

# Integrating Project-Based Learning with Teaching-Learning-Assessment Alignment: A Case Study of “Integrated Communication and Navigation Signal Design and Acquisition”

Jing Peng<sup>1, 2, \*</sup>, Jiachong Chang<sup>1, 2</sup>, Sixin Wang<sup>1, 2</sup>, Hongqi Yu<sup>1, 2</sup>,  
Hang Gong<sup>1, 2</sup>, and Xiaohui Liu<sup>1, 2</sup>

<sup>1</sup> College of Electronic Science and Technology, National University of Defense Technology, China;

<sup>2</sup> National Key Laboratory of Navigation and Space-Time Technology, College of Electronic Science and Technology, National University of Defense Technology, China.

\* pengjing@nudt.edu.cn

**Abstract.** This study addresses the persistent gaps in engineering graduate education—theory application disconnection, insufficient practical demand traction, and one-dimensional assessment—by proposing a deeply integrated pedagogical model that merges project-based learning (PBL) with teaching-learning-assessment alignment. Using the engineering topic of “integrated communication and navigation signal design and acquisition” for low Earth orbit (LEO) constellations as a case, we detail the design rationale and implementation. The model follows a real engineering workflow (“demand analysis–problem definition–solution design–test verification”) and embeds formative and summative assessment throughout the PBL cycle. Teaching practice shows that the approach effectively enhances students’ innovative practice and complex problem-solving abilities, as evidenced by their success in national discipline competitions. The findings offer insights for cultivating higher-order thinking and innovation in engineering graduates, and for talent-training reform in the context of new quality productive forces.

**Keywords:** project-based learning; teaching-learning-assessment alignment; integrated communication-navigation signal design; engineering graduate education.

## 1. Introduction

LEO constellations serve as backup and enhancement systems for satellite navigation. Through integrated communication-navigation technology, they can fuse communication and navigation functions within the same signal scheme, achieving “dual-service capability with a single signal transmission,” which reduces constellation cost and improves overall service capability [1, 2]. Integrated signal design is a core teaching content of the “Navigation Signal Design” chapter in the graduate course Satellite Navigation Positioning Theory and Technology. Building on prerequisite knowledge, students are expected to design integrated signal waveforms for LEO constellations that meet common technical requirements, solve rapid acquisition problems, and conduct practical verification on digital platforms.

However, the traditional “knowledge lecture and practice session” approach suffers from three main shortcomings:

**Theory-application disconnect:** Students often learn isolated knowledge points without appreciating the complexity of applying them in engineering. They lack understanding of the relationship between integrated signal requirements and course objectives, as well as the practical constraints and receiver-algorithm adaptations.

**Insufficient practical demand traction:** Teaching relies mainly on reproductive verification experiments, lacking design-oriented flexibility driven by engineering needs. Students struggle to translate abstract theory into research practice [3].

**One-dimensional assessment:** Conventional in-class experiments, exams, and reports adopt a forward-design approach that primarily tests knowledge mastery, failing to assess students’ ability

to construct knowledge autonomously, exercise higher-order thinking, or solve complex engineering problems [4, 5].

This paper takes the PBL design of “integrated communication-navigation signal design and acquisition” as an entry point and integrates it with teaching–learning–assessment alignment.. Driven by authentic engineering problems, it employs stepwise inquiry and PBL higher-order thinking activities to guide students through recreating the innovation process, letting them experience “design” rather than mere “reproduction.” The paper first presents the integrated design philosophy and analyzes the intrinsic logic of deep integration. It then develops a PBL instructional design based on the specific knowledge points and a student-centered assessment system. Finally, it summarizes the innovative features and evaluates teaching effectiveness using students’ actual competition achievements.

## **2. Integrated Design Philosophy of PBL and Teaching-Learning-Assessment Alignment**

PBL is a student-centered, systematic teaching method that guides students to investigate authentic, complex, and challenging problems or tasks, producing demonstrable outcomes through sustained inquiry, teamwork, and practical exploration, thereby achieving autonomous knowledge construction and competency development [3, 6, 7].

Teaching-learning-assessment alignment organically integrates teachers’ “teaching,” students’ “learning,” and the “assessment” of teaching effectiveness into a coherent system with consistent goals, mutual support, and flexible adjustment. Compared with the separated teaching-learning-assessment mode, alignment centers on “student-centeredness,” requiring clear, measurable learning objectives that serve as both the targets of teaching/learning and the criteria for assessment [8, 9, 10]. In instructional design, the logic shifts from forward-design (“objectives → activities → assessment”) to backward design that starts with the desired level of objective attainment. In implementation, assessment permeates the whole teaching process, synchronizing with activities and enabling real-time adjustment to promote improvement [4, 11].

PBL and alignment have natural synergies:

Shared student-centered philosophy. PBL integrates teaching, learning, and assessment activities, transforming the teacher’s role from “knowledge transmitter” to “learning designer” [12]. Alignment, taking students’ key-competency enhancement as the starting point, turns the teacher into a designer of learning activities, a process observer, and a builder of learning scaffolds and environments, fostering an inquiry- and innovation-oriented culture [7,13].

Alignment can be deeply embedded throughout PBL [14]. At the initial stage, objectives and assessment criteria are formulated, guiding students to design technical roadmaps and implementation plans. During implementation, PBL assessment operates as a dynamic, multi-dimensional mechanism—using classroom discussions, phased presentations, group collaboration, blended learning, and peer/teacher evaluation—to track learning activities and outcomes [15]. At the conclusion, formative and summative assessment results generate improvement suggestions and optimize the teaching plan.

Integration empowers competency formation under “authentic problems and authentic contexts.” Driven by major engineering demands and real technical problems, PBL can leverage the goal orientation and competency-assessment criteria of alignment [16] to conduct backward design of teaching practices. By designing a ladder problem chain, it recreates real research scenarios and technical challenges, constructing an “immersive” research-practice environment that guides students through the complete innovation process while incorporating interdisciplinary and multi-dimensional considerations (e.g., cost, compatibility) to enhance system-thinking-based problem-solving ability.

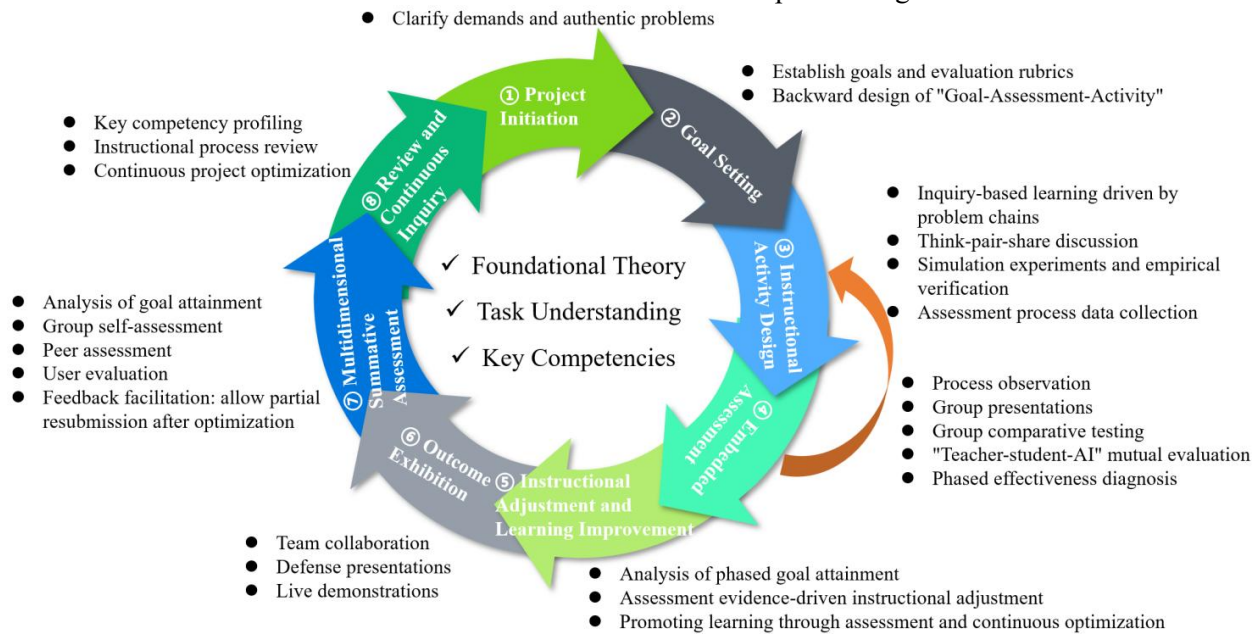


Fig. 1 Integrated design framework of PBL and teaching-learning-assessment alignment

### 3. Instructional Design and Implementation Based on “Integrated Communication- Navigation Signal Design and Acquisition”

The instructional goal is to design an integrated signal scheme for mega-LEO constellations following the engineering workflow “demand analysis–problem definition–solution design–test verification,” enabling students to master core design methods and produce an efficient integrated scheme.

#### 3.1 Demand Analysis (2 in-class hours)

Background: LEO satellites offer high received signal power, low latency, and large bandwidth, providing higher-precision positioning enhancement. However, traditional space-based systems isolate communication and navigation, failing to meet popularized, high-timeliness, integrated service demands. Separate constellation construction leads to huge redundant investment; increasing mega-constellations intensify spectrum scarcity; and separated information hinders future 6G “multi-functionality in one network” applications.

Problem Chain 1: With integrated technology development, mobile communication and navigation positioning are becoming mutually empowering. The core technology is integrated signal design—integrating communication, navigation, etc., into a single satellite to achieve “ubiquitous connectivity” across remote areas, deserts, and oceans, providing new services such as direct satellite connectivity for public phones, industrial terminals, and emergency rescue. What aspects of integrated signal design can be explored?

Group discussion: Think-Pair-Share or structured discussion guides students to explore information fusion, signal fusion, and integrated scheme design, comparing different solutions.

Embedded assessment: Groups submit design ideas or system framework diagrams. Multi-dimensional evaluation (teacher-student-machine) covers design concept, cost, complexity, feasibility, and user experience.

#### 3.2 Phase 2: Problem Definition (2 in-class hours)

Problem Chain 2: LEO satellites exhibit high dynamics and significant Doppler shifts. Traditional OFDM suffers severe inter-carrier interference, while OTFS (a 6G candidate) shows strong robustness in high-dynamic channels. What challenges arise if integrated signal design is adopted?

Project topic: Through structured discussion, students identify three technical bottlenecks: “multi-satellite rapid acquisition, high-dynamic precise tracking, and communication-navigation cooperative high-precision positioning.” Innovative multiple-access techniques are needed to compress acquisition time; Doppler estimation methods must be optimized to improve synchronization accuracy; and cooperative positioning algorithms must balance functionality.

Embedded assessment: Teacher commentary via process observation and logical consistency; group peer evaluation continuously optimizes the design, ultimately forming a full-chain “modulation–acquisition–tracking–positioning” solution.

### 3.3 Solution Design (Group design & discussion, 8 extra- class hours)

Problem Chains 3–5: Address rapid-acquisition directions (terminal-side fast algorithms vs. satellite-side new modulations), high-dynamic tracking challenges (OTFS channel-estimation complexity), and positioning-coverage conflicts (four-satellite vs. single-satellite Doppler).

Practice content: Students, based on OTFS principles and prior acquisition theory, design a Doppler-code-phase division multiple access (DFCP-DMA) rapid-acquisition scheme, fractional-Doppler precise estimation methods, and integrated positioning algorithms. Using MATLAB/SystemVue, they model and simulate integrated signals, implement frame-structure design, rapid-acquisition, and interference-suppression verification, and propose an evaluation indicator system.

Embedded assessment: Submission of discussion minutes, simulation code, and phased test results. Group “bug-checking” and intra-group peer evaluation; teacher assesses feasibility, code readability, algorithm innovation, and teamwork.

### 3.4 Test Verification (Advanced practice, 16 extra- class hours)

Practice content: Simulate DFCP-DMA acquisition time with MATLAB; use a LEO constellation digital-twin platform or USRP hardware to build simulated satellite-ground links for multi-scenario performance testing (bit error rate, positioning accuracy). Groups record typical problems, discuss solutions, and propose optimized designs for different application scenarios.

Embedded assessment: Submission of test reports; live demonstrations with performance-based comparative evaluation.

### 3.5 Outcome Presentation (2 in- class hours)

**Practice content:** Groups present project outcomes and exchange optimization suggestions.

**Embedded assessment:** A rubric-based summative assessment (40% of total grade) covers solution completeness/feasibility, report logic/presentation, and defense performance. To emphasize feedback, students may revise and resubmit parts of their reports based on peer/teacher comments.

## 4. Innovative Features and Teaching Effectiveness

The integrated design exhibits three innovative characteristics:

1) Comprehensive knowledge-system reconstruction through interdisciplinary PBL practice and alignment. Driven by real technical problems from major engineering projects, the design integrates multi-course knowledge (e.g., digital signal processing, satellite communication, navigation principles, integration). For instance, it couples Fourier transform with OTFS delay-Doppler mapping and traditional acquisition/tracking techniques with DFCP-DMA schemes, reconstructing the professional knowledge system and bridging the underlying logic between complex scientific problems and professional knowledge.

2) Ability transformation from theory to practice via a “laddered problem chain” and heuristic teaching. Facing actual engineering demands and technical challenges, the problem-chain design recreates real research thinking and concepts, constructing an “immersive” teaching environment

that guides students through the complete research process while incorporating interdisciplinary and multi-dimensional practice to enhance systems- thinking-based problem-solving.

3) Exploration of a “dual-helix” talent-cultivation model of “innovative application and frontier exploration.” On one hand, oriented toward major engineering needs, it leverages high-tech interdisciplinary advantages and precise user-demand matching, designing a cultivation path of “scientific problem–technological innovation–competency shaping.” On the other hand, focusing on frontier areas like OTFS modulation and high-precision positioning, it fills gaps in existing curricula (e.g., “large-scale constellation integration technology”) and ensures teaching content keeps pace with industry development through the team’s latest research outcomes, forming a symbiotic model where professional knowledge empowers frontier innovation.

The course case and extended PBL topics have supported graduate students’ participation in electronic-information discipline competitions and innovation-entrepreneurship projects, realizing the transformation of value shaping, competency cultivation, and innovative practice. The achievements supported by this case are summarized in Table 1.

Table 1. Course Knowledge Points, Extended PBL Topics, and Supported Graduate Student Competition Achievements

| Course Knowledge Point                                                         | PBL Topic                                                                                                           | Achievement                                                                                                                   |
|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| Integrated communication navigation signal design                              | LEO satellite integrated communication-navigation signal scheme                                                     | 19th China Graduate Electronic Design Competition National First Prize (2024)                                                 |
|                                                                                | OTFS integrated communication-navigation signal scheme design based on deep learning                                | 12th “Datang Cup” National College Student New Generation Information Communication Technology Competition Third Prize (2024) |
|                                                                                | Orthogonal time-frequency-space technology leading 6G satellite internet integrated communication-navigation future | 2024 National University of Defense Technology ICAN Innovation and Entrepreneurship Competition Second Prize                  |
| Integrated constellation time reference establishment and time synchronization | 6G integrated communication-sensing base station trusted time synchronization system                                | 20th China Graduate Electronic Design Competition National Second Prize (2025)                                                |
|                                                                                | Large-scale constellation time reference establishment and maintenance system                                       | 19th China Graduate Electronic Design Competition Regional First Prize, National Second Prize (2024)                          |
|                                                                                | LEO constellation time synchronization digital twin platform and experimental system                                | 8th Hunan Provincial Graduate Electronic Design Competition First Prize (2024)                                                |
| Integrated signal acquisition and tracking                                     | BeiDou short message post-disaster intelligent emergency search and rescue system                                   | 2024 National College Student Internet of Things Competition Regional First Prize (2024)                                      |
|                                                                                | Intelligent location information monitoring system based on BeiDou short messages                                   | 2024 National College Student Internet of Things Competition Regional Second Prize                                            |
|                                                                                | Portable intelligent monitoring system for outdoor sports based on BeiDou short messages                            | 18th China Graduate Electronic Design Competition Regional Third Prize (2023)                                                 |

## 5. Summary

This paper explores the intrinsic connections between PBL and teaching-learning-assessment alignment and proposes a deeply integrated pedagogical model that combines goal orientation with

whole-process embedded assessment. In design and implementation, based on authentic complex engineering problems, the model horizontally integrates cutting-edge technologies (navigation, communication, LEO internet, OTFS modulation) with the knowledge points of the Satellite Navigation Positioning Theory and Technology course. Guided by the cultivation of comprehensive innovative practice capabilities and combined with scientific problems and actual engineering scenarios, it conducts backward design of teaching activities and accompanying assessment, effectively enhancing students' innovative thinking and comprehensive practical abilities. This pedagogical reform paradigm can be extended to the practical teaching and curriculum construction of electronic-information course clusters, ultimately empowering the cultivation of high-level innovative talents for new spatiotemporal information services.

## Acknowledgements

The source of the research project funding: Educational and Teaching Research Project of National University of Defense Technology (U202402), Key Project of Teaching Reform in Regular Undergraduate Colleges and Universities of Hunan Province in 2025 (202502000004).

## References

- [1] Liu, B., Zhao, Y., et al. Integrated signal design and processing for LEO satellites. *Space-Integrated-Ground Information Networks*, 2023,4(03): 40-47.
- [2] Dou, C., Wu, Y., et al. LEO satellite constellation network architecture and key technologies enabled by integrated communication-sensing-computing fusion. *ZTE Communications*. 2024, 30(05): 9-15.
- [3] Belle, S. et al. Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*. 2010(83): 39–43.
- [4] Shi, Q., Cheng, X., et al. Exploration of an integrated teaching-learning-assessment experimental teaching system for theoretical economics based on research-project approach. *Heilongjiang Education (Higher Education Research & Evaluation)*. 2025(07): 59-64.
- [5] Li, X., Wang, W., & Qie, H. Research on multi-integrated evaluation methods for new engineering project-based learning: A case study of the "Smart Society and Big Data Intelligence" course. *Research in Higher Education of Engineering*, 2023(06): 27-33.
- [6] Larmer, J., et al. *Gold standard PBL: Essential project design elements*. Guangming Daily Press. 2019.
- [7] Dimitra Kokotsaki, Victoria Menzies, et al. Project-based learning: A review of the literature. *Improving Schools*, 1-11,2016.
- [8] Liu, H., Wu, T., et al. Construction and practice of a "four-module, dual-driver" teaching model for molecular biology experiments based on PBL theory. *University Biology Teaching Research*, 2025, 15(06):43-49.
- [9] Wang, T., & Wang, Y. The alignment of teaching, learning, and assessment in project-based learning and its realization. *Teaching and Management*, 2026 (07): 1-6..
- [10] Su, Y., & Chen, L. Reconstructing the classification framework of educational objectives to clarify the direction of teaching-learning-assessment alignment: A review of A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives (2nd ed.). *Chemistry Education*, 2022(9): pp. 129.
- [11] Zhang, H. High school English reading teaching practice based on teaching-learning-assessment alignment. *Advances in Education*, 2024, 14(6): 697-705.
- [12] Barak, M. et al. From 'doing' to 'doing with learning': Reflection on an effort to promote self-regulated learning in technological projects in high school. *European Journal of Engineering Education*, 37, pp.105–116.
- [13] Kovácsné Pusztai, K. Evaluation of Project-Based Learning. *Acta Didactica Napocensia*, 14(1),2021:64-75.

- [14] Michael J. Prince; Richard M. Felder. Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. *Journal of Engineering Education*. Volume 95, Issue 2. 2006: pp.123-138.
- [15] Soumaya Argoubi, et al. Design thinking and project-based learning implementation through competency-based model and criterion-referenced assessment. *Proceedings of the 20th international CDIO conference, ESPRIT, Tunis, Tunisia, June 10-13, 2024*.
- [16] Walter F., Chris S. et al. Implementing and operationalising integrative approaches to sustainability in higher education: the role of project-oriented learning. *Journal of Cleaner Production*, vol 133, 2016: 126-135.