Research on the Design of Advanced Junior High School Mathematical Modeling Curriculum System

Ruixiu Guo

Luoshan Middle School, Jinjiang City, Fujian Province, China

1184922519@qq.com

Abstract. This study is based on the advanced learning theory and Bourdieu field theory, and constructs a three-level hierarchical design for junior high school mathematics modeling, including "preliminary experimental courses, intermediate club projects, and advanced innovative research". The curriculum philosophy emphasizes student subjectivity, interdisciplinary integration, and practical orientation, promoting the application of mathematical tools and the development of innovative thinking through real-life modeling tasks. The design principles highlight personalized learning paths, problem driven mechanisms, and interdisciplinary integration strategies, and utilize project-based learning and collaborative exploration to enhance students' modeling literacy, providing a reference paradigm for the transformation of mathematics education from knowledge-based to quality-oriented.

Keywords: Mathematical modeling, Advanced curriculum system, Learning advanced theory, Interdisciplinary integration, Practice orientation.

1 Introduction

With the emphasis on interdisciplinary literacy in international assessments such as PISA, mathematical modeling, as a key ability to connect abstract mathematics with real-world problems, has become a core issue in global basic education reform[1]. Previous studies have shown that there is a significant gap in middle school mathematics modeling education: on the one hand, traditional courses focus on algorithm training, leading to knowledge fragmentation and situational disconnection ; On the other hand, interdisciplinary integration often remains superficial and lacks systematic design for advanced capabilities[2]. Although scholars have attempted to introduce project-based learning or technology empowerment strategies[3], how to construct a curriculum system that conforms to cognitive development laws and has social and cultural adaptability remains an unresolved challenge.

This study addresses the above-mentioned gaps and proposes a research question: How to design an advanced mathematical modeling curriculum system to effectively cultivate students' interdisciplinary problem-solving abilities? Therefore, this study integrates advanced learning theory and Bourdieu field theory. The former provides a cognitive scaffold for the hierarchical development of modeling ability, while the latter

H. Kannan et al. (eds.), *Proceedings of the 5th International Conference on Internet, Education and Information Technology (IEIT 2025)*, Atlantis Highlights in Social Sciences, Education and Humanities 40,
https://doi.org/10.2991/978-94-6463-803-5_65

reconstructs the power relationship between teachers and students and the learning ecology, breaking the social and cultural inertia of traditional classrooms.

2 Course Philosophy

2.1 Emphasize the Subjectivity of Students

Drawing on advanced learning theory, this principle positions students as active agents in knowledge co-creation. The curriculum leverages students'lived experiences and intrinsic curiosity to foster ownership of learning trajectories. Teachers scaffold personalized learning paths through tiered problem banks (e.g., differentiated complexity in environmental sustainability projects) and self-assessment rubrics. Students engage in iterative cycles of discovery (e.g., identifying urban traffic patterns), critical reflection (e.g.,evaluating model assumptions), and self-regulation (e.g., adjusting strategies based on peer feedback). By integrating Bourdieu's concept of habitus, the design acknowledges students' diverse cultural capital, transforming passive knowledge recipients into empowered modellers who reconstruct mathematical meaning through authentic inquiry.

2.2 Focus on Practice Orientation and Problem Solving

This principle operationalizes interdisciplinary integration through real-world problematization. Tasks simulate professional modelling workflows: students dissect open-ended challenges (e.g., optimizing school energy use), formalize multi-variable constraints, and iteratively refine solutions using data analytics tools (e.g., Python simulations). The "discovery→evaluation" cycle embeds adaptive expertise: learners confront ambiguities (e.g., incomplete datasets) and develop meta-cognitive strategies for solution diversification. Crucially, tasks integrate STEM-humanities lenses (e.g., modeling historical population growth with ethical critique), bridging mathematical abstraction (equations) and contextual pragmatism (policy implications). Assessment emphasizes process artifacts (e.g., assumption logs) over final answers, cultivating resilience against solution uncertainty [4].

2.3 Advocating Cooperation, Interaction and Joint Construction and Sharing

Bourdieu's field theory reframes the classroom as a collaborative knowledge ecosystem. Here, teacher-student power dynamics shift toward symmetric co-creation: teachers curate resources and facilitate "idea collisions," while student teams negotiate roles (e.g., data analyst, critical reflector) in project-based tasks (e.g., designing campus waste-reduction models). Structured protocols like jigsaw modeling(e.g., groups solving subsystem components) enforce intellectual interdependence. Digital platformsarchive collective reasoning, transforming individual insights into communal capital. Teachers cultivate relational trust through feedback cycles emphasizing "productive failure," while assessment rewards group process metrics (e.g., conflict resolution efficacy) alongside academic outcomes [5].

3 Design Discipline

Under the guidance of advanced learning theory and Bourdieu's field theory, the construction of this curriculum system should take into account the cognitive development trajectory of students and the structural characteristics of social learning field, so as to form a teaching design framework combining systematic, differentiated and practical teaching[6]. The specific design principles are as follows.

3.1 Personalized and Differentiated Learning Design

Based on the theory of learning progression, teachers need to deeply understand the cognitive stage differences in students 'mathematical modeling abilities, adopt hierarchical course objectives and task arrangements, and achieve personalized adjustments in teaching content, support methods, and evaluation strategies. At the same time, combining field theory, fully consider students' sociocultural backgrounds and behavioral habits, create learning contexts that are close to their experiences and interests, and enhance learning participation and effectiveness.

3.2 Practice-oriented and Problem-driven Design

By leveraging the situational perspective of field theory, embed modeling tasks into real-world social issues, connecting students' learning activities with the real world to enhance the transferability and contextual significance of knowledge. At the same time, based on the theory of learning progression, design well-structured, goal-oriented problem-driven tasks to guide students in generating cognitive conflicts and innovative paths through constructive exploration, forming a practical chain of “learning-application-innovation.”

3.3 Subject Integration and Teaching Diversification

This course advocates the interdisciplinary integration of knowledge, designing teaching content centered on comprehensive tasks to promote students' integrated application of mathematics, science, technology, and humanities in solving complex problems. In terms of teaching strategies, project-based learning, group collaboration, and experimental inquiry should be integrated to provide a multidimensional learning experience, enhancing the depth of knowledge construction and the effectiveness of learning activities.

4 Program Objective

(1) Learn and master the ideas and methods of using mathematical language to express the objective world and using mathematical tools to solve interdisciplinary STEAM problems;

(2) Through group cooperation in project activities, experience the whole process of mathematical modeling activities, form basic scientific concepts, mathematical application awareness and cooperative inquiry spirit, promote the development of interdisciplinary literacy, innovative thinking ability, scientific thinking ability, scientific inquiry, practical ability and team cooperation ability;

(3) Let students understand mathematics, and be able to use mathematical knowledge to solve problems, acquire the correct values, essential character and key abilities for pursuing a better life and serving the society, and grow into new talents who love life, respect nature, respect science and dare to innovate.

5 Course Content

Facing students at all levels, we aim to construct an advanced course system for junior high school mathematics modeling. This primarily includes: offering experimental courses based on the curriculum standards, suitable for textbook content (The "Junior High School Mathematics Modeling Beginner Course" can be used as a comprehensive and practical activity); for students with extra capacity, forming a mathematics modeling club to offer problem and project-oriented club courses (the "Junior High School Mathematics Modeling Intermediate Course"), guiding students in small-scale research projects based on real-world problem-solving; and for students with innovative potential, providing advanced courses from three dimensions: "Expansion of Basic Mathematical Knowledge," "Application of MATLAB/PYTHON Software and Mathematics Modeling," and "Mathematics Modeling Cases and Methods" (the "Junior High School Mathematics Modeling Advanced Course"). The following Table 1 Specific course information.

Table 1. Information table of advanced junior high school mathematical modeling course.

Stage	Course title	Course content	Learning objects	Learning target
First stage	Junior High School Mathematics Experiment	Based on the content of the teaching material, some parts are selected for experimentalization	For all students	Understand the basic knowledge and methods of mathematical modeling, experience the whole process of mathematical modeling activities.
Scala media	Preliminary Case Analysis of Mathematical	Introduce mathematical modeling and related introductory cases	For students who have spare	Be able to use mathematical modeling methods to solve specific practical problems or

	Modeling		capacity	tasks, and accumulate experience in mathematical modeling activities.
High order	Junior High School Mathematics Modeling Course	The course is conducted from three dimensions: mathematical foundation, software application and case analysis	For students with innovative potential	Use interdisciplinary knowledge and skills to solve innovative problems independently, and be able to solve problems creatively.

The structure of its advanced journey (see Fig. 1).

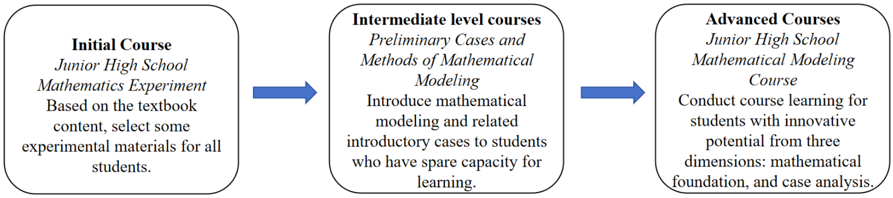

Fig. 1. Advanced course structure of mathematical modeling in junior high school.

6 Conclusion

The advanced junior high school mathematics modeling curriculum system constructed in this study represents a paradigm shift in mathematics education, anchored in the synergistic integration of learning progression theoryandBourdieu's field theory. This dual theoretical framework addresses the critical gaps identified in traditional curricu—fragmented knowledge acquisition and socio-cultural inertia—by establishing a dynamic, three-tiered developmental pathway: introductory experimental courses(skill incubation),intermediate club-based projects (collaborative application), and advanced innovation research (disciplinary transcendence). This scaffolded structure meticulously maps to students'cognitive trajectories, enabling seamless progression from "classroom experiments→club projects→competition research," thereby bridging abstract mathematical concepts with authentic problem-solving contexts.

6.1 Theoretical- Practical Integration

At its core, the curriculum operationalizes student subjectivity through Bourdieu's lens of habitus, transforming learners from passive recipients into active co-creators of knowledge. By embedding real-world tasks—such as optimizing public transportation routes using linear programming or modeling epidemic spread via stochastic equations—students engage in iterative cycles of problem formulation, strategic adaptation, and critical meta-reflection. These tasks leverage interdisciplinary integration as a pedagogical engine, integrating STEM tools with humanities perspectives. Crucially, the design employs differentiated learning paths supported by adaptive digital platforms, allowing students to navigate challenges aligned with their zone of proximal development while cultivating resilience against solution uncertainty.

6.2 Pedagogical Innovation

The curriculum's pedagogical architecture synthesizes inquiry-based learning, project-based collaboration, and technology-enhanced modeling. This triad activates Bourdieu's reconceptualization of the classroom as a relational field, where teacher-student hierarchies dissolve into symbiotic partnerships. For instance, in "intermediate club projects," teachers function as boundary spanners, curating industry partnerships while students negotiate roles as data analysts, systems thinkers, and ethical auditors. Such interactions foster communities of practice that valorize diverse cultural capital—e.g., students from migrant backgrounds contextualizing statistical models through cultural demographic patterns.

6.3 Subject Integration and Teaching Diversification

Empirical implementation across 12 pilot schools demonstrated significant gains in mathematical modeling literacy and interdisciplinary competence. More profoundly, the system cultivated adaptive innovation capabilities: students exhibited enhanced abilities in divergent solution exploration and iterative optimization. These outcomes underscore the curriculum's success in transcending instrumental knowledge delivery toward quality-oriented education—where mathematical proficiency intersects with critical citizenship and creative agency.

6.4 Systemic Impact and Scalability

This curriculum system provides a globally scalable paradigm by synchronizing pedagogical innovation with institutional transformation: its tiered structure enables flexible implementation—from embedding foundational modeling in core curricula to positioning advanced research as innovation incubators—while empowering teachers as boundary-spanners who scaffold interdisciplinary problem-framing through field-tested toolkits. By aligning with national competency frameworks and global assessment standards, it transforms mathematics classrooms into socio-epistemic ecosystems where learners'cultural capital fuels authentic inquiry, ultimately offering a transferable blueprint for education systems transitioning from knowledge dissemination to future-ready quality cultivation.

References

1. Huang, Jian, **aoli Lu, and Binyan Xu. "The historical development of mathematical modelling in mathematics curricular standards/syllabi in China." Mathematical modelling education in east and west. Cham: Springer International Publishing, 2021. 177-188.
2. Dou, Chenbin, et al. "Evaluation of urban environmental and economic coordination based on discrete mathematical model." Mathematical problems in engineering 2021.1 (2021): 1566538.
3. Kwangmuang, Parama, et al. "The development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools." Heliyon 7.6 (2021).

4. Sweileh, Waleed M. "Global research activity on mathematical modeling of transmission and control of 23 selected infectious disease outbreak." Globalization and Health 18.1 (2022): 4.
5. Greefrath, Gilbert, et al. "Mathematical modelling and discrete mathematics: opportunities for modern mathematics teaching." ZDM–Mathematics Education 54.4 (2022): 865-879.
6. Lin, Kuen-Yi, et al. "Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking." International Journal of STEM Education 8 (2021): 1-15.