores

    # Hybrid score
    content_scores["hybrid_score"] = (
        alpha * content_scores["content_score"] +
        beta * content_scores["cf_score"]
    )
```

```python
    # Rank and return
    recs = content_scores.sort_values(by="hybrid_score", ascending=False).head(top_k)
    return recs[["topic_name", "content_score", "cf_score", "hybrid_score"]]

# -------------------------------
# Generate recommendations for ALL users and topics
# -------------------------------
all_results = []

for user in df["user_id"].unique():
    for topic in df["topic_name"].unique():
        try:
            # Get recommendations for this user-topic combination
            recs = hybrid_recommend(user, topic, top_k=5)

            # Add input user and topic to the results
            recs = recs.copy()
            recs["input_user"] = user
            recs["input_topic"] = topic

            all_results.append(recs)

        except Exception as e:
            print(f"Skipping {user}, {topic} due to error: {e}")
            continue

# Combine into one DataFrame
if all_results:
    final_recs = pd.concat(all_results, ignore_index=True)

    # Reorder columns for readability
    final_recs = final_recs[["input_user", "input_topic", "topic_name", "content_score",

    # Save to CSV
    final_recs.to_csv("all_hybrid_recommendations.csv", index=False)

    print("Exported all recommendations to all_hybrid_recommendations.csv")
    print(f"Total recommendations generated: {len(final_recs)}")

    # -------------------------------
    # Show a quick sample
    # -------------------------------
    print("Example Recommendations:")
    print(final_recs.head(15).to_string(index=False, float_format="%.3f"))
else:
    print("No recommendations were generated. Check for errors above.")
```

```
Exported all recommendations to all_hybrid_recommendations.csv
Total recommendations generated: 7300
Example Recommendations:
input_user                   input_topic                                     topic_name
  content_score  cf_score  hybrid_score
    user_1    Unit 8 Safety and Security                      Unit 8 Safety and Security
         1.000     4.000         2.500
    user_1    Unit 8 Safety and Security                 Unit 2 Input and Output Devices
         0.070     4.000         2.035
    user_1    Unit 8 Safety and Security Unit 1 Types and Components of Computer Systems
         0.061     3.667         1.864
    user_1    Unit 8 Safety and Security                 Unit 5 The effects of using ICT
         0.070     2.857         1.464
    user_1    Unit 8 Safety and Security                Unit 3 Storage Devices and Media
         0.070     2.833         1.452
    user_1 Chapter 16 Marketing Strategy                   Chapter 15 The Marketing Mix
         0.223     4.333         2.278
    user_1 Chapter 16 Marketing Strategy                   Chapter 14 The Marketing Mix
         0.223     4.250         2.237
```

```
     user_1 Chapter 16 Marketing Strategy              Chapter 25 Analysis of Accountants
           0.027     4.400          2.213
     user_1 Chapter 16 Marketing Strategy                    Chapter 23 Income Statements
           0.027     4.000          2.013
     user_1 Chapter 16 Marketing Strategy                   Chapter 16 Marketing Strategy
           1.000     3.000          2.000
     user_1  Chapter 13 The Marketing Mix                    Chapter 15 The Marketing Mix
           0.517     4.333          2.425
     user_1  Chapter 13 The Marketing Mix                    Chapter 14 The Marketing Mix
           0.517     4.250          2.384
     user_1  Chapter 13 The Marketing Mix              Chapter 25 Analysis of Accountants
           0.029     4.400          2.215
     user_1  Chapter 13 The Marketing Mix                    Chapter 23 Income Statements
           0.029     4.000          2.015
     user_1  Chapter 13 The Marketing Mix                       Chapter 24 Balance Sheets
           0.029     3.667          1.848
```

In [30]:

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import mean_squared_error, mean_absolute_error, precision_score, re
from sklearn.model_selection import train_test_split
import warnings
warnings.filterwarnings('ignore')


final_recs = pd.read_csv("all_hybrid_recommendations.csv")


df = pd.read_csv(r"C:\Users\Rizwana\Desktop\studyoclock project\interactions_real.csv")

#Statistics and overview
print("BASIC STATISTICS")
print("=" * 50)
print(f"Total recommendations generated: {len(final_recs):,}")
print(f"Number of unique users: {final_recs['input_user'].nunique()}")
print(f"Number of unique topics: {final_recs['topic_name'].nunique()}")
print(f"Number of input topics: {final_recs['input_topic'].nunique()}")
print()

#SCORE DISTRIBUTION ANALYSIS
print("SCORE DISTRIBUTION")
print("=" * 50)
print("Hybrid Score Statistics:")
print(final_recs['hybrid_score'].describe().round(3))
print("\nContent Score Statistics:")
print(final_recs['content_score'].describe().round(3))
print("\nCF Score Statistics:")
print(final_recs['cf_score'].describe().round(3))

#Visualization: Score Distributions
plt.figure(figsize=(15, 5))

plt.subplot(1, 3, 1)
sns.histplot(final_recs['hybrid_score'], bins=30, kde=True)
plt.title('Distribution of Hybrid Scores')
plt.xlabel('Hybrid Score')

plt.subplot(1, 3, 2)
sns.histplot(final_recs['content_score'], bins=30, kde=True)
plt.title('Distribution of Content Scores')
plt.xlabel('Content Score')

plt.subplot(1, 3, 3)
```

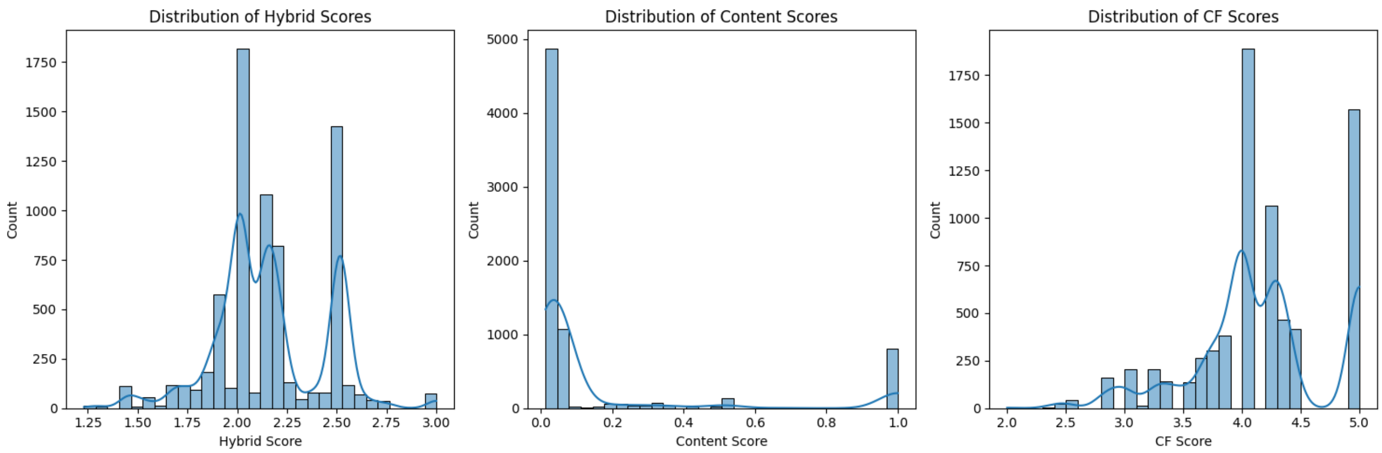
```
sns.histplot(final_recs['cf_score'], bins=30, kde=True)
plt.title('Distribution of CF Scores')
plt.xlabel('CF Score')

plt.tight_layout()
plt.savefig('score_distributions.png', dpi=300, bbox_inches='tight')
plt.show()

#CORRELATION ANALYSIS
print("CORRELATION ANALYSIS")
print("=" * 50)
correlation_matrix = final_recs[['hybrid_score', 'content_score', 'cf_score']].corr()
print("Correlation Matrix:")
print(correlation_matrix.round(3))

plt.figure(figsize=(8, 6))
sns.heatmap(correlation_matrix, annot=True, cmap='coolwarm', center=0, fmt='.3f')
plt.title('Correlation between Recommendation Scores')
plt.savefig('correlation_heatmap.png', dpi=300, bbox_inches='tight')
plt.show()

#TOP-N RECOMMENDATION ANALYSIS
#Create a binary relevance column (assuming ratings > 3 are relevant)
df['relevant'] = (df['rating'] >= 3).astype(int)

#Merge recommendations with actual interactions to find relevant items
eval_data = final_recs.merge(
    df[['user_id', 'topic_name', 'rating', 'relevant']],
    left_on=['input_user', 'topic_name'],
    right_on=['user_id', 'topic_name'],
    how='left'
)

eval_data['relevant'] = eval_data['relevant'].fillna(0)  # Not interacted = not relevant

# 5. PRECISION AND RECALL AT K
def precision_recall_at_k(df, k=5):
    results = []
    for user in df['input_user'].unique():
        user_recs = df[df['input_user'] == user].nlargest(k, 'hybrid_score')
        relevant_count = user_recs['relevant'].sum()
        precision = relevant_count / k if k > 0 else 0
        recall = relevant_count / df[(df['input_user'] == user) & (df['relevant'] == 1)]
        results.append({'user': user, 'precision': precision, 'recall': recall})
    return pd.DataFrame(results)

precision_recall_df = precision_recall_at_k(eval_data, k=5)

print("PRECISION AND RECALL AT K=5")
print("=" * 50)
print(f"Average Precision@5: {precision_recall_df['precision'].mean():.3f}")
print(f"Average Recall@5: {precision_recall_df['recall'].mean():.3f}")

#NDCG (Normalized Discounted Cumulative Gain)
def calculate_ndcg(df, k=5):
    ndcg_scores = []
    for user in df['input_user'].unique():
        user_recs = df[df['input_user'] == user].nlargest(k, 'hybrid_score')
        relevance_scores = user_recs['relevant'].values
        # Calculate ideal DCG
        ideal_relevance = np.sort(relevance_scores)[::-1]  # Sort in descending order
        dcg = sum((2 ** rel - 1) / np.log2(idx + 2) for idx, rel in enumerate(relevance_
        idcg = sum((2 ** rel - 1) / np.log2(idx + 2) for idx, rel in enumerate(ideal_rel
        ndcg = dcg / idcg if idcg > 0 else 0
        ndcg_scores.append(ndcg)
    return np.mean(ndcg_scores)
```

```python
avg_ndcg = calculate_ndcg(eval_data, k=5)
print(f"Average NDCG@5: {avg_ndcg:.3f}")

#USER ENGAGEMENT ANALYSIS
user_engagement = eval_data.groupby('input_user').agg({
    'hybrid_score': 'mean',
    'relevant': 'sum',
    'topic_name': 'count'
}).rename(columns={'topic_name': 'total_recommendations', 'relevant': 'relevant_recommen

user_engagement['engagement_rate'] = user_engagement['relevant_recommendations'] / user_

print( "USER ENGAGEMENT ANALYSIS")
print("=" * 50)
print("Top 10 Most Engaged Users:")
print(user_engagement.nlargest(10, 'engagement_rate')[['engagement_rate', 'relevant_reco

#Visualization: User Engagement
plt.figure(figsize=(12, 5))

plt.subplot(1, 2, 1)
sns.histplot(user_engagement['engagement_rate'], bins=20, kde=True)
plt.title('Distribution of User Engagement Rates')
plt.xlabel('Engagement Rate')

plt.subplot(1, 2, 2)
sns.scatterplot(data=user_engagement, x='hybrid_score', y='engagement_rate', alpha=0.6)
plt.title('Hybrid Score vs Engagement Rate')
plt.xlabel('Average Hybrid Score')
plt.ylabel('Engagement Rate')

plt.tight_layout()
plt.savefig('user_engagement_analysis.png', dpi=300, bbox_inches='tight')
plt.show()

#TOPIC POPULARITY ANALYSIS
topic_popularity = final_recs['topic_name'].value_counts().head(15)
topic_quality = eval_data.groupby('topic_name')['relevant'].mean().sort_values(ascending

plt.figure(figsize=(15, 6))

plt.subplot(1, 2, 1)
sns.barplot(y=topic_popularity.index, x=topic_popularity.values)
plt.title('Top 15 Most Frequently Recommended Topics')
plt.xlabel('Number of Recommendations')

plt.subplot(1, 2, 2)
sns.barplot(y=topic_quality.index, x=topic_quality.values)
plt.title('Top 15 Highest Quality Topics (Relevance Rate)')
plt.xlabel('Relevance Rate')

plt.tight_layout()
plt.savefig('topic_analysis.png', dpi=300, bbox_inches='tight')
plt.show()

#HYBRID MODEL COMPONENT ANALYSIS
component_analysis = final_recs[['content_score', 'cf_score', 'hybrid_score']].describe(

print(" HYBRID MODEL COMPONENT ANALYSIS")
print("=" * 50)
print(component_analysis)

#Visualization: Component influence
plt.figure(figsize=(12, 5))
```

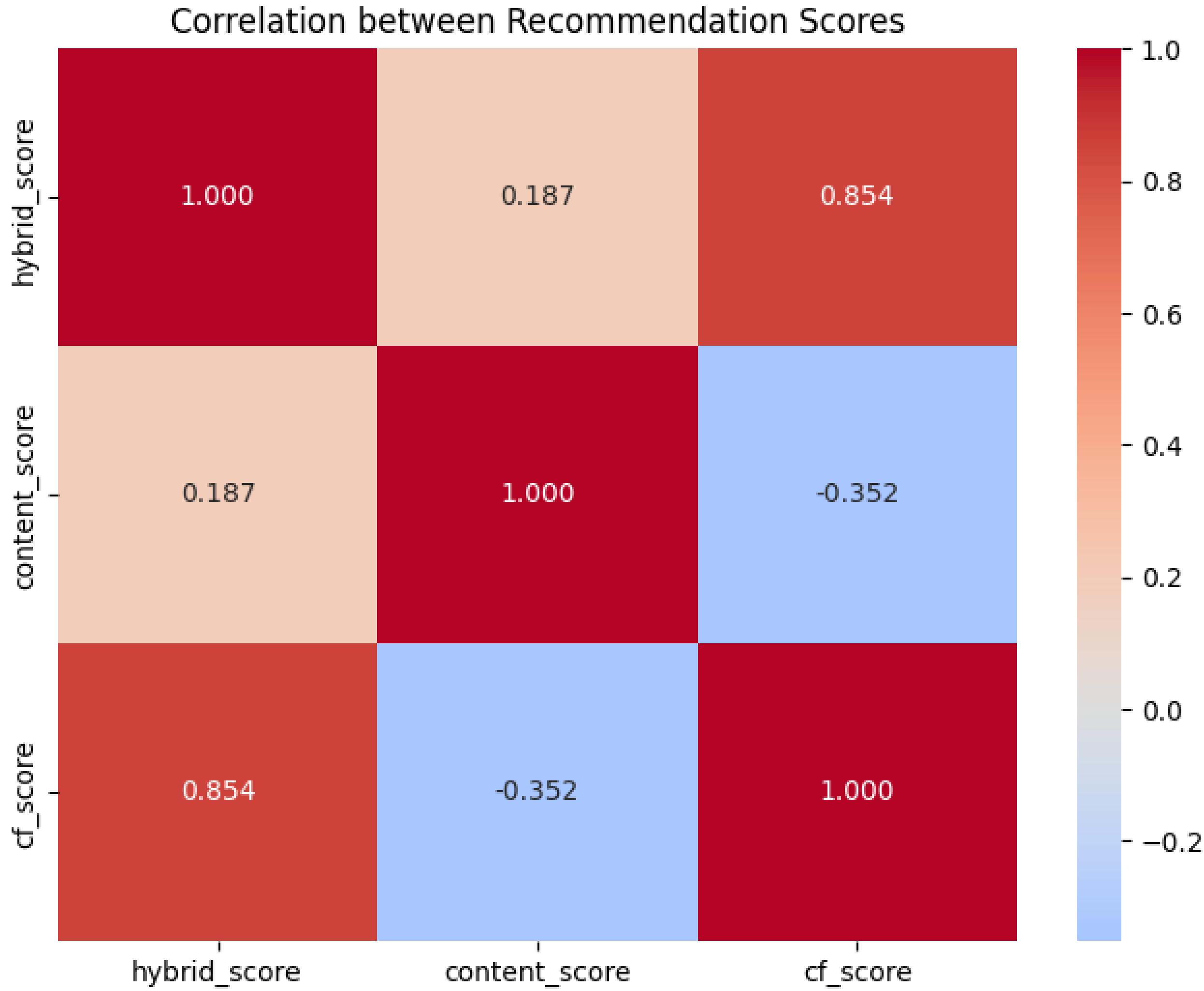
```python
plt.subplot(1, 2, 1)
sns.scatterplot(data=final_recs.sample(1000), x='content_score', y='cf_score',
                hue='hybrid_score', palette='viridis', alpha=0.6)
plt.title('Content vs CF Scores Colored by Hybrid Score')
plt.xlabel('Content Score')
plt.ylabel('CF Score')

plt.subplot(1, 2, 2)
sns.boxplot(data=final_recs[['content_score', 'cf_score', 'hybrid_score']])
plt.title('Distribution of All Score Types')
plt.xticks(rotation=45)

plt.tight_layout()
plt.savefig('component_analysis.png', dpi=300, bbox_inches='tight')
plt.show()

#Conclusion
print("\n" + "=" * 60)
print(" COMPREHENSIVE EVALUATION REPORT")
print("=" * 60)
print(f"Total Recommendations: {len(final_recs):,}")
print(f"Average Precision@5: {precision_recall_df['precision'].mean():.3f}")
print(f"Average Recall@5: {precision_recall_df['recall'].mean():.3f}")
print(f"Average NDCG@5: {avg_ndcg:.3f}")
print(f"Average User Engagement Rate: {user_engagement['engagement_rate'].mean():.3f}")
print(f"Average Hybrid Score: {final_recs['hybrid_score'].mean():.3f}")
print(f"Content-CF Correlation: {correlation_matrix.loc['content_score', 'cf_score']:.3f

#Save evaluation metrics to CSV
evaluation_metrics = pd.DataFrame({
    'metric': ['Precision@5', 'Recall@5', 'NDCG@5', 'Engagement_Rate', 'Avg_Hybrid_Score
    'value': [
        precision_recall_df['precision'].mean(),
        precision_recall_df['recall'].mean(),
        avg_ndcg,
        user_engagement['engagement_rate'].mean(),
        final_recs['hybrid_score'].mean(),
        correlation_matrix.loc['content_score', 'cf_score']
    ]
})

evaluation_metrics.to_csv('evaluation_metrics.csv', index=False)
print("Evaluation metrics saved to evaluation_metrics.csv")
print("All visualizations saved as PNG files")
```

```
BASIC STATISTICS
==================================================
Total recommendations generated: 7,300
Number of unique users: 20
Number of unique topics: 67
Number of input topics: 73

SCORE DISTRIBUTION
==================================================
Hybrid Score Statistics:
count    7300.000
mean        2.158
std         0.277
min         1.231
25%         2.012
50%         2.140
75%         2.417
max         3.000
Name: hybrid_score, dtype: float64

Content Score Statistics:
```

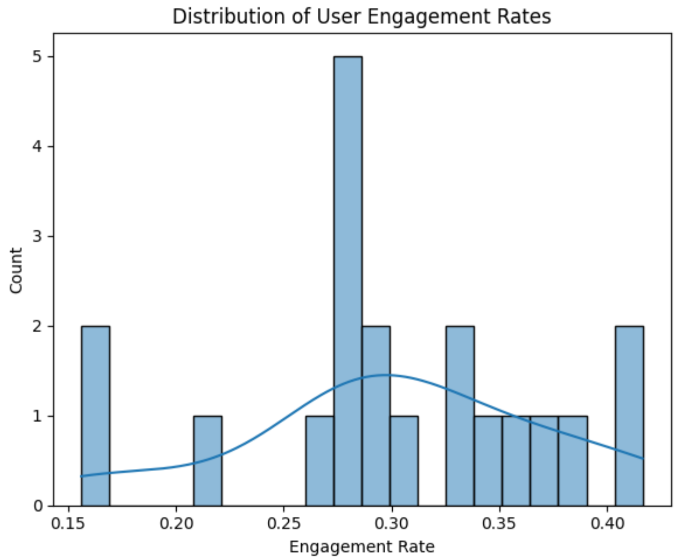
```
count    7300.000
mean        0.166
std         0.308
min         0.014
25%         0.029
50%         0.038
75%         0.058
max         1.000
Name: content_score, dtype: float64

CF Score Statistics:
count    7300.000
mean        4.150
std         0.582
min         2.000
25%         3.833
50%         4.000
75%         4.400
max         5.000
Name: cf_score, dtype: float64
```

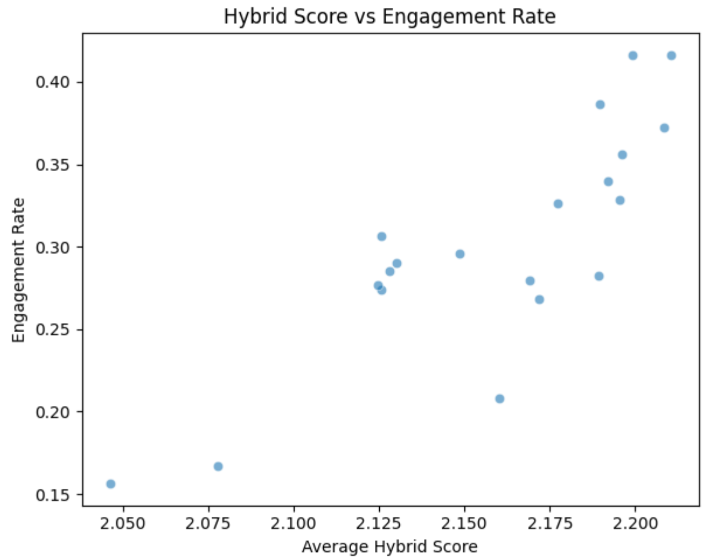



```
CORRELATION ANALYSIS
==================================================
Correlation Matrix:
               hybrid_score  content_score  cf_score
hybrid_score          1.000          0.187     0.854
content_score         0.187          1.000    -0.352
cf_score              0.854         -0.352     1.000
```



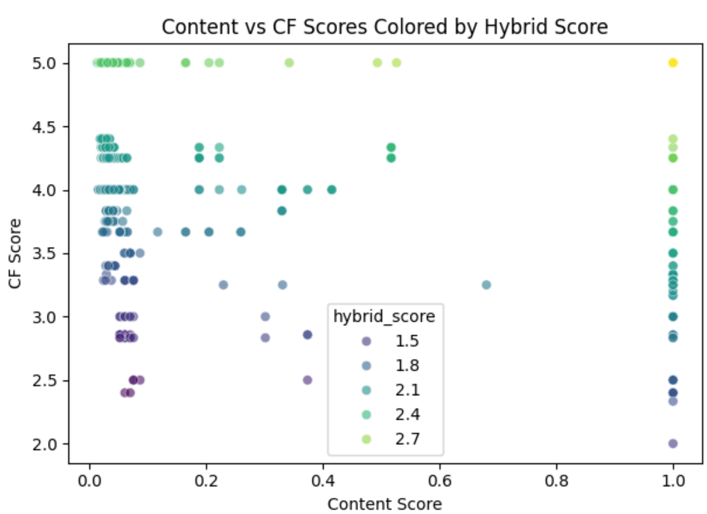

```
PRECISION AND RECALL AT K=5
==================================================
Average Precision@5: 0.590
Average Recall@5: 0.026
Average NDCG@5: 0.748
USER ENGAGEMENT ANALYSIS
==================================================
Top 10 Most Engaged Users:
            engagement_rate  relevant_recommendations
input_user
user_11               0.416                     152.0
user_8                0.416                     152.0
user_7                0.386                     141.0
user_17               0.373                     136.0
user_3                0.356                     130.0
user_2                0.340                     124.0
user_6                0.329                     120.0
user_16               0.326                     119.0
user_4                0.307                     112.0
user_15               0.296                     108.0
```

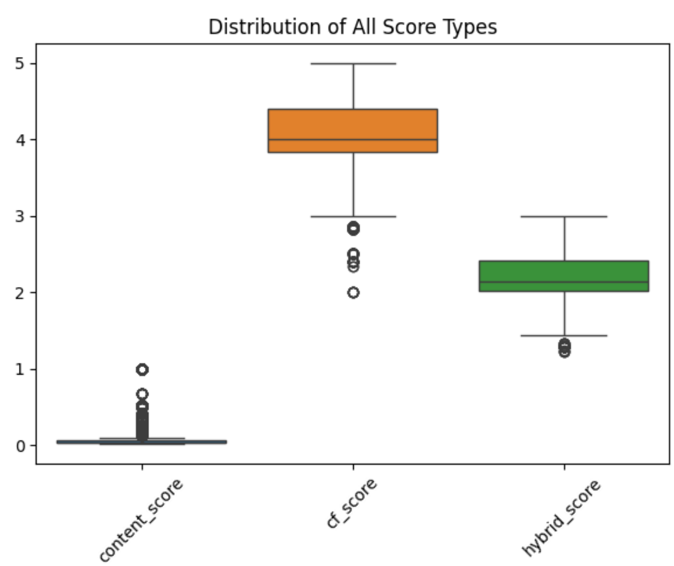




🔧 HYBRID MODEL COMPONENT ANALYSIS

```
==================================================
       content_score  cf_score  hybrid_score
count       7300.000  7300.000      7300.000
mean           0.166     4.150         2.158
std            0.308     0.582         0.277
min            0.014     2.000         1.231
25%            0.029     3.833         2.012
50%            0.038     4.000         2.140
75%            0.058     4.400         2.417
max            1.000     5.000         3.000
```






```
============================================================
```

```
 COMPREHENSIVE EVALUATION REPORT
============================================================
Total Recommendations: 7,300
Average Precision@5: 0.590
Average Recall@5: 0.026
Average NDCG@5: 0.748
Average User Engagement Rate: 0.302
Average Hybrid Score: 2.158
Content-CF Correlation: -0.352
Evaluation metrics saved to evaluation_metrics.csv
All visualizations saved as PNG files
```

In [ ]: