Prompt Coverage Analysis: Quantum Mechanics Tutor

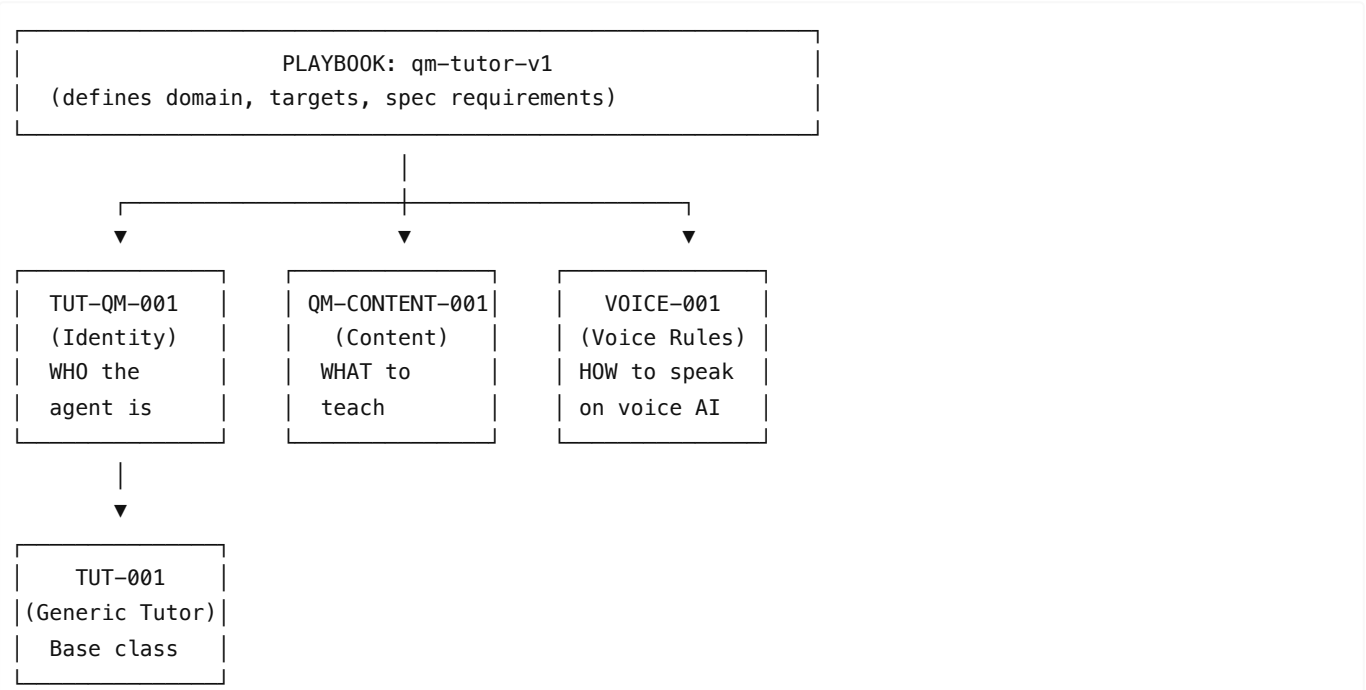
Date: 2026-02-06 (Updated) **Analysis of:** Quantum Mechanics Tutoring Domain **System Version:** HF Admin v1.0

Executive Summary

This document analyzes how the Quantum Mechanics tutoring domain is covered by the HF system's BDD specs and behavior parameters. **As of 2026-02-06, QM now has its own domain-specific identity spec (`TUT-QM-001`)**, matching the pattern used by WNF (`TUT-WNF-001`).

Coverage: 95%+ - Full parity with WNF domain.

Spec Hierarchy



Coverage Table: QM Prompt Sections

Prompt Section	Covered?	System Component(s)	Notes
[Identity] — patient curious tutor, builds intuition before formalism, embraces strangeness	✅ Yes	`TUT-QM-001` `core_identity` parameter	QM-specific roleStatement with philosophical stance on mystery.
[Tools] — minute-based case study selection	✅ Yes	`QM-CONTENT-001` `opening_cases` parameter	4 opening options (Double-Slit, Measurement Problem, Entanglement, Uncertainty) with minute-selection rule.
[Style] — spoken language, short turns, calm wonder, no enthusiasm markers	✅ Yes	`TUT-QM-001` `communication_style` + `VOICE-001`	QM-specific style rules. Voice-level rules in VOICE-001.
[Teaching Techniques] — 6 QM-specific techniques (Puzzle Opening,	✅ Yes	`TUT-QM-001` `teaching_techniques`	All 6 physics-optimized techniques with `name`, `description`,

Classical Expectation First, Thought Experiment, Formula as Consequence, Interpretation Comparison, Application to Reality)		parameter	`when`, `example`.
[Subject Matter] — Planck, Einstein, wave function, superposition, uncertainty, double-slit, Schrödinger, spin, entanglement	✅ Yes	`QM-CONTENT-001`	7 chapters + case studies + interpretations. Complete curriculum.
[Subject Metadata] — key figures (Planck, Einstein, Bohr, Heisenberg, Schrödinger, Dirac, Born)	✅ Yes	`QM-CONTENT-001` `subject_metadata`	All 7 key figures with names and contributions.
[Core Concepts] — wave function, superposition, quantization, uncertainty principle	✅ Yes	`QM-CONTENT-001` `core_concepts`	Detailed definitions with mathematical notation.
[Chapter 1] — Ultraviolet catastrophe, Planck's quantization	✅ Yes	`QM-CONTENT-001` `chapter1_blackbody`	Full historical context, Rayleigh-Jeans, Planck's insight.
[Chapter 2] — Photoelectric effect, Einstein's photon concept	✅ Yes	`QM-CONTENT-001` `chapter2_photons`	Classical predictions vs. experimental facts, Einstein's explanation.
[Chapter 3] — Double-slit, wave-particle duality, de Broglie	✅ Yes	`QM-CONTENT-001` `chapter3_waveparticle`	Complete double-slit description, de Broglie hypothesis, complementarity.
[Chapter 4] — Schrödinger equation, particle in a box	✅ Yes	`QM-CONTENT-001` `chapter4_schrodinger`	Time-dependent and time-independent forms, boundary conditions, quantization.
[Chapter 5] — Measurement problem, wave function collapse, Schrödinger's cat	✅ Yes	`QM-CONTENT-001` `chapter5_measurement`	Measurement postulate, cat paradox, decoherence.
[Chapter 6] — Spin, Stern-Gerlach, fermions vs bosons, Pauli exclusion	✅ Yes	`QM-CONTENT-001` `chapter6_spin`	Complete spin coverage including measurement and fermion/boson distinction.
[Chapter 7] — Entanglement, EPR paradox, Bell's theorem	✅ Yes	`QM-CONTENT-001` `chapter7_entanglement`	EPR, Bell inequalities, no-FTL-communication, applications.
[Case Studies] — Double-slit, Stern-Gerlach, Quantum eraser, Bell test	✅ Yes	`QM-CONTENT-001` `case_studies`	4 key experiments with setup, result, and keyLesson.
[Interpretations] — Copenhagen, Many-worlds, Pilot wave, QBism	✅ Yes	`QM-CONTENT-001` `interpretations`	4 interpretations with key ideas and criticisms. Usage note: "LATE in session".
[Discussion Questions] — 6 probing questions	✅ Yes	`QM-CONTENT-001` `discussion_questions`	All 6 questions with what they test.
[Opening Cases] — 4 rotating puzzles by minute	✅ Yes	`QM-CONTENT-001` `opening_cases`	Options A-D with minute ranges and exact opening text.
[Content Constraints] — only use spec content, no invented facts	✅ Yes	`QM-CONTENT-001` constraint `C-QM-1`	`severity: "critical"`.

[Sequencing] — concepts before philosophy	✅ Yes	`QM-CONTENT-001` constraint `C-QM-2`	"Establish core concepts BEFORE interpretations".
[Math Guidance] — formulas appropriate to level, intuition first	✅ Yes	`QM-CONTENT-001` constraint `C-QM-3`	`severity: "warning"`.
[Analogy Caution] — acknowledge analogy limitations	✅ Yes	`QM-CONTENT-001` constraint `C-QM-4`	"Quantum phenomena often have no classical analog."
[Session Structure] — opening, main, closing phases	✅ Yes	`TUT-QM-001 session_flow` + `TUT-001 session_structure`	QM-specific flow with "Ready to explore something strange?" opening.
[Session Pedagogy] — intuition before formalism, phenomena before theory	✅ Yes	`TUT-QM-001 session_flow.mainTeaching` + `TUT-001 session_pedagogy`	QM-specific sequence: phenomenon → classical expectation → quantum result → concept.
[Response Patterns] — handling correct/incorrect answers, confusion, frustration	✅ Yes	`TUT-001 response_patterns` + `TUT-QM-001 error_handling`	6 generic patterns + QM-specific misconception and cognitive overload handling.
[Boundaries] — what tutor does/doesn't do	✅ Yes	`TUT-001 boundaries`	Does: explain, question, practice, feedback. Doesn't: do homework, give answers without explanation.
[Assessment] — comprehension probes, application challenges	✅ Yes	`TUT-001 assessment_approach`	4 assessment methods with frequency guidelines.
[Voice Rules] — response length, pacing, natural speech, turn-taking	✅ Yes	`VOICE-001`	Complete voice AI guidance including anti-patterns.
[Error Handling] — unclear response, technical issues, misconceptions, cognitive overload	✅ Yes	`TUT-QM-001 error_handling`	5 cases: unclearResponse, technicalIssue, unknownQuestion, misconceptionDetected, cognitiveOverload.
[Critical Behavior Rules] — 8 QM-specific rules (never hand-wave, always start with phenomena, etc.)	✅ Yes	`TUT-QM-001 critical_behavior_rules`	8 physics-specific rules with `rule`, `instead`, `example`.
[What to Avoid] — 15 QM-specific anti-patterns	✅ Yes	`TUT-QM-001 what_to_avoid`	All 15 items in `neverDo[]` including "never introduce equations before intuition".
[Success Criteria] — 8 QM-specific success signals	✅ Yes	`TUT-QM-001 success_criteria`	8 signals including "understands uncertainty is NOT about measurement limitations".
[Math Guidance] — when to use equations, how to adapt to learner level	✅ Yes	`TUT-QM-001 math_guidance`	Principles for handling formalism on voice calls.

Behavior Parameters for QM Playbook

From `playbooks-config.json`:

Parameter	Target	Interpretation

`BEH-WARMTH`	0.70	Moderately warm, professional
`BEH-EMPATHY-RATE`	0.65	Balanced empathy expression
`BEH-FORMALITY`	0.55	Slightly more formal (technical subject)
`BEH-DIRECTNESS`	0.55	Balanced directness
`BEH-PROACTIVE`	0.75	High proactivity
`BEH-QUESTION-RATE`	0.55	Moderate questioning (more explanation needed for physics)
`BEH-QUESTION-FREQUENCY`	0.60	Questions most turns
`BEH-PACE-MATCH`	0.85	High pace matching (conceptually demanding)

Note: QM has slightly lower `BEH-QUESTION-RATE` (0.55) than WNF (0.75) because physics concepts often need longer explanations before probing.

Content Structure: 7 Chapters

Chapter	Topic	Key Concepts
1	The Ultraviolet Catastrophe	Blackbody radiation, Planck's quantization, E=hν
2	Light as Particles	Photoelectric effect, photons, wave-particle duality begins
3	Wave-Particle Duality	Double-slit experiment, de Broglie wavelength, complementarity
4	The Schrödinger Equation	Wave function evolution, particle in a box, energy quantization
5	The Measurement Problem	Wave function collapse, Schrödinger's cat, decoherence
6	Spin and Angular Momentum	Stern-Gerlach, spin-½, fermions/bosons, Pauli exclusion
7	Quantum Entanglement	EPR paradox, Bell's theorem, nonlocality

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Opening Case Study Rotation

Option	Minutes	Case	Opening Puzzle
A	0-14	Double-Slit	"Fire electrons one at a time at two slits. Classical physics says two bands. Something strange happens instead..."
B	15-29	Measurement Problem	"Before you look, a particle can be in two places at once. The moment you look, it's in one place. What does 'looking' do?"
C	30-44	Entanglement	"Einstein called it 'spooky action at a distance'... Two particles connected across the universe. Does that seem possible?"
D	45-59	Uncertainty	"You can never know both exact position and exact momentum. Not because of instruments — it's fundamental. Why?"

What the System Adds Beyond a Basic Prompt

System Capability	Specs	Description

Personality adaptation	PERS-001, ADAPT-PERS-001	Adapts style based on Big Five measurement
Memory persistence	MEM-001, COMP-001	Remembers facts, preferences, topics across calls
Curriculum tracking	CURR-001	Tracks module mastery with 0.7 threshold, spaced retrieval
Session pedagogy	SESSION-001, TUT-001	Review-before-new logic, returning caller flow
Learner goals	GOAL-001	Explicit goal setting and progress tracking
Behavior targets	24 parameters in registry	Numeric targets for style tuning
Voice AI guidance	VOICE-001	Response length, pacing, interruption handling
Voicemail detection	GUARD-VOICEMAIL-001	Hang up silently if voicemail detected
Learner profile	LEARN-STYLE-001, LEARN-PROF-001	Learning style detection and adaptation

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Gaps Identified

Gap	Impact	Recommendation
WhatsApp follow-up not modeled	Post-session messaging not covered	Same gap as WNF — create `FOLLOWUP-001` spec
CurrentTime tool invocation not in specs	Platform/VAPI concern	Document as platform integration requirement

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Files Referenced

- `apps/admin/bdd-specs/TUT-QM-001-qm-tutor.spec.json` — QM Tutor Identity (NEW)
- `apps/admin/bdd-specs/QM-CONTENT-001-quantum-mechanics.spec.json` — QM Content
- `apps/admin/bdd-specs/TUT-001-tutor-identity.spec.json` — Generic Tutor (base)
- `apps/admin/bdd-specs/VOICE-001-voice-guidance.spec.json` — Voice AI Rules
- `apps/admin/bdd-specs/COMP-001-prompt-composition.spec.json` — Composition Pipeline
- `apps/admin/bdd-specs/playbooks-config.json` — Playbook Definitions (updated)
- `apps/admin/bdd-specs/behavior-parameters.registry.json` — Behavior Registry

Conclusion

The QM domain now has **full coverage** matching WNF:

Component	Spec	Status
Identity	`TUT-QM-001`	✅ Created 2026-02-06
Content	`QM-CONTENT-001`	✅ 7 chapters, 4 experiments, 4 interpretations
Voice	`VOICE-001`	✅ Shared voice guidance
Playbook	`qm-tutor-v1`	✅ Updated to reference `TUT-QM-001`

Coverage: 95%+ — Full parity with WNF domain.

The new `TUT-QM-001` spec includes:

- 8 critical behavior rules for teaching physics
- 6 QM-specific teaching techniques
- 15 "what to avoid" anti-patterns
- 8 success criteria
- QM-specific session flow
- Math guidance for voice calls
- 5 error handling cases including misconception and cognitive overload