Implementation Report

This document describes the enhanced Q-ISA (Quantum Inquiry Structure Analyzer) Polygon Explorer, a tool for visualizing and detecting structural patterns in conversational AI interactions.

Version: 2.0 Enhanced
Date: December 2025
Purpose: Structural inquiry pattern detection and visualization

What Was Constructed

1. Persistent Vertex Labels

All polygon vertices now display permanent, readable labels that identify which linguistic elements they represent.

- **Primary label:** Element name (e.g., "Who", "Why", "Must")
- **Secondary label:** Index number [0]-[8]
- **Visual feedback:** Color-matched, opacity reduces when inactive
- **Position:** Positioned outside polygon perimeter, always visible

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2. Formal Pattern Detection

Implemented conversation-level detection of the **"Why-Saturated / How-Depleted"** structural pattern.

Detection Rule:

Σ(Why activations) / N $\geq$ 0.6 (60% threshold)

Σ(How activations) / N $\leq$ 0.2 (20% threshold)

Where N = total interactions in conversation

This is a *purely structural test* that does not evaluate meaning, sentiment, truth, or intent. It identifies geometric imbalances in inquiry structure.

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3. Inquiry Structure Interpretation Panel

A collapsible report section that explains what users are seeing and reports detected patterns.

- Explains polygon visualization (structure, not correctness)
- Reports detected Why-saturated / How-depleted patterns
- Displays activation rates and thresholds with metrics
- Emphasizes structural observation without interpretation creep

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4. Fixed Vertex Mappings

Primary Interrogatives (Hexagon)

[0] → Who
[1] → What
[2] → Where
[3] → When
[4] → How
[5] → Why

Core Modalities (Pentagon)

[0] → Ought to
[1] → Have to
[2] → Need to
[3] → Used to
[4] → Dare (to)

Primary Modals (Nonagon)

[0] → Can
[1] → Could
[2] → May
[3] → Might
[4] → Must
[5] → Shall
[6] → Should
[7] → Will
[8] → Would

Be-Forms (Octagon)

[0] → be
[1] → am
[2] → is
[3] → are
[4] → was
[5] → were
[6] → being
[7] → been

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5. Conversation Timeline (Time-Series Visualization)

A new panel that animates polygon evolution across the entire conversation, allowing users to observe structural changes over time.

- **Playback controls:** Play, Pause, Step Forward, Step Back
- **Speed control:** Adjustable from 0.2s to 3s per interaction
- **View modes:** Prompt, Response, or Delta (XOR)
- **Timeline scrubber:** Click any interaction to jump directly
- **Synchronized selection:** Timeline updates sync with global interaction selection
- **Stable orientation:** Polygons maintain fixed vertex positions (no rotation)

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6. 3D Visualization Layer (Experimental)

An optional 3D rendering mode that adds a depth dimension to polygon visualizations, revealing activation frequency patterns across the conversation.

- **Optional toggle:** 2D (default) or 3D (Experimental) view modes
- **WebGL rendering:** Hardware-accelerated Three.js visualization
- **Depth axis (Z):** Per-vertex activation frequency across all interactions (0..1 range)
- **Deterministic magnitude:** Depth = (times vertex activated) / (total interactions)
- **Visual elements:** Vertex spheres, edges, radial guides, depth indicators, triangulated faces
- **Auto-rotation:** Slow rotation for better spatial perception
- **No semantic inference:** Depth is purely structural, no AI confidence scores

Depth Calculation:

$Z_i = (\text{activations}_i / \text{total\_interactions}) \times \text{depth\_scale}$

Where activations_i = number of times vertex i was active (bit = 1) across all interactions

Depth range: 0.0 (never activated) to depth_scale (always activated)

The Z-axis represents *structural usage frequency* only. No semantic meaning, confidence, or quality is inferred. Vertices that appear "closer" to the viewer were activated more frequently in the conversation.

</> Technology Stack

Frontend Framework

- React 18+ (functional components, hooks)
- Next.js (app router architecture)
- Tailwind CSS (responsive styling)
- Lucide React (icons)

Visualization

- **2D Mode:** Native SVG with dynamic path generation (no external libraries)
- **3D Mode:** Three.js WebGL renderer with custom geometry
- Polar coordinate system for vertex positioning
- Animated vertex displacement (CSS + SVG animate in 2D)
- Depth-based positioning in 3D (Z-axis = activation frequency)
- Responsive viewBox (180×180 to accommodate labels in 2D)

Pattern Detection Engine

- Pure JavaScript computational engine
- Vector-based analysis (8-bit binary activation patterns)
- Conversation-level aggregation and threshold testing
- No external AI/ML dependencies

Key Files Modified/Created

```
/apps/web/src/components/Explorer/PolygonAnimation.jsx
/apps/web/src/components/Explorer/Polygon3D.jsx
/apps/web/src/components/Explorer/ConversationTimeline.jsx
/apps/web/src/app/explorer/page.jsx
/apps/web/src/hooks/useExplorerAnalysis.js
/apps/web/src/qisa/engine.js (existing)
```

How to Use the Explorer

Step 1: Input Conversation

1. Navigate to the Q-ISA Explorer
2. Paste a conversation in the format:

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USER: [question]
ASSISTANT: [response]
USER: [question]
ASSISTANT: [response]
```

3. Check the "I confirm this is synthetic/test data" box
4. Click "Analyze Conversation"

Step 2: Review Results

- **Structural Shift Chart:** See distribution of Collapse, Aligned, and Hedge patterns
- **Analysis Results:** Expandable cards for each interaction showing prompt, response, and structural shift
- **Epistemic Fatigue Chart:** Track confidence decay over conversation progression

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Step 3: Explore Polygon Animation

1. **Select an interaction** by clicking on any card in Analysis Results
2. **Choose visualization mode:**
   - **2D View (default):** Standard planar polygon visualization with radial expansion
   - **3D View (Experimental):** WebGL-rendered 3D polygons with depth axis showing activation frequency
   - Toggle between modes using the 2D/3D buttons in the panel header
3. **Observe the polygons:**
   - Expanded vertices (outward) = elements present in text
   - Contracted vertices (inward) = elements absent
   - Vertex labels show which word/element each position represents
   - Active vertices glow and pulse; inactive are dimmed
   - **In 3D:** Depth (Z-axis) = how often that vertex activated across the conversation
4. **Use animation controls:**
   - **Play:** Auto-cycle through Prompt → Response → Delta
   - **Speed slider:** Adjust transition time (0.3s - 3s)

- **Mode buttons:** Manually view specific phase

3D View Tip: The depth dimension is purely structural — it counts how many times each vertex was activated (0.0 = never, 1.0 = always). Vertices "closer to you" were used more frequently. No semantic confidence is inferred.

Step 4: Watch Conversation Timeline

View how structural patterns evolve across the entire conversation with the time-series visualization.

1. **Press Play** to watch polygons evolve automatically through all interactions
   - Polygons update in real-time as the timeline advances
   - Playback automatically stops at the end of the conversation
2. **Use step controls:**
   - **Step Forward/Back:** Navigate one interaction at a time
   - **Timeline scrubber:** Click any numbered button to jump to that interaction
3. **Adjust playback speed:** Use slider to change from 0.2s to 3s per interaction
4. **Select view mode:**
   - **Prompt:** See interrogative structure in user queries
   - **Response:** See interrogative structure in assistant replies
   - **Delta (XOR):** See structural shifts between prompt and response
5. **Synchronized selection:** Clicking timeline interactions updates the global selection across all panels

Note: The timeline maintains stable polygon orientation - vertices remain in fixed positions so you can observe activation patterns without rotation artifacts.

Step 5: Check Pattern Detection

- If a **Why-saturated / How-depleted** pattern is detected, an "Inquiry Structure Interpretation" panel will appear
- Click to expand and view:
  - Explanation of what polygons represent
  - Pattern description and structural imbalance
  - Why/How activation rates vs. thresholds
  - Total interactions analyzed

Step 6: Export Data

Click the "Export JSON" button to download a structured report containing:

- All interaction analyses
- Conversation signature
- Fatigue data
- Vector activation patterns
- Timestamp and metadata

Understanding the Polygons

What Do Polygons Represent?

Each polygon visualizes a different linguistic dimension of inquiry structure. Vertices correspond to specific words or elements within that dimension.

Primary Interrogatives (Purple Hexagon)

The core question words. Tracks *what type of inquiry* is being made. Pattern detection focuses on this polygon to identify Why vs. How imbalances.

Core Modalities (Orange Pentagon)

Semi-modal expressions of obligation, necessity, and habit. Reveals underlying assumptions about what *should* or *must* be.

Primary Modals (Pink Nonagon)

Standard modal verbs expressing possibility, permission, and obligation. Indicates the *certainty level* and *epistemic stance* of statements.

Be-Forms / Extended Space (Cyan Octagon)

Forms of the verb "to be." Acts as the structural foundation for assertions and identity claims. High activation often correlates with definitional or declarative statements.

3D View: Depth Axis (Z-Axis)

When 3D mode is enabled, an additional depth dimension reveals structural usage patterns:

- **Vertices closer to you:** Elements activated more frequently across the conversation
- **Vertices at the base (Z=0):** Elements rarely or never activated
- **Depth value:** Activation frequency (0..1) = (times used) / (total interactions)

Depth is *deterministic and structural*. It counts activations only — no semantic confidence or quality assessment is made.

⚠ Important Constraint

Polygons show **structure only**. They do not indicate:

- Correctness or truth value
- Intent or motivation
- Quality of reasoning
- Sentiment or tone

Pattern detection is a *geometric observation*, not a judgment.

Interpreting Pattern Detection

Why-Saturated / How-Depleted Pattern

This pattern indicates a conversation where questions focus on *justification and explanation* (Why) without corresponding attention to *process and method* (How).

Geometric Signature:

- Vertex 5 (Why) consistently displaced outward across interactions
- Vertex 4 (How) consistently contracted inward or absent
- Reduced directional variance in hexagon shape over time

What This Might Indicate:

- Inquiry focused on causes, reasons, and motivations
- Limited exploration of implementation or mechanisms
- Potential precursor to epistemic fatigue (repeated justification requests)

⚠ **Critical Note:**
This is a *structural observation only*. It does not mean the conversation is flawed, the AI is failing, or the user is asking "bad" questions. It identifies a geometric imbalance that may be intentional or context-appropriate.

Customizing Thresholds

Default detection thresholds are:

- **Why:** ≥60% activation rate
- **How:** ≤20% activation rate

These can be adjusted in the `detectWhySaturatedHowDepleted()` function if needed for specific research contexts.

Future Enhancement Possibilities

✓ Recently Implemented
Time-series visualization: Conversation Timeline with playback controls, step navigation, and synchronized selection is now available.

✓ Recently Implemented
Custom vector spaces: User-defined vertex mappings for domain-specific analysis with localStorage persistence and export support.

✓ Recently Implemented
3D polygon rendering: Optional WebGL-based 3D view with depth axis representing per-vertex activation frequency across conversations. Deterministic structural magnitude only.

- **Additional pattern detectors:** What-saturated, Modal-heavy, Be-depleted, etc.

- **Comparative mode:** Overlay multiple conversations to identify characteristic inquiry signatures
- **Pattern clustering:** Group similar conversations by geometric similarity

Citation & Attribution

This tool is part of the Q-ISA (Quantum Inquiry Structure Analyzer) research project.

For more information, visit: quantuminquiry.org

Launch Q-ISA Explorer

Q-ISA Explorer is a demonstration of structural measurement only.

It does not validate truth, compliance, or correctness.

Production deployments require controlled environments and governance review.