

Analysis of AI Thinking Traces in KSAO Extraction

Methodological Insights from Gemini 2.5 Pro's Reasoning Processes

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GitHub Repository: https://github.com/actonbp/KSAO_WFD

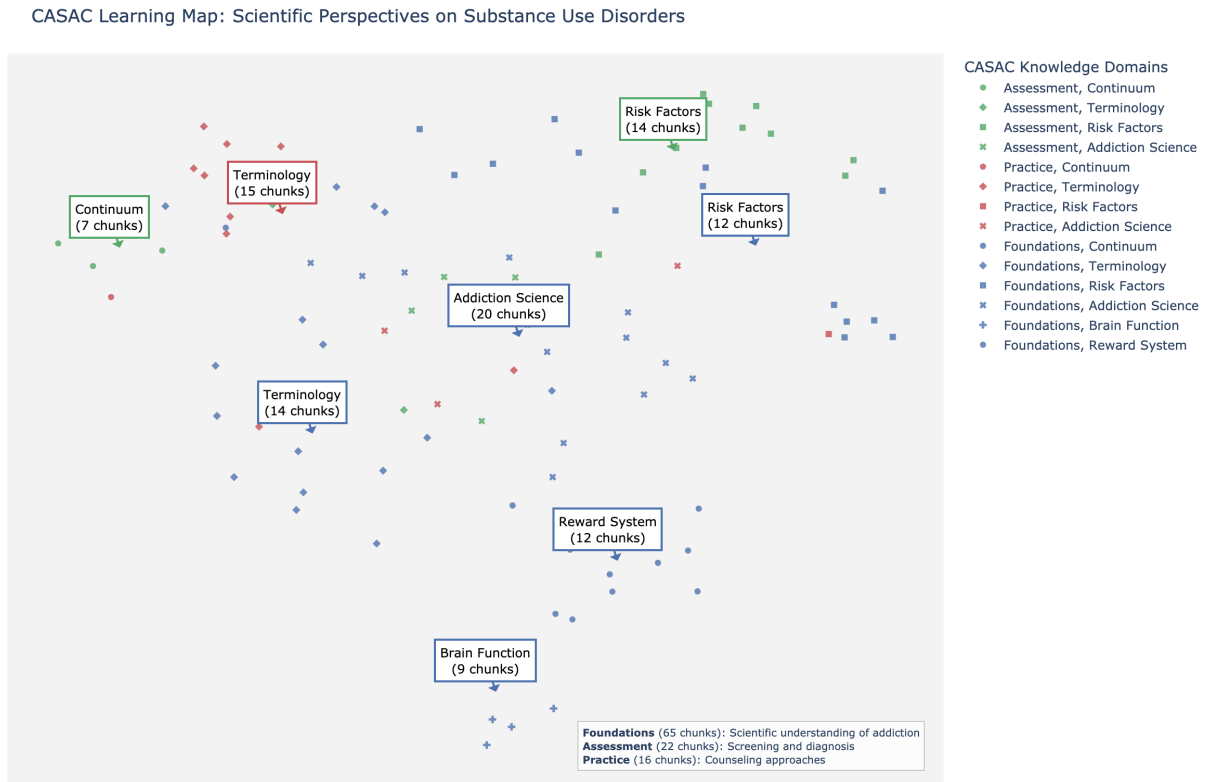


Figure 1: CASAC Learning Map

i Executive Summary

This report analyzes the thinking processes employed in a multi-stage AI-assisted approach to competency extraction. By examining thinking traces captured during the analysis of addiction counseling textbook materials, we've documented effective methodologies for KSAO identification and relationship mapping. This meta-analysis reveals generalizable principles for competency mapping that can be applied across diverse professional fields, offering valuable insights for both AI-assisted and human-led curriculum development efforts.

0.1 Analysis Information

Document Status: WORKING DRAFT (Version 1.0)

Last Updated: May 18, 2025

Source Document: Credentialed Alcoholism and Substance Abuse Counselor (CASAC) Textbook

Analysis Date: May 18, 2025

Model Used: Google Gemini 2.5 Pro Preview

Chapters Analyzed: Chapters 1-9 and Appendices (Complete Textbook Analysis)

Analysis Type: Comprehensive Thinking Trace Meta-Analysis

Chapter 1

Introduction

This report presents a meta-analysis of the thinking traces generated by Google’s Gemini 2.5 Pro model during the process of KSAO extraction from CASAC textbook chapters. While the companion report “Integrated KSAO Framework” presents the results of this analysis, this document focuses on the process itself - examining how the AI approached the task, what patterns emerged in its reasoning, and what methodological insights can be gained.

The analysis of thinking traces provides valuable insights into effective methods for competency extraction and offers transparency into how the AI-derived framework was developed. This meta-level understanding can inform both future AI-assisted competency mapping projects and traditional human-led curriculum development efforts.

1.1 Acknowledgments

Note

The methodological analysis presented in this report was made possible through collaborative efforts and support from multiple sources. We would like to express our gratitude to:

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- Anthropic for Claude Code assistance in documentation and report preparation
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- The AI ethics community for developing standards for transparent AI research reporting
- Fellow researchers in the fields of computational approaches to workforce development
- Practitioners who provided feedback on the practical implications of these methodological insights

We are particularly grateful to those who encouraged the documentation and analysis of thinking traces as a way to enhance transparency in AI-assisted research.

Text Extraction

Initial Identification

Classification

Relationship Mapping

Meta-Analysis

Chapter 2

Methodology

2.1 Data Sources

The thinking traces analyzed in this report were generated during the comprehensive analysis of all textbook chapters:

Note

1. **Chapter 1:** Covering SUD terminology, neurobiology, models of addiction, risk factors, etc.
2. **Chapter 2:** Focusing on systems of care, telehealth, harm reduction, etc.
3. **Chapter 3:** Covering screening, assessment, and treatment planning processes.
4. **Chapter 4:** Focusing on counseling methods and therapeutic approaches.
5. **Chapter 5:** Examining case management and service coordination.
6. **Chapter 6:** Covering evidence-based practices in substance use disorder treatment.
7. **Chapter 7:** Examining professional, ethical, and legal responsibilities.
8. **Chapter 8:** Covering documentation, record-keeping, and clinical supervision.
9. **Chapter 9:** Focusing on cultural competence and special populations.
10. **Appendices:** Including commonly used drugs, mental health conditions, etc.
11. **Integration Process:** The trace from combining the individual chapter analyses

2.2 Analysis Approach

Important

Prompt Used for Thinking Trace Analysis:

“You are an expert in meta-cognitive analysis and curriculum development methodology. I need you to analyze the thinking traces generated by an AI during the process of extracting Knowledge, Skills, Abilities, and Other characteristics (KSAOs) from substance use disorder counseling textbook materials.

Please analyze these thinking traces to: 1. Identify common themes, patterns, and approaches used across different chapter analyses 2. Highlight key methodological insights about effective KSAO extraction processes 3. Summarize the most effective reasoning processes observed 4. Identify variations in approach between different chapters and their effectiveness 5. Extract generalizable principles for KSAO identification that could be applied in other domains

Focus particularly on: - The sequencing of analytical steps - How decisions were made about classification (K vs S vs A vs O) - How relationships between KSAOs were identified - Methods used for

resolving ambiguities or overlaps - Effective strategies for comprehensive coverage of material”

The thinking traces themselves were analyzed using Gemini 2.5 Pro with a specialized prompt that asked the model to: - Identify common themes, patterns, and approaches used across analyses - Highlight key methodological insights about KSAO extraction - Summarize the most effective reasoning processes - Identify variations in approach between different chapters - Extract generalizable principles for KSAO identification

Chapter 3

Thinking Process Analysis

3.1 Meta-Analysis of AI Thinking Traces for KSAO Identification

Document Purpose: This document provides a meta-analysis of AI thinking traces generated during the process of identifying Knowledge, Skills, Abilities, and Other Characteristics (KSAOs) from chapters of a Substance Use Disorder (SUD) counselor textbook. It aims to help curriculum developers understand effective KSAO identification methodologies and how AI reasoning can be leveraged for competency mapping.

3.1.1 1. Common Themes, Patterns, and Approaches Used Across Analyses

Across the provided thinking traces, several common themes, patterns, and approaches employed by the AI for KSAO extraction are consistently evident:

- **Systematic Phased Approach:** The AI consistently breaks down the KSAO identification task into logical, sequential phases. This structured methodology ensures comprehensive coverage and systematic analysis. The typical phases include:
 - **Initial Read-through/Skimming:** Gaining a high-level understanding of the chapter’s content, key concepts, and overall structure.
 - * *Example (Appendices_ksao_analysis):* “Phase 1: Initial Read-through and Key Concept Noting... Here are my initial high-level observations and concepts related to KSAOs...”
 - * *Example (Chapter_5_ksao_analysis):* “Phase 1: Initial Read-Through and High-Level Understanding... My initial impression is that this chapter is rich with information...”
 - **Detailed Section-by-Section Analysis:** A more granular examination of the text, often following the chapter’s own organizational structure, to pinpoint potential KSAOs.
 - * *Example (Chapter_4_ksao_analysis):* “Phase 2: Section-by-Section Identification of Explicit and Implicit Competencies.” The AI then processes “SECTION: INTRODUCTION,” “SECTION: OVERARCHING ISSUES,” etc.
 - **KSAO Identification and Derivation:** Extracting explicitly stated competencies and inferring implicit ones from the text. Action verbs (e.g., “recognize,” “utilize,” “demonstrate”) and statements of need (“counselors must understand...”) are key indicators.
 - * *Example (Appendices_ksao_analysis):* From Job Task “Recognize how addiction effects the brain,” the AI derives “Explicit KSAO Idea 1: Knowledge of the neurobiology of addiction.”
 - **Categorization (K, S, A, O):** Assigning each identified competency to one of the KSAO categories (Knowledge, Skill, Ability, Other Characteristic).
 - * *Example (Chapter_1_ksao_analysis - Hypothetical):* “Knowledge of addiction theories: K (Knowledge),” “Empathy: A (Ability) or O (Other Characteristic).”

- **Attribute Analysis:** Defining further characteristics for each KSAO, such as specificity, malleability, explicit/tacit nature, relevant O*NET codes, and prerequisites.
 - * *Example (Chapter_3_ksao_analysis):* For each KSAO: “Classification,” “Specificity Level,” “Related O*NET Categories,” “Stability/Malleability,” “Explicit/Tacit,” “Prerequisites.”
- **Relationship Mapping:** Analyzing hierarchies, dependencies, and developmental sequences among the identified KSAOs.
 - * *Example (Chapter_6_ksao_analysis):* “Phase 4: Identifying Hierarchical Structure” which considers Dimensions, Sub-dimensions, Developmental Sequence, and Foundations.
- **Consolidation and Refinement:** Merging duplicate or highly similar KSAO “ideas” into a single, well-defined KSAO, and refining names and descriptions for clarity.
 - * *Example (Appendices_ksao_analysis):* “(Self-correction: I’ve been labeling them ‘KSAO Idea X’. I will now formalize them into the KSAO list, merging duplicates and refining descriptions.)”
- **Structured Organization and Presentation:** Systematically organizing the final KSAOs, often thematically or by professional domains, using tables or structured lists.
- **Leveraging Text Structure:** The AI effectively uses the inherent structure of the source material (e.g., chapter outlines, section headings, pre-existing competency lists like the IC&RC Job Tasks) to guide its analysis and organize the findings.
 - *Example (Appendices_ksao_analysis):* “The IC&RC Job Tasks (competencies) will form the backbone of the KSAO list.”
 - *Example (Chapter_8_ksao_analysis):* The AI processes “TYPES OF DOCUMENTATION” by looking at “1. Client Administrative Information,” “2. Substance Use Screening and Assessment,” etc.
- **Distinction Between Explicit and Implicit Competencies:** The AI consistently attempts to identify competencies that are directly stated in the text versus those that are implied by the context or descriptions of tasks and responsibilities.
 - *Example (textbook_ksao_analysis - Chapter 1 content):* Under “Phase 2: Section-by-Section Deep Dive,” the AI explicitly notes “Explicit:” and “Implicit:” competencies.
- **Focus on Action Verbs and Prescriptive Language:** The AI pays close attention to verbs (e.g., “identify,” “utilize,” “collaborate,” “assess,” “document”) and prescriptive statements (e.g., “counselors need to,” “it is important to,” “counselors should”) to derive KSAOs and determine their nature (often distinguishing K from S).
 - *Example (Chapter_9_ksao_analysis):* Initial annotations look for phrases like “mandates for professional and ethical conduct” (K), “advocates...provide for the right care” (S).
- **Iterative Processing:** The AI often revisits and refines its initial extractions, merging similar items, clarifying descriptions, and ensuring consistency in categorization. This iterative self-correction is crucial for quality.

3.1.2 2. Key Methodological Insights About How the AI Approached KSAO Extraction

The AI’s KSAO extraction process reveals several important methodological insights:

- **Pattern Recognition for KSAO Types:** The AI appears to use patterns in language to infer KSAO types:
 - Statements about understanding, knowing facts, or being familiar with concepts typically lead to “Knowledge” KSAOs.
 - * *Example (Chapter_7_ksao_analysis):* “Understand core principles of case management” leads to **Knowledge of Case Management Principles**.
 - Descriptions of performing actions, applying techniques, or demonstrating proficiency typically lead to “Skill” KSAOs.
 - * *Example (Chapter_6_ksao_analysis):* Text on MI OARS skills directly leads to “Skill in

- Using Open-Ended Questions (MI),” etc.
 - Descriptions of broader, more innate or general capacities lead to “Ability” KSAOs.
 - * *Example (Chapter_4_ksao_analysis)*: “critical thinking skills help analyze information...” leads to **Ability to Apply Critical Thinking**.
 - Statements about necessary attitudes, values, traits, or commitments lead to “Other Characteristic” KSAOs.
 - * *Example (Chapter_5_ksao_analysis)*: “counselor must believe in the client’s potential for recovery” leads to **Other Characteristic: Belief in Client Potential for Recovery**.
- **Decomposition of Complex Competencies**: The AI frequently breaks down broad competency statements or job tasks from the source material into more granular, distinct KSAOs.
 - *Example (Appendices_ksao_analysis)*: The job task “Collaborate with multidisciplinary teams, other professionals and client supports to determine and provide care” is decomposed into “Skill in interprofessional collaboration,” “Implicit KSAO Idea 2: Knowledge of the roles of different professionals,” and “Implicit KSAO Idea 3: Communication skills.”
- **Contextual Interpretation**: The AI doesn’t just do keyword spotting; it interprets phrases within the context of professional SUD counseling to derive relevant KSAOs.
 - *Example (Chapter_8_ksao_analysis)*: The section “Why Document?” leads to KSAOs about risk management, substantiating services, and meeting legal requirements, all interpreted within a clinical documentation context.
- **Use of Pre-existing Frameworks When Available**: When the source text provides a structured list (like IC&RC job tasks in *Appendices_ksao_analysis*), the AI uses this as a primary scaffold for KSAO extraction, a top-down approach.
- **Inferential Extraction from Narrative Text**: For prose chapters, the AI engages in a bottom-up process, inferring KSAOs from descriptive statements, explanations of concepts, and discussions of counselor roles and responsibilities.
 - *Example (textbook_ksao_analysis - Chapter 1 content)*: “Theories of Causation (biological/disease, moral, blended)” leads to **Knowledge of Addiction Models/Theories**.
- **Handling of Missing or Problematic Input (Chapter_1_ksao_analysis)**: When faced with missing text, the AI’s methodology shifts to outlining its *intended* process and demonstrating it with a hypothetical example. This highlights a robust underlying design that can articulate its steps even if it cannot execute them on the provided input.
- **Cross-Referencing and Synthesis (especially in Appendices_ksao_analysis)**: The AI attempts to connect information across different sections or appendices. For instance, knowledge described in one appendix is linked to job tasks outlined in another. This demonstrates an ability to synthesize information.

3.1.3 3. Summarizes the Reasoning Processes That Were Most Effective

Several reasoning processes employed by the AI appear particularly effective for KSAO extraction:

- **Direct Translation from Explicit Competency Statements**: When the text provides explicit job tasks, lists of responsibilities, or statements like “counselors need to X,” the AI’s direct translation of these into KSAOs is highly effective and reliable.
 - *Example (Appendices_ksao_analysis)*: Almost every job task from Appendix A was effectively translated into one or more KSAOs.
 - *Example (textbook_ksao_analysis - Chapter 1 content)*: The “Importance for SUD Counselors” section listed functional requirements (e.g., “Accurate Assessment and Diagnosis”), which were effectively converted to skills (**Skill in SUD Assessment and Diagnosis**).

- **Systematic Decomposition of Tasks/Statements:** Breaking down broader statements into constituent knowledge and skill components is a powerful reasoning process.
 - *Example (Chapter_9_ksao_analysis):* “knowledgeable about and abide by all laws, regulations, policies, and ethical codes” leads to both K: Legal/Ethical Framework Mastery and A: Application of legal/ethical framework.
- **Inferential Reasoning Based on Functional Descriptions:** The AI effectively infers KSAOs from descriptions of *what needs to be done* or *what a concept entails*.
 - *Example (Chapter_4_ksao_analysis):* Descriptions of “Shared Decision-Making (SDM)” and “The SHARE Approach” lead to K: Knowledge of SDM models (e.g., SHARE) and S: Skill in implementing SDM steps.
- **Hierarchical and Relational Analysis:** The AI’s ability to analyze dependencies (e.g., knowledge precedes skill) and to group KSAOs into broader dimensions is a sophisticated reasoning process. This moves beyond simple listing to creating a structured competency model.
 - *Example (Chapter_3_ksao_analysis):* The AI identifies “Knowledge of EBTs for CODs” as a prerequisite for “Skill in Adapting EBTs... for CODs.”
- **Attribute-Based Differentiation:** The process of assigning detailed attributes (specificity, malleability, explicit/tacit) to each KSAO represents a refined reasoning process. It allows for a nuanced understanding of each competency.
 - *Example (Chapter_5_ksao_analysis):* “Skill: Group Facilitation” is described as “Both (explicit techniques, tacit process management)” for its Explicit/Tacit Orientation, which is a nuanced and accurate assessment.
- **Use of Guiding Questions/Frameworks (Implicit):** Although not always explicitly stated as “I am asking myself X,” the AI’s consistent output format suggests it is implicitly working through a series of questions for each piece of text:
 - What does a counselor *need to know* here? (-> Knowledge)
 - What does a counselor *need to be able to do* here? (-> Skill)
 - What underlying *capacity* is required? (-> Ability)
 - What *trait or value* is implied? (-> Other Characteristic)

3.1.4 4. Variations in Approach Between Different Chapters and Why They Might Occur

The AI’s approach shows subtle but important variations based on the nature of the input text:

- **Structured vs. Narrative Input:**
 - **Structured Input (e.g., Appendices_ksao_analysis with IC&RC Job Tasks):** The AI adopts a more **top-down** approach. The pre-defined job tasks serve as high-level competencies, which are then parsed and supplemented by detailed knowledge from other appendices. The focus is on categorizing and elaborating on existing competency statements.
 - * *Why:* The source text itself provides a competency framework, making this the most efficient and direct method.
 - **Narrative Input (e.g., Chapter_2_ksao_analysis, Chapter_6_ksao_analysis):** The AI employs a more **bottom-up** approach. It scans the descriptive prose, identifies keywords, action verbs, and conceptual explanations, and then synthesizes these into KSAOs.
 - * *Why:* Narrative chapters explain concepts and principles without necessarily providing a direct list of “tasks.” KSAOs must be inferred from the information presented. For example, a description of CBT techniques leads to KSAOs about knowing and applying those techniques.
- **Presence of Explicit “Counselor Role/Importance” Sections:**
 - Some chapters (like the “textbook_ksao_analysis” for Chapter 1, or Chapter 8 on Documentation) have sections that explicitly state “Importance for SUD Counselors” or list “Documentation Skills.” In these cases, the AI can directly translate these statements into KSAOs, similar to how it handles job tasks.
 - *Example (textbook_ksao_analysis - Chapter 1 content):* The AI leverages the “Importance for

SUD Counselors” section (p. 25-26) to directly extract skills like “Accurate Assessment and Diagnosis” and “Treatment Planning.”

- *Why*: These sections act like mini-competency lists within the narrative, providing explicit pointers.
- **Handling of Different KSAO Types Emphasis:**
 - Chapters focused on foundational science (e.g., “textbook_ksao_analysis” - Chapter 1) yield a high proportion of “Knowledge” KSAOs.
 - Chapters focused on interventions (e.g., Chapter 6 on EBPs) yield many “Knowledge” (of theories/models) and “Skill” (in applying techniques) KSAOs.
 - Chapters focused on professional conduct (e.g., Chapter 9 on Ethics) yield many “Knowledge” (of codes/laws), “Skill” (in ethical decision-making), and “Other Characteristic” (e.g., integrity, self-awareness) KSAOs.
 - *Why*: The AI’s output naturally reflects the dominant content type of the source material.
- **Response to Technical Issues (e.g., Chapter_1_ksao_analysis with missing text, or OCR errors in Chapter 4 and others):**
 - The AI explicitly notes when text is missing or unreadable.
 - In the Chapter_1_ksao_analysis trace, the AI shifts its approach entirely to demonstrating its *intended* methodology using a hypothetical example, because it cannot perform an actual analysis.
 - *Why*: This is an adaptive response to input failure, prioritizing demonstration of capability over futile attempts to analyze missing data.

In essence, while the AI’s core multi-phase methodology and KSAO attribute framework remain consistent, its initial extraction strategy (top-down vs. bottom-up) and the type of KSAOs predominantly identified vary logically with the structure and content of the source material.

3.1.5 5. Generalizable Principles for KSAO Identification in Professional Competency Mapping

The AI’s effective processes highlight several generalizable principles for robust KSAO identification:

1. **Employ a Structured, Multi-Phased Methodology:** Break down the complex task of KSAO identification into manageable phases (e.g., initial overview, detailed analysis, categorization, attribute assignment, relationship mapping, validation). This ensures systematic coverage and reduces oversight.
2. **Leverage Existing Professional Frameworks:** If available, start with established job task analyses, competency models, or professional standards (like the IC&RC domains/tasks). These provide a validated, top-down scaffold.
3. **Systematically Analyze Diverse Source Materials:** Go beyond a single textbook. Include job descriptions, regulatory guidelines, expert interviews, and research literature to get a comprehensive view of required competencies.
4. **Distinguish Between Explicit and Implicit Competencies:** Not all KSAOs are explicitly stated. Develop skills in inferring implicit requirements from descriptions of tasks, responsibilities, challenges, and desired outcomes.
5. **Focus on Actionable Verbs and Functional Descriptions:** When analyzing text, pay close attention to verbs and descriptions of functions to determine if a K, S, A, or O is being implied. (“The counselor *must be able to assess*...” strongly suggests a Skill).
6. **Standardize KSAO Definitions and Attributes:** For each KSAO, use a consistent format:
 - Clear, concise **Name/Title**.
 - Comprehensive **Description** of what it entails in the professional context.
 - Accurate **Classification** (K, S, A, O).
 - Consider additional relevant **Attributes** (e.g., specificity, malleability, explicit/tacit nature, criticality, learning difficulty) to inform curriculum design.
7. **Map Interrelationships and Hierarchies:** Competencies are interconnected. Identify:
 - **Prerequisites:** What KSAOs are needed before others can be developed?

- **Component KSAOs:** How do granular KSAOs build up to broader competencies or job tasks?
 - **Developmental Sequences:** Is there a logical order for acquiring related KSAOs?
8. **Iterate, Refine, and Validate:** KSAO identification is an iterative process. Initial lists should be reviewed, refined, and consolidated. Crucially, the identified KSAOs and the resulting competency model should be validated with subject matter experts and practitioners in the field.
 9. **Contextualize KSAOs:** Always define KSAOs within the specific context of the profession and the roles/responsibilities involved. The same nominal skill (e.g., “communication”) can have very different applications and proficiency levels across professions.
 10. **Consider the “Other Characteristics” (O):** Don’t neglect the less tangible but often critical personal attributes, values, and ethical orientations essential for effective professional practice. These often underpin the successful application of knowledge and skills.
-

3.1.6 Conclusion and Best Practices for KSAO Identification and Competency Mapping

This meta-analysis highlights that a systematic, analytical, and attribute-rich approach to KSAO identification, as modeled by the AI, is highly effective. For curriculum developers, understanding these AI reasoning processes can inform their own methodologies and demonstrate how AI can be a powerful tool in competency mapping.

Best Practices for KSAO Identification and Competency Mapping:

1. **Define Purpose and Scope Clearly:** Be explicit about why the KSAO identification is being done (e.g., curriculum design, job role definition, certification development) and the scope of the analysis (e.g., specific roles, levels of expertise).
2. **Use a Hybrid Approach:** Combine top-down methods (starting from existing competency frameworks or job tasks) with bottom-up methods (extracting from diverse textual and expert sources).
3. **Involve Subject Matter Experts (SMEs):** SMEs are crucial for validating KSAOs, defining proficiency levels, contextualizing competencies, and ensuring the final framework is accurate and relevant to the profession.
4. **Maintain a Centralized KSAO Dictionary:** As KSAOs are identified, store them in a structured database or dictionary with their full definitions and attributes. This aids consistency and reusability.
5. **Develop a Visual Competency Model:** Represent the relationships between KSAOs (hierarchies, clusters, pathways) visually. This helps in understanding the overall competency architecture and is invaluable for curriculum structuring.
6. **Link KSAOs Directly to Learning Objectives and Assessments:** The ultimate goal for curriculum developers is to ensure educational programs effectively develop the target KSAOs. Each KSAO should translate into one or more measurable learning objectives, and assessments should be designed to evaluate their attainment.
7. **Leverage AI as an Augmentation Tool:**
 - AI can rapidly process large volumes of text to perform initial KSAO extraction and categorization, saving significant human effort.
 - AI can help identify patterns and relationships that might be less obvious to human analysts.
 - AI can assist in maintaining consistency in terminology and formatting.
 - However, human oversight, critical judgment, and contextual understanding remain essential for refining AI outputs, validating KSAOs, and making final decisions, especially for nuanced or tacit competencies.
8. **Prioritize and Weight KSAOs:** Not all KSAOs are equally critical or difficult to develop. Engage SMEs to help prioritize KSAOs for curriculum focus based on factors like job relevance, criticality for safety/ethics, and frequency of use.
9. **Plan for Regular Review and Updates:** Professions evolve, and so do the KSAOs required for competence. Establish a process for periodically reviewing and updating the competency framework and KSAO dictionary.

By adopting these best practices, curriculum developers can create robust and relevant competency frameworks. The AI's methodical approach, as seen in its thinking traces, provides a valuable template for breaking down this complex task and demonstrates the potential for AI to significantly assist in the foundational work of competency mapping.

Chapter 4

Applications of Thinking Process Insights

The methodological insights extracted from the AI's thinking processes can be applied in several ways:

Tip

1. **Curriculum Development:** Human curriculum developers can adopt similar systematic approaches when analyzing educational content for competency mapping.
2. **Prompt Engineering:** Future AI-assisted KSAO extraction projects can benefit from refined prompts that incorporate the most effective reasoning structures identified here.
3. **Validation Methods:** The thinking processes reveal what sources and reasoning patterns provide the strongest evidence for including particular KSAOs, which can inform validation approaches.
4. **Methodology Training:** Educators and workforce development specialists can be trained in systematic approaches to competency identification using the patterns observed in the AI's reasoning.

Chapter 5

Limitations and Considerations

While the analysis of thinking traces provides valuable insights, several limitations should be noted:

Note

1. **AI-Specific Reasoning:** Some aspects of the AI's thinking process may not directly translate to human reasoning approaches.
2. **Model Limitations:** Despite analyzing the complete textbook, the AI's reasoning processes have inherent limitations in their ability to fully capture all nuances in professional competency development.
3. **Implicit Assumptions:** The AI may make implicit assumptions or connection leaps that aren't fully documented in the thinking traces.
4. **Domain Specificity:** The approaches documented here are specific to substance use disorder counseling and may need adaptation for other domains.

Chapter 6

Conclusion

The analysis of AI thinking traces reveals a rich, systematic methodology for KSAO extraction that combines close text analysis, inference, categorization, and relationship mapping. By documenting and analyzing these processes, we gain not only a better understanding of how the KSAO framework was developed but also valuable insights that can enhance human-led competency mapping efforts.

The systematic, phase-based approach observed across analyses suggests a generalizable methodology that could be adapted for competency mapping in various professional domains beyond substance use disorder counseling. This represents a significant contribution to the field of workforce development, offering both process transparency and methodological advancement.

6.1 Feedback and Future Directions

As a working draft, this methodology report will continue to evolve. We welcome feedback from researchers, educators, and AI practitioners interested in applied AI methodologies for competency mapping.

Planned Methodological Advancements

1. **Prompt Engineering Research:** Systematic testing of alternative prompting strategies
2. **Human-AI Collaboration Models:** Development of hybrid approaches combining AI and human expertise
3. **Validation Protocols:** Creation of validation methods for AI-derived competency frameworks
4. **Cross-Model Comparison:** Analysis of thinking processes across different AI models and architectures
5. **Domain Transfer Experiments:** Testing methodology generalization to other professional domains
6. **Longitudinal Process Analysis:** Tracking methodological evolution as AI capabilities advance

To contribute to these methodological advancements or provide feedback, please visit the [GitHub repository](#) or contact the primary author directly.

Chapter 7

Appendix: Technical Implementation

This appendix provides the actual code implementation for key components of the technical pipeline, with special focus on the thinking trace analysis process. These scripts demonstrate the sophisticated multi-stage approach used to capture and analyze AI reasoning.

7.1 A1. OCR Text Extraction with Thinking Trace Feature

The OCR text extraction utilized Gemini 2.5 Pro's multimodal capabilities combined with thinking trace capturing functionality:



```
#!/usr/bin/env python
import os
import base64
import argparse
from pathlib import Path
from PIL import Image
import io
from google import genai
from dotenv import load_dotenv
import time
import json

# Load environment variables from .env file (contains GEMINI_API_KEY)
load_dotenv()

# Get the API key
api_key = os.environ.get("GEMINI_API_KEY")
if not api_key:
    raise ValueError("GEMINI_API_KEY environment variable not found. Please set it in your .env file.")

# Initialize the Gemini API client
client = genai.Client(api_key=api_key)

# Current model version
GEMINI_MODEL = "gemini-2.5-pro-preview-05-06" # Updated to use Gemini 2.5 Pro

# Process a single page and extract text using Gemini API with thinking traces enabled
def extract_text_from_page(img):
    """
    Extract text from a single image using the Gemini 2.5 Pro API.

    Args:
        img: PIL Image object containing the page to process

    Returns:
        String containing the extracted text, with thinking process
    """
    # Convert the image to base64
    base64_image = image_to_base64(img)

    # Add thinking trace instructions
    instruction_prefix = "Think carefully step-by-step to extract this text. Show your detailed reasoning."

    # Create the request content with the image and thinking trace instructions
    contents = {
        "parts": [
            {
                "inline_data": {
                    "mime_type": "image/png",
                    "data": base64_image
                }
            },
            {
                "text": instruction_prefix + "\n\nYour primary goal is to extract ALL text from this page."
            }
        ]
    }

    # Call the Gemini API with enhanced configuration
    response = client.models.generate_content(
        contents,
        model=GEMINI_MODEL,
        config=genai.Config(
            max_output_tokens=1024,
            top_p=0.95,
            top_k=64,
            temperature=0.7,
            thinking_config=genai.ThinkingConfig(
                enabled=True,
                max_tokens=1024
            )
        )
    )
    return response.text
```




```
#!/usr/bin/env python3
import os
import json
import argparse
from pathlib import Path
from dotenv import load_dotenv
from google import genai
import time

# Load environment variables
load_dotenv()

# Configure the Gemini API client
api_key = os.environ.get("GEMINI_API_KEY")
if not api_key:
    raise ValueError("GEMINI_API_KEY environment variable not found. Please set it in your .env file.")

# Initialize the client
genai_client = genai.Client(api_key=api_key)

# Current model version
GEMINI_MODEL = "gemini-2.5-pro-preview-05-06"

def analyze_chapter_with_thinking_traces(chapter_text, output_file):
    """
    Analyze the chapter text using Gemini 2.5 Pro to extract KSAOs with detailed thinking traces.

    Args:
        chapter_text: The text from a single chapter
        output_file: Path to save the analysis results

    Returns:
        The analysis text and thinking traces
    """

    prompt = """
    You are an expert in curriculum development and competency mapping for substance use disorder (SUD) counseling.
    You need to analyze the following textbook content to identify the complete set of Knowledge, Skills,
    and Other Characteristics (KSAOs) required for SUD counselors.

    For each identified KSAO, provide:
    1. A clear name/title
    2. A complete description
    3. The classification (Knowledge, Skill, Ability, or Other characteristic)
    4. The specificity level (general or specialized)
    5. Related O*NET occupational categories
    6. Stability/malleability classification (whether this KSAO is relatively fixed or can be developed)
    7. Explicit/tacit orientation (whether this is explicitly taught or tacitly acquired)
    8. Prerequisites or developmental relationships (what must be learned before this)

    Additionally, identify any hierarchical structure among these KSAOs:
    - Which KSAOs represent dimensions vs. sub-dimensions
    - How KSAOs relate to each other in terms of development sequence
    - Which KSAOs serve as foundations for others

    I NEED YOU TO DOCUMENT YOUR COMPLETE THINKING PROCESS IN DETAIL:
    1. First, carefully read through the textbook content and note key concepts related to KSAOs
    2. For each section or chapter, identify explicit and implicit competencies
    3. Categorize each KSAO, considering its nature (K, S, A, or O)
    4. Analyze relationships between KSAOs to identify hierarchies and dependencies
    """

    response = genai_client.generate_text(
        model=GEMINI_MODEL,
        contents=[chapter_text, prompt],
        stream=False
    )

    # Save the analysis results
    with open(output_file, 'w') as f:
        f.write(response.text)

    return response.text
```





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def gather_thinking_traces(input_dir="output/full_analysis"):
    """Gather all thinking traces from chapter analyses."""
    input_path = Path(input_dir)

    if not input_path.exists():
        print(f"Error: Input directory {input_dir} not found!")
        return None

    # Find all thinking process files
    thinking_files = [f for f in input_path.glob("*_thinking_process.txt")
                      if not "integrated" in f.name]

    if not thinking_files:
        print(f"No thinking process files found in {input_dir}")
        return None
```

```
#!/bin/bash

# This script renders both Quarto reports using enhanced templates

echo "==== Rendering Enhanced KSAO Framework Report ===="
echo "Generating HTML..."
cd docs
/usr/local/bin/quarto render ksao_framework_report.qmd --output ksao_framework_report.html
echo "Generating PDF with xelatex..."
/usr/local/bin/quarto render ksao_framework_report.qmd --to pdf --output ksao_framework_report.pdf --]

echo "==== Rendering Enhanced Thinking Trace Analysis Report ===="
echo "Generating HTML..."
/usr/local/bin/quarto render thinking_trace_analysis_report.qmd --output thinking_trace_analysis_repor
echo "Generating PDF with xelatex..."
/usr/local/bin/quarto render thinking_trace_analysis_report.qmd --to pdf --output thinking_trace_anal
cd ..

echo "==== Reports Generated ===="
echo "KSAO Framework Report: docs/ksao_framework_report.html and docs/ksao_framework_report.pdf"
echo "Thinking Trace Analysis Report: docs/thinking_trace_analysis_report.html and docs/thinking_trac
```