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# Development and Empirical Research on Competency Indicators for Starlink Design-based Learning Innovation Courses

Chih-Chao Chung[1], Shi-Jer Lou[2], Yuh-Ming Cheng[3*]

[1] General Education Center, National Tainan Junior College of Nursing, Tainan 700, Taiwan, ROC
ccchung@mail.ntin.edu.tw

[2] Graduate Institute of Technological and Vocational Education, National Pingtung University of Science and Technology, Pingtung 912, Taiwan, ROC
lou@mail.npust.edu.tw

[3] Department of Computer Science and Information Engineering, Shu-Te University, Kaohsiung 824, Taiwan, ROC
cymer@stu.edu.tw

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**Abstract.** This study aimed to enhance a Starlink Design-based Learning (DBL) Innovation course at a Science and Technology university by formulating competency indices, course content, assessment tools, and instructional materials. Thirteen experts in satellite communication, spectrum management, satellite applications, launch, and system integration employed the fuzzy Delphi method to evaluate the significance of the capability indices. Taking 39 junior students enrolled in practical courses as the subjects, this study conducted an 18-week quasi-experimental teaching and used importance-performance analysis to explore the impact of the Starlink DBL Innovation course on student learning effectiveness. This study identified five key capability indices, encompassing the Starlink system, satellite communication technology, spectrum management, satellite network applications, and sustainable satellite technology development, with 21 specific indicators. The Starlink system index garnered the highest importance according to the experts' evaluations. According to the IPA results, 21 indicators were classified into the four categories of Keep Up the Good Work, Concentrate Here, Low Priority, and Possible Overkill, which were used to provide specific and feasible suggestions for course improvement so as to adjust the teaching content and methods in a targeted manner and thereby improve student learning experience and effectiveness. At the same time, this study proposed a number of relatively low-importance performance indicators that were present in the overall evaluation of the students, which may provide new directions in future teaching and research and are worth further in-depth research and exploration. These findings could inform the development of the Starlink DBL Innovation course and other relevant thematic courses, offering a pioneering framework for interdisciplinary technology education and cultivating adept graduates. This research contributed to the literature by providing practical tools to elevate technology-focused curricula.

**Keywords:** design-based learning, Starlink, competency indicators, education reform

## 1 Introduction

In recent years, satellite technology has experienced rapid development. The decreasing costs of satellite production and replacement, coupled with the ability to fill the spatial gap for 5G, have accelerated the global deployment of low Earth orbit (LEO) satellites. The infrastructure bill proposed by U.S. President Biden, allocating 1.2 trillion USD for infrastructure development, includes a direct entry into the field of satellite communication through broadband network projects. This positions the LEO satellite industry as a crucial component of infrastructure development [1-3]. Several international giants are actively involved in LEO satellite deployment. Companies such as SpaceX, founded by Elon Musk (CEO of Tesla), are driving the LEO satellite internet project known as Starlink. Similarly, Jeff Bezos, founder of Amazon, initiated a LEO satellite networking project named Kuiper. Other players include Telesat, a Canadian satellite communications company, and the British telecommunications firm Eutelsat OneWeb, which are both making significant investments in this arena [4-6].

According to data from the Satellite Industry Association (SIA) in the U.S., the global satellite industry's total revenue reached USD 270.6 billion in 2020, indicating a positive outlook for the global LEO industry

* Corresponding Author

[3]. In Taiwan, the space industry has been designated as one of the six core strategic industries. The Space Development Act was passed in May 2020, allocating 40 billion NTD from 2021 to 2024 for the development of the first experimental LEO satellite communication technology and system implementation domestically [7, 8]. The Taiwanese government has further declared its ambition to make Taiwan a part of the international supply chain for aviation and satellite industries' components, subsystems, or related services by 2030, aiming to seize significant business opportunities.

In light of this, the Industrial Development Bureau of the Ministry of Economic Affairs in Taiwan announced the launch of Taiwan's Low Earth Orbit Satellite Ground Equipment Flagship Team on December 9, 2021. This initiative involves a collaboration between the Industrial Technology Research Institute (ITRI) and Aerkomm, a global aerospace communication service provider, who signed an international memorandum of understanding (MoU). This partnership aims to cooperate within the satellite ground terminal equipment supply chain. Additionally, Taiwan's Industrial Development Bureau has approved the Low-Earth Orbit Satellite Ground Communication Equipment Development Subsidy Program, comprising five research and development initiatives [9, 10]. These initiatives cover household terminal equipment, mobile vehicle terminals, semiconductor power components, and pivotal components for ground receiving stations [7, 11].

Surveying the international players involved in LEO satellite deployment, SpaceX, led by CEO Elon Musk, stands out as particularly active. Musk announced the Starlink project, a space-based high-speed internet initiative, in Seattle in 2015. Currently, Starlink is the world's largest satellite constellation, with a relatively mature satellite network service. The goal is to deploy over 12,000 satellites in LEO, forming a high-quality, low-cost broadband network that can effectively cover the entire globe. It is anticipated that upon completion, Starlink will generate annual revenues exceeding $30 billion [6, 12]. Observing the current dynamics of emerging industries and related policy planning directions, it is evident that LEO communication satellite technology is a thriving emerging industry expected to develop vigorously in the next decade [3]. The demand for talent in this field is significant, and there is an urgent need for educational institutions to cultivate such talent. In view of this, our research was based on the perspective of nurturing talent in LEO communication satellites, using Starlink as the thematic focus for curriculum development.

Furthermore, with the launch of the Ministry of Science and Technology's Next-Generation Communication System Key Technology Development Project in 2021, focusing on areas such as B5G, 6G, and LEO satellites, early research to promote industry-academia collaboration has been initiated. In the context of the development trends of next-generation communication systems, breakthroughs in knowledge, technology, and innovative application methods require the support of emerging technologies. This includes the integration of interdisciplinary, cross-domain, and cross-field applications such as new Internet of Things applications, autonomous unmanned vehicle applications, public safety applications, full-coverage network applications, smart healthcare, implantable device applications, and immersive applications [13]. Additionally, satellites possess advantages such as wide coverage, shorter ground station construction time, and lower costs, making them suitable for specific application needs. In Taiwan, they can be employed for the development of network services in remote areas, catering to sectors like agriculture, forestry, fisheries, transportation, environmental monitoring, and wildlife tracking.

Given the flourishing development of the Starlink-related industry and the future application trends of 5G and 6G, cultivating knowledge and application concepts related to Starlink and 6G among technology university students is essential. This preparation is anticipated to enhance students' competitiveness for future interdisciplinary team collaboration and involvement in 6G-related industries, thereby meeting the demands of the industry for talent. This highlights the necessity and significance of developing an innovative Starlink course in technological universities through this project.

The promotion of emerging technology-themed intellectual competency courses such as Starlink, post-5G, and 6G needs to integrate learning content, processes, and results in a contextual framework. This integration should establish meaningful connections to enable learners to achieve genuine understanding. Deep understanding requires continuous guidance within the contextual framework and instructional strategies. Learners need the ability to explore on their own, and during exploration, and they must be provided space and opportunities for practical experiences to externalize ideas. Simultaneously, this approach allows for feedback within the learning context, making the learning process more robust. In this regard, Doreen Nelson's 2004 proposed design-based learning (DBL), incorporating design concepts into the curriculum, emphasizes hands-on implementation and action-oriented concepts. It innovates teaching methods and provides students with comprehensive learning experiences [14]. Related studies indicated that DBL can stimulate student interest and enhance learning performance and intellectual development [15]. When applied to skill learning activities, it can improve students' creativity performance [16]. It also has positive effects on STEM learning and the acquisition of knowledge about scientific concepts [17, 18].

Given these considerations, this study approached the cultivation of talent in LEO communication satellites, using Starlink as the focal point for curriculum development. The Starlink innovation project course was designed using a DBL approach. The emphasis was on integrating the application of emerging technology, specifically Starlink-related technologies, into the curriculum and teaching methods. This approach aimed to allow students from technology universities to gain a deeper understanding of Starlink's future development trends and opportunities through hands-on practical exercises and innovative thinking. The objectives of this study were threefold, and each is explained as follows:

(1) To establish the competency indices for the Starlink DBL Innovation course;

(2) To explore the significance of these competency indices within the context of the Starlink DBL Innovation course;

(3) To explore the impact of the Starlink DBL Innovation course on the learning effectiveness of the student performance indicators.

## 2 Literature Review

This research centered around the synthesis of the Starlink initiative with the DBL paradigm, culminating in the establishment of the Starlink DBL Innovation course. This distinctive program aimed to enhance university students' competence in Starlink-related domains. The study involved an in-depth inquiry into pertinent literature and correlated research, delving into the evolutionary trajectory of both DBL and Starlink to inform program development.

### 2.1 Design-based Learning

In recent times, DBL has emerged as a valuable educational paradigm, fostering innovation within teaching methodologies. This approach leverages design methodologies to address intricate structural challenges, broaden cognitive horizons, and facilitate non-verbal thinking [19]. The concept of design thinking aims to fuel problem-solving through creative solutions and translate them into tangible outcomes, thereby instilling strategies for problem elucidation, resolution, and collaborative teamwork [20]. Central to design thinking is the prioritization of human needs, encompassing not only discerning user preferences but also unearthing latent requirements that users themselves may not have identified [21].

Originating from the ideas of Doreen Nelson and influenced by John Dewey, DBL champions a hands-on and practical educational philosophy. Nelson's approach emphasizes experiential learning, asserting that profound comprehension arises from unearthing fundamental principles within the curriculum—a process best achieved through hands-on engagement. This framework encourages inventive problem-solving, melding knowledge, skills, and attitudes within structured learning contexts. It guides students toward becoming independent, lifelong learners who are proactive, adept communicators, and engaged contributors within society [19].

Nelson 2004 considered the operational mode of DBL as a curriculum approach rooted in backward design thinking that can be divided into 6.5 steps [14, 22]:

**Establish the learning goals.** The teachers start by contemplating the key themes, concepts, and standards from the curriculum standards or syllabus, and then establishing the ultimate instructional objectives.

**Formulate the core questions.** Based on the identified learning goals, the teachers pose a core question worth exploring.

**Integrate core questions with a real-world context.** The core question is combined with a real-world context, designing a practical task representing a never-before-seen challenge for the students to undertake, thereby gaining an understanding of the learning focus.

**Continuously apply the assessment criteria.** The teachers continuously apply assessment criteria derived from the curriculum design throughout the learning process.

**Create student prototypes.** Upon receiving the practical task, the students create prototypes in accordance with the assessment criteria to demonstrate their understanding.

**Provide teacher assessment and guidance.** The teachers assess learning needs from the students' prototype implementations and intervene to guide the course.

**Allow student revision and completion.** After undergoing enriched and empowered guidance, the students revisit and revise their prototypes to achieve a comprehensive understanding of the learning focus, eventually producing finished practical works.

### 2.2 Development and Applications of Starlink Technology

In 2020, Taiwan ushered in the era of 5G mobile communication technology, transforming human lifestyles and introducing novel interactive experiences. However, global challenges remain in extending broadband services to underserved regions, due to network infrastructure and cost limitations. The International Telecommunication Union (ITU) reports that 3.7 billion people (49% of the global population) lack internet access, with 670 million residing in areas devoid of mobile broadband networks [5, 23].

To address such connectivity gaps, LEO satellite communication offers the advantages of reduced transmission times, low latency, and broad coverage. This technology can bridge gaps in network coverage, especially in remote or complex settings, thus enhancing the stability of mobile services. Starlink, in collaboration with terrestrial mobile networks, extends coverage to mobile platforms like aircraft, vehicles, and ships, ensuring comprehensive satellite broadband access [8].

Starlink's development encompasses key aspects:

**Satellite design.** Streamlined and lightweight Starlink satellites employ advanced technologies, including high-power Ku/Ka band antenna arrays and dual fiber optic connections. These innovations lower manufacturing costs, enhance efficiency, and bolster global high-speed internet access feasibility.

**Satellite deployment.** Starlink's extensive satellite constellation offers global coverage with lower orbital altitudes and reduced latency. Interconnected satellites ensure low-latency global network coverage, delivering high-speed internet to users.

**Network architecture.** Starlink's system involves thousands of satellites and ground stations, facilitating data traffic reception, forwarding, and inter-satellite data transfer. This architecture enables global high-speed internet access.

**Application development.** Beyond internet access, Starlink finds utility in emergency and military communications, as well as the Internet of Things, offering efficient communication solutions.

As discussed above, Starlink's satellite internet technology, characterized by low latency and high bandwidth, holds significant promise for educational applications. It can enable remote learning, network connections for schools, access to online educational resources, support for online testing, and more. These applications pave the way for educational innovations empowered by Starlink.

## 3 Research Design and Implementation

### 3.1 Research Design

This research attempted to establish capability indices for the Starlink DBL Innovation course and assess their relevance within a science and technology university, as depicted in Fig. 1. The initial phase involved a literature review and expert consultations to formulate the capability indices specific to the Starlink DBL Innovation course. Subsequently, experts participated in a fuzzy Delphi expert questionnaire to ascertain the relative importance of the capability indices. These findings provided a foundation for developing pedagogical models and course materials.

Furthermore, this study conducted an 18-week quasi-experimental teaching program, mainly focusing on the Starlink DBL Innovation course. The importance-performance analysis (IPA) method was used to comprehensively explore the impact of this course on student learning effectiveness.

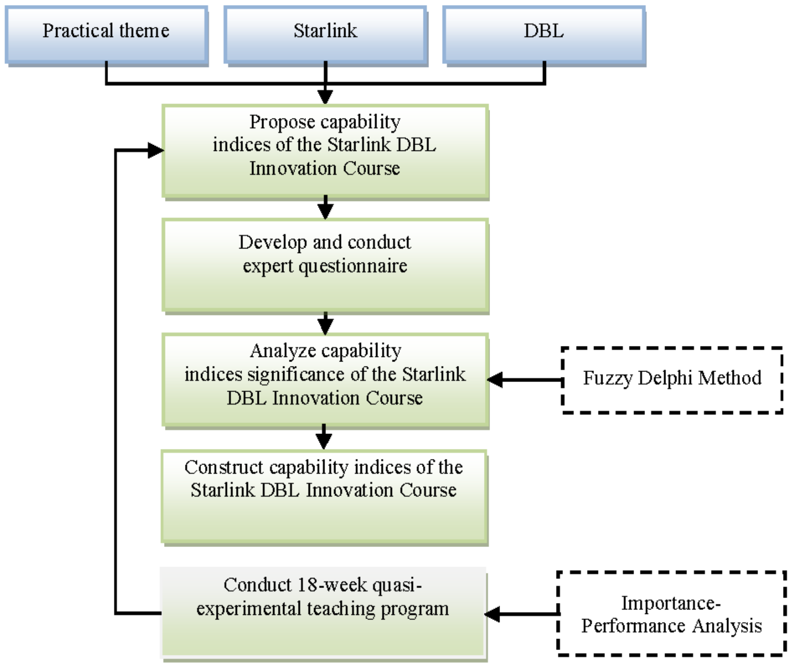


**Fig. 1.** Research flowchart

### 3.2 Research Methods

The fuzzy Delphi method adopted in this study was a combination of the Delphi method and fuzzy theory. This method can improve the shortcomings of the traditional Delphi method by using triangular fuzzy numbers while at the same time solving the limitations of human fuzziness, which is an effective method for constructing indicators. Therefore, this study adopted the fuzzy Delphi method to construct the capability indices of the Starlink DBL Innovation course.

The fuzzy Delphi method represents the central tendency of data in the form of an interval and integrates the experts' opinions using the membership function in fuzzy theory. The range is between 0 and 1. The greater the degree of agreement, the closer the membership value is to 1, and 0 on the contrary [24]. This study adopted the method of defuzzifying the fuzzy set. First, the concept of the membership function of the maximal set and the minimal set was assumed, and the total membership value of the actual measured indices was calculated. Then, the max-min method was used to integrate the fuzzy weight evaluation values of the experts; after defuzzifying, the values of $\mu R$, $\mu L$, and $\mu T$ were obtained. The steps of the fuzzy Delphi method are as follows:

(1) Screen the preference scale of capability indices.
(2) Obtain triangular fuzzy numbers of capability indices.
(3) Find the $\mu r$.
(4) Find the $\mu l$.
(5) Establish the $\mu t$ of the capability indices.
(6) Screen the indicators.

When verifying the teaching effectiveness of the Starlink DBL Innovation course, this study adopted the IPA method for evaluation. IPA is a common tool in management and market research, typically used to evaluate the performance of products, services, or specific attributes based on two factors: importance and actual performance [25]. IPA is also widely used in the field of education, mainly for evaluating and improving teaching activities, courses, or educational programs, including teaching content evaluation, course improvement, student satisfaction evaluation, and learning environment evaluation [26, 27]. Therefore, this study evaluated the importance of the performance indicators of the Starlink DBL Innovation course to understand the learning status of the students and which teaching content needed improvement.

### 3.3 Research Subjects

The main subjects of this study were experts involved applying the fuzzy Delphi methods. In terms of the questionnaire, a total of 13 experts and scholars from industry and academia with rich experience in satellite communication technology, spectrum management, satellite applications, satellite launches, and Starlink integration were invited to participate in the survey. As shown in Table 1, all respondents had more than ten years of experience and were of considerable importance and representativeness. This study mainly focused on revising and confirming the significance of integrating the Starlink theme into the capability indices of various dimensions in course design, thereby planning the Starlink DBL Innovation course for the science and technology university.

In addition, in terms of the research subjects for experimental teaching, 39 junior students who had taken this practical topic course were studied to understand their situation in practical topic learning.

**Table 1.** Background of experts

| Code of experts | | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Education level | | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 3 |
| Years of service | | 3 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 3 | 4 |
| Expertise | Satellite communication technology | V | V | | | | V | V | V | | | | | |
| | Satellite applications | V | V | | V | V | V | V | | V | V | | V | |
| | Satellite launch | V | | V | | | V | | | | | V | | |
| | System integration | V | | | | | V | | | | | | | V |
| | Others | | | V | | V | | | V | | V | V | | V |

Educational level code: 1_Doctor, 2_Master, 3_Bachelor
Years of service code: 1_less than 5 years, 2_6-10 years, 3_11-15 years, 4_over 16 years

### 3.4 Research Tools

Through a literature review, this study identified the important teaching points in the Starlink DBL Innovation course and invited the respondents to provide corrective suggestions to develop the dimensions of the course. On this basis, the research tools were developed and an expert questionnaire was designed. The questionnaire included three parts: an introduction to questionnaire-filling methods, basic data on the respondents, and the questionnaire questions. Among them, the research focused on the questionnaire questions, including the five main dimensions of the Starlink system, satellite communication technology, spectrum management, satellite network applications, and sustainable development of satellite technology, as well as 21 assessment indicators. The significance of the capability indices of the Starlink DBL Innovation course was then explored.

### 3.5 Questionnaire Validity for Experts

The validity of the research tools and the adopted content of the questionnaire was explored through a review of relevant theory and literature, on the basis of which the draft questionnaire was constructed. Three experts with rich experience in fields such as Starlink DBL were interviewed to obtain their revision opinions, which were then used to revise and design the questionnaire, thus ensuring the questionnaire had sufficient expert content validity.

## 4 Results and Discussion

Based on the research purposes and literature review, capability indices for the Starlink DBL Innovation course for engineering students at the science and technology university were constructed, a fuzzy Delphi method expert questionnaire survey was conducted, and an IPA of the student competencies was performed. The analysis results are explained below.

### 4.1 Expert Questionnaire Survey Analysis Based on Fuzzy Delphi Method

Through reviewing the literature, this study developed an expert questionnaire on the capability indices of the Starlink DBL Innovation course based on the fuzzy Delphi method. After the focused interviews with three relevant experts in Starlink DBL, the main framework of the capability indices for the Starlink DBL Innovation course was revised. As shown in Table 3, the main dimensions included five items: the Starlink system, satellite communication technology, spectrum management, satellite network applications, and sustainable development of satellite technology. After adding and revising the items, 21 detailed assessment indicators remained, as shown in Table 2.

**Table 2.** Significance analysis of the capability indices of the Starlink DBL Innovation Course: primary dimension

| No. | Items of main dimensions | μL | μR | μT | Ranking |
|---|---|---|---|---|---|
| 1 | Starlink system | 0.812 | 0.383 | 0.715 | 1 |
| 2 | Satellite communication technology | 0.790 | 0.407 | 0.692 | 2 |
| 3 | Spectrum management | 0.693 | 0.516 | 0.588 | 5 |
| 4 | Satellite network applications | 0.782 | 0.415 | 0.684 | 3 |
| 5 | Sustainable development of satellite technology | 0.769 | 0.429 | 0.670 | 4 |

**(1) Significance analysis of the capability indices in the main dimensions.** Thirteen experts were invited to give subjective value judgments based on the current teaching application status of the Starlink DBL Innovation course, thereby obtaining the assessment values of each question from the experts and scholars. According to the analysis results of an expert questionnaire survey based on the fuzzy Delphi method, the suitability score ranged from 0.588 to 0.715. As shown in Table 3, the items with the highest significance score were the Starlink system, with a score of 0.715, followed by satellite communication technology, with a score of 0.692, satellite network applications, with a score of 0.684, sustainable development of satellite technology, with a score of 0.670, and spectrum management, with a score of 0.588. In summary, the results of the expert questionnaire all scored above 0.6, which was within the acceptable range. The research team assessed the capability indices of the main dimensions, and all of them were retained.

**(2) Significance analysis of the detailed indicators: secondary dimensions.** This study explored the suitability scores of the 21 capability indices for the Starlink DBL Innovation course. According to the expert questionnaire survey analysis, the suitability scores of the assessment indicators ranged from 0.625 to 0.748. As shown in Table 3, the expert questionnaire results were all above 0.6, which was acceptable. The research team recommended retaining all assessment indicators, as detailed below.

*(1) In terms of the Starlink system.* 1-1 (background and purpose of the system) was the most significant capability index, with a score of 0.735, while 1-3 (number of satellites in the system) was the second-most significant capability index, with a score of 0.724, followed by 1-5 (future prospects of the system capability index), with a score of 0.715.

*(2) In terms of satellite communication technology.* 2-1 (fundamental principles of satellite communication) was the most significant capability index, with a score of 0.748, followed by 2-2 (history of satellite communication) and 2-4 (development trend of satellite communication) which both were the second-most significant capability indices, with a score of 0.699.

*(3) In terms of spectrum management.* 3-4 (spectrum management of the Starlink system) was the most significant capability index, with a score of 0.676, while 3-3 (policies and regulations of spectrum management) was the second-most significant capability index, with a score of 0.672, followed by 3-1 (fundamental principles of spectrum management), with a score of 0.669.

*(4) In terms of satellite network applications.* 4-1 (main applications of satellite networks) was the most significant capability index, with a score of 0.715, while 4-2 (the impact of the Starlink system on future applications) was the second-most significant capability index, with a score of 0.707, followed by 4-3 (the future applications and challenges of satellite networks), with a score of 0.669.

*(5) In terms of the sustainable development of satellite technology.* 5-4 (sustainable development) was the most significant capability index, with a score of 0.669, while 5-3 (earthquake hazard monitoring) was the second-most significant capability index, with a score of 0.663, followed by 5-2 (precision agriculture production), with a score of 0.657.

**Table 3.** Significance analysis of capability indices of the Starlink DBL Innovation course: secondary dimension

| Primary dimension | Secondary dimension | μL | μR | μT | Ranking |
|---|---|---|---|---|---|
| (1) Starlink system | (1-1) Background and purpose of the system | .844 | .348 | .748 | 1 |
| | (1-2) Technical characteristics of the system | .755 | .447 | .654 | 5 |
| | (1-3) Number of satellites in the system | .821 | .373 | .724 | 2 |
| | (1-4) Use of the system | .804 | .391 | .707 | 4 |
| | (1-5) Future prospects of the system | .812 | .383 | .715 | 3 |
| (2) Satellite communication technology | (2-1) Fundamental principles of satellite communication | .844 | .348 | .748 | 1 |
| | (2-2) History of satellite communication | .798 | .399 | .699 | 2 |
| | (2-3) Structure and characteristics of satellite communication | .753 | .458 | .648 | 4 |
| | (2-4) Development trend of satellite communication | .798 | .399 | .699 | 2 |
| (3) Spectrum management | (3-1) Fundamental principles of spectrum management | .769 | .431 | .669 | 3 |
| | (3-2) International mechanism of spectrum management | .754 | .446 | .654 | 4 |
| | (3-3) Policies and regulations of spectrum management | .772 | .429 | .672 | 2 |
| | (3-4) Spectrum management of the Starlin system | .775 | .424 | .676 | 1 |
| | (3-5) Challenges and future development of spectrum management | .749 | .452 | .648 | 5 |
| (4) Satellite network applications | (4-1) Main applications of satellite networks | .812 | .383 | .715 | 1 |
| | (4-2) Impact of the Starlink system on future applications | .804 | .391 | .707 | 2 |
| | (4-3) Future applications and challenges of satellite networks | .769 | .431 | .669 | 3 |
| (5) Sustainable development of satellite technology | (5-1) Global climate and environmental monitoring | .729 | .480 | .625 | 4 |
| | (5-2) Precision agriculture production | .757 | .444 | .657 | 3 |
| | (5-3) Earthquake hazards monitoring | .762 | .437 | .663 | 2 |
| | (5-4) Sustainable development | .769 | .431 | .669 | 1 |

### 4.2 Thematic Activity Planning and Design of the Starlink DBL Innovation Course

This study used the results of the expert questionnaire analysis mentioned above as the basis for the design of the Starlink DBL Innovation course, with a student-centered philosophy as the core of the course design, as shown in Table 4. Firstly, this study engaged in collaborative discussions with educators to identify the key focal points of the curriculum and establish the teaching objectives (concepts related to Starlink). Subsequently, a core question worthy of exploration was formulated (i.e., how to enhance network coverage using Starlink), thereby defining a problem within the curriculum. Following this, the core question of the curriculum was integrated with real-life scenarios to design a practical task. This task was presented to student groups as an unprecedented challenge that fostered an understanding of the key learning points (i.e., providing novel design challenges and innovative applications for full network coverage). Furthermore, the teachers used the course content to design assessment criteria that were consistently applied throughout the learning process (i.e., establishing evaluation standards; innovative application methods).

Next, referring to the significance analysis results of the capability indices of the Starlink DBL Innovation course, adjustments were made proportionally to its traditional content. The program mainly focused on units of the Starlink system and other satellite system. The course content and the weekly site management of this 18-week course were as follows: In weeks one to three, the students learned the background and purpose of Starlink; in weeks four to six, they learned the basics of satellite technology; in weeks seven to nine, they learned how to use satellite observation technology to monitor the Earth; in weeks 10 to 12, they learned how to use satellite technology to develop commercial applications; in weeks 13 to 15, they studied policy and legal issues related to satellite internet; and in weeks 16 to 18, they studied the innovation and development trends of satellite internet.

After six weeks of course learning, the students engaged in student-led projects that fostered their abilities to experiment and enhanced their creativity, imagination, and innovative design skills). Upon receiving the project task, the students created prototypes to show their understanding after referring to the assessment criteria. Subsequently, the teachers assessed the students' learning needs and intervened with guided courses (i.e., Starlink-based virtual reality teaching or Starlink simulation-based instruction). Finally, after the students had been enriched and empowered through the guided courses, they revisited and revised their prototypes (i.e., they revised their designs, optimizing innovative applications for full network coverage), culminating in a comprehensive understanding of the learning objectives and the production of practical works.

**Table 4.** Planning table of Starlink DBL Innovation course

| Week | Syllabus | Introduction |
|---|---|---|
| 1-3 | In week 1, students will understand the background and purpose of Starlink and learn the basics of satellite internet. In weeks 2 and 3, students will delve into satellite communication technology and network architecture. | Course introduction<br>1. Starlink system |
| 4-6 | In week 4, students will learn the basics of satellite technology, including satellite design, manufacturing, and launch. In weeks 5 and 6, students will learn how to remotely control satellites and how to perform satellite maintenance and repair. | 1. Starlink system<br>2. Satellite communication technology |
| 7-9 | In week 7, students will learn how to use satellite observation technology to monitor the Earth and how to collect and analyze remote sensing data. In weeks 8 and 9, students will further study satellite remote sensing technology and learn how to apply these technologies to different application scenarios. | 2. Satellite communication technology<br>3. Spectrum management |
| 10-12 | In week 10, students will learn how to use satellite technology to develop commercial applications, including logistics, agriculture, and environmental monitoring. In weeks 11 and 12, students will design and develop relevant business solutions and learn how to implement them. | 3. Spectrum management<br>4. Satellite network applications |
| 13-15 | In week 13, students will study policy and legal issues related to satellite internet, including spectrum allocation, privacy protection, and security. In weeks 14 and 15, students will learn how to formulate and implement corresponding policies and legal measures to ensure the healthy development of satellite internet. | 4. Satellite network applications<br>5. Sustainable development of satellite technology |
| 16-18 | In week 16, students will study the innovation and development trends of satellite internet and discuss possible future application scenarios and business models. In weeks 17 and 18, Students will gain further understanding of the possibilities for sustainable development and innovation in satellite technology. | 5. Sustainable development of satellite technology |

### 4.3 Importance-performance Analysis (IPA) of Student Competencies

After 18 weeks of course teaching, the results of the post-test learning performance questionnaire survey were collected to evaluate the student performance indicators. Taking into account the importance of the performance indicators from the experts, IPA was used to analyze the teaching effectiveness of the Starlink DBL Innovation course, as shown in Table 5. The 21 sub-performance indicators were further classified into four categories, as shown in Fig. 2 and explained below.

Quadrant I (Keep Up the Good Work): There were six performance indicators in this quadrant, including a3, a4, b2, b4, d1, and d2, indicating that the student learning performance and importance scores for these performance indicators were higher than the overall average and belonged to the Keep Up the Good Work quadrant. This indicated that the student performance in concepts related to the Starlink system satellite scale, usage, satellite communication development history and trends, as well as satellite network applications, met the expected goals of this course.

Quadrant II (Concentrate Here): There were three performance indicators in this quadrant: a1, a5, and b1, indicating that the student learning performance scores for these performance indicators were lower than the overall average but higher than the overall average and belonged to the Concentrate Here quadrant. As a part of the course design that needed urgent improvement, the results indicated that teaching resources should be prioritized for the students to learn about the Starlink system background, purpose, future prospects, and basic principles of spectrum management, so as to strengthen their development in these performances.

Quadrant III (Low Priority): There were eight performance indicators in this quadrant: a2, c1, c2, c3, c4, e1, e2, and e3, indicating that the student learning performance and importance scores for these performance indicators were lower than the overall average and belonged to the Low Priority quadrant.

Quadrant IV (Possible Overkill): There were four performance indicators in this quadrant: b3, c5, d3, and e4, indicating that the students had higher learning performance scores than the overall average in these performance indicators but lower indicator importance scores than the overall average and belonged to the Possible Overkill quadrant. In other words, during the design of this course, efforts could be made to effectively enhance student performance in satellite communication structure, the future development of spectrum management, future applications of satellite networks, and sustainable development. In the future, the results could serve as an important reference for adjusting teaching resources and correcting teaching objectives.

In summary, this study was based on an objective evaluation of the importance of the performance indicators by experts and the subjective evaluation of the student performance in these performance indicators, and used the IPA method for evaluation, aiming to serve as the basis for improving the Starlink DBL Innovation course. The IPA classified 21 sub-indicators into four categories: Keep Up the Good Work, Concentrate Here, Low Priority, and Possible Overkill, which provided a targeted adjustment of the teaching content and methods in terms of making course refinements so as to improve the students' learning experience and effectiveness. In terms of the relatively high-importance performance indicators, the parts where students perform well should be consistently maintained. On the contrary, if students perform worse than expected, these indicators should be prioritized for course improvement. In terms of the relatively low-importance performance indicators, if students perform worse than expected, these indicators should be included as a secondary improvement direction for course refinement. At the same time, the parts where students perform better can not only serve as a reference for adjusting teaching resources but are also worth noting. These items may guide new directions in future teaching innovations.

**Table 5.** IPA of student competencies

| Secondary dimension | No. | Importance | Performance | Importance Z score | Performance Z score | Quadrant |
|---|---|---|---|---|---|---|
| (1-1) Background and purpose of the system | a1 | 0.748 | 0.677 | 1.88 | -1.01 | II |
| (1-2) Technical characteristics of the system | a2 | 0.654 | 0.685 | -0.88 | -0.65 | III |
| (1-3) Number of satellites in the system | a3 | 0.724 | 0.710 | 1.17 | 0.48 | I |
| (1-4) Use of the system | a4 | 0.707 | 0.728 | 0.67 | 1.29 | I |
| (1-5) Future prospects of the system | a5 | 0.715 | 0.690 | 0.91 | -0.42 | II |
| (2-1) Fundamental principles of satellite communication | b1 | 0.748 | 0.692 | 1.88 | -0.33 | II |
| (2-2) History of satellite communication | b2 | 0.699 | 0.720 | 0.44 | 0.93 | I |
| (2-3) Structure and characteristics of satellite communication | b3 | 0.648 | 0.720 | -1.06 | 0.93 | IV |
| (2-4) Development trend of satellite communication | b4 | 0.699 | 0.720 | 0.44 | 0.93 | I |
| (3-1) Fundamental principles of spectrum management | c1 | 0.669 | 0.686 | -0.44 | -0.60 | III |
| (3-2) International mechanism of spectrum management | c2 | 0.654 | 0.677 | -0.88 | -1.01 | III |
| (3-3) Policies and regulations of spectrum management | c3 | 0.672 | 0.673 | -0.36 | -1.18 | III |
| (3-4) Spectrum management of the Starlin system | c4 | 0.676 | 0.664 | -0.24 | -1.59 | III |
| (3-5) Challenges and future development of spectrum management | c5 | 0.648 | 0.703 | -1.06 | 0.16 | IV |
| (4-1) Main applications of satellite networks | d1 | 0.715 | 0.735 | 0.91 | 1.60 | I |
| (4-2) Impact of the Starlink system on future applications | d2 | 0.707 | 0.735 | 0.67 | 1.60 | I |
| (4-3) Future applications and challenges of satellite networks | d3 | 0.669 | 0.725 | -0.44 | 1.15 | IV |
| (5-1) Global climate and environmental monitoring | e1 | 0.625 | 0.681 | -1.74 | -0.83 | III |
| (5-2) Precision agriculture production | e2 | 0.657 | 0.676 | -0.80 | -1.05 | III |
| (5-3) Earthquake hazards monitoring | e3 | 0.663 | 0.688 | -0.62 | -0.51 | III |
| (5-4) Sustainable development | e4 | 0.669 | 0.702 | -0.44 | 0.12 | IV |

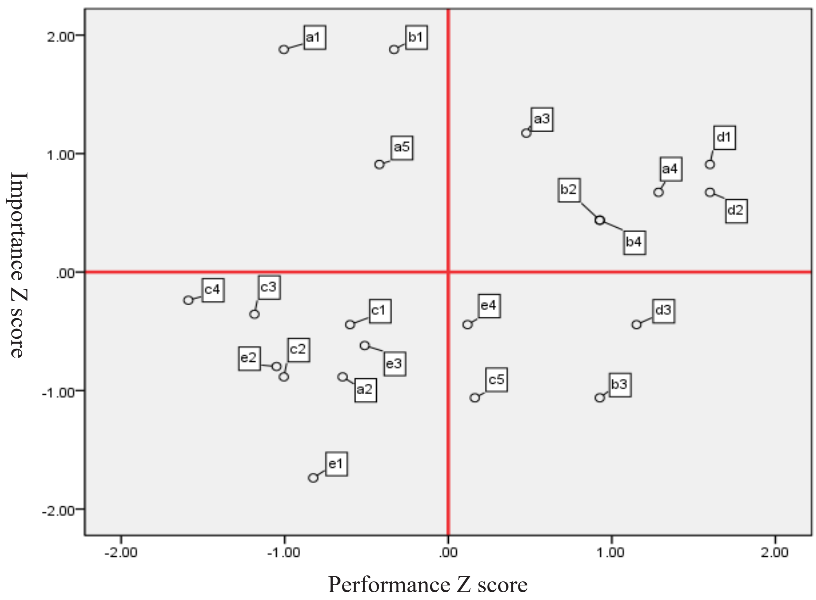


**Fig. 2.** IPA Four-quadrant graph

## 5 Conclusions and Suggestions

This study explored the capability index significance of a Starlink DBL Innovation course based on a fuzzy Delphi expert questionnaire, and the results could provide a reference for the development of the Starlink DBL Innovation course and teaching activity design, as well as the IPA of the student competencies.

### 5.1 Conclusions

**(1) This study constructed five major capability indices and 21 detailed indicators for the Starlink DBL Innovation course.** According to the relevant materials of the Starlink DBL Innovation course collected through a literature review, this study used a fuzzy Delphi expert questionnaire to analyze the significance of the capability indices and finally obtained five major capability indices: the Starlink system, satellite communication technology, spectrum management, satellite network applications, and sustainable development of satellite technology. These indices contained 21 detailed indicators in the secondary layer.

**(2) Among the five major capability indices of the Starlink DBL Innovation course, the Starlink system carried the highest weight.** This study used a fuzzy Delphi expert questionnaire to conduct a capability index significance analysis of the Starlink DBL Innovation course, in which the Starlink system capability index carried the most weight, followed by satellite communication technology, satellite network applications, the sustainable development of satellite technology, and spectrum management.

**(3) This study designed a thematic activity based on the results of the significance analysis of the 21 detailed indicators of the Starlink DBL Innovation course.** This study used a fuzzy Delphi expert questionnaire to analyze the significance of the 21 detailed indicators based on the five major capability indices. The detailed indicators that ranked the highest in significance were: 1-1 (background and purpose of the system), 2-1 (fundamental principles of satellite communication), 3-4 (spectrum management of the Starlink system), 4-1 (main applications of satellite networks), and 5-4 (sustainable development). These were used as a foundation for the design of the student-centered thematic activity in the Starlink DBL Innovation course.

**(4) This study integrated the importance of the performance indicators for the Starlink DBL Innovation course with student performance to analyze the sustainable optimization of the course and innovative teaching.** This study adopted the IPA method, innovatively integrated objective and subjective evaluation methods, and successfully integrated the evaluations of experts and students, making this study different from previous studies. In terms of the course optimization, specific items were proposed to continuously provide support for the relatively high-importance performance indicators while focusing on important fields where student performance was not as expected. Furthermore, IPA was used to determine the priorities, thus enabling the effective allocation of teaching resources and improving student learning effectiveness in specific fields. This study provided a targeted and continuous course improvement plan, which helped improve the students' learning experience and effectiveness and provided valuable references for future related research and teaching practices.

### 5.2 Suggestions

Based on the above research conclusions, this study proposed the following suggestions:

**(1) Use the five major capability indices and the 21 detailed indicators constructed in this study as an important reference for Starlink DBL Innovation course planning.** This study proposed five major capability indices and 21 detailed indicators, and conducted a fuzzy Delphi expert questionnaire survey to explore their relative significance. Through empirical research, the results were verified to have reference value. It is suggested that science and technology universities use the results of this study as a blueprint when planning and implementing practical courses related to Starlink DBL Innovation courses, and plan course content and teaching activities according to the most significant indicators, so as to meet the needs of cultivating students' abilities and industrial talents.

**(2) Use the capability indices of the Starlink DBL Innovation course as a reference for assessing students' course learning effectiveness.** The capability indices of the Starlink DBL Innovation course developed in this study gathered expert opinions and consensus that could be used as a reference for promoting Starlink-related education curriculum planning and design in science and technology universities and used as an indicator for assessing students' learning effectiveness. However, practical applications require fine-tuning based on the theme of the activity being performed to meet the needs of the course.

**(3) Use IPA to conduct long-term tracking research and continuously improve the course content.** Long-term learning performance tracking should be conducted to comprehensively verify the effectiveness of the course through IPA and evaluate the long-term development of the students to gain a deeper understanding of the Starlink course and ensure that the impact of the course teaching plan is effective. At the same time, this study proposed a number of relatively low-importance performance indicators where the students performed well, which may guide new directions in future teaching and research and are worth further in-depth research and exploration.

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