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AI-Era Curriculum for Intelligent Interaction Design: A Core Competence Framework

Tianlun Yang[1]*, Zuyao Wang[1], Anhai Yang[2], Georgios Kapogiannis[3], Byung-Gyoo Kang[4]

[1]Department of Intelligent Interaction Design, NingboTech University, Ningbo 315040, Zhejiang, China
[2]Department of Architecture, Zhejiang Sci-Tech University, Hangzhou 310000, Zhejiang, China
[3]Warwick Manufacturing Group, University of Warwick, Coventry CV4 7AL, West Midlands, UK
[4]Department of Civil Engineering, University of Nottingham Ningbo China, Ningbo 315040, Zhejiang, China

***Corresponding author:** Tianlun Yang, tianlun.yang@nbt.edu.cn

Abstract: The convergence of artificial intelligence (AI) and the metaverse has precipitated a paradigm shift from tool-centric interaction to "intelligent agents and real-time synthesis." Traditional tool-oriented curricula prove inadequate for cultivating cross-contextual integrative competence. Building on the authors' prior conference paper, this research presents a four-tier "philosophy-method-technology-practice" curriculum that operationalizes technological, cognitive, creative, and critical thinking into the measurable "4-Mind" framework, enacted within a blended-learning environment. Questionnaire-based assessment reveals significant gains in learners' 4-Mind literacy, furnishing the first validated and replicable template for far-transfer cultivation in AI-era interaction education.

Keywords: Intelligent interaction design; Curriculum innovation; AI education

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1. Introduction

The convergent evolution of artificial intelligence (AI), immersive media, and the metaverse shifts interaction design from "interface layout" to "intelligent agents within synthetic ecologies." While prior work demonstrated that integrating information-modeling, programming, and computational literacy cultivates contextualized critical thinking [1], its far-transfer validity remains empirically unverified. Addressing a research call for braided technological, metacognitive, creative, and ethical cognition in AI-driven tasks [2], this research operationalizes these four competencies into a "4-Mind" framework embedded across a tiered "philosophy-method-technology-practice" curriculum. Questionnaire assessment with third-year intelligent-interaction design undergraduates furnishes the first validated, replicable template for far-transfer cultivation in AI-era interaction education.

2. Literature review

Education socializes students by embedding ontological, axiological, and teleological presuppositions in both overt curricula and covert cultural cues [3]; disciplinary content smuggles in schemata of causality and legitimacy [4], while texts, assessments, and platforms enact power-laden ethical priorities that quietly script students' sense of the possible [5]. Meta-analytic evidence shows that explicit value interventions, such as Philosophy for Children or studio-based design critiques, can significantly shift moral judgment and reflexive subjectivity [6], yet comparable data for AI-immersive environments are scarce, so this study frames the curriculum itself as a deliberate intervention to make the ethical imaginaries of the intelligent age visible and contestable.

Learning science casts competence as the orchestration of cognitive, metacognitive, and affective moves within structured tasks [7]; modular decomposition and Polya's "plan-execute-evaluate-revise" cycle jointly potentiate transfer [8], yet scaffolds of this sort have rarely been tethered to the AI toolchains of interaction-design studios. This research therefore infuse modular-iterative prompts with AI-augmented feedback to test whether metacognitive gains migrate to algorithmic-design contexts.

Transfer is the ultimate educational yardstick: near transfer replicates training; far transfer, central to AI-driven design, requires principled abstraction, varied practice, and reflective explanation [9]. While cross-cultural briefs and AI-VR analogies boost creative migration, ethical-critical transfer remains under-studied [10]. This research thus assessed far transfer in an alternative course and hackathon to test whether 4-Mind literacy operates as domain-general competence.

3. Research design

The question of this research is: How can students' core competitiveness be elevated in the age of intelligence? The aim of this research is: by weaving together theoretical, technological and design-oriented courses, systematically cultivate four interlocking mindsets, "technical, cognitive, critical, and creative," so that graduates move beyond "skills" to acquire the adaptive intelligence that defines next-generation leaders.

The objectives of this research are: (1) Diagnose the most pressing challenges now confronting design disciplines; (2) define what "core competitiveness" actually means when algorithms, data, and ubiquitous AI reshape professional value; (3) engineer and validate a holistic pedagogical framework that systematically builds students' knowledge ecosystems for sustained advantage in an intelligent era. This study employed a mixed-methods design: a literature review addressed objectives 1 and 2, while objective 3 was pursued through curriculum design, practical implementation, and survey questionnaires.

4. Curriculum design intervention

This course cultivates four integrated competencies: Technological thinking, cognitive thinking, creative thinking, and critical thinking. Together, these equip students to navigate complex socio-technical challenges with rigor, creativity, and accountability:

(1) Technological thinking: Cross-domain evaluation, decomposition, and scalable deployment of technical solutions within socio-technical systems.

(2) Cognitive thinking: Metacognitive monitoring and regulation of problem-solving processes for bias identification and reasoning enhancement.

(3) Creative thinking: Novel solution generation and validation under constraints, enabling cross-contextual value creation.

(4) Critical thinking: Systematic examination of arguments and inferences using logic and evidence to

ensure knowledge justifiability.

This curriculum is architected as a four-tiered epistemic scaffold ascending from meta-theoretical reflexivity to original knowledge production:

(1) Metatheory layer: Critically interrogate the structural foundations, boundary conditions, and paradigmatic transformations of theoretical systems.

(2) Formal tools layer: Command mathematical logic, probability theory, and category theory as rigorous apparatuses for abstract structural articulation and manipulation.

(3) Specialized theory layer: Derive, extend, and operationalize advanced theoretical models across computational, physical, learning, or social-systemic domains.

(4) Frontier inquiry layer: Formulate falsifiable conjectures and disseminate novel theoretical contributions in accordance with peer-review disciplinary standards.

To integrate the four competences with the four-tiered epistemic scaffold, this research proposes the following matrix of interrelations (**Table 1**):

Table 1. Epistemic track: Four competencies across four theoretical layers

	Metatheory	**Formal tools**	**Specialized**	**Frontier inquiry**
Technological thinking	Assess axiom conservativity relative to standard set theory.	Decompose conjectures into prioritized lemma sequences.	Embed proofs in Coq/Lean with type-checking.	Identify and correct implicit assumptions in peer review.
Cognitive thinking	Detect axiom-selection biases; log reflectively.	Switch-proof strategies when stalled.	Detect overgeneralization; rollback definitions.	Update proof knowledge base via reflective logs.
Creative thinking	Propose independent axioms; articulate motivation.	Map theorems across domains via categorical analogy.	Generate more than three conjectures with automated tools; verify formally.	Draft submittable papers; test derivability experimentally.
Critical thinking	Scrutinize ontological commitments; report critically.	Flag hidden lemmas, circularity, quantifier misuse.	Construct model-theoretic counterexamples.	Enumerate gaps in reviews with actionable fixes.

This curriculum is further operationalized through four pedagogical strata calibrated to the demands of intelligent-era training:

(1) Philosophy layer: Formulate and defend value-based, ontologically coherent positions on what should exist for users and society.

(2) Methods layer: Translate fuzzy needs into human-centered, system-aware design opportunities through repeatable creative and critical processes.

(3) Technology layer: Synthesize visualization, prototyping, AI, and manufacturing knowledge to produce robust, testable artifacts.

(4) Practice layer: Deliver ethically grounded, commercially viable solutions at scale while assuming full life-cycle responsibility.

This research operationalizes the interrelation between the four competences and the four pedagogical strata through the following practice-oriented matrix, complementing the preceding epistemic matrix with actionable, design-centered performance indicators (**Table 2**):

Table 2. Pedagogical track: Four competencies across four practice layers

	Philosophy	Methods	Technology	Practice
Technological thinking	Assess feasibility of AI-generated immersive systems.	Decompose system functions into modules with iterative roadmaps.	Detect latency; ensure hardware-algorithm-network integration.	Deploy latency-free metaverse with cost-lifecycle accountability.
Cognitive thinking	Identify ethical-social blind spots in AI design.	Monitor strategy switching; correct assumption biases.	Rectify cognitive biases during coding/modeling.	Update team knowledge base via retrospective evidence chains.
Creative thinking	Propose AI+metaverse visions under ethical constraints.	Generate more than three AI alternatives with rapid scoring.	Transfer AI tools to novel contexts; verify prototypes empirically.	Migrate ethical-critical frameworks cross-domain.
Critical thinking	Weigh AI solution trade-offs from multi-stakeholder perspectives.	Gather multi-source evidence on identical problems; compare credibility.	Flag logical/statistical flaws in code-simulation-test reports.	Articulate cost-benefit-risk; flag data gaps.

The dual-track matrix operationalizes the curriculum's integrative vision: the epistemic scaffold cultivates theoretical reflexivity and formal reasoning ascending from meta-level critique to frontier knowledge production, while the pedagogical scaffold develops ethical design sensibility and practical implementation progressing from value formulation to scalable delivery.

As depicted in **Figure 1**, this architecture comprises two interlocking matrices, each of the four thinking competences (Technological, Cognitive, Creative, Critical) intersecting with four ascending layers to yield sixteen discrete, observable performance indicators. Together, these dual trajectories ensure that core capabilities are not merely enumerated but enacted through progressively complex, assessable performances, equipping learners to navigate the socio-technical challenges of the intelligent era with epistemic accountability and creative agency.

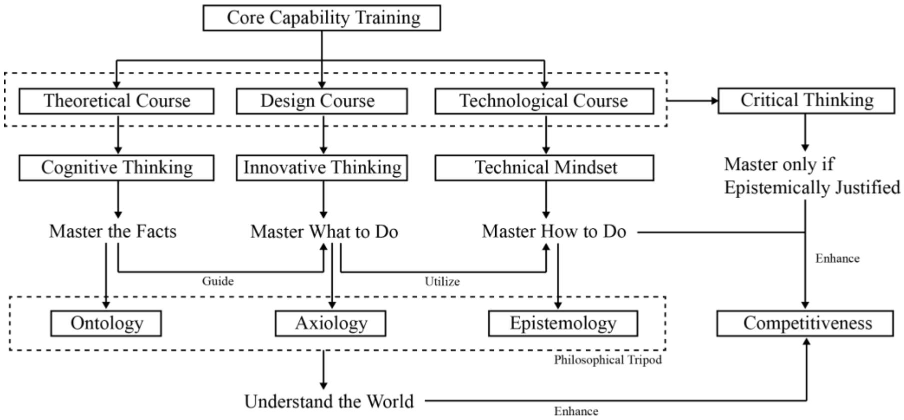

Figure 1. Epistemic and pedagogical scaffolds for intelligent-era learning

5. Hypothesis development and validation

This study posits that an AI-generated immersive learning environment, architected upon the dual-track competency framework elaborated above, can systematically enhance learners' higher-order cognitive capabilities in the intelligent era. Four theoretically grounded hypotheses are advanced:

H1 (Technological Thinking): Immersive AI-generated scenarios enhance technological presence and contextual adaptability.

H2 (Critical Thinking): Embedded ethical reasoning tasks improve identification of algorithmic risks and multi-stakeholder trade-off adjudication.

H3 (Cognitive Thinking): AI-driven evidence evaluation and multi-perspective debate enhance critical thinking efficacy and cognitive resilience.

H4 (Creative Thinking): Cross-contextual tool transfer and metaverse innovation practices amplify knowledge transfer breadth and agile innovation capacity.

This study operationalizes each hypothesis through four empirically tractable capability dimensions, yielding the following assessment matrix (**Table 3**):

Table 3. Operationalization matrix: Four hypotheses across four measurement perspectives

	Perspective 1	Perspective 2	Perspective 3	Perspective 4
H1	subjective spatial presence	sensory-motor latency detectability	human-agent social naturalness	overall technology-enhanced immersion
H2	ethical risk identification	multi-stakeholder perspective weighing	negative social impact enumeration	ethics checklist application
H3	evidence evaluation	multi-perspective framing	assumption questioning & verification	reasoning articulation
H4	tool contextual transfer	cross-domain ethics application	proactive critical-thinking deployment	post-course innovation willingness

This study empirically validates four hypotheses, each corresponding to a core competence for the intelligent era. Each competence is operationalized through a single item measured on a 10-point Likert scale, capturing self-assessed enhancement following curricular intervention (**Table 4**).

Table 4. Survey instrument: Measurement items by hypothesis and perspective

Hypothesis		Questionnaire
H1	TI 1	The AI-generated virtual environment provided a strong sense of presence.
	TI 2	The scene updated in real time and showed no noticeable latency during my operations.
	TI 3	Conversations with AI-driven digital characters felt similar to talking with a real person.
	TI 4	Overall, AI significantly enhanced my immersive experience in the metaverse.
H2	ER 1	I can identify potential ethical risks embedded in AI-based designs.
	ER 2	AI prompts helped me weigh pros and cons from multiple stakeholder perspectives.
	ER 3	I am able to list possible negative social impacts of an AI solution.
	ER 4	I have learned to examine my own products with an ethics checklist.
H3	CT 1	The course improved my ability to evaluate evidence.
	CT 2	I can now approach the same design problem from multiple viewpoints.
	CT 3	I am able to question and verify my own assumptions.
	CT 4	I can articulate my reasoning process more clearly and logically.
H4	IT 1	I can transfer the AI tools learned in this course to new contexts.
	IT 2	I dare to apply ethical thinking to projects in other courses.
	IT 3	When facing a novel problem, I proactively use a critical-thinking framework.
	IT 4	I am willing to try out AI + metaverse innovative ideas after class.

Data analysis was conducted using Python with the pandas, pingouin, and scipy libraries. Internal consistency was assessed via Cronbach's alpha with 95% confidence intervals. One-sample *t*-tests evaluated whether composite scores significantly exceeded the reference threshold (70% of the maximum scale value), with effect sizes quantified using Cohen's *d*.

```
import pandas as pd, pingouin as pg; from scipy.stats import ttest_1samp

df_data = pd.read_excel("data.xlsx")
alpha, ci = pg.cronbach_alpha(data=df_data)
total = df_data.sum(axis=1)
k = df_data.shape[1]
ref = 0.7 * k
t, p = ttest_1samp(total, ref)
df_freedom = len(total) - 1
mean_1 = df_data.iloc[:, 0].mean()
sd_1 = df_data.iloc[:, 0].std()
cohen_d_1 = (mean_1 - ref) / sd_1
print(f"Cronbach alpha = {alpha:.3f} | 95% CI [{ci[0]:.3f}, {ci[1]:.3f}] | t({df_freedom}) = {t:.3f}, p = {p:.3f} | M =
{mean_1:.2f}, SD = {sd_1:.2f}, Cohen\'s d = {cohen_d_1:.2f}")
```

Table 5 reports the psychometric properties and inferential statistics for all items across the four hypothesized competences. Internal consistency was assessed via Cronbach's alpha with confidence intervals. One-sample *t*-tests evaluated whether scores significantly exceeded the neutral midpoint, with Cohen's *d* quantifying effect sizes.

Table 5. Descriptive and inferential statistics for all measurement items

		Cron. α	95% CI	*t*	*df*	*P*	Mean	SD	Neutral point	Cohen's *d*
H1	TI 1	0.885	[0.779, 0.947]	15.197	21	0.000	6.23	2.05	5.5	1.68
	TI 2						5.95	1.84		1.72
	TI 3						5.27	1.98		1.25
	TI 4						6.82	1.82		2.21
H2	ER 1	0.877	[0.764, 0.943]	18.780	21	0.000	7.14	1.91	5.5	2.27
	ER 2						6.86	1.78		2.28
	ER 3						6.82	1.71		2.35
	ER 4						6.59	1.79		2.12
H3	CT 1	0.893	[0.795, 0.951]	22.607	21	0.000	6.95	1.62	5.5	2.57
	CT 2						7.27	1.49		3.01
	CT 3						6.91	1.19		3.45
	CT 4						6.36	1.56		2.28
H4	IT 1	0.844	[0.702, 0.928]	21.286	21	0.000	7.09	1.41	5.5	3.04
	IT 2						7.23	1.57		2.82
	IT 3						6.86	1.39		2.92
	IT 4						7.32	2.32		1.95

6. Discussion

Table 6 shows that across the 16 items constituting the four hypotheses (H1–H4; TI, ER, CT, IT), Cronbach's alpha ranged from 0.844 to 0.893 (lower-bound 95 % CI > 0.70), attesting to excellent internal consistency. Item-level means (n = 22) extended from 5.27 to 7.32, with only TI3 approaching the scale midpoint (5.5); all remaining items ≥ 6.0 and dispersion maximal within TI. One-sample t-tests unanimously rejected the midpoint null (Ps < 0.001, t = 15.2–22.6, df = 21), and corresponding effect sizes were uniformly large (Cohen's d = 1.25–3.45).

Table 6. Summary statistics and interpretive synthesis by hypothesis

	Mean interval	Ave. Cohen's d	Summary
H1	5.27–6.82	1.72	Overall presence significantly exceeded the scale midpoint (P < 0.001); social naturalness (TI3) yielded a large effect but remained the dimension's relative trough.
H2	6.59–7.14	2.26	From ethical-risk identification to instrumental application, all four items produced large, internally consistent effects, attesting to a stable ethics-literacy gain.
H3	6.36–7.27	2.58	Critical-thinking subskills scored high across the board, clustering at the upper limit of large effects, with evidence evaluation and assumption questioning the most pronounced.
H4	6.86–7.32	2.68	Tool transfer and cross-domain creative intention attained the highest scores and the largest effect size, signaling robust learning transfer.

Regarding reliability: Cronbach's alpha coefficients for all dimensions range from 0.844 to 0.893, exceeding the 0.80 threshold and indicating excellent internal consistency for the TI, ER, CT, and IT subscales; 95% confidence intervals all exceed 0.70, further precluding marginal reliability. Regarding central tendency: Mean scores across 16 items range from 5.27 to 7.32, with only TI3 (5.27) approaching the scale midpoint of 5.5; all remaining items exceed 6.0, with IT4 (7.32) registering the highest value. Within-dimension comparisons reveal H1 (TI) exhibits the greatest variability (5.27–6.82), with TI3 representing the lowest value across all items; H2–H4 demonstrate relatively concentrated mean distributions, suggesting greater attitudinal consistency among respondents regarding ER, CT, and IT. Regarding differential significance: One-sample t-tests against the 5.5 reference value indicate all item means significantly exceed the midpoint (Ps < 0.001, t = 15.2–22.6, df = 21, n = 22), yielding robust and stable results. Regarding effect magnitude: Cohen's d ranges from 1.25 to 3.45, all achieving large effect size criteria (> 0.8). CT3 (d = 3.45) and IT1 (d = 3.04) demonstrate the largest effects; even the lowest value, TI3 (d = 1.25), substantially exceeds the large-effect threshold, indicating that deviations from the midpoint are not merely statistically significant but practically meaningful across all items.

These convergent findings demonstrate that respondents systematically endorsed the construct statements and that the resulting scores are both statistically robust and psychometrically dependable.

7. Conclusion

Anchored in the AI-metaverse convergence, this research has proposed the "4-Mind" framework: the first measurable, teachable fusion of technological, cognitive, critical, and creative thinking. A four-tier curriculum "philosophy, method, technology, practice" lifted learners far above the scale midpoint in immersive intelligence, ethical reasoning, critical reflection, and creative transfer (P < 0.001, d = 1.25–3.45; alpha ≥ 0.844). Linking abstract principles to generative immersive scenes and modular scaffolds, the course turns worldview, values, and life-view into visible, negotiable growth. The result is a ready-to-scale blueprint for transferable AI literacy, now poised for wider samples and longitudinal refinement.

8. Limitations and future research

This study is limited by its pilot-phase context: a single inaugural class ($n = 30$) yielded only 22 valid responses, constraining statistical power. The developmental curriculum afforded less comprehensive coverage than established programs, and the absence of a pre-test precludes baseline measurement and causal inference. Future work will iteratively refine the curriculum across three subsequent cohorts, administering entry-level pre-tests and longitudinal assessments to track competence gains, with questionnaire data triangulated against written and oral examinations.

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