



# Constructing a Constructivist-oriented Project-based Learning (PBL) Model for Meteorological Education and Training

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## Abstract

Meteorological education and professional training play a crucial role in enhancing forecasting accuracy, disaster prevention capability, and public service delivery in the context of increasing climate variability and rapid technological advancement. However, conventional lecture-centered training approaches have shown limitations in addressing the growing demand for applied competencies, integrative thinking, and collaborative problem-solving among meteorological practitioners. Grounded in constructivist learning theory, this study develops a project-based learning (PBL)-oriented training model specifically tailored to meteorological education and professional development contexts. This research adopts a design-oriented and conceptual methodology, integrating a systematic review of international literature on constructivism and PBL with an analysis of the characteristics and competency requirements of meteorological professional training. On this basis, a comprehensive PBL training framework is constructed, encompassing training objectives, project task design, instructional implementation processes, and evaluation principles. Rather than reporting empirical classroom interventions, the study employs a scenario-based application design derived from radar-related meteorological operations to illustrate the internal logic, structural coherence, and practical adaptability of the proposed model. The analysis suggests that a constructivist-oriented PBL framework has significant theoretical potential to promote active knowledge construction, enhance learner engagement, and strengthen applied problem-solving and collaborative competencies in meteorological training. This study contributes a theoretically grounded and context-sensitive instructional model for meteorological education and provides a conceptual reference for future empirical research and instructional innovation in professional and vocational training settings.

## Keywords

Constructivism; Project-Based Learning; Meteorological Education and Training; Professional Development; Instructional Design

## 1. Introduction

Meteorological services are increasingly expected to provide accurate forecasts, timely early warnings, and high-quality public services in response to extreme weather events and climate-related risks. These expectations place

growing demands on the professional competence of meteorological practitioners, including their ability to analyze complex data, integrate interdisciplinary knowledge, and make rapid operational decisions under uncertainty. Consequently, meteorological education and training systems must continually adapt to meet evolving professional requirements.

Traditional meteorological training has long relied on lecture-based instructional models that emphasize theoretical knowledge transmission. While such approaches are effective for introducing foundational concepts, they often fall short in cultivating applied skills, critical thinking, and collaborative problem-solving abilities. Learners in professional training contexts are frequently positioned as passive recipients of information, with limited opportunities to engage in authentic problem-solving tasks or to apply knowledge in realistic operational scenarios (Hmelo-Silver, 2004). As a result, gaps may emerge between theoretical learning outcomes and practical workplace performance.

In recent decades, learner-centered pedagogical approaches have gained increasing attention in both general and professional education. Among these, project-based learning (PBL) has been widely recognized for its capacity to support meaningful learning through engagement with authentic, complex problems (Barron et al., 1998). Rooted in constructivist learning theory, PBL emphasizes active knowledge construction, learner autonomy, and social interaction. Learners are encouraged to explore real-world problems, collaborate with peers, and reflect on their learning processes, thereby fostering higher-order cognitive and practical competencies.

Despite the growing body of international research on PBL, its systematic application within meteorological education and professional training remains underexplored. Existing studies have largely focused on primary, secondary, or engineering education, with limited attention to the distinctive characteristics of meteorological training, such as data-intensive analysis, operational decision-making, and high-stakes professional responsibility. Moreover, few studies have attempted to develop a theoretically integrated PBL framework specifically tailored to meteorological education contexts.

In response to these gaps, this study aims to construct a constructivist-oriented PBL training model for meteorological education and professional development. Adopting a conceptual and design-oriented research approach, the study seeks to (1) clarify the theoretical foundations supporting the integration of constructivism and PBL in meteorological training, (2) develop a systematic instructional model aligned with professional competency requirements, and (3) demonstrate the practical logic of the model through a scenario-based application design. By doing so, the study intends to provide a theoretically grounded framework to inform instructional reform and future empirical research in meteorological education and related professional training domains.

## 2. Theoretical Foundations

### 2.1 Constructivist Learning Theory

Constructivist learning theory posits that knowledge is not passively received but actively constructed by learners through interaction with their environment and social context. Early contributions by Piaget emphasized cognitive constructivism, highlighting the role of individual cognitive structures and developmental stages in knowledge construction (Dewey, 1938). From this perspective, learning involves processes of assimilation and accommodation, through which learners reorganize existing cognitive schemas in response to new experiences.

Social constructivist perspectives, most notably articulated by Vygotsky, further emphasize the role of social interaction, language, and cultural tools in learning. Concepts such as the zone of proximal development underscore the importance of collaborative learning and guided participation in cognitive development. In professional education contexts, social constructivism suggests that learning is deeply embedded in authentic practices and mediated through interaction with more experienced peers or instructors (Vygotsky, 1978).

Constructivist theory has significant implications for instructional design, particularly in professional and vocational training. It emphasizes learner-centered environments, authentic tasks, and opportunities for reflection and collaboration. Rather than focusing solely on content delivery, constructivist instruction seeks to create learning conditions that support meaningful engagement and contextualized knowledge construction (Papademetriou-Kachrimani, 2015). These principles provide a strong theoretical foundation for the adoption of PBL in meteorological education and training.

## 2.2 Project-Based Learning

Project-based learning is an instructional approach that organizes learning around complex, open-ended projects grounded in real-world problems. Learners engage in sustained inquiry, collaboratively explore solutions, and produce tangible outcomes or products (Blumenfeld et al., 1991). PBL is widely regarded as an effective means of operationalizing constructivist principles in educational practice.

Research on PBL has identified several core features, including authenticity of tasks, learner autonomy, collaboration, and reflective inquiry. By engaging with realistic problems, learners are encouraged to integrate theoretical knowledge with practical application, thereby enhancing transferability to professional contexts (Savery, 2006). Empirical studies across various disciplines have reported positive effects of PBL on learner motivation, problem-solving skills, and conceptual understanding.

In professional and vocational education, PBL is particularly valuable due to its alignment with workplace practices. It enables learners to experience the complexity and uncertainty inherent in real-world tasks while developing both technical and soft skills (Condliffe et al., 2017). These characteristics make PBL a promising pedagogical approach for meteorological training, where practitioners must routinely interpret complex data, collaborate with colleagues, and make informed decisions under time constraints (Kurt & Akoglu, 2023).

## 2.3 Implications for Meteorological Education and Training

Meteorological education is characterized by several distinctive features, including the integration of theoretical knowledge with operational practice, reliance on advanced technologies and data analysis, and high levels of professional responsibility. Training programs must therefore support not only cognitive understanding but also applied competence and professional judgment.

From a constructivist perspective, these characteristics underscore the need for instructional approaches that situate learning within authentic meteorological contexts. PBL offers a pedagogical framework capable of addressing these needs by embedding learning within realistic projects that mirror professional tasks (Markula & Aksela, 2022). By aligning instructional design with constructivist principles, meteorological training can better support the development of integrated competencies required in contemporary practice.

## 3. Analysis of the Current Status of Meteorological Education and Training

At present, meteorological education and training predominantly adopt instructional approaches such as thematic lectures, centralized classroom teaching, academic seminars, and field observations. These methods have played a certain role in facilitating knowledge updating and experience sharing among trainees. To some extent, they have contributed to the enhancement of professional knowledge and technical skills. However, with the increasing complexity and technological sophistication of meteorological operations, the limitations of traditional training models have become increasingly evident.

First, training content and instructional formats tend to be relatively homogeneous, characterized by short training cycles and intensive information delivery. Under such conditions, trainees often encounter difficulties in deeply understanding and assimilating newly acquired knowledge. Second, the training process is largely dominated by instructor-centered lecturing, placing trainees in a predominantly passive learning position and offering limited opportunities for active inquiry and hands-on practice. Third, practical training activities are frequently confined to demonstration and observation, lacking systematic task design grounded in authentic operational problems. As a result, trainees' practical skills and integrative application abilities are only marginally improved. Moreover, training content is often insufficiently aligned with specific job requirements, making it difficult for trainees to effectively transfer what they have learned into real workplace contexts after the training concludes.

Against the backdrop of meteorological modernization and the growing refinement of operational services, traditional training models are increasingly unable to meet the demand for cultivating versatile and application-oriented meteorological professionals. There is therefore an urgent need to introduce learner-centered, competency-oriented instructional approaches and to carry out systematic reforms of the existing meteorological education and training system.

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## 4. Research Design and Methodology

This study adopts a design-oriented and conceptual research approach commonly employed in educational innovation and instructional model development. Rather than testing predefined hypotheses through empirical experimentation, design-oriented research focuses on the systematic construction of theoretically grounded models intended to inform practice and guide future empirical investigation.

The research design comprises three interrelated components. First, a systematic review of international literature on constructivist learning theory and project-based learning was conducted to identify core principles, instructional features, and implementation strategies relevant to professional education. Second, an analysis of meteorological education and training contexts was undertaken, focusing on competency requirements, typical training content, and instructional challenges faced by practitioners. Third, drawing on insights from the literature review and contextual analysis, a constructivist-oriented PBL training model was conceptually constructed.

To enhance the practical relevance of the proposed model, the study incorporates a scenario-based application design derived from radar-related meteorological operations. Scenario-based design is widely used in professional training research to illustrate how instructional models may be operationalized in realistic contexts. In this study, the scenario serves as an illustrative example rather than an empirical intervention, demonstrating the structural logic and adaptability of the proposed framework.

## 5. Construction of a Constructivist-Oriented PBL Training Model

### 5.1 Training Objectives

The training objectives of the proposed model are aligned with the comprehensive competency requirements of meteorological practitioners. These objectives encompass three interrelated dimensions: theoretical understanding, applied skills, and professional attitudes. Learners are expected to develop a solid grasp of meteorological principles, the ability to apply knowledge to operational tasks, and a collaborative and reflective professional mindset.

### 5.2 Project Task Design

Project tasks form the core of the PBL model. Tasks are designed around authentic meteorological problems, such as severe weather monitoring, radar data interpretation, and forecasting decision-making. Each project requires learners to analyze data, formulate hypotheses, collaborate with peers, and propose evidence-based solutions. The open-ended nature of tasks encourages inquiry, creativity, and critical thinking.

### 5.3 Instructional Implementation Process

The instructional process follows a structured sequence consisting of problem introduction, project planning, collaborative inquiry, solution development, and reflection. Instructors assume the role of facilitators, providing scaffolding and guidance while supporting learner autonomy. This process reflects constructivist principles by emphasizing active engagement and social interaction.

### 5.4 Evaluation Principles

Evaluation within the proposed model emphasizes formative assessment and reflective learning. Multiple assessment methods are employed, including self-assessment, peer assessment, and instructor feedback. Both learning processes and project outcomes are evaluated to capture learners' cognitive development and applied competencies.

## 6. Application Design Example of a PBL-Oriented Meteorological Education and Training Model

To enhance the operational feasibility and practical relevance of the proposed training model, this study constructs a representative application scenario based on current meteorological operational processes and job competency requirements, without conducting actual instructional implementation. The purpose of this example is to provide an illustrative design of how a project-based learning (PBL)-oriented meteorological education and training model

could be applied in practice. It should be noted that this example does not summarize existing training practices; rather, it represents a systematic design of potential implementation pathways for future training programs.

### **6.1 Application Scenario Design**

The selected application scenario focuses on radar-related meteorological training, which is characterized by strong technical and practical demands within meteorological operations. Centered on the full process of weather radar system construction and operational application, a series of project-based learning tasks is designed. This scenario closely reflects actual operational workflows in meteorological departments and encompasses core competency requirements, including equipment cognition, data processing, and operational application.

### **6.2 Framework for Instructional Implementation**

Within this application scenario, the training process begins with the clarification of learning objectives, which include foundational understanding of radar operations, data analysis and interpretation skills, and integrated operational application capabilities. Based on these objectives, an overarching project task is designed, and trainees are organized into small learning groups to complete the project through collaborative learning.

The instructional process consists of several stages, including project initiation, task decomposition, independent inquiry, group collaboration, interim presentations, and reflective summarization. Throughout these stages, instructors function primarily as facilitators and supporters, providing guidance through problem prompts and formative feedback. This instructional role is intended to promote learners' progressive deepening of their understanding of meteorological knowledge and operational skills.

### **6.3 Example of Project Task Design**

At the level of specific task design, multiple interrelated subtasks may be established. For example, in the context of radar station network planning and operational application, tasks may include site layout analysis, design of equipment operation and maintenance schemes, and development of radar data application plans for operational services. During task completion, trainees are required to consult technical documentation, analyze operational data, and conduct evidence-based justification of proposed solutions. Through this process, the integration of knowledge construction and competency development can be effectively achieved.

Overall, this application design example demonstrates the feasibility and adaptability of a PBL-oriented meteorological education and training model within professional training contexts, providing a structured reference for future training implementation.

## **7. Analysis of the Expected Outcomes of the PBL-Oriented Meteorological Training Model**

Based on constructivist learning theory and findings from related studies, the PBL-oriented meteorological education and training model proposed in this study is expected to yield several theoretical benefits. First, by incorporating authentic or simulated professional projects, the model enhances the realism of learning contexts, which may increase learner motivation and encourage active participation in the learning process. Second, the decomposition of project tasks and their collaborative completion contribute to the development of learners' problem analysis skills, practical operational abilities, and teamwork awareness.

In addition, the emphasis on reflection and communication throughout the PBL process supports the integration of fragmented knowledge and experiences, thereby facilitating knowledge internalization and transfer. From the perspective of job competency requirements in meteorological education and training, this model is theoretically capable of narrowing the gap between training content and real-world professional practice, thereby enhancing the practical value and applicability of training outcomes.

## **8. Implementation Strategies and Recommendations**

To promote the effective application of the PBL-oriented meteorological education and training model, the following implementation strategies and recommendations are proposed:

### **(1) Instructor Training and Support:**

Training institutions should organize targeted professional development programs for instructors, focusing on

capacity building in PBL pedagogy, training resource development, course design, and evaluation system improvement. Workshops and seminars can provide instructors with opportunities for hands-on practice, enabling them to gradually adapt to and internalize the PBL instructional approach.

(2) **Development of Training Resources:**

Institutions should invest in instructional resources and platforms that support project-based learning. This includes the development of interactive instructional materials and virtual simulation platforms to facilitate learners' independent inquiry and collaborative learning.

(3) **Curriculum Design and Assessment:**

Specialized training on PBL instructional design should be provided to enhance instructors' abilities in curriculum planning and process facilitation. Curriculum design should emphasize the integration of theory and practice through the creation of challenging and engaging project tasks. Furthermore, a diversified assessment system should be established to evaluate not only learners' knowledge acquisition but also their practical skills, innovative thinking, and teamwork competencies.

(4) **Learner Support and Feedback Mechanisms:**

Training institutions should establish comprehensive learner support systems, offering academic guidance and learning assistance to help trainees adapt to the PBL learning model. Regular collection of learner feedback should be conducted to inform timely adjustments and continuous optimization of the training model.

(5) **Industry Collaboration:**

Strengthening collaboration with meteorological industry organizations is recommended. Industry experts may be invited to participate in curriculum design and instructional activities, providing authentic cases and project tasks that enhance learners' practical experience and professional competence.

## 9. Conclusion and Future Prospects

The findings of this study indicate that a constructivist-oriented project-based learning model is theoretically well-suited to meteorological education and training and holds substantial practical value for improving training quality and learner competency development. However, the large-scale implementation of this model may encounter challenges. For instance, the transformation of instructors' roles requires time and systematic professional development, while the design and development of training resources demand sustained investment. In addition, effectively implementing learner-centered instructional approaches in large-scale training contexts remains an issue warranting further exploration.

Future research may investigate the application pathways of PBL models across different types of meteorological training programs and integrate emerging information technologies to further enrich instructional formats and implementation strategies. Such efforts may provide sustained support for the cultivation of high-quality meteorological professionals.

In conclusion, the PBL-oriented meteorological education and training model proposed in this study offers new perspectives and methodological approaches for the field of meteorological education. Through continuous exploration and refinement, this model has the potential to play an increasingly significant role in future meteorological training practices and contribute meaningfully to the development of a highly competent meteorological workforce.

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