

Construction of an Indicator System and Enhancement Strategies for Artificial Intelligence Literacy of Primary and Secondary School Teachers

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Abstract: *With the progress of artificial intelligence technology, there are great changes on the structure of competence framework of primary and secondary school teachers; clarification of its connotation and construction of an operable indicator system is an issue worthy of attention in the domain of educational technology research. Existing studies have shown divergences among technological cognition, ethical criticism and pedagogical transformation without having a special analytical framework which suits the professional characteristics of primary and secondary school teachers. Deconstructing the artificial intelligence literacy of primary and secondary school teachers into 5 dimensions: intelligent technology cognition, data-driven teaching decision-making, intelligent educational resource design, human-machine collaborative teaching implementation and intelligent educational ethics judgment based on the task-situation analysis approach, constructing a three-level indicator system, getting indicator weights by the analytic hierarchy process. Based on our results, we delineated three stages of literacy development through observing the laws of capability growth, designing a layered and progressive content framework for learning, creating a support system from three aspects - technological resources, learning communities, and self-diagnosis - forming a complete research chain from dimension definition, indicator quantification, to pathway design giving theoretical reference for the assessment and cultivation in this field.*

Keywords: *Primary and secondary school teachers; artificial intelligence literacy; indicator system; analytic hierarchy process; enhancement pathways*

Introduction

With the evolution of artificial intelligence technology, it evolved from being a teaching assistant into an endogenous component of the education system. Intelligent recommendation, automatic grading and generative content creation applications were deeply involved in every aspect of the teaching process of primary and secondary schools, bringing about profound changes to the professional competency structure of teachers. They need to balance between algorithmic decision-making references and their own educational judgment, keeping dominant control over the teaching process while letting intelligent systems take up some instruction functions. Two major shortcomings in current research include: Divergence among the three perspectives (technological cognition, ethical criticism, pedagogical transformation) affects the definition of literacy connotation, and there does not exist any unified framework that is specific to primary and secondary school teachers; most of the existing studies are only at the level of theoretical exposition without an operable indicator system and quantitative weighting scheme, failing to provide a clear reference tool for competency assessment. We aim to construct an artificial intelligence literacy indicator system for primary and secondary school teachers, clarify its dimensionality structure and determine the indicator weights according to our design, then enhance pathways accordingly, providing an academic basis for theoretical deepening and tool development.

1. Connotation Analysis and Structural Dimensions of Artificial Intelligence Literacy for Primary and Secondary School Teachers

1.1 Conceptual Evolution of Teacher Competency Structure in Intelligent Education Scenarios

The intervention of artificial intelligence technology into the education system will lead to profound changes in the professional competency structure of teachers: rather than adding new technical operation items to the existing competency framework, it profoundly changing teachers' cognitive style, decision-making logic and teaching action paradigm. The application form such as intelligent recommendation, automatic grading, learning analytics and generative content creation is deeply involved in each link of teaching design, implementation and evaluation, and intelligent systems began to play its part with a certain "initiative" in the teaching process. Breaks the traditional view that technology is just an external auxiliary tool for teaching, and there appears a complex collaboration between teachers and intelligent systems, turning technological elements from peripheral conditions of the teaching environment to intrinsic parts of the teaching system^[1].

Shift of teacher's role requires a restructure of competencies. The diversified ways of gaining knowledge has challenged the idea that teachers are the only source of knowledge. Knowledge presentation tasks, practice feedback and learning diagnosis can be done by intelligent systems which calls for shifting teachers' core value towards learning design, process guidance and pedagogical judgment. New competency needs arise – not just knowing how technology works, but when, what boundary it applies to, and what is the consequence of technological intervention? In concept, different from digital literacy (emphasizes on information processing capabilities) "artificial intelligence literacy" pays more attention to unique requirements such as understanding algorithmic logic, recognizing data-driven decision-making mechanisms and grasping the features of human-machine interaction. Defining the conceptual boundaries avoids overgeneralization of its connotation.

1.2 Theoretical Analysis of the Constituent Elements of Artificial Intelligence Literacy

For the parts of artificial intelligence literacy, there are three representative analysis from academia: Technological Cognition Perspective believes that literacy refers to the understanding and operation capability of artificial intelligence technology; emphasizing that teachers should have a basic principle and typical application scenario of artificial intelligence familiarity. Coming out from the assumption that we need a technological understanding so that we can use them effectively. Ethical Criticism Perspective emphasizes value judgment about technological applications like algorithmic fairness, data privacy protection, maintain student autonomy etc., which believe that ethical reflection capability is an indispensable part of the literacy structure. Pedagogical Transformation Perspective inherits the theory of pedagogical content knowledge (PCK), claims that what teachers really need to develop is "artificial intelligence pedagogical knowledge" – i.e. how they can properly transform technology into teaching improvement in particular grade level and subject context^[2].

Despite having their rational cores, there are different shortcomings in terms of their explanatory power: Technological cognition puts teachers in a passive position as users of technology, undervaluing the independence of educational professional judgment; If the ethical criticism perspective is at the core of the literacy structure, then it will have some relative weaknesses in terms of technological understanding and pedagogical application capabilities; The pedagogical transformation perspective strictly follows the essence of the characteristics of the teaching profession without theoretical self-consciousness to criticize the technology itself. No single perspective can reflect the multi-dimensional requirements of primary and secondary school teacher competencies under intelligent education scenarios. We need to combine the foundation of technological cognition, the value framework of ethical criticism, and the implementation context of pedagogical transformation into one overall and unified framework as the theoretical prerequisite for establishing the subsequent indicator system.

1.3 Deconstruction of Literacy Dimensions for the Primary and Secondary School Teacher Group

Three stages: elementary school stage, junior high school stage, and senior high school are at different level of cognitive development, subject knowledge structure, and classroom teaching organization method; therefore, they have different priority scenarios when applying intelligent technologies. Moreover, the teaching tasks of primary and secondary school teachers involve various differentiated fields (classroom teaching, learning analytics, assignment design, individual tutoring,

home-school communication) with structurally different demand on teacher's competencies. Span of school stages and variety of tasks determine that the dimensional structure of artificial intelligence literacy for primary and secondary school teachers cannot be directly transplanted from existing framework in higher education or vocational education, it should be deconstructed according to the real situational characteristics of primary and secondary education^[3].

Based on the task-situation analysis approach, we found five dimensions of artificial intelligence literacy for primary and secondary school teachers including intelligent technology cognition (basic concepts understanding, working principle and function of artificial intelligence), data-driven teaching decision-making (ability to identify teaching problems and adjust strategy according to learning data), intelligent educational resource design (capacity to generate, screen and optimize teaching content by means of intelligent tools), human-machine collaborative teaching implementation (the ability to coordinate one's own teaching behavior with system functions in real classroom) and intelligent educational ethics judgment (sensitivity to risks like algorithmic bias, data privacy and technological dependency, making sound judgments); they progress step-by-step from cognitive foundation to practical application followed by value reflection; ethical judgment is a constraining force going across all these dimensions.

2. Construction Logic of the Indicator System for Artificial Intelligence Literacy of Primary and Secondary School Teachers

2.1 Theoretical Basis and Design Principles for the Construction of the Indicator System

The logical relationships between indicators and the granularity of an indicator should be answered theoretically when constructing the indicator system. Competency hierarchy theory gives directions about designing a hierarchical structure; it breaks down competency development into three increasingly higher levels – foundational cognition, practical application, and innovative generation which are reflected by indicators at the cognitive comprehension level, indicators at the operational transformation level and indicators at the autonomous construction level within the literacy indicator system. Taxonomy of educational objectives give operational reference to describe behavior of indicators based upon the cognitive dimension so that there will be distinguishable hierarchies of cognitive requirement and behavioral performance for indicators at each level thus avoiding any overlap or confusion in their description at different levels.

Four basic principles according to the above theory when we design the indicator: Content Validity Principle means that all important aspects of literacy will be covered by the indicators, omit any aspect which is not essential, and avoid including irrelevant ones.; Discrimination Principle means that these indicators could distinguish the competency difference between teachers at different levels, without convergence in evaluation result., Appropriateness Principle means that the difficulty level of the indicators match with the actual working scenario for primary and secondary school teachers, and the situation tasks included should be what they really face (or may face) during their professional activity.; Conciseness Principle means that the indicator system has a theoretical self-consistency and practical operability, control the total number of indicators but ensure enough coverage. Four principles constraint each other and govern the form and contents of the indicator system^[4].

2.2 Determination of the Hierarchical Structure and Core Indicators of the Indicator System

According to the above mentioned dimensional deconstruction framework and design principles, we organize our indicator system at three levels. First level indicators are macro dimensions of literacy including five categories like intelligent technology cognition, data-driven teaching decision-making, intelligent educational resource design, human-machine collaborative teaching implementation, and intelligent educational ethics judgment -- they are relative independent domains of competencies; Second level indicators unfold from each first level indicator with respect to specific sub-domains of competency. For example, intelligent technology cognition unfolds into three second level indicators: cognition of basic principles of artificial intelligence, cognition of types of intelligent educational tools, and judgment of technological evolution trends. Data-driven teaching decision-making unfolds into three second level indicators: interpretation of learning data, identification of teaching problems, and dynamic adjustment of strategies. Third level indicators manifest observable behaviors of competency through behavioral description. Every third level indicator has some typical behavioral examples as a reference criterion for evaluation.

In making decisions about our core indicators, we consider both comprehensiveness of theory coverage and academic consensus. Theoretical coverage: if more than one third level indicators set for a second-level indicator, these indicators must fully cover the core connotation of this competency sub-domain with no conspicuous omission of competency elements; Academic Consensus: handle marginal competency elements under academic controversy carefully, prioritize those indicator content which are highly recognized by the academic community. Keep the words open for controversial indicators so as to allow further study to revise them based upon empirical data. Specify clearly the descriptor of an indicator rather than vague statements which can cause deviation in understanding among different evaluators, and indicators at all levels shall be consistent regarding language style and depth of description.

2.3 Calculation Method and Rationality Justification of Indicator Weight Determination

Allocation of indicator weights has direct impact on validity of the indicator system in evaluating teacher's competency levels. Importance of indicators at different levels vary from the whole literacy structure so that we need systematic ways to determine its calculation. Analytic hierarchy process (AHP) can transform expert's experience into quantitative weights through building judgment matrices. Essence of AHP is to break down complicated multi-factor decision making problems into simple pairwise comparison for minimizing subjective influence on weighting result. Weight calculation involves three steps: construction of judgment matrix, computing eigenvector and consistency testing. Experts will make pairwise comparisons about the relative importance between indicators at each level with a nine-point scale method; then use consistency ratio to check whether the logical consistency of experts' judgments are within an acceptable range^[5].

Theoretical weight of pedagogical transformation oriented indicators should exceed that of pure technological cognition oriented indicators because it's basically what makes up artificial intelligence literacy for primary and secondary school teachers - ultimate value is improving teaching practice instead of having technical knowledge: cognitive understanding is just the starting point of competency development but transforming into teaching practice is where literacy really plays its educational role. Intelligent educational ethics judgment doesn't have too large independent weight reflecting through its regulating effect on performance of indicator in other dimensions and considered as a constraining condition in specific evaluations. Scientificity of weight calculation depends on the right choice of experts panel and strictly consistent test of judgment matrix; calculated result gives us the basis for quantitative operation when applied in further evaluation.

3. Enhancement Pathways for Artificial Intelligence Literacy of Primary and Secondary School Teachers

3.1 Division of Literacy Growth Stages Based on the Laws of Competency Development

The cultivation of artificial intelligence literacy for teachers should follow the intrinsic law of competency development. The difference exists in qualitative features at various levels of learners about their cognitive structure, experiential foundation and learning need; the enhancement path shall be adapted according to the staging logic of growth. According to classic description of the transition from novice to expert in competency development theory, taking account of the peculiarities of using intelligent technology by primary and secondary school teachers, we divided the literacy development into three stages: Firstly is an adaptation stage which means the period that teachers are in basic cognition and preliminary experiment with intelligent educational tools. Teachers pay attention to a sense of security in technical operation and acquisition of some basic functions, adopt a tentative attitude towards the effect of technology application in teaching; Secondly is an integration and application stage referring to the period that teachers have already obtained some experience in technology use, they can embed intelligent tools systematically into teaching design, start paying attention to the compatibility and effectiveness between technological tools and teaching objectives and subject content^[6]. Finally is a deepening stage which refers to the period that teachers' usage of technology has been mature enough so as to explore further ways to improve teaching quality through technology.

Innovation leading: An advanced level of literacy development. At this level, teachers are able to judge the educational applicability of different technologies based on a deep understanding of the principles of intelligent technology and rich practical teaching experiences, and creatively changing

their way of technology application in accordance with the demands of some teaching scenarios. The transition between stages will not happen automatically, which requires the cooperation of external support conditions and activating teachers themselves as the main agent's reflective awareness. Significance of stage division is giving us reference coordinates for further designing hierarchical learning content so that there won't have any mismatching of cognitive load and reducing the motivation of learning because of uniform training arrangement.

3.2 Construction of a Layered and Progressive Learning Content Framework

Based on such staged differences in literacy development we need to take into account the characteristics of layered progression while designing learning content for teachers at different developmental stages so that they can get appropriate learning resources and tasks suitable for their competency levels. For the first adaptation stage, the focus of the learning content needs to highlight functional cognition and basic operations of intelligent educational tools – use of modules (basic usage procedures of common intelligent teaching platforms), reading data from intelligent learning analytics tools or basic operational norms for intelligent courseware generation tools; organization of content by specific task operation decreases the cognitive threshold to guarantee learners' initial engagement. For the integration and application stage, the learning content has to focus on developing competency at an instruction strategy level: strategies for setting precise teaching objectives based on multidimensional learning data, selection/reorganization of intelligently recommended educational resources, designing/flexibly applying human-machine collaborative classroom interaction models. The emphasis here is on the deep integration between technological application capability and instructional design capability.

Learning content for the innovation-leading stage: Critical examination of educational applications of cutting-edge intelligent technologies; Methods for autonomously building school-based intelligent teaching models; Analysis and coping strategies for ethical dilemmas in complex intelligent education scenarios. Mostly through authentic problem inquiry, in-depth discussion to stimulate autonomy and innovative potential of teachers. The learning content among three levels are spiral ascending structure. Content at every level consolidate and deepen the competencies from the previous stage but introduce and cultivate new competency elements so as not to fragment or repeat between stages^[7].

3.3 Construction Logic of a Multi-Dimensional Collaborative Support System

To enhance teachers' artificial intelligence literacy, besides relying on single input from training courses, systematical support is needed within the school's organization environment. The construction of support system includes three aspects: technological resource support, professional learning communities and self-diagnosis tools. For technological resource support, we need to construct a resource repository of intelligent educational tools for teachers who could provide tool classification retrieval, description of application scenarios, and teaching use examples in reducing information search cost and trial error cost when teachers explore independently. To build up professional learning communities, by constructing a teacher learning network via an intelligent teaching research platform, teachers can have asynchronous discussions or peer assistance about real problems they encountered during intelligent teaching practice which promotes the flow and sharing of tacit teaching knowledge inside the group. As regards self-diagnosis tools, by building a teacher's literacy self-assessment scale and competency visualization report according to the indicator system, teachers can identify their competency weakness and make personalized learning pathway plans accordingly.

A closed loop exists in which technological resources provide contents/operational objects for discussions by learning communities and experiences exchanged by learning communities could be fed back to optimize/update the resource repository. The results obtained through self-diagnosis may assist with selection of technological resources or identification of themes for community activities. Technological resources deal with accessibility of learning content while learning communities build up a learning ecosystem of social interactions and self-diagnosis tools empower teachers' metacognitive monitoring capability on their learning process. A synergy of the three is a sustainable support ecosystem for literacy enhancement.

Conclusion

We made systematical efforts from various aspects including conceptual analysis to dimensional

deconstruction, indicator setting to weight allocation, stage division to pathway design around constructing an indicator system and enhancing strategies for artificial intelligence literacy of primary and secondary school teachers. In terms of theoretical aspect, we clarified the boundary of artificial intelligence literacy compared with other similar concepts; constructed a five-dimensional literacy framework focusing on primary and secondary education context through combining three perspectives (technological cognition, ethical criticism, and pedagogical transformation) based on competency hierarchy theory and taxonomy of educational objectives provides theoretical basis for the hierarchical structure of the indicators. In terms of methodology aspect, we adopted a three-level indicator structure to transform macro dimensions into measurable behavioral performances, and the analytic hierarchy process systematically quantified experts' experiences into weight coefficients for each dimension gives us a construction scheme balancing between theoretical foundation and quantitative computation. In terms of application aspect, we divided staged pathways of literacy growth according to the laws of competency development, built a layered and progressive learning content framework and a multi-dimensional collaborative support system which enable our indicator system to play assessment and developmental guidance roles. There are some limitations existing in our study: our indicator system was not tested for reliability and validity with large-scale empirical data, and the rationality of weight allocation needs empirical validation. Future research can be developed such as designing teacher literacy assessment tools based on our system, test structural fitness via exploratory and confirmatory factor analysis, calibrate weight allocation with assessment data, explore differential characteristics of literacy structures among teachers at different school stages or subjects etc., so as to refine our indicator system in a more targeted way.

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