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Development and Assessment of Innovative Pedagogical Approaches through a Starlink DBL Course*

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This study aims to develop capability indices, practical thematic course content, assessment tools, teaching materials and aids, for the Starlink DBL Program at the Science and technology university. Fuzzy Delphi Method was used as a research method. Thirteen experts and scholars in relevant fields of satellite communication technology, spectrum management, satellite applications, satellite launch, and system integration were invited to conduct significance assessments of capability indices of the Starlink DBL Program. This serves as the basis for the development of practical courses, assessment tools, and teaching materials and aids for the Starlink DBL Program. The research results show that the capability indices of the Starlink DBL Program include 5 major capability indices: the Starlink system, satellite communication technology, spectrum management, satellite network applications, and sustainable development of satellite technology, with a total of 21 detailed indicators. Most experts believed that the Starlink system capability index weighed most, followed by satellite communication technology, satellite network applications, sustainable development of satellite technology, and spectrum management. Through experimental teaching, it was found that the student-centered 6.5-step implementation special activities of the Starlink DBL Innovation Course can help students transfer knowledge. Analysis from the questionnaire survey shows that most students expressed positive satisfaction with this Starlink DBL Innovation Course.

Keywords: design-based learning; technological universities; Starlink; competency indicators; education reform

1. Introduction

In recent years, satellite technology has experienced rapid development, driven by the reduction in satellite production and replacement costs and its integration with 5G technology. This synergy has accelerated the global deployment of low-Earth orbit (LEO) satellites. The infrastructure plan proposed by U.S. President Biden, allocating 1.2 trillion USD, includes significant investments in satellite communication within broadband network projects, positioning the LEO satellite sector as a crucial component of infrastructure development [1, 2]. International industry leaders, such as SpaceX and Amazon.com founder Jeff Bezos, have initiated ambitious LEO satellite networking projects like "Starlink" and "Kuiper," respectively. Other major players, including Telesat and OneWeb, have also made substantial investments in this domain [3, 4].

In 2020, the global satellite industry achieved a total revenue of $270.6 billion, as reported by the U.S. Satellite Industry Association (SIA) [5]. Among international players in the low Earth orbit satellite landscape, SpaceX, led by CEO Elon Reeve Musk, stands out with its proactive approach. In 2015, Musk unveiled the Starlink project, an ambitious space-based high-speed internet initiative, in Seattle [6]. Currently, Starlink is the largest satellite constellation globally, with relatively mature satellite network services. Its goal is to deploy over 12,000 satellites in low Earth orbit, forming a high-quality, cost-effective global broadband network. Post-deployment, it's expected to generate over $30 billion in annual revenue [7]. Given these dynamics and policy directions, low Earth orbit communication satellite technology is a thriving emerging industry for the next decade. The demand for related talent and education necessitates educational institutions' preparation. Therefore, this study approaches from the angle of nurturing low Earth orbit communication satellite talents, centering curriculum development around the theme of "Starlink."

Promoting courses in emerging technological themes like Starlink, 5G, and 6G necessitates contextual integration to foster meaningful learning experiences. Deep comprehension requires sustained contextual guidance and strategic teaching interventions. Learners must be empowered for self-discovery, supported by practical exploration and feedback within the learning context. Design-Based Learning (DBL), proposed by Doreen Nelson, embeds design concepts into curricula,

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emphasizing hands-on and action-based learning, fostering holistic learning experiences [8, 9]. Research indicates DBL sparks interest, enhances performance, and stimulates intelligence development [10, 11]. Applied in skill-based learning, it boosts creativity [12]. DBL exhibits positive impacts on STEM learning and students' acquisition of scientific conceptual knowledge [13, 14].

In view of this, this study attempts to approach the cultivation of low-Earth orbit communication satellite talents from the perspective of Starlink as the theme of course development, plan the "Starlink Innovation Special Course" based on DBL for teaching design, emphasizing the integration of emerging technology and Starlink-related technology applications into courses and teaching, and enable students of the Science and technology university to further understand the future development trends and opportunities of Starlink through hands-on practice and innovative thinking teaching strategies. The three research purposes of this study are as follows:

(1) Constructing the "Innovative Starlink DBL Course".
(2) Investigating the Impact of the "Innovative Starlink DBL Course" on Knowledge Transfer.
(3) Exploring Student Satisfaction with the "Innovative Starlink DBL Course".

2. Literature Review

This study focuses on Starlink and integrates the concept of DBL to develop the "Starlink DBL Innovation Program," which promotes the development of Starlink-related knowledge and abilities among university students. Based on this, an exploration of important literature and related research will be conducted on the development of DBL and Starlink.

2.1 Design-Based Learning (DBL)

Design-Based Learning has been a worthwhile educational orientation for promoting innovative teaching in recent years [9]. The design methodology can develop the ability of weak structural problems, expand the scope of cognitive development, and help interpersonal communication and non-verbal thinking [8]. Design thinking aims to inspire people to use creativity to solve problems and implement them into concrete actions, thereby learning strategies for defining problems, problem-solving, and teamwork [15]. The central idea of design thinking is to put people first, not only knowing what users want but also discovering hidden needs that even users themselves have not discovered [16]. Design-Based Learning was proposed by Doreen Nelson. Nelson was deeply influenced by John Dewey and believed that learning should be carried out through a "hands-on and practical" approach, emphasizing that the highest level of learning is the ability to discover common principles hidden in the curriculum, which must be experienced and integrated by students through hands-on practice. At the same time, it encourages creative problem-solving, integrates knowledge, skills, and attitudes in designed learning contexts, and guides students to become lifelong learners of autonomous action, communication, and social participation [8, 11].

This study adopts the DBL operational model proposed by Nelson [17], employing the curriculum perspective of backward design encompassing 6.5 steps [18, 19]: (1) Teachers begin by identifying the essential subject pillars, concepts, and standards from the curriculum guidelines, establishing ultimate instructional objectives. (2) Pose an inquiry-worthy core question. (2.5) Integrate the core question with real-world context, design a practical task challenging student with an "unseen" mission, aiding comprehension of learning focal points. (3) Teachers consistently apply the curriculum design assessment criteria throughout the learning process. (4) Students, upon receiving the practical task, create prototypes aligned with the assessment criteria, showcasing their understanding. (5) Teachers assess learning needs from student prototypes, intervening with guided instruction. (6) After enriched guided instruction, students revise prototypes to achieve a comprehensive understanding of learning focal points, culminating in tangible outputs.

2.1.1 Development and Applications of Starlink Technology

According to a report by the International Telecommunication Union (ITU), 3.7 billion people worldwide (49% of the global population) are unable to access the Internet, and 670 million people live in areas completely without mobile broadband networks [4, 20]. To address the issue of network coverage, low-Earth orbit satellite communication has the advantages of short transmission time, low latency, and wide coverage, which can meet ground network gaps such as: In complex environments or remote regions, the coverage of local area networks with low economic efficiency is low, and the mobile devices/applications/services signals are unstable or interrupted. Working together with mobile communication networks, the Starlink can be applied to mobile platforms such as airplanes, cars, or ships to provide 100% coverage of satellite broadband network services.

Therefore, the problem of the difficult deployment of communication equipment in remote areas can be solved, and the significance of satellite communication technology is also highlighted [6]. The development and application of Starlink technology mainly involve the following aspects:

(1) Satellite design: Starlink utilizes many advanced technologies, such as high-power antenna arrays in the Ku/Ka frequency band and dual fiber optic connections. These designs can reduce satellite manufacturing costs, improve satellite efficiency, and make global high-speed internet access more feasible.
(2) Satellite deployment: Starlink achieves global coverage through large-scale satellite deployment, with each satellite having a lower orbital height than traditional satellites and shorter network latency.
(3) Network architecture: Starlink's network architecture is a system composed of thousands of satellites and ground stations. Through such a network architecture, Starlink can achieve global high-speed internet access.
(4) Applications development: In addition to providing internet access, Starlink can also be applied in other fields such as emergency communication, military communication, and the Internet of Things.

In summary, the low latency and high bandwidth of Starlink satellite internet technology provide many possibilities for its applications in the field of education. For example, achieving long-distance teaching and education in remote areas, providing network connections for schools, providing online learning resources, supporting online testing and exams, etc., which can provide educational applications and reference directions for students regarding Starlink. In conclusion, Starlink's satellite internet technology, marked by low latency and high bandwidth, offers numerous possibilities for educational applications [19].

3. Research Design and Implementation

3.1 Research Design

This study aims to develop the capability indices of the "Starlink DBL Program" and explore their significance in science and technology university. Firstly, after a literature review and expert interviews, capability indices of the Starlink DBL Program have been developed. Furthermore, experts were invited to conduct a Fuzzy Delphi expert questionnaire to confirm the relative significance of capability indices, which serve as a reference for the subsequent construction of teaching models and course content. This study mainly uses the Fuzzy Delphi method and conducts literature analysis, expert interviews, and questionnaire surveys.

3.2 Research Methods

The Fuzzy Delphi Method (FDM) adopted in this study is 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 adopts the Fuzzy Delphi Method to construct the capability indices of the Starlink DBL Program. The Fuzzy Delphi Method represents the central tendency of data in the form of an interval and integrates the experts' opinions using the concept of 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 [21]. 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 experts; after defuzzifying, the values of μR, μL, and μT were obtained. The steps of the Fuzzy Delphi Method are as follows: (1) screening the preference scale of capability indices; (2) obtaining triangular fuzzy numbers of capability indices; (3) finding the μR; (4) finding the μL; (5) establishing the μT of the capability indices; and (6) screening the indicators.

3.3 Research Subjects

The main subjects of this study are experts involved in 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 launch, and system integration of Starlink were invited. As shown in Table 1, all respondents have more than 10 years of experience and are of considerable importance and representativeness. This study mainly focuses 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 Program for the science and technology university.

3.4 Research Tools

Through a literature review, this study identified the important points in Starlink DBL Program teaching and invited the respondents to provide corrective suggestions to develop the dimensions of the

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.

Starlink DBL Program. On this basis, the research tools were developed and an expert questionnaire was designed. The questionnaire includes three parts: an introduction to questionnaire-filling methods, basic data on respondents, and questionnaire questions. Among them, the research focuses on questionnaire questions, including 5 main dimensions such as the Starlink system, satellite communication technology, spectrum management, satellite network applications, and sustainable development of satellite technology, and 21 assessment indicators, as shown in Tables 3 and 4. The significance analysis of capability indices of the Starlink DBL Program was then explored.

Regarding student satisfaction with the "Starlink DBL Course," this study employed a self-developed questionnaire comprising four dimensions: Course Content Planning (Cronbach's alpha = 0.838), Innovative Teaching Approaches by Instructors (Cronbach's alpha = 0.851), Effectiveness of Innovative Thinking Learning (Cronbach's alpha=.826), and Problem-Solving Learning Experience (Cronbach's alpha = 0.823). The questionnaire comprised a total of 12 items. The overall questionnaire's Cronbach's alpha coefficient was .865, indicating a high level of consistency among the dimensions, rendering item deletion unnecessary. The satisfaction survey was conducted after the course's completion, providing insights into students' contentment levels with the course.

3.4.1 Questionnaire Validity for Experts

The validity of research tools and the adopted content of the questionnaire have been 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 revision opinions, which were then used to revise and design the questionnaire. Therefore, this questionnaire has sufficient expert content validity.

3.4.2 Thematic Activity Planning and Design of the Starlink DBL Program

This study used the results of the expert questionnaire analysis mentioned above as the basis for the design of the Starlink DBL Program, with the "student-centered" philosophy as the core of the course design, as shown in Table 2. Next, referring to the significance analysis results of the capability

Table 2. Planning Table of Starlink DBL Program

Week	Syllabus	Introduction
1–3	Students will gain an understanding of the background, purpose, and basics of satellite internet, as well as delve into satellite communication technology and network architecture.	Course introduction 1. Starlink system
4–6	Students will learn the basics of satellite technology, covering satellite design, manufacturing, launch, remote control, maintenance, and repair.	1. Starlink system 2. Satellite communication technology
7–9	Students will learn to utilize satellite observation technology for Earth monitoring, collecting, and analyzing remote sensing data, and applying these skills to various application scenarios.	2. Satellite communication technology 3. Spectrum management
10–13	Students will explore the application of satellite technology in commercial sectors like logistics, agriculture, and environmental monitoring, designing and implementing business solutions. They will also delve into policy and legal aspects concerning satellite internet, encompassing spectrum allocation, privacy protection, and security considerations.	3. Spectrum management 4. Satellite network applications Fundamental Prototype Implementation Unit
14–17	Students will study the formulation and implementation of policies and legal measures to ensure the growth of satellite internet. They will also explore innovation and trends in satellite internet, discussing potential future applications and business models.	4. Satellite network applications 5. Sustainable development of satellite technology Advanced Innovative Implementation Unit
18	Students will gain further understanding of the possibilities for sustainable development and innovation in satellite technology.	Final Presentation of Achievements

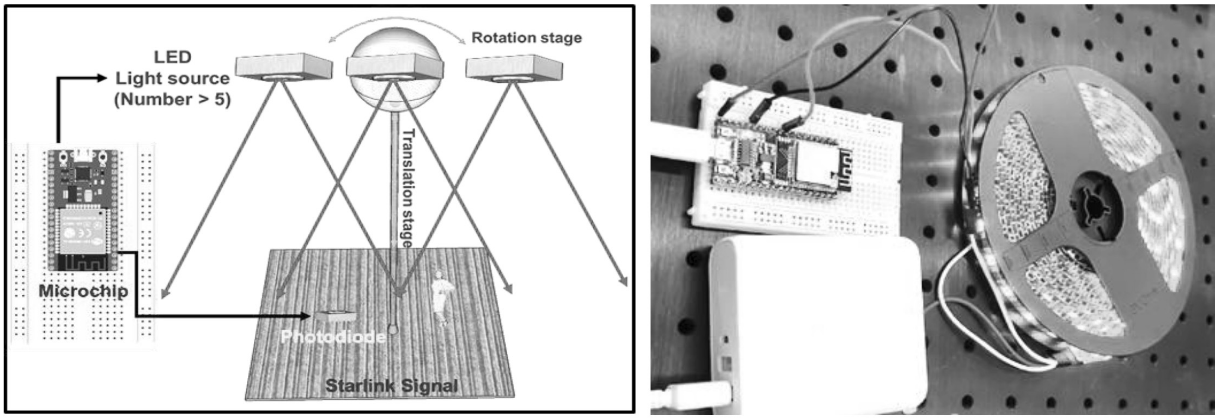

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Fig. 1. Illustration of the Scientific Demonstration Tool for Quantifying Starlink Technology Service Signals (a: Starlink Technology Service Signal Schematic; b: Microchip and LED Light Source).

indices of the Starlink DBL Program, adjustment was made proportionally to the traditional content of the 18-week Starlink DBL Program. The program mainly focuses on units of the "Starlink system" and "satellite system." The course content and the weekly site management are as follows: In weeks 1 to 3, students will understand the background and purpose of the Starlink; in weeks 4 to 6, they will learn the basics of satellite technology; in weeks 7 to 9, they will learn how to use satellite observation technology to monitor the Earth; in weeks 10 to 12, they will learn how to use satellite technology to develop commercial applications; in weeks 13 to 15, they will study policy and legal issues related to satellite internet; and in weeks 16 to 18, they will study the innovation and development trends of satellite internet.

Furthermore, this study designs the "Exploring Space Networks: Innovative Applications of Starlink" hands-on project, comprising a Fundamental Prototype Implementation Unit (3 weeks) and an Advanced Innovative Implementation Unit (4 weeks). This project is scheduled to be conducted from Week 10 to Week 17, with a culmination in the Week 18 final presentation. In the Fundamental Prototype Implementation Unit, the study aims to present the space physics phenomena and knowledge of Starlink technology. To achieve this, a scientific demonstration tool for quantifying Starlink signal technology, as shown in Fig. 1, was designed. The tool materials encompass a microchip, LED light source, adjustable-height translation stage, electronically controlled rotation stage, photodiode, etc. Through this tool's implementation, students simulate a network of 12,000 densely distributed Low Earth Orbit satellites, gaining insights into the advantages of Starlink technology and its principles of network services.

4. Results and Discussion

Aligned with the research objectives and literature exploration, this study constructs competency indicators for the "Starlink DBL Course" aimed at engineering students in a technological university. A Fuzzy Delphi expert questionnaire survey was conducted to establish these indicators. Subsequently, experimental teaching was carried out, employing a mixed-method approach to gather data on students' learning experiences. The subsequent analysis of these findings is detailed below.

4.1 Expert Questionnaire Survey Analysis based on Fuzzy Delphi Method

This study, informed by literature such as Starlink DBL, formulated an "Expert Questionnaire on Capability Indices of the Starlink DBL Program Based on the Fuzzy Delphi Method." Following focused interviews with three pertinent Starlink DBL experts, the core framework of capability indices for the Starlink DBL Program underwent revisions. The primary dimensions comprise five elements: the Starlink system, satellite communication technology, spectrum management, satellite network applications, and sustainable development of satellite technology. With additional inputs and modifications, a total of 21 detailed assessment indicators were identified.

4.1.1 Significance Analysis of the Capability Indices in the Primary Dimensions

Thirteen experts were invited to provide subjective assessments of the current instructional application status of the Starlink DBL Program, obtaining assessment values for each question from these experts and scholars. Based on the analysis of an expert questionnaire survey utilizing the Fuzzy

Table 3. Significance analysis of capability indices of the Starlink DBL Program

Primary dimension/Secondary dimension	μL	μR	μT	Ranking
Starlink system	**0.812**	**0.383**	**0.715**	**1**
(1-1) Background and purpose of the system	0.844	0.348	0.748	1
(1-2) Technical characteristics of the system	0.755	0.447	0.654	5
(1-3) Satellite quantity of the system	0.821	0.373	0.724	2
(1-4) Use of the system	0.804	0.391	0.707	4
(1-5) Future prospects of the system	0.812	0.383	0.715	3
Satellite communication technology	**0.790**	**0.407**	**0.692**	**2**
(2-1) Fundamental principles of satellite communication	0.844	0.348	0.748	1
(2-2) History of satellite communication	0.798	0.399	0.699	2
(2-3) Structure and characteristics of satellite communication	0.753	0.458	0.648	4
(2-4) Development trend of satellite communication	0.798	0.399	0.699	2
Spectrum management	**0.693**	**0.516**	**0.588**	**5**
(3-1) Fundamental principles of spectrum management	0.769	0.431	0.669	3
(3-2) International mechanism of spectrum management	0.754	0.446	0.654	4
(3-3) Policies and regulations of spectrum management	0.772	0.429	0.672	2
(3-4) Spectrum management of the Starlink system	0.775	0.424	0.676	1
(3-5) Challenges and future development of spectrum management	0.749	0.452	0.648	5
Satellite network applications	**0.782**	**0.415**	**0.684**	**3**
(4-1) Main applications of satellite networks	0.812	0.383	0.715	1
(4-2) Impact of the Starlink system on future applications	0.804	0.391	0.707	2
(4-3) Future applications and challenges of satellite networks	0.769	0.431	0.669	3
Sustainable development of satellite technology	**0.769**	**0.429**	**0.670**	**4**
(5-1) Global climate and environmental monitoring	0.729	0.480	0.625	4
(5-2) Precision agriculture production	0.757	0.444	0.657	3
(5-3) Earthquake hazards monitoring	0.762	0.437	0.663	2
(5-4) Sustainable development	0.769	0.431	0.669	1

Delphi Method, the suitability scores ranged from 0.588 to 0.715. As indicated in Table 3, items with the highest significance scores are as follows: "1. Starlink system," scoring 0.715, followed by "2. satellite communication technology," scoring 0.692, "4. satellite network applications," scoring 0.684, "5. sustainable development of satellite technology," scoring 0.670, and "3. spectrum management," scoring 0.588. In summary, the results of the expert questionnaire all exceed 0.6, falling within an acceptable range. The research team assessed the capability indices of the primary dimensions, and all were retained.

4.1.2 *Significance Analysis of the Detailed Indicators: Secondary Dimensions*

This study explores the suitability scores of the 21 capability indices of the Starlink DBL Program. According to the expert questionnaire survey analysis based on Fuzzy Delphi Method, the suitability scores of the assessment indicators range from 0.625 to 0.748. As shown in Table 3, the expert questionnaire results are all above 0.6, which is acceptable. The research team recommends retaining all assessment indicators, as detailed below.

(1) In terms of the "Starlink system," "1–1" stands out as the most significant capability index, scoring 0.735. Following closely is the second significant capability index, "1–3," with a score of 0.724. Subsequently, the "1–5" capability index holds importance, with a score of 0.715.

(2) In the context of "satellite communication technology," "2–1" stands out as the most significant capability index, scoring 0.748. Following closely, both "2–2" and "2–4" are regarded as the second significant capability indices, each with a score of 0.699.

(3) In terms of "spectrum management," "3–4" is the most significant capability index, scoring 0.676; "3–3" is the second significant capability index, scoring 0.672, followed by the "3–1" capability index, scoring 0.669.

(4) In terms of "satellite network applications," "4–1" is the most significant capability index, with a score of 0.715; "4–2" is the second significant capability index, with a score of 0.707; followed by the "4–3" capability index, with a score of 0.669.

(5) In the aspect of the "sustainable development of satellite technology," "5–4" is the most

significant capability index, scoring 0.669; "5–3" is the second significant capability index, scoring 0.663; followed by the "5–2" capability index, scoring 0.657.

4.2 Analysis of Student Knowledge Transfer Process in the "Starlink DBL Course"

Regarding the analysis of students' knowledge transfer process in the "Starlink DBL Course," this study implemented the operational model of the DBL curriculum proposed by Nelson [17]. Throughout this process, the research collected textual data such as unit learning sheets and reflections on students' learning journeys to comprehend the actual state of knowledge transfer. The execution of the "Starlink DBL Course" according to the 6.5 steps of Nelson's model is elaborated upon as follows:

Step 1: What Do I Need to Teach?

Initially, this study collaboratively discussed and designed the core themes, subject concepts, and standards for the "Starlink DBL Course" with the instructing faculty. This involved identifying five major competency indicators: Starlink System, Satellite Communication Technology, Spectrum Management, Satellite Network Applications, and Sustainable Satellite Technology Development. These indicators were integral in establishing the course's instructional objectives. Through expert discussions, the "Starlink DBL Course" was formulated to prioritize student-centeredness. It aimed to develop practical hands-on projects related to Starlink, implemented through the Design-Based Learning model. This approach enables students to comprehend the background, objectives, and applications of the Starlink satellite internet project. Furthermore, it provides students with real-world problem-solving contexts, fostering an awareness of the significance of addressing global internet connectivity challenges and nurturing their interdisciplinary skills in emerging technology applications.

Step 2: Identify a "Problem"

Subsequently, this study devised thought-provoking learning questions related to Starlink, fostering reflection and group discussions among students. For instance, "Q1: In today's era of advanced high-speed internet technology, people enjoy fast internet access, HD video streaming, instant messaging, and other online activities. However, at the same time, many remote areas and developing countries still experience digital disparities, lacking stable and high-speed internet connectivity. Did you know? Please try to search online for relevant information and record the results of your group discussion." Through this guided question, students' curiosity and interest are aroused, encouraging them to gather information from various sources to understand real-world issues of mobile networks and contemplate potential solutions.

S0102: Mobile networks are so prevalent in our daily lives that people can conveniently use smartphones and tablets with WiFi anywhere, anytime. It's hard to believe that there are still places without internet.

S0204: In certain remote regions, such as mountains, islands, and even underdeveloped countries, network infrastructure and technological foundations need improvement, resulting in inconvenient access to network resources.

Step 2.5: State as a "Never-Before-Seen"

Following group discussions, students comprehend the core issues underlying the ideal scenario of a limitless network. This study intertwines the curriculum with real-world contexts, devising a "never-before-seen" project activity such as the "Exploring Space Networks: Innovative Applications of Starlink." Through this, student groups are guided to undertake challenging tasks, promoting an understanding of the course's focal points. They delve into innovative applications and hands-on projects, stimulating creative thinking about problems and the search for solutions.

S0203: The theme of "Exploring Space Networks" is so cool! I never thought I would have a chance to learn about developments like Starlink, satellite technology, and low Earth orbit satellites. It feels really challenging.

S0501: I found out from my online research that there's more to internet connectivity than just WiFi-there's Starlink satellite internet technology. Do we truly have the capability to address the issue of inconvenient internet access in remote areas? For instance, smart agriculture, emergency rescue, and environmental monitoring aren't familiar fields for us.

Step 3: Set Criteria for Assessment

Based on the integration of expert opinions using the Fuzzy Delphi method, this study has identified the 5 major competence indices of the Starlink DBL Course, forming the assessment criteria for the course. These indices encompass 21 evaluation standards. Through this framework, the knowledge-based learning outcomes of students across various units of the Starlink DBL Course are evaluated. Additionally, regarding the assessment standards for the outcomes of the "Exploring Space Networks: Innovative Applications of Starlink" project, they include aspects like the completeness, innovativeness, cost-effectiveness, and feasibility of technical solutions presented in the project reports. At the course outset, the teacher provides a comprehensive explanation of the standards and requirements that the project solutions should adhere to, providing students with clear goals and direction during the design process.

S0401: After the teacher's explanation, I realized that this course has 5 major competence indices and 21 evaluation standards. Starlink satellite technology feels quite complex that require teamwork and collaborative effort to complete the project.

S0703: The assessment criteria for the innovative application project of Starlink technology cover aspects like innovativeness, cost, technical performance, efficiency, and sustainability. These are the key factors we need to consider for our project's theme and solution strategies.

Step 4: Let students "Give It a Try"

This study employs a hands-on instructional strategy and designs the "Starlink DBL Course" with the fundamental prototype unit titled "Simulating Starlink." The teacher guides students in prototyping according to the assessment criteria, enabling them to grasp the principles and knowledge related to Starlink satellite technology, as depicted in Figs. 2 and 3. This unit encourages students to engage in problem investigation within their groups, gather relevant data and resources, while the teacher offers necessary guidance and support, allowing room for independent thinking and creative practice. This serves as a crucial reference for problem formulation, solution exploration, design, and experimentation in the "Exploring Space Networks: Innovative Applications of Starlink" project.

S0101: Through the engaging "Simulating Starlink" activity, we understood the concept behind Starlink technology – setting up a network of 12,000 low Earth orbit satellites to create an aerial data transmission station. While the transmission rate isn't significantly different from 4G, 5G, or fiber-optic networks, the advantage lies in its unrestricted coverage area and geographical location independence. As long as you have an antenna to receive the signal, you can connect to the Starlink network.

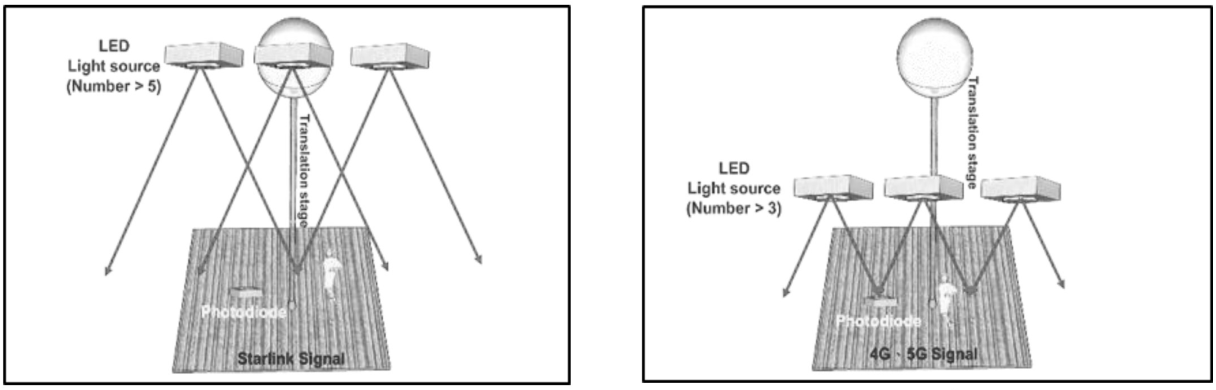

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Fig. 2. Experimental Tool Demonstrating Signal Differences between Starlink Technology (a) and 4G, 5G, and Fiber Optic Networks (b).

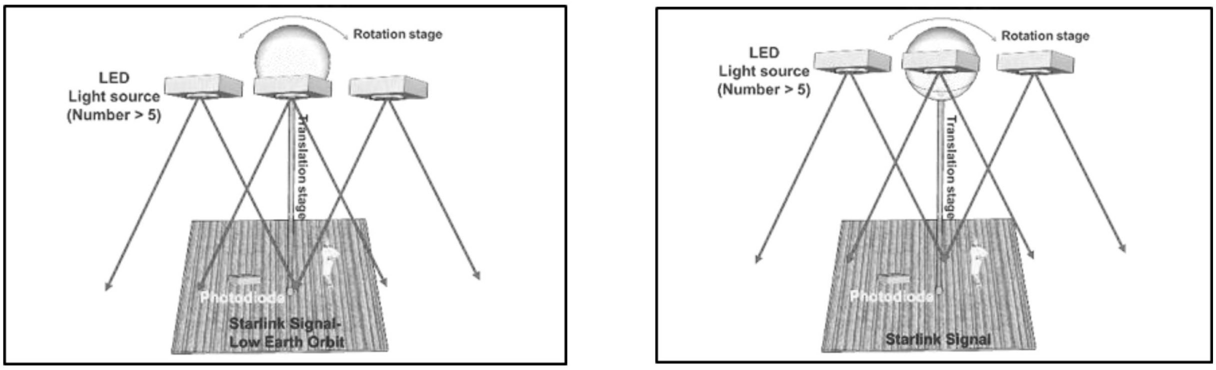

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Fig. 3. Experimental Tool Illustrating Signal Differences of Starlink Technology at Different Orbital Heights (a: Low Earth Orbit Satellite Signal Schematic; b: Medium Earth Orbit Satellite Signal Schematic).

S0203: During the practical experiment (as shown in Fig. 2), the teacher taught us to wire the microchip and LED. We simulated the LED quantity of densely placed low Earth orbit satellites in Starlink, which was greater than that of 4G, 5G, or fiber-optic networks. This helped us better understand the signal strength and distribution differences between Starlink's technology and 4G, 5G, and fiber-optic networks.

S0602: In the experiment simulating the impact of different orbital heights on signal reception (as depicted in Fig. 3), we used the same LED quantity and moved the platform to measure the strength difference of low Earth orbit satellite signals. This demonstrated that compared to the time delay (500–600 ms) of commonly used geosynchronous orbit communication satellites, low Earth orbit communication satellites had excellent performance (25–35 ms). This practical experiment allowed us to understand abstract space physics phenomena and parameters more easily.

Step 5: Teach Guided Lessons

After completing the foundational prototype unit "Starlink Simulation," students, guided by individualized instruction from the teacher, have acquired a fundamental understanding of the concepts related to the "Starlink DBL course." Following this, the research proceeds with the advanced innovation implementation unit, where each student group is tasked with completing the "Exploring Space Networks: Innovative Applications of Starlink" project. The teacher instructs student groups to brainstorm project topics and identify pressing issues that can be addressed through innovative solutions. For instance, topics such as emergency disaster relief and recovery, smart cities, space agriculture, interstellar education, and cosmic observation are chosen by students (as indicated by student feedback). These project themes merge the features of Starlink technology with the potential for innovation in various domains. Throughout the project implementation, teachers assist students in overcoming challenges encountered during the innovation process. Essential technical and knowledge support is provided to students while encouraging them to explore and experiment with novel approaches to problem-solving. This approach aids students in addressing design challenges effectively and enhancing the quality of their project proposals.

S0101: Our project is titled "Innovative Applications of Starlink in Emergency Disaster Relief and Recovery." It emphasizes using Starlink satellite communication technology to provide reliable communication networks for emergency response and post-disaster recovery efforts. Our aim is to conduct practical tests of relevant technology.

S0201: Our group's topic is "Innovative Applications of Starlink in Smart City Planning and Information Transmission." We primarily focus on leveraging Starlink satellite communication technology to enhance urban planning, information transmission, and the overall quality of city life. We intend to develop related applications and systems.

S0301: Our chosen theme is "Innovative Applications of Starlink in Space Farming and Sustainable Food Production." We are exploring how to use Starlink technology for farming and food production in space environments, supporting future space exploration and sustainable development of colonies.

S0601: Rural education is our concern. Our topic is "Innovative Applications of Starlink in Distance Education and Education Equality." We are considering how to utilize Starlink communication technology to establish a global distance education platform that promotes educational equality, enabling students from any location to access high-quality education.

S0901: Our project is titled "Exploring the Cosmos with Starlink: Astronomy and Space Exploration." We aim to harness the potential of Starlink communication technology for space exploration and astronomical observation. We plan to design and implement remote-controlled telescopes, allowing students to embark on captivating cosmic adventures under the starlit sky.

Step 6: Students Revise Design

In this step of the research, students will revise and improve their group design proposals based on their learning experiences, as well as guidance and feedback from the teacher. They will further enhance their project designs according to the assessment criteria, as shown in Table 4. It's important to note that this process may involve multiple iterations, with students continuously optimizing their designs to ensure alignment with problem requirements and assessment standards. This iterative process aims to achieve a comprehensive understanding of the learning objectives and produce practical outcomes.

Through these refinements and improvements, the projects will become more closely aligned with real-world application scenarios, becoming more challenging and innovative. Simultaneously, the focus will be on fostering active learning and hands-on experience among students, enabling them to attain a thorough and in-depth learning outcome within the projects. This approach cultivates interdisciplinary skills and innovative thinking. Such a learning experience will contribute to students' future professional development and application in relevant fields.

Through the implementation plan of the aforementioned 6.5 steps, the Starlink DBL course offers students a diversified learning experience, nurturing their innovative thinking and problem-solving abilities. Simultaneously, the course guides students to delve into the applications and significance of space networking, creating a challenging and creative learning environment that encourages students to unleash their creativity in project implementation [10, 22]. Feedback from student outcomes indicates that the majority of students actively engage in experiential and hands-on learning, merging Starlink technology with relevant topics to further enhance the novelty and practicality of their projects.

By following the approach of the 6.5 steps, students are motivated to actively participate in their projects, exploring the potential of utilizing Starlink satellite technology to address real-world issues. Moreover, they gain firsthand experience and comprehension of the importance of technological innovation in problem-solving through practical applications [9, 18]. This aids in enhancing students' learning effectiveness in technology and boosts their future competitiveness in the job market.

4.3 Student Satisfaction Analysis of "Starlink DBL Course"

After 18 weeks of experimental teaching, a questionnaire survey was conducted to understand the satisfaction of students with the "Starlink DBL Course." The following sections will explain the findings in four dimensions: course content planning, innovative teaching methods by instructors, learning outcomes in innovative thinking, and the learning experience in problem-solving, as presented in Table 5.

4.3.1 Course Content Planning Satisfaction Analysis

In terms of course content planning satisfaction, the average scores for each item range from 5.87 to 6.11, with an overall dimension average of 5.965 (standard deviation = 0.845). The t-value is 14.340, indicating a significant difference. This suggests that the majority of students hold a positive view

Table 4. Comparison Table of Case Students' Project Texts

Case Student Project Title	Teacher Guidance and Feedback Suggestions	Student Revised Approach
Innovative Applications of Starlink in Emergency Disaster Relief and Post-Disaster Recovery	• Suggested incorporating real-life cases and scenario simulations into the project. For instance, exploring how to utilize Starlink technology to establish temporary communication networks during disasters to support emergency relief efforts and post-disaster recovery. (Simulate communication tests during simulated disaster situations to analyze communication effectiveness.)	• Design and establish a simulated emergency response command center for disaster scenarios. Simulate the use of Starlink technology to establish a real-time and stable communication network, facilitating the coordination and transmission of rescue information. • Through field visits or simulated post-disaster scenarios, simulate the use of Starlink technology for post-disaster data collection and transmission. Analyze the extent of damage and impact after the disaster to support post-disaster recovery and reconstruction efforts. • Develop an emergency communication system suitable for disaster environments and conduct communication performance tests to ensure reliability and stability.
Innovative Applications of Starlink in Space Agriculture and Sustainable Food Production	• This project requires a deeper understanding of the current status of space agriculture technology. It focuses on utilizing Starlink technology to address communication and information transmission challenges in space agriculture, aiming to enhance production efficiency and sustainable food production.	• Design a space farm model that utilizes Starlink technology for real-time monitoring of parameters such as plant growth, soil moisture, and light intensity. Based on the data collected, adjust irrigation and nutrient supply to maximize crop yield. • Establish a sustainable food production system that utilizes Starlink technology for remote management and monitoring, ensuring the stability and quality of food supply. • Simulate the development of intelligent agricultural machinery suitable for space farming, utilizing Starlink communication technology for remote control and autonomous operation.
Innovative Applications of Starlink in Remote Teaching and Education Equality	• Remote teaching platforms should incorporate considerations for educational equality, addressing how students from distant or remote areas can fully participate in learning and breaking the barriers of uneven educational resources. Starlink technology can be leveraged to establish digital libraries, online educational resource sharing platforms, and more to provide enhanced learning opportunities.	• Design a remote teaching platform that includes features such as online courses, digital libraries, and resource sharing. Utilize Starlink technology to ensure stable and high-speed internet connectivity. • Develop digital learning applications that support educational equality and utilize Starlink technology to extend educational resources to remote areas or schools with limited resources. • Conduct assessments and research on remote teaching to explore the actual impact of Starlink technology on enhancing educational equality and improving students' learning outcomes.

towards the content planning of the "Starlink DBL Course," including the knowledge related to Starlink technology, the course structure that allows smooth understanding and progression, and the engaging nature of the content.

4.3.2 Instructor's Innovative Teaching Methods Satisfaction Analysis

Regarding satisfaction with the instructor's innovative teaching methods, the average scores for each item range from 5.61 to 5.66, with an overall dimension average of 5.632 (standard deviation = 1.056). The t-value is 9.521, indicating a significant difference. This shows that most students positively acknowledge the innovative teaching methods employed in the "Starlink DBL Course," including diverse teaching approaches such as lectures, hands-on activities, and project-based learning. Students are satisfied with interactive methods like class discussions, group collaboration, as well as the instructor's professional knowledge and teaching abilities.

4.3.3 Innovative Thinking Learning Outcomes Satisfaction Analysis

Regarding satisfaction with innovative thinking learning outcomes, the average scores for each item range from 5.55 to 5.74, with an overall dimension average of 5.658 (standard deviation = 0.996). The t-value is 10.220, indicating a significant difference. This indicates that most students express positive satisfaction with the innovative thinking learning outcomes in the "Starlink DBL Course." They find the difficulty level of the project-based course appropriately challenging, allowing them to achieve the expected learning objectives. Students also express satisfaction with the outcomes of their group projects.

4.3.4 Problem-Solving Learning Experience Satisfaction Analysis

In terms of satisfaction with problem-solving learning experience, the average scores for each item range from 4.87 to 5.92, with an overall dimension average of 5.395 (standard deviation = 1.073). The t-value is 8.009, indicating a significant difference. This reveals that most students hold a positive view towards the problem-solving learning experience in the "Starlink DBL Course." They believe that the course can be applied in real-life situations or future career development. Students are satisfied with the course learning environment, support measures, and the availability and accessibility of learning resources [23].

5. Discussions

In this section, we engage in discussions centered around the outcomes of the study, emphasizing the significance of the Starlink DBL course. We also address the limitations of our work and present concise conclusions that align with the stated objectives:

Table 5. Student Satisfaction Analysis of the Starlink DBL Course

Dimension/Item	**Average**	**Standard Deviation**	**t-value**	**Ranking**
(1) Course Content Planning	**5.965**	**0.845**	**14.340*****	**1**
1-1 The course content includes knowledge related to Starlink technology	6.11	0.863	15.032***	1
1-2 The course structure enables students to understand and follow the course content smoothly	5.92	0.997	11.880***	2
1-3 The course content is progressively structured and engaging	5.87	0.906	12.719***	3
(2) Innovative Teaching Methods by Instructors	**5.632**	**1.056**	**9.521*****	**3**
2-1 Satisfaction with diverse teaching methods (lectures, hands-on activities, projects)	5.66	1.400	7.298***	1
2-2 Satisfaction with instructors' professional knowledge and teaching abilities	5.61	1.079	9.171***	3
2-3 Satisfaction with interactive methods like class discussions and group collaboration	5.63	1.025	9.816***	2
(3) Learning Outcomes in Innovative Thinking	**5.658**	**0.996**	**10.220*****	**2**
3-1 The course achieves the expected learning goals and outcomes	5.68	1.068	9.720***	2
3-2 Satisfaction with the outcomes of practical project work	5.55	1.267	7.554***	3
3-3 Satisfaction with the difficulty level and challenge of the course	5.74	1.005	10.654***	1
(4) Problem-Solving Learning Experience	**5.395**	**1.073**	**8.009*****	**4**
4-1 The course can be applied to real-life situations or future career development	5.92	1.024	11.570***	1
4-2 Satisfaction with the availability and accessibility of learning resources provided	5.39	1.198	7.178***	3
4-3 Satisfaction with the learning environment and support measures offered	4.87	1.379	3.883***	2

5.1 Construction of Five Major Competence Indicators and 21 Sub-Indicators for the "Starlink DBL Course"

Through a literature review and Fuzzy Delphi expert questionnaire analysis, we constructed five major competence indicators for the Starlink DBL course. The "Starlink System" indicator emerged as the most crucial, followed by "Satellite Communication Technology," "Satellite Network Applications," "Sustainable Development of Satellite Technology," and "Spectrum Management." These indicators, comprising 21 sub-indicators, provide a robust framework for interdisciplinary learning and skill development.

5.2 Student-Centric Implementation of the "Starlink DBL Course" 6.5-Step Project Activities Facilitates Knowledge Transfer

Our innovative Starlink DBL course, designed around these indicators, emphasizes project-based learning and fosters creativity, critical thinking, and collaboration. The 6.5-step plan ensures a supportive environment for students to explore and apply theoretical knowledge. This approach facilitates effective knowledge transfer and positively impacts students' learning outcomes and future career development.

5.3 Most Students Exhibit Positive Satisfaction with the "Starlink DBL Course" Analysis

Analysis of student satisfaction reveals positive feedback across various dimensions, affirming the effectiveness of our course. Students appreciate active learning, practical experiences, and the integration of Starlink technology in project activities. The course enhances innovation and practicality, motivating students to actively engage and apply satellite technology to real-world challenges, thus boosting their competitiveness in future workplaces.

5.4 Limitations

While our study demonstrates the success of the Starlink DBL course, we acknowledge its limitations. The scope of our assessment may not capture the full spectrum of potential challenges or variations in student experiences. Continuous refinement is necessary to adapt the course to evolving educational needs.

5.5 Curriculum Enhancement Recommendations

In future Starlink DBL course iterations, it is advised to extensively apply the five major competency indicators and 21 sub-indicators across diverse fields like technology, engineering, agriculture, and education. This broadening of application ensures specific and enriched course content, fostering interdisciplinary knowledge and skills among students. This strategic preparation equips them to effectively address challenges in future technological advancements and problem-solving.

Enhancing interdisciplinary collaboration within the "Starlink DBL Course" framework proves beneficial. This elevation of collaborative elements, especially in practical projects, enables students to deeply apply Starlink technology to real-world issues. In response to student feedback on the "Starlink DBL Course," refining teaching methods through interactive approaches, such as group discussions and hands-on activities, is recommended. These enhancements actively engage students, promoting deep learning and an overall elevated learning experience.

6. Conclusions

In conclusion, the discussions highlight the significance of our innovative Starlink DBL course in promoting interdisciplinary learning and skill development. The positive feedback from students underscores its effectiveness in enhancing learning outcomes and preparing students for future challenges. Acknowledging the limitations, we remain committed to refining and expanding the course to ensure its continued success.

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