A MODEL FOR IMPROVING THE DESIGN INNOVATION ABILITY OF DESIGN STUDENTS IN UNIVERSITIES IN SHANDONG PROVINCE

SUN MENGQI
6319002021

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Educational Administration Innovation
Graduate School of Education
Siam University
Academic Year 2026
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Title	A Model for Improving the Design Innovation Ability of Design Students in Universities in Shandong Province
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Abstract

Title A Model for Improving the Design Innovation Ability of Design Students in Universities in Shandong Province

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(Associate Professor Dr. Boonmee Nenyod) (Dr. LeeHsing Lu)

This study aimed to develop and validate a model to enhance the design innovation ability (DIA) of design students at universities across Shandong Province. Guided by social cognitive theory, the digital literacy framework, knowledge management theory, and the technology acceptance model (TAM), this study examined the effects of creative self-efficacy (CSE), digital literacy (DL), intrinsic motivation (IM), and knowledge sharing (KS) on design innovation ability. It employed multimedia-supported instruction (MSI) as a mediating variable and technology acceptance (TA) as a moderating variable in empirical research.

Employing a mixed-methods approach, the study collected 467 valid questionnaires. Structural equation modeling (SEM) analyzed the questionnaire data, complemented by focus group discussions with eight students from diverse backgrounds using a structured discussion guide, and qualitative analysis of focus group discussion data. The findings revealed that creative self-efficacy, digital literacy, intrinsic motivation, and knowledge sharing all had significant positive effects on design innovation ability. Multimedia-supported instruction partially mediated the relationships between these four antecedent variables and design innovation ability. Technology acceptance exerted a significant negative moderating effect on the relationship between multimedia-supported instruction and design innovation ability, indicating that students with lower levels of technology acceptance benefited more from multimedia-supported instruction. Qualitative analysis further revealed underlying mechanisms, such as feedback loops, participation in authentic projects, and peer collaboration, in the innovation formation process.

Based on these findings, the study proposes the "Design Innovation Ability Enhancement Model" and outlines practical strategies across three levels: institutional, instructional, and student. Theoretically, this research expands the application of TAM and social cognitive theory in design education. In practice, it provides data-driven insights and educational pathways to cultivate innovative design talent in the digital era.

Keywords: design innovation ability, creative self-efficacy, digital literacy, intrinsic motivation, knowledge sharing, multimedia-supported instruction, technology acceptance, higher education.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

1.1.1 The Origin of Innovative Abilities

Innovation ability, as an intrinsic capacity for organizations or regions to continuously generate new knowledge, products, and processes, has emerged as a central topic in contemporary innovation research and practice. Its theoretical origins can be traced back to Schumpeter's (1934) concept of "creative destruction," which regards innovation as the fundamental driving force behind economic dynamic development. Subsequently, the proposition of the "National Innovation System" (Lundvall, 1985) further elucidated the pathways for innovation ability from the perspectives of macro-level institutions and interaction mechanisms.

Entering the 21st century, scholars have proposed systemic models of organizational innovation capacity. Zawislak et al. (2012) posited that innovation ability comprises four constituent elements: technological development ability, operational ability, management ability, and transactional ability, emphasizing an organization's ability to achieve technology absorption, knowledge transformation, and commercial application. Following this, researchers such as Lawson and Samson (2001) and Romijn and Albaladejo (2002) further enriched the theoretical framework of innovation ability by examining dimensions including organizational structure, R&D capabilities, and learning mechanisms.

Moreover, the dynamic capabilities theory in strategic management (Teece et al., 1997) underscores an organization's ability to rapidly adapt, integrate, and reconfigure resources in a changing environment, which overlaps significantly with innovation capacity. Thus, innovation ability not only represents an organization's capacity to generate innovative outputs but also embodies its critical organizational attributes for coping with uncertainty and achieving sustained competitive advantage.

1.1.2 Research on Design Innovation Ability

Design innovation ability (DIA), as a core indicator of comprehensive competence and practical skills among design students, has recently become an important topic across design education, innovation management, and educational technology research. In this study, DIA refers to students' ability to generate original and useful ideas, solve complex design problems, and transform creative concepts into practical design outcomes, which is consistent with prior conceptualizations of creativity and creative performance (Tierney & Farmer, 2002; Zhou & George, 2001).

Internationally, research on design innovation ability began relatively early and covers a broad range. Mumford and Gustafson (1988) proposed the "Creativity Syndrome" model, arguing that innovation ability is a composite psychological structure encompassing cognitive, motivational, emotional, and behavioral dimensions. Hargadon and Sutton (1997) further emphasized the core role of "knowledge recombination" and "cross-domain thinking"

in design innovation, suggesting that innovation stems from novel combinations of existing knowledge.

Brown (2009) introduced the concept of "Design Thinking," highlighting human-centered orientation, interdisciplinary integration, and rapid prototyping as critical elements for enhancing design innovation ability. Likewise, the OECD (2019) Future of Education 2030 framework identified "innovation ability" as one of the key competencies for future societies, advocating higher education approaches such as project-based learning, problem-solving orientation, and integration with digital technologies.

In China, under policies like "Mass Entrepreneurship and Innovation", the "New Engineering" initiative, and the "Design+" education philosophy, universities increasingly emphasize cultivating students' Design Innovation Ability. Research mainly focuses on ability components, influencing factors, and instructional interventions.

Regarding ability components, scholars generally consider DIA to include creative thinking, problem-solving, cross-disciplinary integration, digital technology application, and teamwork skills (Li, 2020; Zhang et al., 2021). Chen & Tsai (2021) highlighted that in today's digital environment, digital literacy and media literacy have become emerging factors affecting DIA.

Influencing factor research has examined individual characteristics (e.g., self-efficacy, motivation), instructional environment (e.g., teaching design, teacher quality), organizational culture (e.g., knowledge-sharing climate), and technological conditions (e.g., teaching platforms and tools). For instance, Zhao (2023) proposed that enhancing Multimedia-Supported Instruction and the use of communication platforms can effectively promote student collaboration and innovative expression.

In terms of intervention approaches, more universities are adopting project-based learning, design studios, and blended teaching models to improve students' practical design and innovation abilities (Wang, 2020). Additionally, some institutions introduce industry projects and cross-disciplinary teaching to promote "industry-education integration," thereby strengthening students' real-world design experience and applied capabilities.

1.2 Background of the Study

Globally, design innovation ability has emerged as a pivotal driving force for economic transformation, enhancing industrial added value and bolstering national competitiveness. Design is not merely perceived as a bridge connecting technology, commerce, and culture, but also stands as a critical force for industrial upgrading, social innovation, and the addressing of complex global challenges (Zhao, 2023). In countries with advanced industrialization and informatization, Design innovation ability directly relates to a firm's core competitiveness and the construction of a national innovation system. Developed nations such as those in Europe and the United States have long prioritized the deep integration of design education with industrial development, fostering a sophisticated ecosystem of education and innovation. These countries emphasize interdisciplinary collaboration, user-centered design, rapid prototyping and iteration, and the application of design thinking methodologies in design education, aiming to cultivate design talent with innovative thinking, practical capabilities, and problem-solving skills (Liu & Gong, 2024). Leading universities such as the Massachusetts Institute of Technology, the Royal College of Art, and Stanford University enable students to hone their innovation skills in authentic design contexts through

project-driven learning, cross-disciplinary teamwork, and industrial collaboration. Meanwhile, these institutions nurture their adaptability and creative problem-solving skills amid uncertainty and complexity.

The evolving landscape of global innovation poses new challenges to traditional design education models. Traditional curricula, predominantly centered on monodisciplinary instruction, emphasize knowledge transmission and skill training but lack systematic training in interdisciplinary integration, the application of digital tools, and the cultivation of innovative thinking. Consequently, some students, when confronted with real-world design tasks, exhibit deficiencies in innovative consciousness, resource integration capabilities, and technological application skills, rendering them ill-equipped to meet the demands of modern industries for comprehensive innovative talent. With the rapid advancement of digital technologies and the continuous expansion of design practice scenarios, traditional education models fall short in terms of teaching media, learning environments, and support for technological applications, failing to fully stimulate students' proactive learning motivation and creativity (Li et al., 2024). Therefore, from a global perspective, researching and cultivating design innovation ability is not only a core task for educational reform and innovative talent cultivation but also a strategic necessity for enhancing national and regional competitiveness and driving high-quality economic development. This necessitates educators and researchers to construct a design innovation education model tailored to the requirements of the new era by integrating interdisciplinary collaboration, enhancing practical capabilities, fostering digital literacy, and systematizing the design of teaching media and technological support, thereby providing students with a learning environment that effectively transforms knowledge, skills, and resources and enhances their innovative output and practical abilities.

In China, amid ongoing economic structural transformation and the sustained promotion of the innovation-driven development strategy, cultivating design innovation capacity has become pivotal in higher education and industrial development. The government considers innovation capacity a key factor in driving high-quality economic development. It has consistently issued policy guidelines underscoring the need for universities to strengthen the cultivation of innovative consciousness and practical skills in talent development. On the one hand, some leading universities have integrated advanced international design education philosophies and curricula, incorporating design thinking, user experience design, and interdisciplinary projects into their teaching, enabling students to hone their innovation and practical skills through real-world projects. On the other hand, regional universities and vocational undergraduate institutions are exploring industry-university-research collaboration models deeply aligned with local industries. By integrating local enterprise projects into course practicals, these universities encourage students to engage in creative design and problem-solving through teamwork, thereby achieving the goal of "learning by doing" and enhancing their comprehensive design abilities (Zhang & Li, 2023).

By applying digital educational technologies, universities have introduced online collaboration platforms, virtual laboratories, and digital prototyping tools to cultivate design innovation skills. These tools not only expand students' learning spaces but also provide richer resources and instant feedback, thereby enhancing their hands-on practical skills and innovative expression in interdisciplinary design tasks (Li et al., 2024). Research indicates that through systematic curriculum design and digital teaching support, students demonstrate significant improvements in both the quantity and quality of innovative outputs, along with

notable enhancements in confidence, creative problem-solving skills, and teamwork abilities in complex design contexts.

To meet this strategic demand, the Shandong provincial government has vigorously promoted higher education reform in recent years, encouraging universities to align with the local economy closely. Through industry-university-research collaboration, university-enterprise joint projects, and the establishment of innovation and entrepreneurship platforms, the government aims to enhance universities' capacity to serve regional economic development. For instance, universities have established innovation design laboratories and industrial practice bases, enabling students to engage in creative design and problem-solving through real-world projects, thereby enhancing their innovation abilities and practical experience (Zhang & Li, 2023).

Despite notable advancements in scientific research capabilities and technological innovation, universities in Shandong still face deficiencies in cultivating design innovation capacity. These issues primarily manifest as insufficient curriculum innovation, limited opportunities for interdisciplinary collaboration, uneven application of digital technology, and a disconnect between practical training and industrial demands (Zhang & Li, 2023). These factors result in students exhibiting deficiencies in innovative consciousness, cross-domain integration, and practical operational skills when confronted with complex design tasks. Therefore, enhancing the design innovation capacity of design students at universities in Shandong is not only a necessary measure to respond to the national innovation-driven development strategy but also a key pathway to drive local economic transformation and upgrade and strengthen universities' functions in serving society. By constructing a scientific cultivation model, integrating educational resources, and optimizing curriculum structures and teaching methods, universities can reinforce students' innovative thinking, practical abilities, and teamwork skills, while also enabling higher education to serve regional economic development better and provide high-quality, innovative talents to support local industrial transformation (Zhang & Li, 2023).

1.3 Statement of the Problem

In Chinese universities, students still encounter multiple challenges during the process of actual learning and design practice. Many students are accustomed to passively receiving knowledge and are unwilling to actively explore and experiment with new approaches (Zhang & Li, 2023). Another significant constraint on innovative capacity is the deficiency in media tool proficiency. In the digital teaching environment, design innovation relies on a variety of digital tools, design software, and online collaboration platforms; however, students' digital literacy and tool-operational capabilities vary widely, making it difficult for them to efficiently integrate resources into complex design tasks (Li et al., 2024). Additionally, insufficient interdisciplinary integration stands as a pivotal problem. Modern design innovation emphasizes the integration of multidisciplinary knowledge, such as the cross-application of art, engineering, marketing, and information technology. However, current university curricula are predominantly structured around single-discipline settings, limiting students' opportunities for training in cross-domain knowledge integration and application (Liu & Gong, 2024).

Existing research has predominantly focused on singular perspectives, such as creativity cultivation, motivation for learning, and teaching resource allocation. However, it lacks a systematic theoretical framework to integrate the complex interactive relationships among

individual psychological traits, digital literacy, teaching media environments, and technology acceptance. In reality, the formation of design innovation ability is a multifactorial, multilevel, interactive process. For instance, students' creative self-efficacy influences not only their initiative and perseverance when facing design tasks but may also modulate their willingness to experiment with new tools and methods (Bandura, 1997). Digital literacy levels directly impact students' proficiency in mastering complex design tools and their efficiency in team collaboration and knowledge-sharing processes (Li et al., 2024). The strength of learning motivation largely determines the time and effort students invest in project-based learning or design workshops, thereby influencing the quality of the innovative outcomes.

Multimedia-supported instruction, as an environmental variable, serves as a bridge between the aforementioned individual factors and design innovation ability. For example, abundant online resources, interactive platforms, and real-time feedback mechanisms can stimulate students' learning interests, promote interdisciplinary collaboration and knowledge-sharing behaviors, and thereby enhance innovative outputs (OECD, 2019). However, the actual utility of such media support is not unidirectional; students' acceptance and attitudes towards technological tools and platforms may reinforce or weaken its effectiveness. According to the Technology Acceptance Model (Davis, 1989), when students perceive tools as easy to use and valuable, they are more likely to use these media resources, thereby generating higher levels of innovation during the learning process. Conversely, technological resistance or usage barriers may undermine the positive effects of Multimedia-Supported Instruction. Therefore, enhancing design innovation ability necessitates a comprehensive consideration from three dimensions: the individual level focuses on creative self-efficacy, digital literacy, and learning motivation; the environmental level emphasizes the optimization of multimedia-supported instruction, collaborative atmospheres, and knowledge-sharing mechanisms; and the technological level pays attention to tool usability, platform design, and technology acceptance. By establishing a systematic model of multifactorial interactions, universities can more scientifically guide decisions on curriculum design, teaching methodologies, and resource allocation, providing empirical support and theoretical foundations for cultivating students' innovative abilities.

1.4 Research Questions

1) What are the key factors that influence the design innovation ability of university design students?

2) How does multimedia-supported instruction affect university students’ design innovation ability?

3) To what extent does technology acceptance moderate the relationship between multimedia-supported instruction and design innovation ability?

4) What model can be formulated and validated to improve the design innovation ability of university design students based on empirical evidence?

1.5 Research Objectives

1) To identify key factors influencing the design innovation ability of university design students.

2) To examine the impact of multimedia-supported instruction on students’ design innovation ability.

3) To analyze the moderating effect of technology acceptance on the relationship between multimedia-supported instruction and design innovation ability.

4) To develop and validate a model for improving the design innovation ability of university design students.

1.6 Significance of the Study

This study centers on enhancing design innovation capabilities among design-major undergraduates in higher education institutions, with significant theoretical value and practical implications for the digital transformation of higher education and the reform of design education.

At the theoretical level, this research integrates multiple theoretical perspectives, including Social Cognitive Theory, the Digital Literacy Framework, Self-Determination Theory, Knowledge Management Theory, and the Technology Acceptance Model (TAM), to construct a systematic conceptual framework. This framework delves into the impact mechanisms of design innovation capabilities among undergraduates across multiple dimensions, encompassing intrinsic psychological factors (such as creative self-efficacy and intrinsic motivation), digital competencies, and Multimedia-Supported Instruction. It fills research gaps concerning the "mediating role of Multimedia-Supported Instruction " and the "moderating role of technology acceptance," thereby advancing the development of theories on design innovation capabilities.

At the practical level, the findings of this study provide robust support for the teaching reform and curriculum design of design-related majors in higher education institutions. By empirically identifying key factors and pathway mechanisms influencing design innovation capabilities among undergraduates, the research results offer actionable intervention strategies for teachers, curriculum developers, and educational administrators, such as optimizing multimedia-supported instruction modalities, enhancing students' digital literacy, and strengthening motivation incentives. These strategies aim to improve students' practical design abilities and innovative outputs, thereby facilitating the cultivation of high-quality design talent.

At the policy level, this study responds to key issues related to the high-quality development of contemporary higher education.By proposing policy recommendations grounded in practical evidence, the research outcomes provide theoretical support and data-driven insights for educational policymakers in areas such as innovative talent cultivation, teaching resource allocation, and digital platform construction, thereby promoting the optimization of regional design education resources and the establishment of a high-level design education system.

1.7 Scope of the Study

1) Scope of Area

This study was conducted at five selected universities in Shandong Province, China: Shandong Normal University, Shandong Engineering Vocational and Technical University, Dezhou College, Shandong University of Art & Design, and Qingdao University of Science and Technology.

The selected institutions included both conventional undergraduate universities and a vocational undergraduate university, representing different institutional contexts for design education.

2) Scope of Population

The research targeted students enrolled in design majors at five representative higher education institutions in Shandong Province: Shandong Normal University, Shandong University of Art & Design, Qingdao University of Science and Technology, Shandong Vocational and Technical University of Engineering, and Dezhou College. The total population of design students across the five institutions was 12,394.

The selection of these institutions ensures diversity in institutional types, geographic distribution, and specialized curricula, thereby providing a holistic representation of the landscape of design education in Shandong Province. The research encompassed multiple design disciplines, including Visual Communication Design, Product Design, Environmental Art Design, and Digital Media Art. By incorporating students from these diverse fields, the study covered a broad spectrum of design practices and educational experiences, reflecting both traditional design education and emerging trends in design innovation. This breadth facilitates the analysis of the mechanisms underlying the formation of design innovation capabilities across different professional contexts, enabling the identification of common factors and discipline-specific influences. The selected institutions vary in their educational orientations, ranging from comprehensive research universities to specialized art and design institutions, offering diverse academic environments, educational resources, and pedagogical approaches. This diversity enhances the generalizability of the research findings to other similar institutions across Shandong Province.

3) Scope of Content

Independent Variables:

Creative Self-Efficacy, Digital Literacy, Intrinsic Motivation, Knowledge Sharing

Mediating Variable: Multimedia-Supported Instruction

Dependent Variable: Design Innovation Ability

Moderating Variables: Technology Acceptance

Control Variables: Age, Gender, Grade, and Major.

4) Scope of Time

The temporal scope of this study spans from December 2024 to December 2025, covering research design, instrument development, data collection, data analysis, and model validation.

1.8 Definition of Terms

Term	Definition
Design Innovation Ability	Design Innovation Ability is defined as the comprehensive ability of undergraduate students to generate original, practically valuable design concepts and to effectively transform these concepts into implementable outcomes during their design learning and practice. This ability encompasses idea generation, which refers to the students' capacity to propose novel and feasible design solutions, as well as problem-solving, reflecting their ability to analyze complex design tasks, formulate strategies, and resolve challenges effectively.
Creative Self-Efficacy	Creative Self-Efficacy refers to an individual's confidence in completing creative tasks and generating novel ideas, serving as an important psychological resource that drives design-related behaviors. Specifically, creative self-efficacy reflects students' confidence in their innovative capabilities, their perceived ability to tackle complex design problems, and their persistence in exploring and pursuing innovative solutions when facing challenges.
Digital Literacy	Digital Literacy measures students' ability to search, evaluate, create, and communicate design information in digital environments. It encompasses technical literacy, emphasizing proficiency in using digital tools, design software, and multimedia platforms; cognitive literacy, reflecting the ability to analyze, integrate, and evaluate digital information to support design decisions and innovation; and social-emotional literacy, which captures students' understanding of the social and cultural contexts of digital media and their ability to communicate and collaborate effectively in team-based design projects.
Intrinsic Motivation	Intrinsic Motivation refers to students' psychological tendency to engage in learning activities voluntarily due to interest, enthusiasm, or a sense of accomplishment derived from design itself, independent of external rewards or pressures. This motivation manifests as proactive exploration, sustained engagement, and the pursuit of personal growth and achievement in learning and design practice.
Knowledge Sharing	Knowledge Sharing denotes students' active behaviors of exchanging, disseminating, and collaborating on design experiences, resources, inspirations, or methods during the learning process. Through sharing and interaction, students contribute to collective knowledge accumulation and enhance overall innovation within collaborative contexts.
Multimedia-Supported Instruction	Multimedia-Supported Instruction refers to the media and technological support provided by higher education institutions through instructional platforms in design education, including online learning systems, AI-assisted tools, and interactive course resources, which enhance students' learning efficiency and the quality of innovative practice. In this study, Multimedia-Supported Instruction

Term	Definition
	captures not only the availability of resources and technical guidance but also students' experiences of teacher-student interactions and peer collaboration through these platforms.
Technology Acceptance	In this study, Technology Acceptance (TA) refers to students' self-reported willingness to try and accept new technologies in design learning. It is conceptually informed by Davis' (1989) Technology Acceptance Model, but operationally treated as a binary grouping variable reflecting students' general acceptance tendency toward new technologies.

CHAPTER 2

LITERATURE REVIEW

This section is devoted to a literature review of each variable, which is described below:

2.1 Introduction

2.2 Theoretical Foundations and Variables

2.3 Relationship Between Variables

2.4 Theoretical Framework

2.5 Conceptual Framework

2.6 Hypotheses

2.7 Operationalization of Variables

2.1 Introduction

This study aims to develop a model for improving the Design Innovation Ability of design students in universities in Shandong Province. Therefore, the literature review section provides a systematic explanation and integrated analysis of each core variable. Regarding theoretical foundations, Social Cognitive Theory, the Digital Literacy Framework, Self-Determination Theory, Knowledge Management Theory, Media Richness Theory, and the Technology Acceptance Model are introduced to establish the theoretical basis for exploring the relationships among the variables.

Regarding the independent variables, creative self-efficacy is the source of students' confidence in their abilities when facing design tasks and innovation challenges, directly affecting the depth of their exploration and their willingness to innovate during the design process. Digital literacy includes students' comprehensive skills in information gathering, technology use, and integrating digital tools. This is not only a vital prerequisite for modern design learning and practice but also an essential guarantee of innovative results. Intrinsic motivation highlights the psychological drive that motivates students to actively participate in design activities out of interest, enthusiasm, and the desire for self-actualization. Its lasting and profound nature often significantly influences creative output. Knowledge sharing is the process by which students actively transmit, combine, and recreate knowledge through teamwork, peer communication, and interdisciplinary interactions, playing an irreplaceable role in stimulating new ideas and improving design solutions.

The mediating variable, multimedia-supported instruction, acts as a connector in this framework. By offering diverse, highly interactive, and resource-rich digital instructional media, it not only helps students access a wider range of learning resources but also significantly improves their efficiency and quality during the stages of creative thinking and presenting results.

The dependent variable, design innovation ability, is the main focus of this study. Design innovation ability encompasses students' capacity to generate novel, original, and practical

design solutions, as well as their skill in thoroughly applying various knowledge, skills, and methods throughout the creative process.

The moderating variable, technology acceptance, reflects students' attitudes and willingness to adopt new technologies and tools. In summary, based on a comprehensive review of existing theoretical and empirical research, this study combines the variables into a unified model to explore their complex relationships and mechanisms, aiming to provide both theoretical support and practical guidance for universities in improving students' design innovation ability.

2.2 Theoretical Foundations and Variables

2.2.1 Social Cognitive Theory

Social Cognitive Theory, first introduced by American psychologist Albert Bandura, remains one of the most influential theories in modern psychology. It suggests that an individual's behavior is not solely determined by either external environmental factors or internal traits but rather by the dynamic interaction among personal factors, behavior, and the environment, known as "Triadic Reciprocal Determinism." In this framework, individuals actively interpret situations during behavior production and skill development, and they influence their own behavioral choices and outcome assessments through self-regulatory processes.

Research on creative self-efficacy, Social Cognitive Theory provides a clear explanation: an individual's creativity is not fixed but develops over time through perceptions of ability, the formation of self-efficacy, and interactions with external resources. Self-efficacy, a key concept in Social Cognitive Theory, reflects a person's confidence in their ability to complete tasks in specific situations. A large body of empirical evidence shows that high levels of self-efficacy can lead individuals to exhibit greater perseverance, exploratory behavior, and problem-solving skills when dealing with complex tasks like design innovation (Bandura, 1997).

Social Cognitive Theory also highlights the important role of observational learning and modeling in developing skills. When integrating digitalization and design education, students can learn indirectly about design techniques, technology use, and creative thinking by watching high-quality design examples shared by teachers, peers, or online sources. This indirect experience, combined with hands-on practice, improves their ability to innovate in design. Additionally, multimedia-supported instruction, as a key learning environment factor, can boost students' confidence and engagement through abundant learning resources, interactive options, and immediate feedback, thereby indirectly promoting the creation of innovative design solutions.

Furthermore, Social Cognitive Theory recognizes the influential role of the environment on individual behavior. In design education, factors like technology acceptance impact students' willingness to adopt new tools and platforms. This willingness interacts with a person's self-efficacy, ultimately shaping the level of design innovation ability. Therefore, applying Social Cognitive Theory to study the design innovation ability of design students in universities in Shandong Province not only helps explain the internal relationships among different variables through the interactive mechanisms of cognition, behavior, and the environment but also provides a strong theoretical basis for developing a model to improve

design innovation ability driven by creative self-efficacy, digital literacy, intrinsic motivation, and knowledge sharing.

2.2.2 Digital Literacy Framework

The "Digital Literacy Framework" has become an essential theoretical tool in the fields of educational technology and information society research in recent years. It provides a structured approach to understanding an individual's knowledge, skills, and attitudes within a digital environment. Originating from studies on information literacy and media literacy, the meaning of digital literacy has expanded beyond basic information retrieval and usage capabilities due to the rapid growth of technologies like the Internet, big data, and artificial intelligence. It now includes multi-dimensional aspects, such as critical understanding of digital technologies, creative application, and social responsibility. According to research by scholars like Ng (2012), digital literacy generally involves technological, cognitive, socio-emotional, and creative dimensions.

In the education sector, the Digital Literacy Framework is seen as a crucial foundation for boosting students' design innovation ability. Gilster (1997) argued that true digital literacy is not just about operating technologies but also involves critical thinking, creative output, and effective communication in a diverse information environment. Martin (2006) highlighted that digital literacy needs contextualized learning experiences that combine technological skills with disciplinary knowledge through project-based learning and interdisciplinary teamwork to reach high-level innovation goals. In design education, improving digital literacy helps students not only master advanced design software, virtual reality, and AI-supported tools but also develop their creative thinking, presentation skills, and cross-platform communication.

In recent years, international organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the European Commission have developed influential reference frameworks for digital literacy and digital competence. UNESCO’s A Global Framework of Reference on Digital Literacy Skills for Indicator 4.4.2 provides a global reference for assessing digital literacy skills and was developed to support the monitoring of Sustainable Development Goal Indicator 4.4.2 (Law et al., 2018). Similarly, the European Commission’s Dig Comp 2.2: The Digital Competence Framework for Citizens identifies five key competence areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving (Vuorikari et al., 2022). These competence areas are closely related to the learning needs of design majors, particularly in digital design and innovation practices, because design students are required to search for and evaluate digital information, communicate and collaborate through digital platforms, create digital content, manage digital safety, and solve design problems using digital tools. Therefore, these international frameworks provide useful theoretical support for understanding how digital literacy contributes to the development of design innovation ability in higher design education.

Therefore, the Digital Literacy Framework not only provides theoretical support for studying the innovation abilities of design students but also provides a logical foundation for the relationships among the relevant variables in the model developed in this study. It emphasizes the comprehensive development of technological, cognitive, social, and creative aspects, aligning with the hypothesized pathway in this study that "digital literacy enhances

design innovation ability by promoting multimedia-supported instruction and creative practice."

2.2.3 Knowledge Management Theory

Knowledge Management Theory emerged in the 1990s, focusing on how organizations can effectively acquire, integrate, share, and apply knowledge resources to boost competitive advantage and innovation capabilities. This theory argues that knowledge is a vital strategic asset, and its management process involves not just collecting and storing information but also creating, sharing, and applying knowledge. Early scholars, such as Nonaka and Takeuchi (1995), introduced the "knowledge creation spiral model," which highlights the mutual transformation process between explicit and tacit knowledge. Through four stages—socialization, externalization, combination, and internalization—this model encourages the ongoing development and innovation of organizational knowledge, providing a systematic framework for future research and demonstrating the dynamic and interactive nature of knowledge management.

In the context of organizational management, Knowledge Management Theory involves not only the development of technological platforms but also soft factors such as organizational culture, leadership, and incentive mechanisms. Davenport and Prusak (1998) noted that knowledge sharing is essential for successful knowledge management, and that sharing behavior depends on a climate of trust, incentive measures, and institutional guarantees. Research shows that knowledge management capabilities significantly impact organizational innovation performance, especially in high-tech and creative industries, where the flow and integration of knowledge often directly influence the quality and speed of innovation outcomes. Moreover, Knowledge Management Theory is closely connected to Information Systems Theory and Organizational Learning Theory, emphasizing that knowledge is not a static resource but a dynamic process that creates value through continuous learning and application.

In the context of digitalization and networking, Knowledge Management Theory has also experienced new developments. More scholars are focusing on the roles of big data, artificial intelligence, cloud computing, and other technologies in knowledge acquisition and analysis, significantly improving the efficiency and accuracy of knowledge management. At the same time, the rise of cross-departmental, cross-regional collaboration and virtual teams has expanded knowledge management from traditional internal organizational processes to global knowledge networks, increasing the openness and share ability of knowledge. Therefore, Knowledge Management Theory not only offers a systematic view for studying organizational knowledge processes but also provides a theoretical foundation for improving organizational learning, innovation, and competitive strength in practice.

2.2.4 Media Richness Theory

Media Richness Theory (MRT), proposed by Daft and Lengel in 1986, is one of the key theories in organizational communication and information processing. It aims to explain why different media vary in their effectiveness for information exchange. The core idea of this theory is that the "richness" of a medium depends on its ability to simultaneously transmit multiple information cues, provide instant feedback quickly, personalize information, and transmit natural language. The richer the medium, the better it can reduce uncertainty and ambiguity in communication, thereby improving understanding accuracy and increasing communication efficiency. For complex, ambiguous tasks, high-richness media (such as

face-to-face communication and video conferencing) should be used; for simple, clear tasks, low-richness media (such as email and bulletin boards) can be employed to lower communication costs.

In education and training, Media Richness Theory offers a key framework for choosing media. For instance, in higher education design innovation courses, when tasks involve exchanging highly abstract design concepts and discussing creative solutions, using media that deliver instant feedback and multimodal information (such as interactive online platforms, virtual reality systems, and video seminars) better supports students' accurate understanding and active participation. On the other hand, for knowledge sharing or standardized skill training, low-richness media (such as online textbooks and recorded videos) can accomplish goals more efficiently and with fewer resources. The growth of digital learning environments has further expanded media options and their combinations, allowing educators to adapt the richness of different media to the teaching goals, task complexity, and learner needs, thereby providing optimal support for teaching and knowledge transfer.

In recent years, researchers have also combined Media Richness Theory with the Technology Acceptance Model (TAM) and Social Cognitive Theory (SCT) to examine changes in students' motivation to learn, self-efficacy, and Design Innovation Ability across different media settings. For instance, students with high digital literacy are more likely to gather and synthesize information from multiple sources in high-richness media, which boosts their creative self-efficacy and willingness to share knowledge. Likewise, students with different levels of technology acceptance may use the interactive features of high-richness media in different ways, which may influence how multimedia-supported learning environments contribute to design innovation ability. These studies suggest that media richness influences not only the effectiveness of information transfer but also, through interactions with personal traits, indirectly impacts learning and innovation outcomes.

2.2.5 Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), proposed by Davis (1989), is one of the most influential theoretical models in information systems and technology adoption research. The model explains technology acceptance through two core beliefs: perceived usefulness and perceived ease of use. This model posits that an individual's willingness to use a technology primarily depends on their perceived usefulness (PU) and perceived ease of use (PEOU) of that technology. Perceived usefulness refers to the extent to which an individual believes that using a technology can improve their work performance or learning efficiency, while perceived ease of use refers to the degree to which an individual believes that using the technology does not require significant effort. Both factors not only directly influence users' attitudes but also, through those attitudes, indirectly influence their behavioral intentions, thereby affecting actual usage behavior.

The theoretical foundation of the TAM model stems from Theory of Reasoned Action (TRA), which posits that attitudes and subjective norms influence an individual's behavioral intention. However, in the context of technology application, it introduces "perceived usefulness" and "perceived ease of use" as core antecedent variables, enhancing the model's applicability and explanatory power in information technology adoption research. As research deepened, Venkatesh and Davis (2000) proposed the TAM2 model, incorporating factors such as social influence processes (e.g., subjective norms and image) and cognitive instrumental processes (e.g., job relevance and result demonstrability) to explain the

formation mechanism of perceived usefulness better. Subsequently, the TAM3 model further introduced antecedents of perceived ease of use, such as computer self-efficacy, perceived external control, and anxiety levels, based on TAM2, further enriching the model structure.

A substantial body of empirical evidence indicates that the TAM model has strong predictive power across fields such as educational technology, e-commerce, and digital media applications. For instance, in digital teaching settings, teachers' and students' acceptance of digital platforms often hinges on whether they believe the platform can significantly enhance learning efficiency (perceived usefulness) and whether it is easy to operate (perceived ease of use). Generally, perceived usefulness has a greater influence on behavioral intention than perceived ease of use, but perceived ease of use indirectly affects usage intention by shaping perceived usefulness. The simplicity and high scalability of the TAM model allow it to be combined with other theoretical models (such as Media Richness Theory, Knowledge Management Theory, and the Digital Literacy Framework) and to incorporate new external variables (like creative self-efficacy, technical support, and intrinsic motivation) to suit specific research contexts, thus providing systematic and scientific support for analyzing technology adoption behaviors.

2.2.6 Innovation and Creativity Theories

Innovation and Creativity Theories form a central theoretical framework that explains the psychological mechanisms, behavioral patterns, and environmental conditions underlying the generation and implementation of new ideas, methods, products, and processes by individuals and organizations. Research in this area highlights that although innovation and creativity are closely connected, they are not entirely interchangeable—creativity is generally seen as the ability to produce new and valuable ideas. Conversely, innovation focuses on the successful transformation of these ideas into reality and their actual impact. Scholars from various disciplines, including psychology, management, and education, have thoroughly explored the meanings, drivers, and outcomes of innovation and creativity, thereby developing several well-established theoretical frameworks.

Early psychological research on creativity was significantly influenced by Guilford (1950), who emphasized that creative potential could not be adequately explained by conventional intelligence measures alone. He advocated a systematic investigation of the cognitive abilities and personality characteristics underlying creative performance. Guilford (1956) subsequently elaborated the Structure of Intellect model, contributing to the development of research on diverse intellectual abilities and creative thinking. This theoretical tradition provides a foundation for understanding creativity as a multidimensional capability relevant to problem-solving and innovation.The componential theory of creativity argued that creativity relies on three main components: domain-relevant skills, creativity-relevant processes, and intrinsic motivation. Creativity depends not only on a person's abilities and thinking styles but also on situational factors, such as organizational support, team atmosphere, and leadership style.

In terms of innovation theory, economic innovation theory emphasizes "creative destruction," arguing that innovation is the driving force of economic development and promotes industrial transformation by introducing new products, technologies, markets, and management methods. Diffusion of Innovations Theory explains how innovations spread and the speed of their dissemination in social systems, highlighting that adoption is affected by innovation characteristics (relative advantage, compatibility, complexity, trialability, and

observability), communication channels, time, and social system traits. Organizational Innovation Theory stresses the importance of structure, culture, strategy, and resources in implementing innovation, asserting that organizational learning, cross-departmental collaboration, and knowledge sharing are essential for successful innovation.

In recent years, research on innovation and creativity has increasingly emphasized interdisciplinary integration and contextual analysis. For example, the development of digital and network technologies has introduced new tools and media for creativity, as well as new models like open innovation, user-driven innovation, and co-creation. The fields of education and training also view creativity and innovation as essential skills, enhancing learners' awareness of innovation and practical abilities through project-based learning, interdisciplinary curriculum design, and digital learning platforms. Research shows that psychological and skill factors, such as creative self-efficacy, digital literacy, knowledge sharing, and intrinsic motivation, along with environmental factors like technology acceptance and media richness, can significantly impact the output and quality of individual innovation.

In summary, Innovation and Creativity Theories highlight the interactive effects of individual cognition, emotions, skills, and social contexts, advocating for multidimensional, multilevel research to fully understand the mechanisms of creative idea generation and transformation. These theories not only provide strong theoretical support for academic research but also offer practical guidance for educational institutions, enterprises, and policymakers in designing strategies to foster innovation and creativity.

2.2.7 Creative Self-Efficacy

2.2.7.1 Definition of Creative Self-Efficacy

Creative self-efficacy (CSE) refers to an individual's confidence in their ability to achieve goals in creative tasks. Tierney and Farmer (2002) first systematically introduced the concept. Creative self-efficacy is a domain-specific self-efficacy belief people hold when facing innovative tasks. Creative self-efficacy acts as the psychological motivator that drives innovative behavior. According to their study, individuals with high creative self-efficacy tend to demonstrate greater autonomy and persistence when confronting design or innovation challenges.

Shalley et al. (2004) expanded the definition of creative self-efficacy, stating that it not only reflects an individual's confidence in his or her own creative abilities but also influences his or her willingness to use imagination and problem-solving skills to generate novel solutions for complex tasks. Woodman et al. (1993) suggested that creative self-efficacy, as part of an individual's psychological traits, is closely linked to creative output and serves as an important indicator of a person's potential for innovation. Bandura (1997) emphasized that self-efficacy refers to individuals' beliefs in their capabilities to organize and execute the actions required to achieve desired outcomes of his or her actions, and that creative self-efficacy, as a task-specific domain, is directly related to an individual's self-efficacy beliefs. Creative self-efficacy, as a belief in one's ability to perform specific tasks, is directly associated with a person's willingness to try and persist in innovative endeavors. Mathisen (2009) also suggested that creative self-efficacy, which includes trust in problem-solving ability, confidence in divergent thinking, and mental toughness in the face of uncertainty, is a vital psychological resource that enables individuals to continue their creative exploration. Ultimately, creative self-efficacy is a cognitive assessment of one’s ability to accomplish

creative tasks. It is a psychological belief that motivates creative behavior. Creative self-efficacy encompasses overall confidence in one's cognitive, affective, and behavioral abilities. Although scholars may focus on different aspects, they all agree that creative self-efficacy is a foundational concept for understanding and predicting individual innovative behavior.

2.2.7.2 Literature on Creative Self-Efficacy

Creative Self-Efficacy (CSE), an important psychological construct related to self-perception and self-assessment in creative tasks, has gained widespread attention in recent years across fields such as education, management, and organizational behavior. In organizational behavior research, Tierney and Farmer (2002) were the first to introduce the concept, highlighting its crucial role in employees' innovative behaviors. They noted that individuals with high creative self-efficacy are more likely to take on challenging tasks and sustain creative efforts despite setbacks or difficulties, resulting in higher creative output in organizational settings. Research indicates that creative self-efficacy not only predicts how often an individual engages in innovative behavior but also correlates positively with the quality and diversity of that behavior (Shalley et al., 2004).

In the field of education, Beghetto (2006) noted that students' creative self-efficacy not only shapes their creative self-identity but also acts as a mediating factor between creative expression and risk-taking behavior. He emphasized the importance of the classroom environment in developing students' creative self-efficacy, and that timely teacher feedback, peer interactions, and openness and autonomy in course design can significantly boost students' perceptions of their creative potential. Mathisen and Brønnick (2009) validated the effectiveness of Problem-Based Learning (PBL) in enhancing students' creative self-efficacy. They found that the PBL approach enabled students to succeed in real-world situations by presenting authentic problems, fostering teamwork, and encouraging creative expression, thereby increasing students' confidence in their creative abilities and improving the quality of their creative work.

From a leadership perspective, Jaiswal and Dhar (2015) suggested that transformational leaders can indirectly boost employees' innovative behavior by inspiring confidence in their own creative abilities. This finding indicates that educators can adopt a similar approach when designing management and incentive systems to enhance students' creative self-efficacy through practical guidance and support. In the context of higher education in China, Zhang & Li (2018) empirical study found that the creative self-efficacy of design students significantly influences the innovative performance of their course projects. It was observed that incorporating positive feedback, designing open-ended tasks, and fostering interdisciplinary project collaboration into the teaching and learning process increased students' self-efficacy, which, in turn, encouraged them to experiment and practice more confidently in design innovation activities.

Scholars' research on creative self-efficacy has focused on somewhat different contexts and objects, however. Scholars agree that an individual's belief in their own creative ability is an important psychological foundation for developing innovative behavior and is influenced by factors such as the teaching environment, learning methods, and support from leadership or teachers. This offers both theoretical support and practical insights for nurturing students' creative skills in college design education, and it also provides a research basis for exploring the roles of teaching media, digital literacy, and other factors in shaping creative self-efficacy (Amabile, T. M. 1983).

2.2.8 Digital Literacy

2.2.8.1 Definition of Digital Literacy

Digital literacy, an essential concept in modern education and information society research, was first introduced by Gilster (1997) to described an individual's ability to acquire, understand, analyze, integrate, and create information in a digital environment. Gilster stressed that digital literacy is not merely the ability to manipulate technological tools but also the ability to think critically and creatively within a multi-information landscape. He highlights that digital literacy encompasses not only operating technological tools but also the capacity to think critically, produce innovative outputs, and communicate effectively in a complex information environment. With the rapid development of information technology and network environments, the meaning of digital literacy has gradually expanded to encompass multiple dimensions, including information literacy, media literacy, ICT skills, social network participation, and digital security awareness. These dimensions have become important indicators of the information-processing and innovation capabilities of modern individuals (Ng, 2012). Ng (2012) proposed a three-dimensional model of digital literacy, categorized into Technical Literacy (TL), Cognitive Literacy, and Social-emotional Literacy.

Ferrari (2013) proposed the European Digital Competence Framework (DigComp), which conceptualizes digital competence through five areas: information, communication, content creation, safety, and problem-solving. The framework highlights that digital competence encompasses not only technical skills but also the knowledge and attitudes required to use digital technologies effectively and responsibly. This perspective provides a broader conceptual foundation for understanding digital literacy in educational contexts.

Technical Literacy emphasizes an individual's proficiency with hardware, software, and digital tools, including basic operational skills such as information retrieval, data processing, and multimedia production.

Cognitive Literacy focuses on the individual's critical thinking, problem-solving, and knowledge construction abilities in the process of information acquisition, analysis, and integration.

Socio-emotional literacy highlights individuals' ability to communicate and collaborate, understand social responsibility, and manage emotions in digital settings. Online interactions showcase social adaptability and ethical judgment.

In higher education, digital literacy not only demonstrates students' mastery of digital tools and technologies but also their ability to build knowledge independently, think creatively, and express themselves through various media in a complex information environment (Martin, 2006). A high level of digital literacy enables students to effectively combine multimodal information, critically assess information sources, and utilize digital technologies for innovative design and knowledge creation, thereby strengthening their creative skills in design learning and practice. As a crucial foundation for design education, digital literacy also supports the development of students' integrative and innovative abilities in interdisciplinary projects, online collaborations, and digital creations.

2.2.8.2 Literature on Digital Literacy

As the digital transformation in education accelerates, the importance of digital literacy (DL) in higher education increases. Digital literacy involves students' mastery of digital technologies, tools, and platforms. It includes their ability to access, analyze, integrate,

and creatively express information in a multimodal environment (Ng, 2012). This skill affects students' learning effectiveness and is essential for developing creative abilities. A high level of digital literacy enables students to quickly sift through information and craft creative solutions for complex design challenges. It also enhances the quality of design work through visualization and prototyping with digital tools.

Zhang et al. (2021) found that students' digital literacy level significantly predicted their ability to produce creative work through an empirical analysis of design college students in a virtual collaboration environment. Digital literacy levels were significant in multi-platform collaboration and interdisciplinary design projects. This indicates that digital literacy not only improves an individual's mastery of information and technology but also boosts the efficiency of knowledge sharing and collaborative innovation within teams. Hobbs (2010) pointed out that media literacy, as a key part of digital literacy, plays a crucial role in developing students' critical thinking skills and information creativity. When faced with large volumes of information and complex design tasks, students with high media literacy can more effectively evaluate the reliability of sources, synthesize diverse knowledge, and apply it creatively in their design work.

Lee and Leung (2020) found through a cross-cultural study that students with high levels of digital literacy were more likely to use multiple sources of information during design iterations proactively. Digital literacy includes user feedback, data analysis, interdisciplinary knowledge, and technological resources. Users showed greater problem-solving skills and flexibility in creative thinking. This ability improves student performance in course design tasks and provides a strong foundation for their future careers. Digital literacy represents technical competence in design education. It is a comprehensive quality that combines cognitive, socio-emotional, and technical skills. Digital literacy provides students with essential support for high-level innovation in complex design environments by enhancing their ability to acquire, analyze, integrate, and express creativity. Therefore, when developing a model to boost the design innovation ability of design students in universities, it is both theoretically sound and practically valuable to consider digital literacy as a key independent variable.

2.2.9 Knowledge Sharing

2.2.9.1 Definition of Knowledge Sharing

Knowledge sharing involves active communication and the dissemination of both explicit and tacit knowledge among individuals or within an organization. The essence of knowledge sharing is in the flow and reuse of knowledge to improve collective learning and innovation performance.

Nonaka and Takeuchi (1995) first described the dynamic process of transforming knowledge from tacit to explicit and back to tacit within organizations through the SECI model (Socialization, Externalization, Combination, Internalization). Research highlights that knowledge sharing involves both the documented transfer of explicit knowledge and the verbal and practical exchange of tacit experience and skills, facilitating the cyclical development of individual and organizational knowledge. Davenport and Prusak (1998) regarded knowledge sharing as a key enabler of successful knowledge management. The study emphasizes that whether sharing occurs depends on the organization's trust environment, incentives, and institutional safeguards. Scholars believe that knowledge sharing is a process of knowledge flow and a crucial prerequisite for organizational

innovation and decision-making. Bock et al. (2005) found that knowledge-sharing intentions were influenced by attitudes toward knowledge sharing, subjective norms, and organizational climate. Their findings also highlighted the roles of anticipated reciprocal relationships and sense of self-worth in shaping knowledge-sharing attitudes and subjective norms.The study indicates that knowledge-sharing behavior is driven by social, cognitive, and motivational factors simultaneously. In education, Huang and Zhang (2019) observed that knowledge sharing happens among students through collaborative projects, classroom discussions, online platforms, and laboratory practices. Experiences, solutions, and ideas are proactively shared, leading to collective wisdom and innovation. Lin (2007) emphasized that in higher design education, knowledge sharing improves communication among team members and boosts the innovation capacity of interdisciplinary collaboration, helping students achieve creative integration and produce high-quality results in complex design tasks.

Different scholars' definitions of knowledge sharing emphasize various aspects, but they all highlight its core features: first, proactivity. Knowledge sharing is not passive reception of information; instead, individual or organizational members take the initiative to transfer and exchange knowledge. Second, multi-level knowledge sharing involves documenting and systematizing explicit knowledge, as well as exchanging tacit experience, skills, and practices. Third, functionality entails that knowledge sharing is not only the dissemination of information but also a crucial mechanism for fostering learning, innovation, collaboration, and enhancing organizational or team capacity. In higher education, knowledge sharing provides a practical foundation for design education, boosting students' innovation and teamwork skills by fostering the exchange and integration of experience, skills, and creativity. This, in turn, supports the development of a conceptual model for designing innovation capabilities in colleges and universities.

2.2.9.2 Literature on Knowledge Sharing Related Literature

In educational management and learning science research, knowledge sharing is widely recognized as a key mechanism for building learning communities, encouraging collaborative innovation, and enhancing creative outcomes. Wang and Noe (2010) noted that the effectiveness of knowledge sharing in higher education depends on institutional arrangements and technological platforms. Knowledge sharing relies on learners' trust, intrinsic motivation, and perceptions of collaboration's value. An environment where knowledge sharing is psychologically insecure or poorly incentivized significantly reduces the frequency of such behavior. Chai et al. (2011) found that the frequency and quality of knowledge sharing are important predictors of students' creative performance, based on an empirical study of interdisciplinary collaborative learning. High-quality knowledge exchange can inspire students to develop more novel and feasible solutions for design tasks, highlighting the direct contribution of knowledge sharing to creative output. Lin (2007), from the perspective of individual motivation and ability, suggested that knowledge-sharing behaviors are influenced by a combination of altruistic and reputational motivations, individual expressive ability, and media literacy. This indicates that knowledge sharing is not only a function of the external environment or system design but also depends on students' creative performance, institutional design, and cognitive and skill levels. With the growth of digital learning environments, Zhu et al. (2021) found that digital platforms such as learning passes, cloud classroom lessons, and other tools can significantly enhance students' knowledge-sharing behaviors. These platforms promote collaborative innovation and

interdisciplinary cooperation through community interactions and information flow, providing new cognitive resources and practical pathways for design education.

Existing research indicates that knowledge sharing in design education is not just about transferring information or experience; it is also a crucial mechanism for integrating cognitive resources, encouraging viewpoint confrontation, and fostering innovation. It offers both theoretical and practical support for improving students' Design Innovation Ability by enhancing students' abilities to cooperate, integrate information, and understand interdisciplinary concepts. Therefore, considering knowledge sharing as a key independent variable when building a model for improving the design innovation ability of design students in universities helps uncover the interactions among individual, environmental, and technological factors and provides practical strategies for educational interventions.

2.2.10 Intrinsic Motivation

2.2.10.1 Definition of Intrinsic Motivation

Intrinsic motivation refers to an individual's drive to perform a behavior for personal interest, pleasure, curiosity, or the challenge of the task itself, rather than for external rewards, punishments, or social pressures. Deci and Ryan (1985) developed Self-Determination Theory to explain the processes underlying intrinsic motivation and self-determined behavior. Within this framework, intrinsic motivation refers to engaging in an activity because of the inherent interest, enjoyment, or satisfaction associated with the activity itself. Subsequent developments of the theory emphasized autonomy, competence, and relatedness as three basic psychological needs that support motivation and psychological development (Deci & Ryan, 2000).They suggest that individuals are intrinsically motivated to satisfy three basic psychological needs: autonomy, competence, and relatedness. Autonomy involves a sense of control over behavioral choices, and intrinsic motivation is significantly increased when students can freely choose their learning methods or directions. Competence reflects how one assesses their ability to complete a task; when students feel they have improved their skills or overcome challenges, they are more likely to stay committed to learning. Relatedness emphasizes the sense of identity and connection gained through social interactions and group participation, which are key motivation factors. This sense of social connection enhances students' motivation to collaborate and share ideas, thus indirectly fostering the development of intrinsic motivation.

In design education, intrinsic motivation appears as students' natural engagement in design projects, creative tasks, or problem-solving activities. Amabile (1996) pointed out that when students find the content of a project interesting or see the task as inherently worthwhile, they naturally mobilize their cognitive resources to think deeply, experiment, and try new ideas, resulting in higher quantity and quality of their creative work. Hennessey and Amabile (2010) further highlighted that intrinsic motivation encourages ongoing exploratory and innovative behaviors, keeping students focused and motivated even when faced with difficulty and uncertainty. Additionally, Ryan and Deci (2000) argued that a high level of intrinsic motivation not only fosters creative thinking but also enhances task persistence, self-directed learning, and offers multiple perspectives on solving complex design problems. Overall, intrinsic motivation is a vital psychological resource in design learning that fuels sustained innovation, active exploration, and autonomous practice—shaping the depth and breadth of learning, and providing both intrinsic motivation and a psychological foundation for students to produce high-quality design work.

2.2.10.2 Literature on Intrinsic Motivation

The role of intrinsic motivation has been validated and refined in the fields of education and innovation research. Amabile's (1996) early model of the components of creativity, though older, remains widely cited in modern research for its view of intrinsic motivation as a key driver of innovative behavior. Ryan and Deci's (2000) Self-Determination Theory highlights that intrinsic motivation improves individuals' learning engagement, task persistence, and psychological well-being. Recent empirical studies support this theory in the context of design education. Found that students' creative output in design projects increased significantly when they perceived the task as interesting, challenging, and personally meaningful. This indicates that intrinsic motivation not only promotes learning engagement but also directly affects creative performance.

In the context of design education in Chinese colleges and universities, Liu et al. (2022) found that course autonomy, open evaluation mechanisms, and positive teacher feedback significantly boosted students' intrinsic motivation, as shown by a survey of undergraduate design students. This increased motivation, in turn, indirectly enhanced students' design innovation ability. This finding suggests that intrinsic motivation is an important psychological factor influencing innovative behavior in design learning.

Additionally, recent cross-cultural studies have also demonstrated that a high level of intrinsic motivation can help students sustain ongoing exploration and creative thinking when tackling complex design tasks and multidisciplinary integration (Zhang et al., 2021).

Research indicates that intrinsic motivation interacts dynamically with the learning environment, task characteristics, and social support. Amabile (1996) suggested that intrinsic motivation is stimulated when the learning task has a clear goal and allows students to make independent choices, thereby enhancing creative thinking and problem-solving abilities. Li et al. (2023) also found that, in team-based and project-based learning contexts, students' intrinsic motivation levels directly predicted their depth of engagement and the quality of creative outcomes in cross-media design tasks. Taken together, these studies suggest that intrinsic motivation, as the psychological link between students' emotional engagement and creative output, has irreplaceable theoretical and practical value in design education, providing important references for educational interventions and curriculum design.

2.2.11 Multimedia-Supported Instruction

2.2.11.1 Definition of Multimedia-Supported Instruction

As a crucial element of educational technology and learning environments, Multimedia-Supported Instruction (MSI) has been defined in various ways by different scholars. Mayer (2009) highlighted that MSI is a systematic design aimed at supporting teaching and learning through multimedia and information technology (IT) resources, with a focus on increasing interactivity and depth of understanding. Clark and Mayer (2016) pointed out that instructional media are not just tools for conveying information. They are essential for improving students' learning efficiency and knowledge retention by optimizing cognitive load, using segmented presentations, and designing content in context. Spector (2014) described Multimedia-Supported Instruction from a systemic standpoint as an integrated system of educational resources that includes hardware, software, platforms, and services, emphasizing the interconnected roles of technology, content, and teaching strategies. Laurillard (2013) emphasized the role of instructional media in practical and innovative

courses, arguing that media support can provide students with simulated environments, interactive experiments, and immediate feedback, thereby greatly enhancing hands-on learning and creative exploration.

Although the definitions from various scholars differ in focus, they all emphasize the central role of Multimedia-Supported Instruction in enhancing the learning experience, optimizing instructional strategies, and promoting learning outcomes. Mayer highlights the importance of multimedia presentations in facilitating cognitive processing. Laurillard (2012) conceptualized teaching as a design science, emphasizing the systematic alignment of learning objectives, instructional activities, assessment, and technology. Her framework suggests that digital technologies should be integrated into pedagogically meaningful learning processes rather than treated as independent determinants of learning effectiveness. This perspective provides a theoretical foundation for examining Multimedia-Supported Instruction as a structured educational environment in design learning.

Clark and Mayer (2016) focused on the alignment between the psychological mechanisms of learning and media design. Spector views the coordination of resources and strategies from a systems integration perspective. Laurillard emphasizes practical and innovative teaching contexts. Multimedia-Supported Instruction combines technology, resources, instructional strategies, learning psychology, and hands-on activities. The effectiveness of media support depends on the type of media, curriculum design, and student behavior. Therefore, in designing professional education, the rational use of multimedia-supported instruction can provide structural, practical, and interactive multidimensional support for the development of design innovation ability.

2.2.11.2 Literature on Multimedia-Supported Instruction

In recent years, the academic community has gathered numerous empirical studies and theoretical analyses on the role of multimedia-supported instruction in higher education, especially in design disciplines. Clark and Mayer (2016) pointed out that a rich-media teaching environment can enhance students' information processing, learning efficiency, and knowledge internalization through multi-channel information presentation and optimized cognitive processing. Sun et al. (2022) found that multimedia-integrated fine arts education had significant positive effects on university students' learning attitudes and learning satisfaction. These findings highlight the potential benefits of multimedia-supported instructional approaches in art education. Zhang et al. (2021) stressed that instructional media not only provide technological tools but also, through multimodal presentations, interactive feedback, and contextualized designs, positively influence learners' learning strategies, independent learning abilities, and creativity. This is especially true in design education, where combining multiple media forms can strengthen the connection between information input and output, thereby enhancing students' design thinking and practice. Lin (2007) suggested that multimedia-supported instruction plays a crucial role in project-based and collaborative learning by facilitating instant feedback, resource sharing, and virtual collaboration platforms to foster knowledge sharing and collaborative innovation. Oo et al. (2024) found that an instructor's strategies for media use and the degree of integration with course content significantly affect students' perceived usefulness of media support, which, in turn, influences their engagement with learning and innovative performance.

Studies by various scholars have demonstrated that the value of multimedia-supported instruction extends beyond its technical aspects to include its integrated support for

instructional strategies, learning behaviors, and innovative practices. Media-rich, multimodal, and interactive features are central to enhancing the effectiveness of media support. Simultaneously, teacher guidance and curriculum integration are crucial factors for achieving optimal outcomes. In design professional education, the strategic allocation and use of Multimedia-Supported Instruction can improve students' knowledge acquisition, creative expression, and innovative practices, thereby strongly supporting the development of Design Innovation Ability.

2.2.12 Technology Acceptance

2.2.12.1 Definition of Technology Acceptance

Technology acceptance involves an individual's attitude, intention to use, and actual use of new technologies or digital tools. In educational settings, this concept focuses on learners' acceptance of instructional platforms, online systems, or digital tools, and their willingness to incorporate them into their learning activities. The Technology Acceptance Model proposed by Davis (1989) is a key framework for understanding this process, emphasizing perceived usefulness and perceived ease of use. The main idea is that these two psychological factors significantly influence users' intention to use a technology. Perceived usefulness is how much a person believes that using a technology will improve their work or learning performance, while perceived ease of use is their subjective judgment of how easy it is to use and learn the technology.

With the development of the TAM model, Venkatesh and Davis (2000) introduced TAM2, which includes social influence processes (e.g., subjective norms, images) and cognitive instrumental processes (e.g., job relevance, outcome demonstrability) to explain better the mechanisms that influence users' perceived usefulness and intention to use. In recent years, technology acceptance has been widely applied in educational technology research to analyze students' usage of online learning platforms, virtual lab systems, collaboration tools, and AI-assisted teaching tools. For example, studies have indicated that students' perceived usefulness and ease of use of digital design tools significantly impact their learning engagement and willingness to practice innovation (Chen and Tsai, 2021; Lee and Leung, 2020). Individual characteristics, instructional support environments, and peer interactions may also influence students' Technology Acceptance (Wang, 2020). Technology acceptance not only reflects an individual's cognitive evaluation and psychological tendency toward new technologies but also their behavioral intention to actively use technology in the learning environment to improve learning efficiency and foster innovation. In design professional education, understanding and measuring students' technology acceptance is highly significant, both theoretically and practically, for optimizing teaching media design, enhancing the effectiveness of digital tool application, and strengthening students' design innovation abilities.

2.2.12.2 Literature on Technology Acceptance

In recent years, technology acceptance has emerged as a key topic in educational technology and innovative learning research. Technology acceptance focuses on explaining learners' attitudes, intentions to use, and actual behaviors when engaging with digital platforms, instructional tools, or information systems. The Technology Acceptance Model (TAM) proposed by Davis (1989) provides a foundational framework for understanding this process, emphasizing perceived usefulness and perceived ease of use as the primary factors influencing user adoption. Perceived usefulness and perceived ease of use are central to

shaping users' intention to use. This model has laid the theoretical groundwork for subsequent research in educational technology and has been widely used to analyze students' acceptance of learning management systems, online course platforms, and digital authoring tools.

Venkatesh and Davis (2000) introduced the TAM2 model by adding social influence and cognitive tool factors. The study extends the model's ability to explain technology-use behavior in educational settings. It highlights that technology acceptance results from individual cognition and is also shaped by social context and task factors. This extended model is widely cited in educational research to understand how students are affected by instructor expectations, peer influence, and task fit when using online learning platforms or design tools.

Empirical research supports the significant role of technology acceptance in learning engagement and creativity. Teo (2011) noted that college students' acceptance of online learning platforms was a strong predictor of their engagement and ability to complete creative tasks, indicating that Technology Acceptance influences how often students use technology and may affect learning effectiveness and innovation output. Dwivedi et al. (2019) re-examined the Unified Theory of Acceptance and Use of Technology (UTAUT) through meta-analysis and structural equation modeling. Their findings highlighted the important role of users' attitudes in explaining behavioral intentions and actual technology use. The study also suggested that the applicability of moderating variables may depend on the research context. These findings provide a broader theoretical perspective for considering individual differences in technology acceptance, although the moderating role of Technology Acceptance in the relationship between Multimedia-Supported Instruction and Design Innovation Ability requires separate empirical examination. This suggests that the interaction between individual traits and environmental factors shapes technology use behavior. In design education, students' acceptance of digital creation platforms, collaboration tools, and virtual design environments is directly related to their capacity to fully utilize technological resources for creative exploration, thereby shaping their potential for design innovation.

Technology Acceptance may influence the strength of the relationship between Multimedia-Supported Instruction and design innovation ability. Students with different levels of technology acceptance may respond differently to multimedia-supported learning environments. Therefore, this study includes technology acceptance as a moderating variable to examine whether the effect of multimedia-supported instruction on design innovation ability varies across different levels of technology acceptance.

2.2.13 Design Innovation Ability

2.2.13.1 Literature on Definition of Design Innovation Ability

Design innovation ability (DIA) describes an individual's overall capacity to generate original and practical design ideas in learning and practice, and to transform them into concrete results. This ability not only involves coming up with ideas but also includes multiple qualities such as problem-solving, cross-media expression, and technical skills (Yang and Cham, 2007). Design innovation ability reflects students' cognitive level, professional skills, capacity to integrate resources, ability to manage complex tasks, and ability to make innovative decisions in uncertain situations.

Mumford and Gustafson's (1988) Creativity Syndrome model posits that the ability to innovate is a complex psychological structure composed of cognitive, motivational,

emotional, and behavioral factors. Hargadon and Sutton (1997) highlighted the key role of knowledge recombination in the innovation process, noting that innovation ability results from the cross-disciplinary integration of existing knowledge. This perspective is helpful for understanding interdisciplinary integration in design innovation, and the concept of design thinking, as introduced by Brown (2009), emphasized the importance of human-centered orientation, interdisciplinary collaboration, and rapid prototyping as important approaches to innovation-oriented design practice. This indicates that this skill depends not only on individual traits but also heavily on the educational environment and practical methods.

In terms of empirical research, Zhang et al. (2021) found that the use of digital tools and collaborative platforms significantly contributed to the innovative performance of design university students. This indicates that the technological environment plays a supportive role in the development of design innovation ability. Chen and Wang. (2020) discovered in a study of Chinese universities that project-driven learning and open-ended design tasks can effectively improve the quality of students' innovation outputs, highlighting the key role of educational interventions in shaping design innovation ability. Liu and Gong (2021) found, through a comparative study across colleges, that cultivating design innovation ability is closely related to individual creative self-efficacy and motivation. The combination of teacher guidance, teamwork, and course structure influences the ability to innovate in design.

Design innovation ability is a multidimensional, multilevel construct that depends on individual cognition, motivation, and psychological traits. It is also significantly influenced by the educational environment, technical support, and practice opportunities. Research by various scholars indicates that this ability not only serves as an important indicator of the overall quality of design students but also plays a crucial role in promoting innovation education and industrial innovation practices. Therefore, by implementing systematic curriculum design, fostering interdisciplinary collaboration, integrating digital technology, and emphasizing project-based learning, college design education can comprehensively enhance students' design innovation abilities, providing a solid foundation for their future careers and social innovation efforts.

2.2.13.2 Design Innovation Ability Related Literature

Design innovation ability refers to an individual's overall capacity to create original and practical design concepts during learning and practice, then turn them into achievable outcomes. The existing literature indicates that this ability has multiple dimensions, including idea generation, problem-solving, cross-media expression, and technological application (Yang and Cham, 2007). The Creativity Syndrome Model proposed by Mumford and Gustafson (1988) suggests that innovation ability results from the interaction among various factors, including cognition, motivation, emotion, and behavior. Design innovation ability offers theoretical support for understanding its psychological mechanism. Hargadon and Sutton (1997) highlight the importance of reorganizing knowledge across different domains in the innovation process and argue that design innovation ability depends not only on individual creative thinking but also on integrating diverse sources of information and knowledge.

At the level of educational practice, Brown's (2009) theory of Design Thinking emphasizes the roles of human-centered orientation, interdisciplinary collaboration, and rapid prototyping in promoting innovation.Dorst (2011) examined the underlying reasoning processes of design thinking, emphasizing abductive reasoning and frame creation as central

elements of design practice. From this perspective, design innovation involves not only generating new ideas but also reframing complex problems and developing alternative approaches to problem-solving. Applied to design education, this theoretical perspective suggests that encouraging students to question existing assumptions and explore multiple problem frames may support the development of their design innovation ability. It provides an actionable pedagogical framework for design education in colleges and universities. Liu and Gong's (2021) study further shows that curriculum design, instructor guidance, teamwork, and the application of digital technology all play important roles in design innovation. Zhang et al. (2021) demonstrated that digital tools and online collaboration platforms can significantly enhance students' innovative output, indicating that the technological environment is a crucial factor in fostering design innovation ability. Sun et al. (2022) Noted that project-driven learning and open-ended tasks can effectively enhance students' innovative performance, suggesting that design education in colleges and universities can establish a framework for teaching and learning. Enhancing students' innovative performance underscores the vital role of educational interventions in developing design innovation ability. This ability not only reflects the individual's creative cognitive level but is also shaped by the educational environment, technological conditions, and collaborative mechanisms, and results from a combination of psychological, cognitive, and practical skills. Existing research highlights that understanding its formation mechanism requires attention to the interactions among individual traits, pedagogical strategies, and technological support, offering a theoretical and practical basis for optimizing and cultivating innovation capacity in college and university design education.

2.3 Relationship between Variables

2.3.1 Relationship between Creative Self-Efficacy and Design Innovation Ability

Creative self-efficacy (CSE) refers to an individual's confidence in their ability to demonstrate creativity in tasks (Tierney and Farmer, 2002). The concept has been widely used in educational and organizational innovation research as an important psychological variable for measuring a person's creative potential. In design education, creative self-efficacy is recognized as a key factor in students' ability to take the initiative to explore new design solutions, solve complex problems, and generate unique ideas.

Mathisen's (2009) study found that college students' levels of creative self-efficacy were significantly and positively associated with their performance on innovative course projects, especially in design courses, where creative self-efficacy notably influences students' willingness to experiment with out-of-the-box design thinking. Jaiswal and Dhar (2015) further observed that creative self-efficacy not only affects students' creative performance but also boosts their task persistence and motivation, which serve as psychological safeguards for sustained engagement in design tasks.

Additionally, Beghetto (2006) suggested that students with higher creative self-efficacy are more likely to adopt proactive exploratory strategies when facing complex tasks, rather than avoiding challenges due to fear of failure. This positive psychological trait is essential for helping design students create original outcomes in their creative work. Karwowski (2011) found in their cross-cultural empirical study that creative self-efficacy acts as a bridge connecting creative thinking, problem-solving skills, and innovative outcomes, especially when dealing with design tasks that involve high levels of uncertainty.

In summary, creative self-efficacy not only influences students' beliefs about innovation on a psychological level but also affects the quality and originality of their design work at a behavioral level. Therefore, in this study's conceptual framework, creative self-efficacy (CSE) is proposed as a predictor of design innovation ability (DIA) among university design students.

2.3.2 Relationship between Digital Literacy and Design Innovation Ability

With the widespread adoption of digital technologies in higher education, digital literacy (DL) has become a key factor shaping students' learning styles and innovation abilities. Ng (2012) proposed that digital literacy includes three dimensions: technical literacy, cognitive literacy, and social contextual literacy, and this comprehensive competency framework provides a foundation for college students to effectively access, evaluate, and apply digital information in complex design tasks. This framework helps students develop essential skills for navigating digital environments. Digital literacy is not only a reflection of operational skills but also an extension of critical thinking and problem-solving skills in digital settings (Ng, 2012).

Hatlevik et al. (2015) examined factors associated with digital competence among Norwegian ninth-grade students. Their findings indicated that students' digital competence varied according to family background, previous academic achievement, and mastery orientation. The study highlighted the importance of considering individual and contextual differences in the development of digital competence. Although the research did not directly examine design innovation, it provides a useful foundation for understanding digital competence as a multidimensional capability shaped by students' learning characteristics and environments.This critical information management ability is considered an important foundation for generating original design ideas. Carretero et al. (2017), identified digital collaboration, content creation, and problem-solving as important dimensions of digital competence, providing a framework for understanding the digital skills relevant to design learning.

Zhang et al.'s (2021) study further highlights that design college students with high digital literacy not only can effectively use various design software and platforms but also show stronger creative integration and execution skills in virtual collaboration and feedback. Additionally, Alam et al. (2022) observed that digital literacy indirectly boosts creative output in design tasks by affecting students' information-seeking behaviors, online communication strategies, and virtual teamwork.

2.3.3 Relationship between Knowledge Sharing and Design Innovation Ability

Knowledge sharing is crucial in higher education, especially in design courses, where collaboration and communication among students are vital to encourage creative thinking. Wang and Noe (2010) argued that knowledge sharing fosters a more innovative environment by improving intra-team communication, feedback processes, and collaborative problem solving.

Lin's (2007) study on higher education in Taiwan found that students' knowledge-sharing behaviors were positively associated with their innovative outcomes in creative projects. Specifically, in project-based learning and workshop settings, students' willingness

to share design ideas and give feedback on others' work notably improved the quality and originality of the overall design output.

Chang et al. (2009) examined the relationships among work role similarity, work familiarity, social identity, and knowledge contribution in organizational settings. Their findings suggested that work familiarity could facilitate knowledge contribution through cognitive and affective dimensions of social identity, highlighting the importance of interpersonal relationships in knowledge-sharing processes. Additionally, Hsu's (2008) study demonstrates that knowledge-sharing behaviors can be conducted more frequently and effectively with the support of digital platforms and pedagogical media, providing technological and social support to boost innovation capacity.

2.3.4 Relationship between Intrinsic Motivation and Design Innovation Ability

Intrinsic motivation refers to an individual's behavioral drive that arises from the interest or challenge of the task itself, rather than from external rewards or pressures (Ryan and Deci, 2000). In innovation-focused learning activities, intrinsic motivation is widely seen as a key psychological factor that encourages students to stay engaged, explore, and experiment with new solutions (Amabile, 1996).

Amabile (1993), in his "Componential Theory of Creativity," emphasized that intrinsic motivation is a necessary condition for creativity. Intrinsic motivation is more likely to stimulate cognitive flexibility and exploratory behavior than extrinsic motivated behavior, especially in open-ended learning situations such as design tasks with unclear goals. Deci and Ryan (1985) further noted that intrinsic motivation enhances self-regulation and perseverance during problem-solving, thereby improving the number of repeated attempts and deeper idea development in design experiments. Moreover, it promotes deeper conceptual understanding in experimental design.

Zhou and George (2001) suggested that supportive environments can encourage individuals to express ideas, explore interests, and engage in non-traditional experimentation, thereby contributing to innovative performance. In design education, such support may help students maintain intrinsic motivation and produce more original design outcomes.

In addition, Grant and Berry (2011) examined the relationship between intrinsic motivation and creativity, emphasizing the moderating role of prosocial motivation and the explanatory role of perspective taking. Their findings indicated that prosocial motivation strengthened the positive association between intrinsic motivation and creativity by encouraging individuals to consider the needs and perspectives of others, thereby generating ideas that were both novel and useful. Although their research was primarily situated in organizational and experimental contexts, it provides a relevant theoretical perspective for understanding how intrinsic motivation may contribute to creative performance in design education.

In recent years, empirical studies on the relationship between intrinsic motivation and innovativeness in higher education have increased. For example, Tang and Chaw (2016) examined the relationship between students' digital literacy and effective learning in a blended learning environment. Their findings indicated that digital literacy competencies were significantly associated with students' effectiveness in technology-supported learning. This provides an empirical basis for considering Digital Literacy as a relevant factor in

students' engagement with multimedia learning resources. However, the study did not directly investigate intrinsic motivation, design project originality, or Design Innovation Ability.

2.3.5 Relationship between Creative Self-Efficacy and Multimedia-Supported Instruction

Creative self-efficacy (CSE) refers to an individual's personal judgment of their ability to produce new and valuable ideas (Tierney and Farmer, 2002). This concept builds upon Bandura's (1986) social cognitive theory of self-efficacy, which has been widely applied in design education to forecast students' creative actions and initiative in open-ended tasks.

Meanwhile, multimedia-supported instruction (MSI) refers to the multimodal and multiplatform technological tools and environmental resources provided to learners during the teaching and learning process, such as online learning platforms, interactive videos, AI design tools, and other resources. In recent years, researchers have started to focus on digital media support, especially on how digital media influence learners' psychological beliefs, including their self-efficacy, through the role of external environmental support.

Lee and Leung's (2020) study found that students who used highly interactive, feedback-based instructional media, such as learning management systems (MSI) and real-time collaborative platforms, during teaching and learning had a significantly greater sense of control and confidence in their tasks, which, in turn, indirectly boosted their creative self-efficacy. Sun and Wang (2020) also observed that in technology-enhanced learning environments with rich visual, audio, and simulation support, students can overcome uncertainty in the design process and strengthen their beliefs in idea generation.

Zhang and Li. (2023), in an empirical study of a design course, observed that instructional media tools not only provide easy access to resources but also help students build confidence in creative expression through various representations. This cognitive reinforcement increases students' likelihood of experimenting with new design methods and conveying diverse creative ideas.

Yilmaz and Goktas (2017) emphasized that in a media-supported environment, students are more likely to receive positive feedback and peer support, thereby gradually developing a self-perception of "I can be creative." This encouraging teaching environment reduces, to some extent, the anxiety associated with innovation failure and enhances students' psychological resilience when working on higher-level design tasks.

In this study, creative self-efficacy is regarded as an antecedent that influences students' engagement with and use of multimedia-supported instruction. Students with stronger creative confidence are more likely to actively use multimedia resources, seek feedback, and participate in iterative learning activities supported by instructional media.

2.3.6 Relationship between Digital Literacy and Multimedia-Supported Instruction

Digital literacy (DL) describes an individual's ability to effectively access, evaluate, integrate, create, and share information in a digital environment (Ng, 2012). As teaching and learning in higher education become more digital, digital literacy has become a crucial skill for students in learning and creative activities using instructional media.

Research has shown that digital literacy not only determines whether students can effectively use instructional media tools but also directly affects their ability to gain meaningful learning experiences from these media. Hatlevik et al. (2015) found that the higher the students' digital literacy, the more they can actively adapt and operate efficiently in the face of instructional media, such as online course platforms, design software, and collaborative tools, demonstrating stronger media adaptability and technological autonomy.

Based on the EU Digital Competence Framework, Carretero et al. (2017) observed that the effectiveness of instructional media platforms in supporting students depends on their ability to navigate information, create digital content, and collaborate. These skills are the core aspects of digital literacy, showing that digital literacy is not only a prerequisite for media use but also "activates" the functional value of media support.

Tang and Chaw (2016) also emphasized that students with higher digital literacy can develop systematic learning strategies, such as information retrieval, critical evaluation, and cross-platform transfer, when using instructional media tools. This, in turn, enhances the depth and efficiency of media use. In addition, Yilmaz and Bayraktar (2014) noted that low levels of digital literacy often lead to cognitive load, operational difficulties, and technological anxiety when students encounter digital learning platforms, thereby reducing the effectiveness and satisfaction with Multimedia-Supported Instruction.

In the field of design education, Sun et al. (2022) found through an empirical study that design students' ability to manipulate digital tools was strongly linked to the amount of feedback, resources, and collaborative support they received from instructional media platforms. In other words, students with higher digital literacy can complete complex creative tasks, such as 3D modeling and online collaborative review, with the help of instructional media, thereby fully utilizing the educational benefits of media support.

2.3.7 Relationship between Intrinsic Motivation and Multimedia-Supported Instruction

Intrinsic motivation (IM) refers to an individual's tendency to engage actively because of interest, enjoyment, or challenge in the activity itself (Ryan and Deci, 2000). In education, intrinsic motivation is considered a key psychological factor that drives sustained learning and deep engagement among students. Research has shown that students' intrinsic motivation is closely associated with their engagement in Multimedia-Supported Instruction, especially when psychological needs such as autonomy, competence, and relatedness are met. (Deci and Ryan, 1985).

Clark and Mayer (2016) observed that an interactive, user-friendly instructional media system that provides immediate feedback can effectively enhance the enjoyment and immersion of the learning experience, thereby increasing students' intrinsic motivation to participate. Keller's (1987) ARCS model emphasizes that instructional design should promote attention, relevance, confidence, and satisfaction, which can enhance students' motivation and engagement in multimedia-supported learning environments.

Chen and Jang (2010) conducted an empirical study that showed Multimedia-Supported Instruction using a self-directed learning platform improved students' sense of control and competence in the course. This, in turn, increased their intrinsic motivation driven by interest and growth, especially in open-ended tasks and creatively designed projects.

Sun et al. (2022) also noted that in design learning environments, digital instructional media—such as online presentation platforms, interactive course modules, and multiple feedback systems—can provide opportunities for ongoing exploration and self-expression, thereby fostering students' intrinsic interest in project design. The more contextualized, personalized, and immediate the medium, the more likely students are to actively engage in higher-order learning activities such as design thinking, problem-solving, and creative expression.

Roca and Gagné (2008) argued that an information system's support for intrinsic motivation is a crucial mediating factor that affects intention to use and continued use behavior. For instructional media, the ease of use, support, and interactivity of the platform itself become important elements that influence students' perceived enjoyment and intrinsic motivation.

In this study, Intrinsic motivation is considered an antecedent of students' engagement with Multimedia-Supported Instruction. Students with stronger intrinsic motivation are more likely to actively explore digital learning resources, use multimedia tools, and participate in self-directed design learning activities.

2.3.8 Relationship between Knowledge Sharing and Multimedia-Supported Instruction

Knowledge sharing (KS) is widely recognized as an important process for organizational learning, teamwork, and innovation (Wang and Noe, 2010). In higher education environments, especially in design programs, Multimedia-Supported Instruction has become a key method for facilitating knowledge exchange and collaborative creativity among students. Multimedia-supported instruction not only provides students with tools for information transfer and content creation but also creates a multi-channel, highly interactive sharing platform that boosts the frequency and quality of knowledge sharing (Hsu, 2008).

Cheng et al. (2009) examined organizational, individual, and technological factors associated with knowledge-sharing behavior among university academics. Their findings highlighted the importance of incentive systems and personal expectations in encouraging knowledge sharing within academic institutions. For instance, cloud-based collaboration tools (e.g., Google Docs, online teaching platforms, interactive forums) can facilitate real-time and delayed knowledge exchange, provide design feedback, and enable collaborative revisions, thus broadening students' perspectives and sources of ideas during project tasks.

Sun et al. (2022) noted that students are more inclined to proactively post ideas, share learning materials, and collaborate on problem-solving when fully supported by instructional media, especially in structured project-based instructional tasks. Such media-based collaboration not only enhances knowledge mobility but also promotes interdisciplinary knowledge integration, thereby generating more diverse design innovations.

Additionally, according to Media Richness Theory, different media vary in their ability to communicate ambiguous and complex information. The more "rich media" (e.g., interactive videos, online whiteboards, voice collaboration platforms) available, the better they are at conveying multidimensional, highly ambiguous information, which improves the efficiency and depth of knowledge sharing (Daft and Lengel, 1986). Choosing and using appropriate instructional media can increase students' perceived value and trust in sharing, thereby motivating them to share knowledge more often.

Huang and Zhang (2019) study also demonstrated that a pedagogical media platform with social interaction and feedback functions can strengthen the circular feedback loop between "knowledge giving" and "knowledge taking," making knowledge sharing more sustainable and contextualized.

In this study, Knowledge sharing is regarded as an antecedent of multimedia-supported instruction. Students who are more willing to exchange ideas and collaborate with peers are more likely to make effective use of multimedia-supported platforms for discussion, feedback, and collaborative design learning.

2.3.9 Relationship between Multimedia-Supported Instruction and Design Innovation Ability

In higher education, particularly in design education, multimedia-supported instruction (MSI) is increasingly becoming a key factor in enhancing students' design innovation ability (DIA). Clark and Mayer (2016) emphasize that MSI is not only a tool for knowledge transfer but also a means of constructing the learning process. They note that the medium of instruction serves not only to transfer knowledge but also as a vital means to build learning environments, support cognitive processing, and encourage innovative thinking. By integrating multimodal information presentation, interactive feedback, and collaborative platforms, instructional media offer students immersive, hands-on learning experiences, thereby boosting their design inspiration and creative potential.

According to Kozma's (1991) "media interactionism," media are not neutral, and the content and form they carry can influence learners' ways of thinking and learning outcomes. In design education, students are often faced with open-ended, complex, and interdisciplinary tasks, and traditional one-way knowledge transfer is no longer enough to meet their developmental needs. Multimedia-supported instruction can improve students' understanding and creative use of design concepts by increasing student engagement, providing immediate feedback, and simulating environments (Sun et al., 2022).

The use of instructional media has been shown to enhance students' "creative cognitive processing" and "design problem-solving skills." In a case study of a design course, Huang and Zhang (2019) demonstrated that introducing interactive platforms encouraged students to exhibit stronger creative thinking and integration skills in teamwork and design prototyping. Additionally, multimedia instructional support can effectively help students receive information through multiple channels—visual, auditory, and kinesthetic—boosting the diversity and depth of their design ideas.

2.3.10 Mediating Role of Multimedia-Supported Instruction in the Relationship between Creative Self-Efficacy and Design Innovation Ability

Creative self-efficacy (CSE) is an innate psychological drive that encourages students' creative actions and design abilities (Tierney and Farmer, 2002). However, whether creative self-efficacy is successfully translated into design innovation ability (DIA) is often influenced by external factors, such as the learning environment and resource support (Jaiswal and Dhar, 2015). Multimedia-supported instruction (MSI), as a key learning context factor, is thought to mediate between the two.

According to Social Cognitive Theory (Bandura, 1986), an individual's self-efficacy must be supported by resources, feedback, and tasks in the external environment to be more effectively translated into actual performance behaviors. Specifically, in design education,

multimedia-supported instruction involves creating student-centered, supportive learning environments through digital tools, visualization platforms, and interactive systems that enable students with high creative self-efficacy to express themselves, try out ideas, make mistakes, and revise, thereby helping generate innovative outcomes (Clark and Mayer, 2016).

It has also been observed that the medium of instruction boosts the behavioral dynamics of self-efficacy. Zhou and George (2001) found that students with high creative self-efficacy showed a greater ability to build design prototypes and express themselves across media when supported by multimedia instruction. In contrast, in environments without media support, although students have creative motivation, their innovative thinking is often limited by the absence of expression tools or imperfect feedback mechanisms.

From the perspective of pathway mechanism, creative self-efficacy can indirectly improve students' design innovation ability by influencing their active exploration, task engagement, and collaborative behavior on the media platform (Sun et al., 2022). Meanwhile, instructional media provide low-cost simulations, rapid prototyping, and peer feedback, which serve as a bridge to turn psychological beliefs into design practices (Mayer, 2005).

2.3.11 Mediating Role of Multimedia-Supported Instruction in the Relationship between Digital Literacy and Design Innovation Ability

In the current landscape of digital transformation in higher education, digital literacy (DL) is widely acknowledged as an important preceding factor that influences students' learning styles and Design Innovation Ability. (Ng, 2012; Carretero et al., 2017). However, digital literacy itself, as a competency trait, is often affected by and interacts with the quality of the pedagogical media environment, which determines how effectively it translates into tangible design innovation results (Zhang et al., 2021).

According to Kozma's (1991) Media and Learning Interaction Theory, the learning medium is not just a channel for information transfer but also a key participant in cognitive processes and skill development. Multimedia-supported instruction (MSI) offers an effective environment for students to apply their digital literacy skills through digital platforms, design software, virtual collaborative spaces, and feedback systems. This approach enhances their design skills and creative output (Clark and Mayer, 2016).

An empirical study by Hatlevik et al. (2015) found that students with high digital literacy were better at integrating information resources and using technological tools for multimodal expression in learning environments supported by instructional media, leading to more original design outcomes. Conversely, in environments with limited media support, even students with strong technological literacy often find their innovative performance limited by the availability of tools and platform functionality.

From the perspective of mediating mechanisms, digital literacy indirectly influences students' cognitive engagement and creative integration in design tasks by shaping their choices, the frequency of use, and proficiency with media resources (Tang and Chaw, 2016). Multimedia-supported instruction can enhance this transformative process, as shown by increased effectiveness, more frequent collaboration, and greater diversity in students' use of technological platforms during the design process.

Sun et al. (2022) further proposed that, in design education, the instructional medium can significantly enhance the development of innovative skills, including key design aspects such as problem-solving, cross-platform collaboration, and user experience awareness, by

strengthening the connection between digital literacy and the practical implementation of ideas.

2.3.12 Mediating Role of Multimedia-Supported Instruction in the Relationship between Intrinsic Motivation and Design Innovation Ability

Intrinsic motivation is widely recognized as a key psychological factor influencing creative behavior and learning outcomes. Ryan and Deci (2000), in Self-Determination Theory, explained that individuals motivated by intrinsic factors are more likely to pursue challenging and innovative tasks over the long term. Amabile (1996) further highlighted that intrinsic motivation is the primary driver of people's engagement in creative activities, especially in complex and uncertain design tasks.

However, whether intrinsic motivation can be successfully translated into creative outputs is often affected by the external learning environment and instrumental support. Multimedia-supported instruction, as a system of educational resources, offers learners tools such as digital platforms, interactive courses, and virtual collaboration systems, which may play a significant mediating role in this process (Clark and Mayer, 2016).

From the perspective of Cognitive Tool Theory (CTT), instructional media are not just channels for information transfer but also serve as cognitive scaffolds that assist learners in externalizing their thinking, expressing creativity, and exploring solutions (Kozma, 1991). When students with higher levels of intrinsic motivation are given adequate media support, they are more likely to feel motivated to explore and experience a sense of achievement in the media environment, thereby improving creative performance in design tasks (Hsu, 2008).

Sun et al. (2022), in a study of design colleges and universities, found that students' intrinsic motivation increased with Multimedia-Supported Instruction, as evidenced by more frequent spontaneous experimentation, iterative modifications, and creative fusion behaviors when using online design platforms and interactive resources. Tang and Chaw (2016) also observed that, in environments with strong media support, students' learning motivation can be continuously triggered through active tool use, ultimately boosting their design innovation.

2.3.13 Mediating Role of Multimedia-Supported Instruction in the Relationship between Knowledge Sharing and Design Innovation Ability

In the current higher education landscape, knowledge sharing has become a vital mechanism for fostering collective wisdom and driving innovation in design education (Wang and Noe, 2010). Students often boost the creativity of design tasks by exchanging ideas, offering feedback, and co-developing solutions in project collaboration, class discussions, and workshops (Lin, 2007).

However, merely being willing to share knowledge and the act of sharing are not enough to automatically lead to innovation. Multimedia-supported instruction (MSI), as an external factor that enhances the learning process, can serve as a mediator between knowledge sharing and design innovativeness. According to Kozma's (1991) theory of media interaction, media are not neutral tools but practical support systems that can influence cognitive processing styles. Through structured information platforms, collaborative tools, and creative resource databases, pedagogical media offer the necessary space and pathways for the flow of knowledge and the generation of ideas.

Clark and Mayer (2016) emphasized that an effective teaching medium can encourage more frequent and efficient communication among students, leading to more organized and

in-depth knowledge-sharing activities and, in turn, promoting the aggregation effect of creative thinking. Hsu's (2008) found that digital instructional media can improve the quality of knowledge interaction among students by providing real-time feedback, visualization tools, and collaborative platforms, thereby supporting the co-construction of solutions in design tasks.

Cheng et al. (2009) identified technological factors as one dimension of knowledge-sharing practices in academic institutions. However, their findings also emphasized the importance of individual motivation and institutional incentives, suggesting that technological support alone may be insufficient to encourage effective knowledge sharing. Sun et al. (2022) further demonstrated that with the help of multimedia resources and online tools, knowledge sharing can be transformed into innovative performance at the design level, and the support of the instructional medium plays a significant role in this. Media support serves as an important bridge in this process.

2.3.14 Moderating Role of Technology Acceptance in the Relationship between Multimedia-Supported Instruction and Design Innovation Ability

In exploring the relationship between information technology and learning outcomes, Davis (1989) established perceived usefulness and perceived ease of use as important constructs for understanding users' acceptance of information technology. Drawing on this theoretical foundation, the present study examines whether students' general willingness to accept new technologies moderates the relationship between Multimedia-Supported Instruction and Design Innovation Ability.

The Technology Acceptance Model (TAM) states that perceived usefulness (PU) and perceived ease of use (PEOU) are two key determinants of users' behavioral intention and actual technology use (Venkatesh and Davis, 2000).

In recent years, with the widespread use of instructional media such as online teaching platforms, digital design tools, and AI-assisted systems in higher education, college students' attitudes toward technology have become an important factor influencing the effectiveness of these tools. Ifinedo (2017) investigated undergraduate students' intentions to continue using blogs for learning and found that attitudes toward blog use, perceived playfulness, self-efficacy, and social-cognitive factors were relevant to technology-related learning intentions. These findings highlight the importance of learners' perceptions and motivation in educational technology use. However, the study did not examine creative performance or the moderating effect of Technology Acceptance on the relationship between Multimedia-Supported Instruction and Design Innovation Ability. The proposed moderation relationship therefore requires direct empirical examination in the present study. When students have a positive attitude toward the instructional platform they use, they are more willing to explore its features, which leads to better conceptualization and expression of design. Moreno and Mayer (2007) proposed a cognitive-affective perspective on learning in interactive multimodal environments. Their review of experimental research identified five instructional design principles—guided activity, reflection, feedback, learner control, and pretraining—that can support effective learning. These principles provide a theoretical basis for considering how interaction and feedback features of Multimedia-Supported Instruction may support students' engagement and understanding during design learning activities.

Lin (2007) further noted that the complexity and interactivity of the instructional medium in design education contexts require students to have a high level of technological

adaptability. Students with different levels of Technology Acceptance may engage with multimedia-supported instruction in different ways. Some students may benefit from structured multimedia guidance because it reduces uncertainty and provides clear learning pathways, whereas others may prefer more flexible and self-directed forms of technology use. Therefore, technology acceptance is included as a moderating variable to examine whether the effect of multimedia-supported instruction on design innovation ability varies across different levels of technology acceptance.

2.4 Theoretical Framework

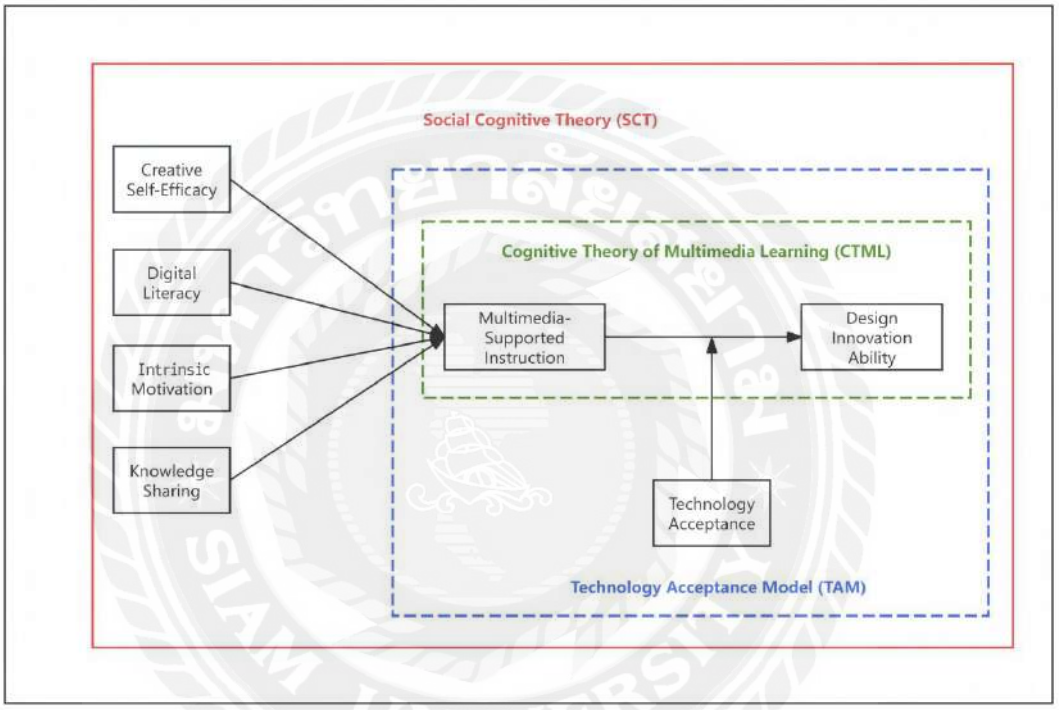


Figure 2.1 Theoretical Framework

The theoretical framework of this study integrates three major theories—Social Cognitive Theory (SCT), the Cognitive Theory of Multimedia Learning (CTML), and the Technology Acceptance Model (TAM)—to explain the mechanisms influencing design innovation ability among university design students in Shandong Province. Grounded in SCT (Bandura, 1986), the model posits that individual cognitive and motivational characteristics, including creative self-efficacy, digital literacy, intrinsic motivation, and knowledge sharing, shape students' learning behaviors and performance outcomes. These four antecedent variables represent the personal cognitive determinants emphasized in SCT and are hypothesized to influence how students engage with and benefit from multimedia-supported instruction in design learning environments.

Aligned with CTML (Mayer, 2005), multimedia-supported instruction is conceptualized as the central mediating mechanism linking students' personal characteristics to their design innovation ability. CTML argues that effective multimedia learning enhances cognitive processing, reduces cognitive load, and facilitates deeper comprehension and creative problem-solving. In the context of design education, multimedia-supported

instruction provides multimodal representations, digital tools, and interactive learning environments that can strengthen students' capacity to integrate information and generate innovative design outcomes. Therefore, this study proposed that multimedia-supported instruction mediates the relationships between the four SCT-based antecedent variables and students' design innovation ability.

To further account for variability in students' engagement with multimedia learning tools, the model incorporates TAM (Davis, 1989) as a moderating framework. Technology acceptance is theorized to condition the effectiveness of multimedia-supported instruction in improving design innovation ability. In other words, students with different levels of technology acceptance may benefit from multimedia-supported instruction in different ways. Integrating TAM as a moderator provides a nuanced understanding of the boundary conditions under which multimedia-supported instruction contributes to design innovation.

2.5 Conceptual Framework

This conceptual framework positions design innovation ability as the outcome, shaped by a dynamic interplay of individual, contextual, and technological factors. At the foundation, the independent variables—creative self-efficacy, digital literacy, intrinsic motivation, and knowledge sharing—represent the personal and cognitive resources that learners bring into the educational process. These resources directly influence students' potential to engage with innovative design tasks.

The mediating variable, multimedia-supported instruction, reflects the institutional and pedagogical mechanisms that enable students' personal traits to be more effectively transformed into learning outcomes. Diverse, interactive, and resource-rich teaching media may act as a bridge between learners' capacities and their innovative performance.

Technology acceptance serves as a moderating variable that conditions the strength of the relationship between multimedia-supported instruction and design innovation ability. It explains whether the effect of multimedia-supported instructional environments on students' design innovation outcomes varies according to students' willingness to accept and use educational technologies. In sum, the framework integrates individual-level traits, teaching media support, and learners' willingness to adopt technology to explain how design innovation ability can be fostered in digital learning contexts.

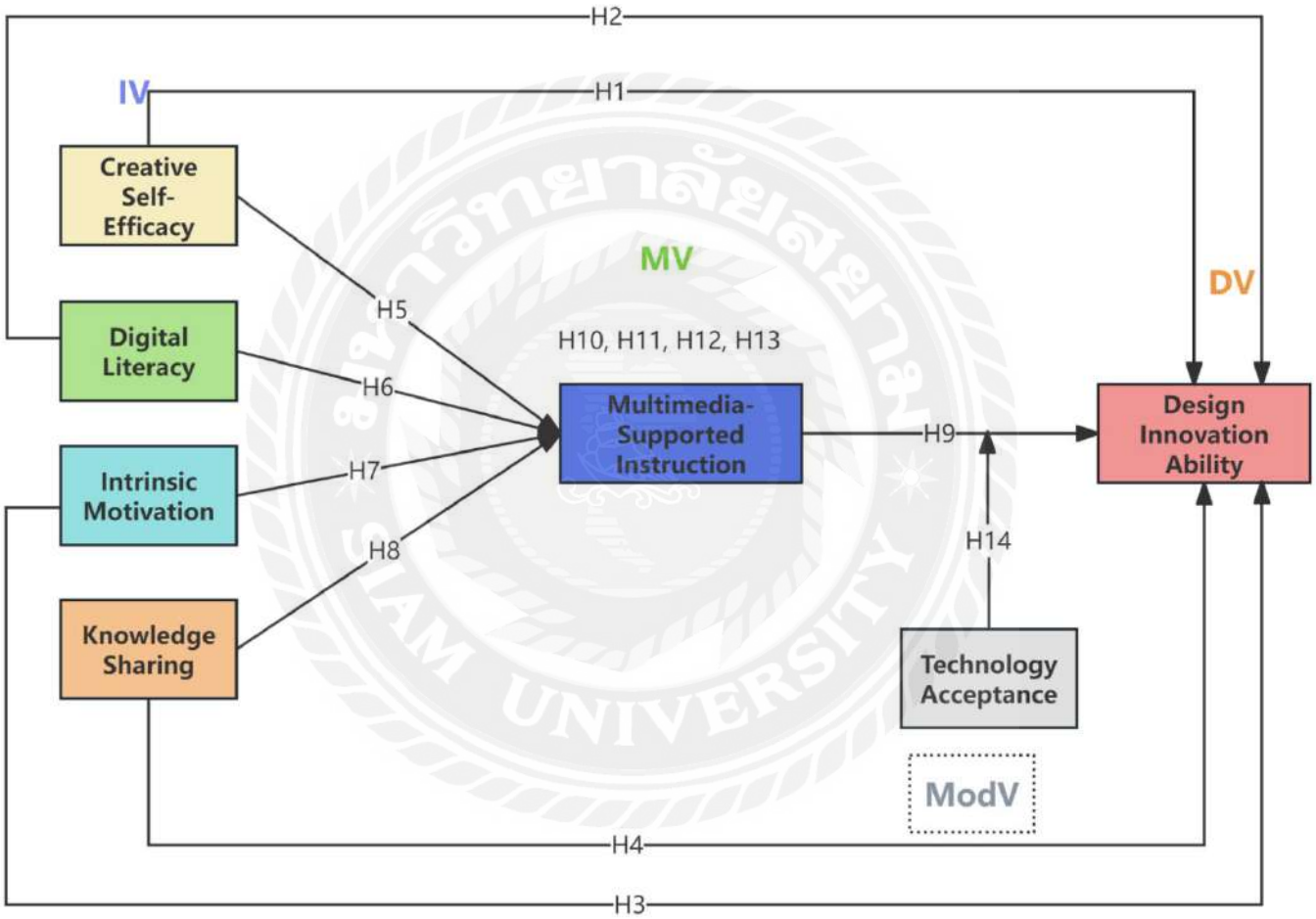


Figure 2.2 Conceptual Framework

2.6 Hypotheses

Based on the preceding theoretical review and conceptual framework, the following hypotheses were proposed.

H1: Creative Self-Efficacy has a significant positive effect on Design Innovation Ability.

H2: Digital Literacy has a significant positive effect on Design Innovation Ability.

H3: Intrinsic Motivation has a significant positive effect on Design Innovation Ability.

H4: Knowledge Sharing has a significant positive effect on Design Innovation Ability.

H5: Creative Self-Efficacy has a significant positive effect on Multimedia-Supported Instruction.

H6: Digital Literacy has a significant positive effect on Multimedia-Supported Instruction.

H7: Intrinsic Motivation has a significant positive effect on Multimedia-Supported Instruction.

H8: Knowledge Sharing has a significant positive effect on Multimedia-Supported Instruction.

H9: Multimedia-Supported Instruction has a significant positive effect on Design Innovation Ability.

H10: Multimedia-Supported Instruction mediates the relationship between Creative Self-Efficacy and Design Innovation Ability.

H11: Multimedia-Supported Instruction mediates the relationship between Digital Literacy and Design Innovation Ability.

H12: Multimedia-Supported Instruction mediates the relationship between Intrinsic Motivation and Design Innovation Ability.

H13: Multimedia-Supported Instruction mediates the relationship between Knowledge Sharing and Design Innovation Ability.

H14: Technology Acceptance moderates the relationship between Multimedia-Supported Instruction and Design Innovation Ability.

2.7 Operationalization of Variables

Referring to the literature review, the operationalization of the variables is presented in Table 2.1 below.

Table 2.1 Operationalization of Variables

Variable	Operational Definition	Scale Item	Reference	Likert Scale
Creative Self-Efficacy	Creative Self-Efficacy refers to an individual's confidence in completing creative tasks and generating novel ideas, serving as an important psychological resource that drives design-related behaviors. Specifically, creative self-efficacy reflects students' confidence in their innovative capabilities, their perceived ability to tackle complex design problems, and their persistence in exploring and pursuing innovative solutions when facing challenges.	**CSE1.** I am confident in my ability to solve problems. **CSE2.** I have the ability to come up with innovative design ideas **CSE3.** I have the ability to further develop the design ideas of others. **CSE4.** I can effectively persuade teammates to consider my design ideas. **CSE5.** I am confident in my ability to come up with innovative design ideas.	Tierney and Farmer (2002); Tierney and Farmer (2011)	5 = Strongly agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly disagree
Digital literacy	Digital Literacy measures students' ability to search, evaluate, create, and communicate design information in digital environments. It encompasses technical literacy, emphasizing proficiency in using digital tools, design	**DL1.** I am proficient in using digital tools (e.g., design software, course platforms).	Hwang et al. (2023)	5 = Strongly agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly disagree

Variable	Operational Definition	Scale Item	Reference	Likert Scale
	software, and multimedia platforms; cognitive literacy, reflecting the ability to analyze, integrate, and evaluate digital information to support design decisions and innovation; and social-emotional literacy, which captures students' understanding of the social and cultural contexts of digital media and their ability to communicate and collaborate effectively in team-based design projects.	**DL2.** I can effectively access and filter learning resources through the Internet. **DL3.** I am able to collaborate and communicate using digital tools. **DL4.** I am able to use digital tools to solve learning difficulties. **DL5.** I can evaluate the reliability of online information and use it to my advantage.		
Intrinsic Motivation (IM)	Intrinsic Motivation refers to students' psychological tendency to engage in learning activities voluntarily due to interest, enthusiasm, or a sense of accomplishment derived from design itself, independent of external rewards or pressures. This motivation manifests as proactive exploration, sustained engagement, and the pursuit of personal growth and achievement in learning and design practice.	**IM1.** I am full of curiosity about the design courses I am studying **IM2.** I believe that difficulties in design projects can be overcome through hard work. **IM3.** I feel happy and satisfied when studying design courses. **IM4.** I studied design because it brings me satisfaction.	Glynn et al. (2011), SMQII	5 = Strongly agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly disagree

Variable	Operational Definition	Scale Item	Reference	Likert Scale
		IM5. Learning the design course content has made my life more meaningful.		
Knowledge Sharing	Knowledge Sharing denotes students' active behaviors of exchanging, disseminating, and collaborating on design experiences, resources, inspirations, or methods during the learning process. Through sharing and interaction, students contribute to collective knowledge accumulation and enhance overall innovation within collaborative contexts.	**KS1.** I am happy to share my knowledge and experience with my classmates. **KS2.** When participating in discussions, I will try to offer my input whenever possible. **KS3.** I am willing to answer questions raised by classmates **KS4.** When my classmates encounter learning difficulties, I am willing to provide help. **KS5.** I think sharing knowledge and experience with others is very fulfilling.	Johnson & Johnson (1999). Cooperative learning literature	5 = Strongly agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly disagree

Variable	Operational Definition	Scale Item	Reference	Likert Scale
Multimedia-Supported Instruction	Multimedia-Supported Instruction refers to the media and technological support provided by higher education institutions through instructional platforms in design education, including online learning systems, AI-assisted tools, and interactive course resources, which enhance students' learning efficiency and the quality of innovative practice. In this study, Multimedia-Supported Instruction captures not only the availability of resources and technical guidance but also students' experiences of teacher-student interactions and peer collaboration through these platforms.	**MSI1.** The multimedia teaching platform provides clear learning guidance and helps me complete my learning tasks. **MSI2.** Multimedia presentations (e.g., videos, visualizations, etc.) can stimulate my creativity in design learning. **MSI3.** Using the multimedia-assisted teaching system allows me to understand design knowledge more intuitively. **MSI4.** The multimedia-assisted teaching system has enhanced my interaction with teachers and classmates. **MSI5.** I feel satisfied and comfortable with the multimedia teaching platform experience	Alam et al. (2022)	5 = Strongly agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly disagree

Variable	Operational Definition	Scale Item	Reference	Likert Scale
Design Innovation Ability	Design Innovation Ability is defined as the comprehensive ability of undergraduate students to generate original, practically valuable design concepts and to effectively transform these concepts into implementable outcomes during their design learning and practice. This ability encompasses idea generation, which refers to the students' capacity to propose novel and feasible design solutions, as well as problem-solving, reflecting their ability to analyze complex design tasks, formulate strategies, and resolve challenges effectively.	**DIA1.** When faced with a problem, I can come up with new design solutions. **DIA2.** I can clearly express my innovative design ideas through sketches, models, or presentations. **DIA3.** I am able to integrate knowledge and ideas from different fields into practical design. **DIA4.** I have the ability to translate innovative design ideas into practical results. **DIA5.** I have confidence in continuously improving my design and innovation capabilities.	Tierney and Farmer (2002); Hocevar (1979); Zhou and George (2001)	5 = Strongly agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly disagree

CHAPTER 3

RESEARCH METHODOLOGY

This chapter focuses on the research methodology as follows:

3.1 Research Design

3.2 Population and Sample

3.3 Research Instrument

3.4 Data Collection

3.5 Data Analysis

3.6 Translation of Research Instruments

3.1 Research Design

This chapter systematically elaborates on the research design, study subjects, sampling methods, research instruments, data collection procedures, and data analysis methods used in this study. A mixed-methods approach, including both quantitative and qualitative research, was adopted to examine the key factors influencing design innovation ability among university design students. The proposed model was subsequently evaluated by experts in terms of propriety, feasibility, and utility.

The study focused on the design innovation ability of design students at universities in Shandong Province, exploring the relationships among these variables through structural equation modeling. Research hypotheses were constructed based on the interactions among variables, and a structured questionnaire was designed to target design students at universities in Shandong Province. The data were analyzed using SPSS and AMOS.

3.1.1 Quantitative Research

The quantitative part of this study aimed to verify the causal relationships among the variables in the conceptual framework through Structural Equation Modeling (SEM), including four independent variables (creative self-efficacy, digital literacy, intrinsic motivation, knowledge sharing), one mediating variable (multimedia-supported instruction), one moderating variable (technology acceptance), and one dependent variable (Design Innovation Ability). The quantitative study used a cross-sectional survey design to test the significance and robustness of the path relationships among variables in a large sample.

The questionnaire was adapted from established validated scales and consisted of six multi-item latent constructs with 30 measurement items, all measured on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). In addition, demographic questions and one categorical item measuring Technology Acceptance were included. After content validity verification by experts using the Index of Item-Objective Congruence (IOC), item analysis, exploratory factor analysis (EFA), and confirmatory factor analysis (CFA), reliability and validity met academic standards. Structural Equation Modeling (SEM) was then used to test the mediating effects, with the moderating effects verified using the interaction-term method and simple-slope analysis (Kline, 2016).

3.1.2 Qualitative Research

Focus group discussions is an effective means of collecting detailed empirical data, particularly suitable for studying rare phenomena retained in respondents' memories. When exploring uncommon phenomena in respondents' recollections, interviews can provide rich research material. This study used focus group discussions to examine core issues in depth, including creative self-efficacy, intrinsic motivation, digital literacy, knowledge sharing, multimedia-supported instruction, and design innovation ability. The research methods were carefully designed to ensure scientific rigor and logical consistency. Focus group discussions is a qualitative research method that collects insights on specific topics through structured discussions with a particular group. This method encourages the gathering of diverse perspectives through interactive dialogues and can yield richer data than individual interviews. The qualitative data were used as supplementary evidence to interpret and contextualize the quantitative findings rather than as an independent theory-building procedure.

The discussions were conducted in a semi-structured format and lasted approximately 90 minutes. The discussion data were analyzed through open coding, axial coding, and selective coding, ultimately summarizing major thematic categories consistent with the quantitative results.

3.2 Population and Sample

3.2.1 Population

The choice of data type and the definition of the population to be studied are crucial components of scientific research, directly affecting the validity of the data and the interpretability of the results. To ensure high external validity, researchers must clearly define the study population and systematically understand the background, behavioral characteristics, and context of the sample before collecting data (Asiamah et al., 2017). The scientific definition of the research population contributes to the representativeness of the data, the generalizability of the results, and the scientific validity of the findings.

This study aimed to explore the design innovation ability of college design students; thus, the target population comprises students enrolled in undergraduate and vocational undergraduate colleges and universities in Shandong Province with design programs. To ensure the sample was representative of the geographic region and type of institution, the study used Stratified Sampling (SS), which divides the total population into several sub-strata with internal similarities and external differences and conducts random sampling within each stratum (Creswell et al., 2011). The specific stratification criteria include two dimensions:

(1) College level: general undergraduate vs. vocational undergraduate;

(2) Geographic region: eastern, central, versus western.

According to this stratification logic, five representative universities were selected as sample institutions: Shandong Normal University, Shandong Vocational and Technical University of Engineering, Dezhou College, Shandong University of Art & Design, and Qingdao University of Science and Technology. These universities represent different institutional types, regional contexts, and design education backgrounds within Shandong Province.

Table 3.1 Demographic Characteristics of Target Institutions

Number	University	Province	Level	Nature
1	Shandong Normal University	Shandong	Undergraduate	Public
2	Shandong Vocational and Technical University of Engineering	Shandong	Undergraduate	private
3	Dezhou College	Shandong	Undergraduate	Public
4	Shandong University of Art & Design	Shandong	Undergraduate	Public
5	Qingdao University of Science and Technology	Shandong	Undergraduate	Public

3.2.2 Sample Size

These universities were selected because they represent different institutional types, regional contexts, and design education backgrounds within Shandong Province. (See Table 3.2).

Table 3.2 Number of Students

Name of Universities	Number of Design Students
Shandong Normal University	726
Shandong Vocational and Technical University of Engineering	1500
Dezhou College	1263
Shandong University of Art & Design	7496
Qingdao University of Science and Technology	1409
Total	12,394

In sample size estimation, the confidence level and margin of error are key parameters that affect the representativeness of the sample and the accuracy of statistical inference. Confidence level refers to the probability that a confidence interval containing the overall parameter will cover the actual parameter in a repeated sampling situation. A commonly used 95% confidence level means that if the sample is repeated 100 times under the same conditions, the confidence interval constructed about 95% of those samples will contain the actual population parameter. Higher confidence levels usually correspond to wider confidence intervals, which increase the reliability of the estimates but may also reduce their precision.

In large-scale social science surveys, controlling sampling error to within 5% is considered an important criterion for achieving reliable results. To ensure that the results are statistically significant and generalizable, the sampling error needs to be scientifically controlled at the research design stage. In addition, Spray and Miller. (1992) pointed out that even under the condition of differences in the distribution of group ability, the use of observation scores as a proxy variable for ability in Differential Item Functioning (DIF) can

still maintain strong detection efficacy with symmetrical overall proportions (e.g., 50% vs. 50%).

To determine the recommended sample size for this study, the calculation requires the following parameters to be explicitly defined: a 95% confidence level, a 5% margin of error, a 50% response rate, and an overall sample size of 12,394. The calculator computes the minimum number of samples required to meet the desired statistical constraints (See Table 3.3).

Table 3.3 Calculation of Student Sample Size

Step	Description	Value
1	Population Size (Total Number of Design Students)	12,394
2	Margin of Error	5%
3	Confidence Level	95%
4	Response Distribution (p)	50%

Parameter setting:

Confidence level 95% (Z=1.96)

Allowable error 5% (e=0.05)

Proportion estimate p=0.5

Design effect: deff=1.10 (after optimization)

Calculation Procedure:

Base sample size (Cochran, 1977):

$$n_0 = \frac{Z^2 \cdot p \cdot (1-p)}{e^2} = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.05)^2} = 384.16 \approx 385$$

Finite aggregate correction (N=12,394):

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

Final recommended sample size: 373 (rounded upwards)

To effectively address missing data due to non-response during the actual survey, researchers typically increase the original sample size during sample size estimation. According to Dillman et al. (2014) recommendation in Internet, Phone, Mail, and Mixed-Mode Surveys: The Tailored Design Method, the sample size should be increased by 10% to 30% from the theoretical value to compensate for the problems caused by sample loss due to failure to contact respondents, refusal to participate, or incomplete questionnaire completion. Similarly, Cochran (1977) emphasized that non-response rates should be taken into account in sample estimation and recommended a moderate upward adjustment of the sample size to ensure that the final adequate sample size obtained meets the requirements of statistical analysis.

The theoretically recommended sample size for this study was calculated to be 373 based on the set confidence level (95%), margin of error (5%), and the overall study population (N = 12,394). In order to increase the actual usability of the sample and reduce

the impact of non-response on the stability of the results, an upward adjustment of 20% was applied, calculated as follows:

$$n_{adjusted} = n \times (1 + Adjust\ the\ scale)$$

$$n_{adjusted} = 373 \times (1 + 0.20)$$

$$n_{adjusted} = 448$$

To maintain the confidence level and estimation precision required by the study, researchers should ensure that the number of survey respondents exceeds the minimum sample size, especially when using data collection methods such as mailed questionnaires or scheduled interviews. The minimum recommended sample size was 373. To reduce the potential impact of non-response and invalid questionnaires, the target sample size was increased by approximately 20%, resulting in a target of about 448 questionnaires. In the actual data collection process, 544 questionnaires were distributed and collected, and 467 valid questionnaires were retained after data screening. Therefore, the final valid sample size exceeded both the minimum recommended sample size and the adjusted target sample size.

3.2.3 Sampling

To further enhance the representativeness of the sample and the precision of statistical inference, this study adopted a proportional sampling strategy to allocate the sample size within strata. Proportional sampling is a technique that allocates samples in proportion to each subgroup's share of the total, ensuring that each stratum's sample proportion corresponds to its actual size in the total (Cochran, 1977). This method is particularly suitable for research contexts with significant group differences, and can effectively reduce sampling bias and improve the validity and stability of the estimated parameter.

In this study, five representative colleges and universities in Shandong Province served as the sample units: Shandong Vocational and Technical University of Engineering, Shandong Normal University, Dezhou College, Shandong University of Art & Design, and Qingdao University of Science and Technology. Based on the number of students enrolled in design majors at each university (totaling 12,394), the sample size was scientifically allocated to ensure that each university's student population was appropriately represented in the final sample, thereby reflecting the structural characteristics of the overall population. By implementing this proportional sampling method, the study ensured balanced representation of students from the five schools, thereby increasing the reliability and generalizability of the findings. (See Table 3.4)

Table 3.4 Proportion of Students in School Design Category

University	Design Student	Percentage	Sample Size
Shandong Normal University	726	5.9%	27
Shandong Vocational and Technical University of Engineering	1500	12.1%	57
Dezhou College	1263	10.2 %	48
Shandong University of Art & Design	7496	60.5%	283

University	Design Student	Percentage	Sample Size
Qingdao University of Science and Technology	1409	11.3%	52
Total	12,394	100%	467

3.2.4 Participant Selection Principles

To ensure data validity and diversity, purposive sampling combined with the principles of maximum variation was used to select eight enrolled design students from a private college in Shandong Province (Shandong Engineering Vocational and Technical College) to form a focus group. The sample composition and inclusion criteria are as follows:

Number and Structure: 8 participants, with group size aligned with the controllability and interactive depth requirements of qualitative research (6–10 participants is optimal).

Grade Variation: Spanning from freshman to senior years (ensuring ≥1 year of design study experience), balancing perspectives from beginners and graduating students.

Gender Representation: At least four females, examining potential gender differences in classroom participation, risk-taking, and feedback preferences.

Major Distribution: Balanced representation across disciplines, including Visual Communication, Environmental Design, Digital Media, etc.

Academic Performance Variation: Includes multiple award winners in innovation design competitions, single award recipients, and non-award winners to examine sources of variation in innovation confidence and strategies.

General Representation: Includes ordinary students who are not labeled to present shared experiences.

All participants signed informed consent forms prior to interviews.

3.3 Research Instrument

3.3.1 Research Instrument's Development

To ensure the validity and reliability of data collection, this study used a structured questionnaire as its primary research tool. The questionnaire design was based on an extensive literature review, theoretical foundations, and established mature scales (Hair et al., 2007). It was appropriately adapted to the research context of design students in Chinese colleges and universities. The questionnaire development and adaptation procedures were informed by the scale development guidelines proposed by DeVellis (2017). Items were adapted from established instruments to fit the context of design education, followed by expert review, pilot testing, and subsequent reliability and validity assessments.

The conceptual framework of this study included four independent variables (creative self-efficacy, digital literacy, intrinsic motivation, and knowledge sharing), one mediating variable (Multimedia-Supported Instruction), one moderating variable (technology acceptance), and one dependent variable, Design Innovation Ability (DIA). Each multi-item construct was measured using items adapted from established empirical scales and standardized to a five-point Likert scale (1 = strongly disagree, 5 = strongly agree) to ensure consistency and comparability across quantitative assessments.

The sources of the questionnaire items for each variable are as follows:

This study employed a conceptual framework that integrates well-established measurement scales and theoretical foundations to examine the determinants of students' design innovation ability.

1) Creative Self-Efficacy Scale (CSE)

The Creative Self-Efficacy (CSE) scale was adapted from Tierney and Farmer (2002) and adjusted to the context of design education. This scale has been widely used in creativity and innovation research and is suitable for measuring individuals' confidence in performing creative tasks. This study further examined the reliability and validity of the adapted scale within the context of design education in Chinese universities.

2) Digital literacy (DL)

Digital literacy (DL) was measured using a scale developed and validated by Hwang et al. (2023). This scale defines digital literacy in the age of artificial intelligence from four dimensions: critical understanding, awareness of the social impact of artificial intelligence, ability to use artificial intelligence technology, and ethical behavior. The original research results showed that the Cronbach's α coefficients for each dimension of the scale were all greater than 0.80, indicating good internal consistency and high reliability (Hwang,et al., 2023).

3) Intrinsic Motivation (IM)

The Intrinsic Motivation (IM) scale was adapted from the Science Motivation Questionnaire II (SMQII) developed by Glynn et al. (2011), used to measure learners' intrinsic drive, interest, and autonomous engagement in tasks. The original SMQII's intrinsic motivation subscale has high reliability, with a Cronbach's alpha coefficient of approximately 0.89; other studies have also reported alpha coefficients between 0.85 and 0.90. This study made appropriate adjustments to the scale based on the designed educational context and will further examine its applicability in the sample of this study.

4) Knowledge Sharing (KS)

The Knowledge Sharing (KS) scale was adapted from the collaborative learning theory of Johnson and Johnson (1999) and related empirical research. It is used to measure students' willingness and behavior to communicate, collaborate, and share design knowledge with peers during the learning process. Several scales developed based on this theory have shown high reliability in different educational contexts, with Cronbach's α coefficients in related research reports typically ranging from 0.80 to 0.90. This study appropriately adjusted the items to suit the characteristics of design courses, in order to test its applicability among design students in Chinese universities.

5) Multimedia-Supported Instruction (MSI)

The mediating variable "Multimedia Support for Instruction" (MSI) scale was adapted from the study of Alam et al. (2022). This scale is used to assess the extent to which teachers use multimedia and digital resources to support student learning in the teaching process. The original scale has shown good reliability and validity in empirical studies. In this study, some items were revised in combination with design education scenarios to test its applicability to design students in Chinese universities.

6) Design Innovation Ability (DIA)

The Design Innovation Ability (DIA) scale was mainly adapted from established measures of creative self-efficacy and creative performance. Specifically, the scale drew on the Creative Self-Efficacy Scale proposed by Tierney and Farmer (2002) and the employee creativity measure developed by Zhou and George (2001). Hocevar's (1979) work on originality and ideational fluency was also considered as a theoretical reference for understanding creative idea generation. These measures have been widely used in creativity and innovation research and are commonly applied to assess individuals' creative confidence, idea generation, creative performance, and innovative output. In this study, the items were adjusted to fit the design education context and to better reflect the learning tasks and innovation performance characteristics of design students in Chinese universities.

7) Technology Acceptance (TA)

Technology Acceptance (TA) was measured using one categorical item that asked whether students were willing to try and accept new technologies in learning and design practice. Responses were coded as 0 = Like to try to accept new technology and 1 = Dislike to try to accept new technology. This variable was used as a moderator in the regression analysis.

To ensure the questionnaire's content validity, a preliminary version was reviewed by five experts in design education and educational psychology. Their feedback was used to refine question wording, ensure consistency across measurement constructs, and remove repetitive or unnecessary items. Afterwards, the study was pretested with 50 design students at a university that did not participate in the primary survey.

The finalized questionnaire contained 30 formal items measuring six multi-item constructs, together with one categorical item measuring Technology Acceptance and six basic demographic questions. The questionnaire served as the basis for data collection for the subsequent quantitative study and as the primary measurement tool for the structural equation modeling (SEM) analysis.

3.3.2 Validity

Content validity is a crucial indicator of whether a research instrument accurately represents the conceptualizations outlined in the research objectives. It focuses on ensuring that each item's content reasonably and accurately reflects the study's focus area. In this study, a questionnaire was created based on the classical scale. Experts in the field were invited to review each item for appropriateness and relevance. The questionnaire's content was examined to ensure thorough coverage of all key concepts and dimensions explicitly presented in the study. Items that were irrelevant or ambiguously stated were avoided to improve the quality of the questionnaire. An index of item-objective congruence (IOC) was used to evaluate the relevance and alignment of each questionnaire item with the study objectives. The IOC includes three score types: +1, 0, and -1, each with a specific meaning:

+1 = the item is clearly consistent with the research objective;

0 = the item is uncertain or needs revision;

-1 = the item is not consistent with the research objective.

$$IOC = \frac{\sum R}{n}$$

where IOC = Index of item-objective congruence value

where ΣR is the sum of expert ratings and n is the number of experts.

Items with an IOC score between 0.00 and 0.59 were not included in the questionnaire. Conversely, items with an IOC score above 0.60 were considered valid (content-validated) items. This approach ensures that only the most appropriate and relevant items are included in the assessment tool, thereby enhancing its content validity.

3.3.3 Reliability Test

Reliability is a crucial indicator of whether a research instrument, such as a questionnaire, produces consistent results over multiple administrations. Cronbach's alpha coefficient (Cronbach's Alpha) is a commonly used method for assessing a scale's internal consistency, inter-item correlations, and measurement reliability. Cronbach's alpha ranges from 0 to 1. When Cronbach's alpha exceeds 0.9, it indicates that the questionnaire has high internal consistency. When $0.8 \leqslant$ Cronbach's Alpha < 0.9, it also signifies high internal consistency. A Cronbach's Alpha between 0.7 and 0.9 estimates good internal consistency. When Cronbach's Alpha is between 0.6 and 0.7, it suggests fair internal consistency that could be improved. If Cronbach's Alpha falls below 0.6, it indicates low internal consistency and the questionnaire needs significant revision.

Reliability refers to the stability and consistency of a measurement device. According to Hair et al. (2019), the current measure of consistency is Cronbach's alpha (See Table 3.5).

Table 3.5 Cronbach's Alpha Coefficient Size Guidelines

Alpha Coefficient Range	Strength of Association
<0.6	Poor
0.6 to <0.7	Moderate
0.7 to <0.8	Good
0.8 to <0.9	Very good
≥0.9	Excellent

3.3.4 Pilot Testing

Pilot testing was conducted to identify potential problems in item wording, questionnaire structure, and administration procedures before the formal survey. Cooper and Schindler (2014) suggest that the sample size should range from 25 to 100 participants.

Table 3.6 Cronbach's Alpha Coefficients

Variable	Number of Items	N	Coefficient of Cronbach's α
Creative Self-Efficacy (CSE)	5	50	0.926
Digital Literacy (DL)	5	50	0.884
Intrinsic Motivation (IM)	5	50	0.892
Knowledge Sharing (KS)	5	50	0.917
Multimedia-Supported Instruction (MSI)	5	50	0.933
Design Innovation Ability (DIA)	5	50	0.924

3.3.5 Focus Group Discussion Outline

A semi-structured discussion outline organized the qualitative component around the seven study variables. The outline included open-ended questions about learning experiences and prompts requesting reasons or specific examples. The full English and Chinese outline is provided in Appendix B.

Creative self-efficacy: participants were asked whether they felt able to demonstrate creativity in design projects, to describe successful design experiences, and to explain how they approached design challenges.

Digital literacy: questions addressed frequently used software, evaluation of online resources, digital ethics, and integration of information from different sources.

Intrinsic motivation: participants discussed the relevance of design learning to their lives, the aspects of projects they found interesting, and their curiosity about emerging trends.

Knowledge sharing: questions explored whether and why students shared ideas, their experiences of helping classmates, and their willingness to exchange knowledge.

Multimedia-supported instruction: participants described the platforms they used, their experiences of accessing resources and interacting with others, and any challenges encountered.

Technology acceptance: questions addressed the ease or difficulty of learning new technologies, their perceived contribution to design learning, and willingness to continue using them.

Design innovation ability: participants described generating novel solutions, integrating ideas across fields, experimenting with materials or techniques, and turning ideas into design outcomes.

Closing questions invited participants to identify the most important influences on their design innovation ability, suggest support that schools or teachers could provide, and raise issues not covered by the questionnaire.

3.4 Data Collection

3.4.1 Ethical Research Procedures

The core ethical concern of this study is protecting the anonymity and privacy of participating students. All collected data, including questionnaire results and demographic information, underwent rigorous coding and de-identification to prevent the leakage of any personally identifiable information. The research team established comprehensive data management standards, and all raw materials are stored in an encrypted system, accessible only to authorized researchers. By ensuring a complete anonymity protection mechanism, this study aimed to create a safe and trustworthy communication environment, enabling students to honestly share their true perspectives and thereby obtain more valuable research information.

In ethical practice, respecting participants' autonomy and informed consent are paramount principles. Before student participation, a clear research briefing was provided, including the research objectives, procedures, potential risks, and benefits, ensuring participants join voluntarily with full knowledge. Students were explicitly informed that their

participation is entirely voluntary and that they could withdraw unconditionally at any stage of the research without incurring any adverse consequences.

Throughout the research process, the research team strictly adhered to ethical guidelines in educational research, upholding the principles of transparency, fairness, and integrity. Any potential conflicts of interest were clearly explained, and the research objectives, methods, and findings were fully disclosed to relevant stakeholders. By implementing these ethical principles, this research not only ensured the protection of the rights and dignity of participating students but also laid a solid foundation for generating genuine and reliable academic insights.

3.4.2 Data Collection Procedures

The data collection process for this study consisted of two phases: a quantitative questionnaire survey and a subsequent focus group interview phase.

In the first phase, quantitative data were collected through structured questionnaires distributed online via Questionnaire Star and paper questionnaires.

The adjusted target sample size was approximately 448 participants after accounting for potential non-response. In the actual survey, 467 valid questionnaires were retained after data screening. Stratified proportional sampling was used in the questionnaire survey to ensure adequate representation of students from different levels of higher education and regions.

The questionnaire was distributed officially through both online and offline methods. During distribution, the principle of proportional stratified random sampling was strictly adhered to, and the number of questionnaires allocated was based on the proportion of students majoring in design in each school to ensure the sample was representative. All collected data were screened for missing values and invalid questionnaires, and those with missing data or deemed invalid were excluded before being entered and analyzed.

In the second phase, to further interpret the quantitative results and gain a deeper understanding of students' real-world experiences regarding creative self-efficacy, digital literacy, multimedia-supported instruction, knowledge sharing, and design innovation capabilities, focus group discussions were conducted following the questionnaire analysis. Discussions included understanding of learning experiences, design task challenges, use of digital tools, support for instructional media, and the development of innovation capabilities. Interviews were conducted with written and verbal consent, and recordings were permitted for transcription and subsequent coding analysis. The recordings were used solely for research purposes and were strictly confidential and anonymized.

3.5 Data Analysis

3.5.1 Quantitative Data Analysis

A mixed-methods research design was employed to gather quantitative data through questionnaires. Following data collection and initial sorting, three types of analyses were performed: (1) variable effects analysis, (2) mediation effects analysis, and (3) moderated statistical analysis, reliability analysis, validity analysis, CFA, SEM, bootstrapping mediation analysis, and moderation regression analysis were conducted.

3.5.2 Qualitative Data Analysis

The qualitative data were collected through focus group discussions with eight design-related university students. The discussions were conducted with participants' consent, recorded, and transcribed for analysis.

The data were analyzed using **NVivo 14** through open coding, axial coding, and topic classification. Word clouds and code-document matrices were also used to identify key themes and patterns. The qualitative findings were compared with the quantitative results to provide contextual interpretation and triangulation.

3.5.3 Hypothesis Testing

The link between the β -value and parameters in structural equation modeling (SEM) is essential for confirming the validity of research hypotheses. SEM enables researchers to analyze complex relationships among multiple variables simultaneously, thereby exploring causal connections between observable and latent variables. SEM estimates both direct and indirect effects using model estimates and path analysis. Various fit indices, such as the Chi-square test, the Root Mean Square Error Approximation (RMSEA), and the Comparative Fit Index (CFI), were employed to evaluate how well the model fits the data. SEM combines causal, measurement, and structural modeling into a single analytical framework, supporting thorough data analysis and hypothesis testing. As Preacher et al. (2010) noted, this method helps researchers draw evidence-based conclusions, test hypotheses, and enhance the explanatory power of data using solid scientific reasoning.

3.6 Translation of Research Instruments

The original questionnaire items were developed in English and then translated into Chinese for data collection. In cross-cultural research, translation is crucial for maintaining the integrity of questionnaire content and making it relevant to the target audience. This study employed reverse translation, a method widely considered a key means of preserving the original meaning of questionnaire items (Brislin, 1970). In cross-cultural survey research, questionnaire translation requires attention to linguistic clarity, conceptual equivalence, and cultural appropriateness (Harkness, 2003). thereby enhancing the reliability and validity of data collection (Behr, 2017).

The questionnaire in this study was translated by two English teachers, both of whom held English translation certificates. One teacher translated the English questionnaire into Chinese, while the other translated the Chinese version back into English to ensure semantic consistency between the two versions. Before the questionnaire was administered, the Chinese version was reviewed to ensure that participants could accurately understand the meaning of each item. The back-translated English version was then compared with the original English version to verify translation accuracy.

CHAPTER 4

RESEARCH RESULTS

This chapter primarily focuses on the analysis of collected data, encompassing 3 sections:

4.1 Quantitative statistical analysis

4.2 Qualitative Analysis

4.3 Research Findings Validation

This study collected quantitative data simultaneously using Wenjuanxing (WJX), an online survey platform widely used in academic research at Chinese universities, and paper questionnaires, distributing and collecting a total of 544 questionnaires. During the data cleaning phase, the research team removed incomplete questionnaires, duplicate submissions, questionnaires with a response time of less than 90 seconds, and invalid samples from paper questionnaires with missing answers or completely identical options. Ultimately, 467 valid questionnaires were obtained, representing a validity rate of 85.8%. This rigorous data screening process ensured the quality, validity, and overall completeness of the data.

Qualitative data came from focus group discussions, aiming to further explore the experiences, perceptions, and behaviors of design-related university students during their learning process, thereby providing contextual supplementation and interpretation to the quantitative results. Discussions were conducted with the participants' consent, and the researcher recorded and transcribed the discussions in real time to ensure the accuracy and completeness of the information. All qualitative data were imported into NVivo 14 software for systematic analysis. Core topics were generated through open coding, axial coding, and topic classification. Word clouds and code-document matrices were used to perform triangulation across data sources, enhancing the reliability and robustness of the analysis.

4.1 Quantitative Statistical Analysis

4.1.1 Sample's Demographic Characteristics

Involves a thorough description and examination of demographic characteristics within a research sample. This process helps researchers better understand participant diversity, ensure the sample is representative, select appropriate statistical models, and interpret findings more accurately.

Table 4.1 Sample Demographic Characteristics

Variable	Option	Frequency	Percent (%)
Gender	Male	178	38.12
	Female	289	61.88
Grade Level	First year	107	22.91
	Sophomore year	135	28.91
	Third year	135	28.91
	Fourth year	90	19.27

Variable	Option	Frequency	Percent (%)
Learning Platform	Super Star Learning	312	66.81
	Tencent Meeting（assist）	155	33.19
Technology Adoption	I like to try to accept new technology	345	73.88
	Dislike to try to accept new technology	122	26.12
Your major	Design majors	467	100
	Non-design majors	0	0
University	Shandong Normal University	27	5.78
	Shandong Vocational and Technical University of Engineering	57	12.21
	Dezhou College	48	10.28
	Shandong University of Art & Design	283	60.6
	Qingdao University of Science and Technology	52	11.13
Total		467	100

Table 4.1 provides a detailed explanation and analysis of the demographic features of the sample, aiming to enhance data understanding, assist in choosing the right model, and enable effective forecasting and analysis. Descriptive statistical analysis of basic information shows that female students in arts programs at Shandong universities outnumber males, making up 61.88% of the total, while males account for 38.12%. Regarding the academic year, 28.91% of respondents were in their second and third year. Over 60% preferred the "Super star learning" as the primary learning platform, with Tencent Meeting accounted for 33.19%. On technology acceptance, 73.88% of respondents expressed willingness to try new technologies. All respondents (467 individuals) were design students, representing 100% of the sample. Among them, 283 students were from Shandong University of Art & Design, constituting 60.60% of the total.

Table 4.2 Descriptive Statistics of Variables

Item	Min	Max	Mean	SD
CSE1	1	5	3.238	1.107
CSE2	1	5	3.576	1.021
CSE3	1	5	3.505	1.003
CSE4	1	5	3.422	1.066
CSE5	1	5	3.338	1.152
Creative Self-Efficacy	1.4	5	3.416	0.878
DL1	1	5	3.567	0.977
DL2	1	5	3.332	1.050
DL3	1	5	3.58	1.052
DL4	1	5	3.373	1.066
DL5	1	5	3.313	1.073

Item	Min	Max	Mean	SD
Digital Literacy	1.2	5	3.433	0.866
IM1	1	5	3.505	1.073
IM2	1	5	3.218	1.144
IM3	1	5	3.448	0.978
IM4	1	5	3.390	1.012
IM5	1	5	3.242	1.151
Intrinsic Motivation (IM)	1.2	5	3.361	0.896
KS1	1	5	3.544	0.942
KS2	1	5	3.559	1.033
KS3	1	5	3.557	1.012
KS4	1	5	3.321	1.029
KS5	1	5	3.572	0.981
Knowledge Sharing	1	5	3.510	0.832
MSI1	1	5	3.572	1.015
MSI2	1	5	3.542	0.969
MSI3	1	5	3.514	1.024
MSI4	1	5	3.514	1.083
MSI5	1	5	3.636	1.108
Multimedia-Supported Instruction	1.2	5	3.555	0.837
DIA1	1	5	3.285	1.078
DIA2	1	5	3.315	1.077
DIA3	1	5	3.340	1.016
DIA4	1	5	3.411	0.999
DIA5	1	5	3.272	1.112
Design Innovation Ability	1.2	5	3.325	0.900

As shown in Table 4.2, the descriptive statistics present the minimum, maximum, mean, and standard deviation of each measurement item and construct. The mean scores of the six core constructs ranged from 3.325 to 3.555, indicating that respondents generally reported moderate to relatively high levels of Creative Self-Efficacy, Digital Literacy, Intrinsic Motivation, Knowledge Sharing, Multimedia-Supported Instruction, and Design Innovation Ability. The standard deviations ranged from 0.832 to 0.900, suggesting acceptable variation among respondents' perceptions.

Table 4.3 Analysis of Differences in Model Variables Across Genders

Variable	Category	Sample size	Mean	SD	t	df	Sig.
CSE	Male	178	3.54	0.84	2.486	465	0.013*
	Female	289	3.34	0.89			
DL	Male	178	3.56	0.8	2.582	406.035	0.010*
	Female	289	3.35	0.9			
IM	Male	178	3.47	0.88	2.006	465	0.045*
	Female	289	3.3	0.9			
KS	Male	178	3.57	0.83	1.275	465	0.203
	Female	289	3.47	0.84			
MSI	Male	178	3.66	0.76	2.162	413.085	0.031*
	Female	289	3.49	0.87			

Variable	Category	Sample size	Mean	SD	t	df	Sig.
DIA	Male	178	3.53	0.85	3.846	465	0.000**
	Female	289	3.20	0.91			

As shown in Table 4.3, an independent-samples t-test was conducted to examine gender differences in CSE, DL, IM, KS, MSI, and DIA. The results showed that no significant gender difference was found in KS ($p > 0.05$), whereas significant gender differences were observed in CSE, DL, IM, MSI, and DIA ($p < 0.05$). Specifically, male students reported higher mean scores than female students on CSE, DL, IM, MSI, and DIA.

Table 4.4 Analysis of Differences in Model Variables Across Grade Levels

Variable	Category	Sample size	Mean	SD	t	df
CSE	First year	107	3.24	0.91	3.123	0.026*
	Sophomore year	135	3.41	0.92		
	Third year	135	3.43	0.87		
	Fourth year	90	3.62	0.75		
DL	First year	107	3.24	0.88	3.435	0.017*
	Sophomore year	135	3.48	0.91		
	Third year	135	3.41	0.84		
	Fourth year	90	3.62	0.79		
IM	First year	107	3.03	0.85	7.03	0.000**
	Sophomore year	135	3.43	0.92		
	Third year	135	3.43	0.91		
	Fourth year	90	3.55	0.80		
KS	First year	107	3.38	0.84	2.973	0.031*
	Sophomore year	135	3.44	0.86		
	Third year	135	3.56	0.82		
	Fourth year	90	3.70	0.77		
MSI	First year	107	3.52	0.90	1.919	0.126
	Sophomore year	135	3.49	0.84		
	Third year	135	3.53	0.83		
	Fourth year	90	3.74	0.76		
DIA	First year	107	3.08	0.88	4.118	0.007**
	Sophomore year	135	3.32	0.90		
	Third year	135	3.45	0.91		
	Fourth year	90	3.45	0.86		

As shown in Table 4.4, a one-way ANOVA was conducted to examine Grade-Level differences in CSE, DL, IM, KS, MSI, and DIA. The results indicate that Grade Level samples showed no significant difference in MSI ($p>0.05$), while statistically significant differences were observed for CSE, DL, IM, KS, and DIA ($p<0.05$). Detailed analysis reveals: Grade Level was significantly different at the 0.05 level for CSE ($F=3.123$, $p=0.026$), with the most notable difference between "Fourth year" and "Freshman year." Similarly, Grade Level showed significance at the 0.05 level for DL ($F=3.435$, $p=0.017$), with significant differences between "Sophomore year" and "Freshman year," and between "Fourth year" and "Freshman year." Grade Level demonstrated significance at the 0.01 level for IM ($F=7.030$, $p=0.000$). Comparative analysis revealed apparent group differences, with average scores indicating "Sophomore year > Freshman year," "Third year > Freshman year," and "Fourth year > Freshman year." For KS, Grade Level was significant at the 0.05 level ($F=2.973$, $p=0.031$), with results showing "Fourth year > Freshman year" and "Fourth year > Sophomore year." Regarding DIA, Grade Level achieved significance at the 0.01 level ($F=4.118$, $p=0.007$), with the key differences being "Sophomore year > Freshman year," "Third year > Freshman year," and "Fourth year > Freshman year."

Table 4.5 Analysis of Differences in Model Variables Across Learning Platforms

Variable	Category	Sample size	Mean	SD	t	df	Sig.
CSE	Super star learning	312	3.48	0.85	2.254	465	0.025*
	Tencent Conference	155	3.29	0.92			
DL	Super star learning	312	3.52	0.84	3.012	465	0.003**
	Tencent Conference	155	3.26	0.89			
IM	Super star learning	312	3.45	0.87	3.108	465	0.002**
	Tencent Conference	155	3.18	0.92			
KS	Super star learning	312	3.58	0.8	2.581	465	0.010*
	Tencent Conference	155	3.37	0.88			
MSI	Super star learning	312	3.63	0.78	2.485	264.771	0.014*
	Tencent Conference	155	3.41	0.93			
DIA	Super star learning	312	3.39	0.89	2.294	465	0.022*
	Tencent Conference	155	3.19	0.91			

Table 4.5 shows that the independent-samples t-test was used to compare differences between Learning Platforms in CSE, DL, IM, KS, MSI, and DIA. The results indicate significant differences ($p<0.05$) across all Learning Platform for these measures. A detailed analysis reveals that the Learning Platform shows significance at the 0.05 level for CSE ($t=2.254$, $p=0.025$), with the Super star learning averaging 3.48, which is significantly higher than Tencent Conference's 3.29. For DL, significance is at the 0.01 level ($t=3.012$, $p=0.003$). The Super star learning 's average of 3.52 is significantly higher than Tencent Conference's 3.26. Similarly, IM demonstrates significance at the 0.01 level ($t=3.108$, $p=0.002$), with Super star learning 's 3.45 notably surpassing Tencent Conference's 3.18. The Learning Platform shows significance at the 0.05 level for KS ($t=2.581$, $p=0.010$), with the Super star learning 's average score of 3.58 being significantly higher than Tencent Conference's 3.37. For MSI, the Learning Platform is significant at the 0.05 level ($t=2.485$, $p=0.014$), with the Super star learning 's average score of 3.63 significantly exceeding Tencent Conference's 3.41. Regarding DIA, the Learning Platform achieves significance at the 0.05 level ($t=2.294$, $p=0.022$), with the Super star learning 's average score of 3.39 surpassing Tencent Conference's 3.19.

Table 4.6 Analysis of Differences in Model Variables Across Technology Acceptance Levels

Variable	Category	Sample size	Mean	SD	t	df	Sig.
CSE	I like to try to accept new technology	345	3.46	0.84	1.734	187.245	0.085
	Dislike to try to accept new technology	122	3.29	0.98			
DL	I like to try to accept new technology	345	3.49	0.83	2.141	191.352	0.034*
	Dislike to try to accept new technology	122	3.28	0.94			
IM	I like to try to accept new technology	345	3.45	0.86	3.471	465	0.001**
	Dislike to try to accept new technology	122	3.12	0.95			
KS	I like to try to accept new technology	345	3.55	0.78	1.461	181.432	0.146
	Dislike to try to accept new technology	122	3.41	0.96			

Variable	Category	Sample size	Mean	SD	t	df	Sig.
MSI	I like to try to accept new technology	345	3.61	0.78	2.295	181.224	0.023*
	Dislike to try to accept new technology	122	3.39	0.96			
DIA	I like to try to accept new technology	345	3.40	0.86	3.166	465	0.002**
	Dislike to try to accept new technology	122	3.10	0.97			

As shown in Table 4.6, an independent-samples t-test was used to examine differences in Technology Acceptance (TAE) among CSE, DL, IM, KS, MSI, and DIA. The results indicate that TAE showed no significant difference in CSE and KS ($p>0.05$), while significant differences were observed for DL, IM, MSI, and DIA ($p<0.05$). A detailed analysis reveals a 0.05-level significance for TAE on DL ($t=2.141$, $p=0.034$). Specifically, the average score for "Like trying to accept new technology" (3.49) significantly exceeds that of "Dislike trying to accept new technology" (3.28). Technology Acceptance showed a 0.01-level significance for IM ($t=3.471$, $p=0.001$). The comparison revealed that the average score of "Like trying to accept new technology" (3.45) was significantly higher than that of "Dislike trying to accept new technology" (3.12). For MSI, Technology Acceptance demonstrated 0.05-level significance ($t=2.295$, $p=0.023$), with the average score of "Like trying to accept new technology" (3.61) notably exceeding that of "Dislike trying to accept new technology" (3.39). Regarding DIA, Technology Acceptance exhibited 0.01-level significance ($t=3.166$, $p=0.002$), where the average score of "Like trying to accept new technology" (3.40) was substantially higher than that of "Dislike trying to accept new technology" (3.10).

Table 4.7 Analysis of Variance in Model Variables Across Schools

Variable	Category	Sample size	Mean	SD	F	p
CSE	Shandong Normal University	27	3.67	0.76	2.864	0.023*
	Shandong Vocational and Technical University of Engineering	57	3.39	0.94		
	Dezhou College	48	3.08	0.88		
	Shandong University of Art & Design	283	3.42	0.86		
	Qingdao University of Science and Technology	52	3.59	0.92		

Variable	Category	Sample size	Mean	SD	F	p
DL	Shandong Normal University	27	3.31	0.80	3.275	0.012*
	Shandong Vocational and Technical University of Engineering	57	3.40	0.84		
	Dezhou College	48	3.04	0.85		
	Shandong University of Art & Design	283	3.5	0.88		
	Qingdao University of Science and Technology	52	3.54	0.81		
IM	Shandong Normal University	27	3.49	0.79	1.900	0.109
	Shandong Vocational and Technical University of Engineering	57	3.21	0.92		
	Dezhou College	48	3.10	0.91		
	Shandong University of Art & Design	283	3.41	0.89		
	Qingdao University of Science and Technology	52	3.45	0.94		
KS	Shandong Normal University	27	3.81	0.74	3.946	0.004**
	Shandong Vocational and Technical University of Engineering	57	3.4	0.85		
	Dezhou College	48	3.17	0.85		
	Shandong University of Art & Design	283	3.52	0.80		
	Qingdao University of Science and Technology	52	3.72	0.84		
MSI	Shandong Normal University	27	3.31	0.79	2.238	0.064
	Shandong Vocational and Technical University of Engineering	57	3.49	0.87		
	Dezhou College	48	3.32	0.93		
	Shandong University of Art & Design	283	3.61	0.81		
	Qingdao University of Science and Technology	52	3.69	0.84		
DIA	Shandong Normal University	27	3.59	0.84	4.100	0.003**
	Shandong Vocational and Technical University of Engineering	57	3.13	0.88		

Variable	Category	Sample size	Mean	SD	F	p
	Dezhou College	48	2.95	0.90		
	Shandong University of Art & Design	283	3.37	0.89		
	Qingdao University of Science and Technology	52	3.50	0.89		

As shown in Table 4.7, a one-way ANOVA was conducted to examine differences among universities in CSE, DL, IM, KS, MSI, and DIA. The results indicated that no statistically significant differences were found for IM and MSI ($p > 0.05$). However, significant differences were observed for CSE ($F = 2.864$, $p = 0.023$), DL ($F = 3.275$, $p = 0.012$), KS ($F = 3.946$, $p = 0.004$), and DIA ($F = 4.100$, $p = 0.003$). These findings suggest that students from different universities showed varying levels of Creative Self-Efficacy, Digital Literacy, Knowledge Sharing, and Design Innovation Ability.

The Qingdao University of Science and Technology showed a significant effect at the 0.05 level for CSE ($F=2.864$, $p=0.023$). The specific comparison results showed that the average value scores of groups with more obvious differences were "Shandong Normal University> Dezhou College; Shandong University of Art & Design> Dezhou College; Qingdao University of Science and Technology> Dezhou College".

The univariate analysis showed a p-value of 0.05 for DL ($F=3.275$, $p=0.012$). The specific comparison results revealed that the average scores of the groups with significant differences were "Shandong Vocational and Technical University of Engineering > Dezhou College; Shandong University of Art & Design > Dezhou College; Qingdao University of Science and Technology > Dezhou College."

The Qingdao University of Science and Technology showed significant differences at the 0.01 level for KS ($F=3.946$, $p=0.004$). Specific comparison results indicate that the mean scores of groups with relatively pronounced differences were as follows:

“Shandong Normal University>Shandong Vocational and Technical University of Engineering; Shandong Normal University>Dezhou College; Qingdao University of Science and Technology>Shandong Vocational and Technical University of Engineering; Shandong University of Art & Design>Dezhou College; Qingdao University of Science and Technology>Dezhou College”。

The Qingdao University of Science and Technology showed significant differences at the 0.01 level for DIA ($F=4.100$, $p=0.003$). Specific comparison results indicate that the mean scores of groups with relatively pronounced differences were as follows:

Shandong Normal University > Shandong Vocational and Technical University of Engineering; Shandong Normal University > Dezhou College; Qingdao University of Science and Technology > Shandong Vocational and Technical University of Engineering; Shandong University of Art & Design > Dezhou College; Qingdao University of Science and Technology > Dezhou College.

4.1.2 Descriptive Statistics of Variables

4.1.2.1 Reliability Analysis

Reliability analysis evaluates the stability and internal consistency of measurement results. In this study, Cronbach ’ s alpha and corrected item-total correlation (CITC) were used to assess the reliability of the questionnaire. In social science research, a Cronbach’s alpha coefficient above 0.70 is generally considered acceptable, while values above 0.80 indicate good internal consistency.

Table 4.8 Reliability Analysis

No. of Items	N	Cronbach's Alpha
30	467	0.939

According to Table 4.8, the questionnaire's overall Cronbach's α exceeds 0.7, indicating that the research data are highly reliable and of high quality and can be used for further analysis.

Table 4.9 Scale Reliability Analysis Results

Variable	No. of Items	N	Cronbach Alpha
Creative Self-Efficacy (CSE)	5	467	0.878
Digital Literacy (DL)	5	467	0.887
Intrinsic Motivation (IM)	5	467	0.891
Knowledge Sharing (KS)	5	467	0.889
Multimedia-Supported Instruction (MSI)	5	467	0.863
Design Innovation Ability (DIA)	5	467	0.905

As shown in Table 4.9, the Cronbach's alpha coefficients for all dimensions exceed 0.8, indicating that the research data possesses high reliability and is suitable for further analysis.

4.1.2.2 Reliability Analysis of Each Construct

Creative Self-Efficacy（CSE）

This study conducted Cronbach's alpha and CITC coefficient tests on the data obtained and performed item-deletion Cronbach's alpha tests for each item. The CITC coefficient assesses item discrimination. Cronbach's alpha should be above 0.7, and the CITC coefficient should exceed 0.5 to meet internal consistency and reliability standards. The results in Table 4.10 show that all CSE scale items had CITC coefficients above 0.5, with Cronbach's alpha reaching 0.878—well above 0.7. The analysis indicates that removing any single item would reduce the Cronbach's alpha below the overall scale value. This confirms that all items meet the necessary criteria and contribute to improving the scale's reliability. As a result, the reliability of the Creative Self-Efficacy (CSE) scale has been effectively enhanced.

Table 4.10 Creative Self-Efficacy (CSE) Reliability Analysis

Variable	Item	Corrected Item-Total Correlation (CITC)	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Creative Self-Efficacy（CSE）	CSE1	0.694	0.856	0.878
	CSE2	0.676	0.860	
	CSE3	0.712	0.852	
	CSE4	0.727	0.848	
	CSE5	0.742	0.844	

Digital Literacy (DL)

According to Table 4.11, the CITC value for each item in DL was above 0.5. Removing any one item would lower the Cronbach's alpha coefficients to 0.866, 0.862, 0.858, 0.860, and 0.865, respectively—all below the benchmark of 0.887. A Cronbach's alpha above 0.7 shows that the item meets requirements and helps improve the scale's reliability.

Table 4.11 Digital Literacy (DL) Scale Reliability Analysis

Variable	Item	Corrected Item-Total Correlation (CITC)	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Digital Literacy (DL)	DL1	0.709	0.866	0.887
	DL2	0.724	0.862	
	DL3	0.745	0.858	
	DL4	0.736	0.860	
	DL5	0.716	0.865	

Intrinsic Motivation (IM)

The data analysis results for Intrinsic Motivation (IM) are as follows: According to the analysis data in Table 4.12, the CITC coefficients for all items in this scale exceed 0.5. At the same time, the Cronbach's alpha coefficients after deleting each item are 0.873, 0.866, 0.873, 0.863, and 0.862, respectively, all below the original benchmark of 0.891. All Cronbach's alpha coefficients are above 0.7, indicating that each item meets the requirements and effectively improves the scale's reliability. Therefore, the data in this study are highly reliable.

Table 4.12 Intrinsic Motivation (IM) Scale Reliability Analysis

Variable	Item	Corrected Item-Total Correlation (CITC)	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Intrinsic Motivation (IM)	IM1	0.708	0.873	0.891
	IM2	0.745	0.866	
	IM3	0.710	0.873	
	IM4	0.759	0.863	
	IM5	0.758	0.862	

Knowledge Sharing (KS)

The data analysis results for Knowledge Sharing (KS) are as follows: According to the reliability analysis results in Table 4.13, the CITC coefficients for all items in this scale exceed 0.5. At the same time, the Cronbach's alpha coefficients after removing each item were 0.866, 0.861, 0.863, 0.873, and 0.862, respectively, all below the original benchmark value of 0.889. All Cronbach's alpha coefficients exceeded 0.7, indicating that each item meets the requirements and effectively improves the scale's reliability. Therefore, the data in this study are highly reliable.

Table 4.13 Knowledge Sharing (KS) Scale Reliability Analysis

Variable	Item	Corrected Item-Total Correlation (CITC)	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Knowledge Sharing (KS)	KS1	0.729	0.866	0.889
	KS2	0.746	0.861	
	KS3	0.740	0.863	
	KS4	0.694	0.873	
	KS5	0.745	0.862	

Multimedia-Supported Instruction（MSI）

The data analysis results for Multimedia-Supported Instruction (MSI) are as follows: According to the analysis data in Table 4.14, the CITC coefficients for all items on this scale exceed 0.5. At the same time, the Cronbach's alpha coefficients after deleting each item are 0.837, 0.831, 0.829, 0.832, and 0.846, respectively, all below the original benchmark value of 0.863. All Cronbach's alpha coefficients are above 0.7, indicating that each item meets the requirements and effectively improves the scale's reliability. Therefore, the data in this study are highly reliable.

Table 4.14 Multimedia-Supported Instruction (MSI) Scale Reliability Analysis

Variable	Item	Corrected Item-Total Correlation (CITC)	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Multimedia-Supported Instruction (MSI)	MSI1	0.675	0.837	0.863
	MSI2	0.704	0.831	
	MSI3	0.705	0.829	
	MSI4	0.695	0.832	
	MSI5	0.644	0.846	

Design Innovation Ability（DIA）

The data analysis results for Design Innovation Ability (DIA) are as follows: According to the analysis data in Table 4.15, the CITC coefficients for all items in this scale exceed 0.5. At the same time, the Cronbach's alpha coefficients after deleting each item were 0.882, 0.887, 0.888, 0.885, and 0.880, respectively, all below the original benchmark value of 0.905. All Cronbach's alpha coefficients exceeded 0.7, indicating that each item meets the requirements and effectively improves the scale's reliability. Therefore, the data in this study are highly reliable.

Table 4.15 Design Innovation Ability (DIA) Scale Reliability Analysis

Variable	Item	Corrected Item-Total Correlation (CITC)	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Design Innovation Ability (DIA)	DIA1	0.773	0.882	0.905
	DIA2	0.751	0.887	
	DIA3	0.746	0.888	
	DIA4	0.759	0.885	
	DIA5	0.784	0.880	

4.1.3 Confirmatory Factor Analysis

4.1.3.1 Model Diagram

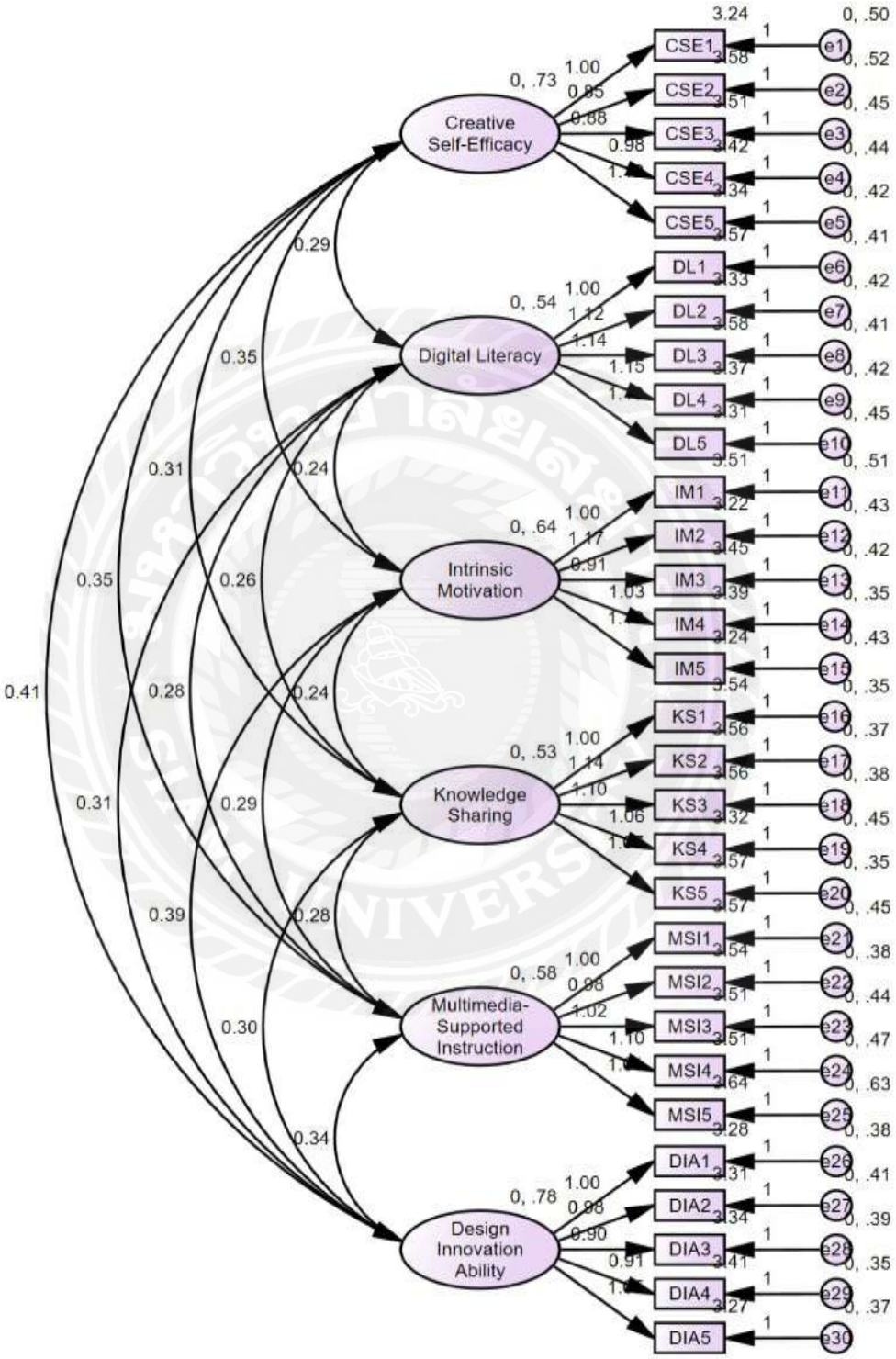


Figure 4.1 Confirmatory Factor Analysis of Variables

4.1.3.2 Model Fitting Index

In constructing structural equation models, the first step is to assess model fit to determine whether the model accurately describes the relationships between observed and latent variables. Evaluating model fit is a complex process because different indices highlight different aspects. Therefore, it is generally recommended to use multiple metrics instead of a single criterion when assessing model quality. This study evaluates model fit using three main indicators: absolute fit indices (χ^2/df, Root Mean Square Error, RMSEA, Goodness-of-Fit Index, GFI, Adjusted Goodness-of-Fit Index, AGFI), relative fit indices (Norm Fit Index, NFI, Incremental Fit Index, IFI), and Tucker-Lewis Index (TLI).

Table 4.16 Measurement Model Fit Indices

Index	Acceptable Value	Statistical value	Fit condition
CMIN	-	552.377	-
DF	-	390	-
CMIN/DF	<3	1.416	Good
GFI	>0.90	0.926	Good
AGFI	>0.90	0.912	Good
RMSEA	<0.08	0.030	Good
NFI	>0.90	0.935	Good
IFI	>0.90	0.980	Good
（TLI）NNFI	>0.90	0.978	Good
CFI	>0.90	0.980	Good

Table 4.16 shows that the x^2/df value is 1.416 (below 3), and the RMSEA is 0.030 (below the standard threshold of 0.08), indicating good model fit. The GFI (0.926), AGFI (0.912), NFI (0.935), IFI (0.980), TLI/NNFI (0.978), and CFI (0.980) all meet high standards. All goodness-of-fit metrics conform to accepted criteria, confirming the model's strong fit.

4.1.3.3 Convergent validity

Composite Reliability (CR) was used to evaluate the internal consistency of each latent construct, while Average Variance Extracted (AVE) was used to assess convergent validity. In general, CR values above 0.70 and AVE values above 0.50 indicate acceptable convergent validity. As shown in Table 4.17, all CR values exceeded 0.70 and all AVE values exceeded 0.50, indicating good convergent validity.

Table 4.17 Factor Load Coefficients

Variable	Item	Non-standard load factor	S.E.	C.R.	P	Standardized load coefficient	CR	AVE
Creative Self-Efficacy (CSE)	CSE1	1				0.771	0.877	0.589
	CSE2	0.850	0.055	15.425	***	0.710		
	CSE3	0.875	0.054	16.270	***	0.744		
	CSE4	0.977	0.057	17.196	***	0.782		
	CSE5	1.119	0.061	18.317	***	0.828		

Variable	Item	Non-standard load factor	S.E.	C.R.	P	Standardized load coefficient	CR	AVE
Digital Literacy (DL)	DL1	1				0.754	0.887	0.611
	DL2	1.123	0.066	16.952	***	0.788		
	DL3	1.136	0.066	17.115	***	0.795		
	DL4	1.148	0.067	17.077	***	0.793		
	DL5	1.133	0.068	16.717	***	0.777		
Intrinsic Motivation (IM)	IM1	1				0.746	0.892	0.623
	IM2	1.167	0.067	17.541	***	0.817		
	IM3	0.912	0.057	15.943	***	0.746		
	IM4	1.026	0.059	17.424	***	0.811		
	IM5	1.183	0.067	17.673	***	0.823		
Knowledge Sharing (KS)	KS1	1				0.777	0.890	0.618
	KS2	1.138	0.063	18.13	***	0.807		
	KS3	1.096	0.062	17.767	***	0.793		
	KS4	1.063	0.063	16.811	***	0.756		
	KS5	1.068	0.06	17.877	***	0.797		
Multimedia-Supported Instruction (MSI)	MSI1	1				0.748	0.865	0.562
	MSI2	0.984	0.061	16.118	***	0.771		
	MSI3	1.024	0.065	15.867	***	0.759		
	MSI4	1.100	0.068	16.117	***	0.771		
	MSI5	1.013	0.070	14.458	***	0.694		
Design Innovation Ability (DIA)	DIA1	1				0.821	0.906	0.657
	DIA2	0.980	0.049	19.834	***	0.805		
	DIA3	0.903	0.047	19.219	***	0.787		
	DIA4	0.909	0.046	19.858	***	0.805		
	DIA5	1.050	0.050	20.901	***	0.836		

Table 4.17 shows that all AVE values are greater than 0.5 and all CR values are greater than 0.7, indicating that the questionnaire's structural model has good convergent validity.

4.1.3.4 Discriminant Validity

Discriminant validity was assessed by comparing the square root of the AVE for each construct with the correlations among constructs. If the square root of AVE is greater than the corresponding inter-construct correlations, discriminant validity is supported. The rationale is that each dimension has an AVE value and correlates with other dimensions. If the square root of the AVE for a factor exceeds the inter-factor correlation coefficient, it indicates strong discriminant validity.

Table 4.18 Discriminant Validity

	Creative Self-Efficacy	Digital Literacy	Intrinsic Motivation (IM)	Knowledge Sharing	Multimedia-Supported Instruction	Design Innovation Ability
Creative Self-Efficacy	**0.768**					
Digital Literacy	0.402**	**0.781**				
Intrinsic Motivation (IM)	0.536**	0.366**	**0.789**			
Knowledge Sharing	0.437**	0.430**	0.366**	**0.786**		
Multimedia-Supported Instruction	0.459**	0.445**	0.414**	0.449**	**0.749**	
Design Innovation Ability	0.475**	0.423**	0.484**	0.430**	0.442**	**0.811**

Note: Diagonal black bold numbers are AVE square root values

Table 4.18 presents the analysis for discriminant validity. The fact that the square root of the average variance extracted (AVE) for each factor exceeds the maximum absolute value of the inter-factor correlation coefficients indicates that the model possesses good discriminant validity.

4.1.3.5 Correlation Analysis

Correlation analysis involved describing and examining the strength and nature of the relationship between two or more variables. An asterisk (*) in the upper right corner of the correlation coefficient shows that a relationship exists; if it is absent, there is no relationship. A correlation coefficient greater than 0 indicates a positive relationship between the two variables, while a value less than 0 signals a negative relationship.

Table 4.19 Pearson Correlation

	CSE	DL	IM	KS	MSI	DIA
CSE	1					
DL	0.402**	1				
IM	0.536**	0.366**	1			
KS	0.437**	0.430**	0.366**	1		
MSI	0.459**	0.445**	0.414**	0.449**	1	
DIA	0.475**	0.423**	0.484**	0.430**	0.442**	1

* $p<0.05$ ** $p<0.01$

As shown in Table 4.19, Pearson correlation analysis was conducted to examine the relationships among CSE, DL, IM, KS, MSI, and DIA. The results showed that all variables were significantly and positively correlated at the 0.01 level. Specifically, CSE was positively correlated with DL (r = 0.402), IM (r = 0.536), KS (r = 0.437), MSI (r = 0.459), and DIA (r = 0.475). These results indicate that the variables included in the model were positively associated with one another and provide preliminary support for further structural equation modeling.

The correlation coefficient between DL and IM is 0.366, significant at the 0.01 level; in DIA, there is a significant positive correlation between DL and IM. The correlation coefficient between DL and KS is 0.430, also significant at the 0.01 level, with a significant positive correlation between DL and KS in DIA. In DIA, the correlation coefficient between DL and MSI is 0.445, significant at the 0.01 level, indicating a positive correlation between the two. The correlation coefficient between DL and DIA is 0.423, significant at the 0.01 level, with DIA showing a significant positive correlation with DL.

The correlation coefficient between IM and KS is 0.366, which is significant at the 0.01 level, suggesting a positive relationship between the two. The correlation coefficient between IM and MSI is 0.414, also significant at the 0.01 level, showing a positive relationship. Additionally, the correlation coefficient between IM and DIA is 0.484, significant at the 0.01 level, indicating a positive relationship.

The correlation coefficient between KS and MSI is 0.449, which is significant at the 0.01 level, indicating a positive relationship. Similarly, the correlation coefficient between KS and DIA is 0.430, demonstrating significance at the 0.01 level and suggesting a notable positive correlation between the two.

The correlation coefficient between MSI and DIA is 0.442, which is statistically significant at the 0.01 level, indicating a strong positive relationship between the two.

4.1.4 The Structural Equation Models and Hypothesis Testing

4.1.4.1 Structural Model Diagram

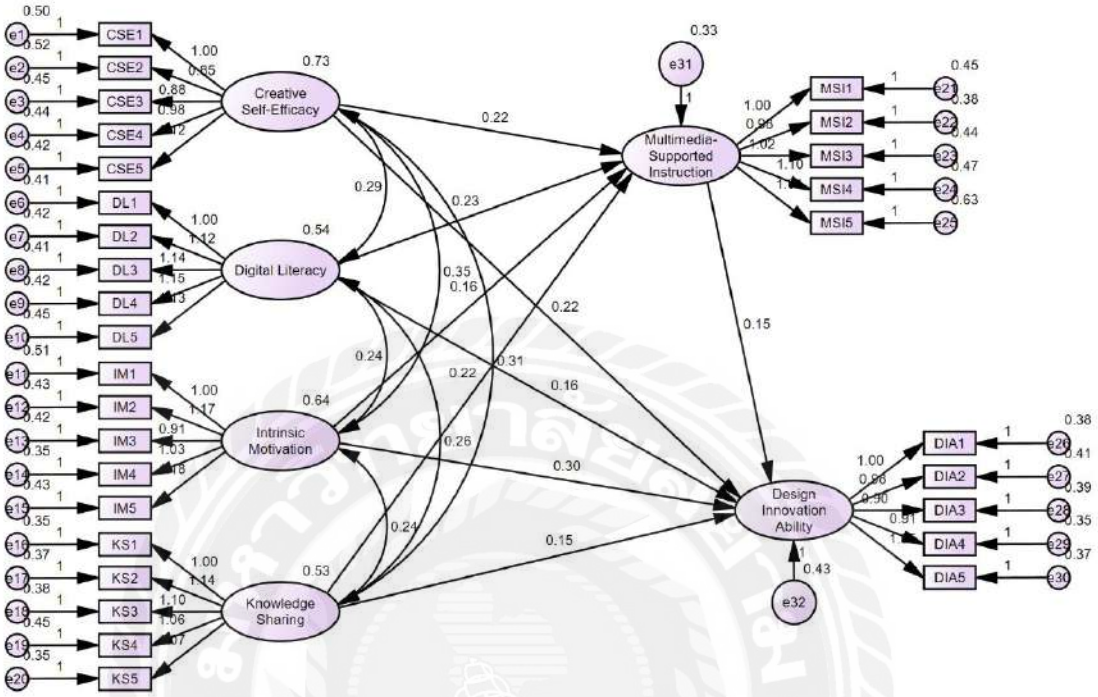


Figure 4.2 Modified Structural Equation Model

4.1.4.2 Model Fitting Index

When constructing structural equation models, the initial step is to evaluate model fit to determine whether the model adequately describes the relationships between observed and latent variables. Assessing model fit is complex because different indices focus on different aspects. Therefore, it is usually recommended to use multiple metrics rather than a single metric to evaluate model quality. This study examined model fit using three main indices: absolute fit indices (χ^2/df, Root Mean Square Error Approximation [RMSEA], and Goodness-of-Fit Index [GFI]) and standardized fit indices (Normed Fit Index (NFI) and Tucker-Lewis Index [TLI]).

Table 4.20 Structural Equation Model Fit Indices

Index	Acceptable Values	Statistical value	Fit condition
CMIN	-	552.377	-
DF	-	390	-
CMIN/DF	<3	1.416	Good
GFI	>0.90	0.926	Good
AGFI	>0.90	0.912	Good
RMSEA	<0.08	0.030	Good
NFI	>0.90	0.935	Good
IFI	>0.90	0.980	Good

Index	Acceptable Values	Statistical value	Fit condition
（TLI）NNFI	>0.90	0.978	Good
CFI	>0.90	0.980	Good

As shown in Table 4.20, the x^2/df value is 1.416 (less than 3), and the RMSEA is 0.030 (below the standard threshold of 0.08), indicating good fit. The GFI (0.926), AGFI (0.912), NFI (0.935), IFI (0.980), TLI, NNFI (0.978), and CFI (0.980) all meet excellent standards. All goodness-of-fit metrics comply with universal criteria, confirming the model's strong fit.

4.1.4.3 Structural Model Hypotheses Testing Results

Table 4.21 presents the standardized path coefficients (β), standard errors (S.E.), critical ratios (C.R.), and significance levels (P-values) for the structural equation model. These values are used to test the hypotheses regarding the relationships among the core variables.

Table 4.21 Hypotheses Test Results

Hypothesis	Path	β	Estimate	S.E.	C.R.	P	Result
H1	CSE→DIA	0.212	0.220	0.06	3.698	***	Supported
H2	DL→DIA	0.136	0.164	0.064	2.566	0.01	Supported
H3	IM→DIA	0.267	0.295	0.059	5.010	***	Supported
H4	KS→DIA	0.124	0.150	0.065	2.305	0.021	Supported
H5	CSE→MSI	0.242	0.216	0.052	4.123	***	Supported
H6	DL→MSI	0.225	0.232	0.057	4.093	***	Supported
H7	IM→MSI	0.170	0.161	0.051	3.138	0.002	Supported
H8	KS→MSI	0.211	0.219	0.058	3.776	***	Supported
H9	MSI→DIA	0.130	0.152	0.068	2.241	0.025	Supported

When $P<0.05$, the path is significant. In this case, the coefficient is positive, indicating that the independent variable has a significant positive effect on the dependent variable.

As shown in Table 4.21, all direct paths in the structural model were statistically significant. CSE had a significant positive effect on DIA ($\beta = 0.212$, C.R. = 3.698, $p < 0.001$), supporting H1. DL had a significant positive effect on DIA ($\beta = 0.136$, C.R. = 2.566, $p = 0.010$), supporting H2. IM had a significant positive effect on DIA ($\beta = 0.267$, C.R. = 5.010, $p < 0.001$), supporting H3. KS had a significant positive effect on

DIA (β = 0.124, C.R. = 2.305, p = 0.021), supporting H4. In addition, CSE, DL, IM, and KS had significant positive effects on MSI, supporting H5 – H8. Finally, MSI had a significant positive effect on DIA (= 0.130, C.R. = 2.241, p = 0.025), supporting H9.

4.1.4.4 Mediation Analysis Results

The results of the mediation effect test were obtained using AMOS 24, with 5000 bootstrap samples generated to validate the mediation effect.

Table 4.22 Mediating Effect Test Results Based on Bootstrapping (N = 5000)

Parameter	Type of effect	Estimate	SE	Lower	Upper	P
CSE→MSI→DIA	direct effect	0.220	0.066	0.096	0.358	0.000
	indirect effect	0.033	0.019	0.003	0.082	0.031
	total effect	0.253	0.063	0.135	0.386	0.000
DL→MSI→DIA	direct effect	0.164	0.073	0.027	0.314	0.017
	indirect effect	0.035	0.021	0.004	0.090	0.029
	total effect	0.199	0.071	0.064	0.343	0.005
IM→MSI→DIA	direct effect	0.295	0.066	0.169	0.427	0.000
	indirect effect	0.024	0.016	0.002	0.067	0.030
	total effect	0.320	0.066	0.194	0.453	0.000
KS→MSI→DIA	direct effect	0.150	0.069	0.022	0.292	0.023
	indirect effect	0.033	0.019	0.005	0.085	0.022
	total effect	0.183	0.067	0.059	0.326	0.005

The confidence interval for the path excludes zero, confirming its significance. All four mediation paths—CSE→MSI→DIA, DL→MSI→DIA, IM→MSI→DIA, and KS →MSI→DIA—are statistically significant. This shows that MSI partially mediates the effects of CSE, DL, IM, and KS on DIA.

4.1.4.5 Moderation Analysis Results

Technology Acceptance moderates the relationship between MSI and DIA.

Table 4.23 Results of Regression Analysis

	B	S.E.	t	p
(Constant)	3.315	0.037	88.987	< 0.001
MSI	0.483	0.045	10.670	< 0.001
Technology Acceptance	-0.215	0.085	-2.522	0.012
MSI*Technology Acceptance	-0.233	0.094	-2.488	0.013
R^2	0.215			
Adjusted R^2	0.21			
F	F=42.231, p=0.000			

dependent variable： DIA
* p<0.05 ** p<0.01

In the moderation analysis, Technology Acceptance was examined as a moderator of the relationship between MSI and DIA. The interaction term between MSI and Technology Acceptance was included in the regression model to test the moderating effect. The coefficient is -0.233 (P < 0.05), indicating that Technology Acceptance negatively moderates the relationship between MSI and DIA.

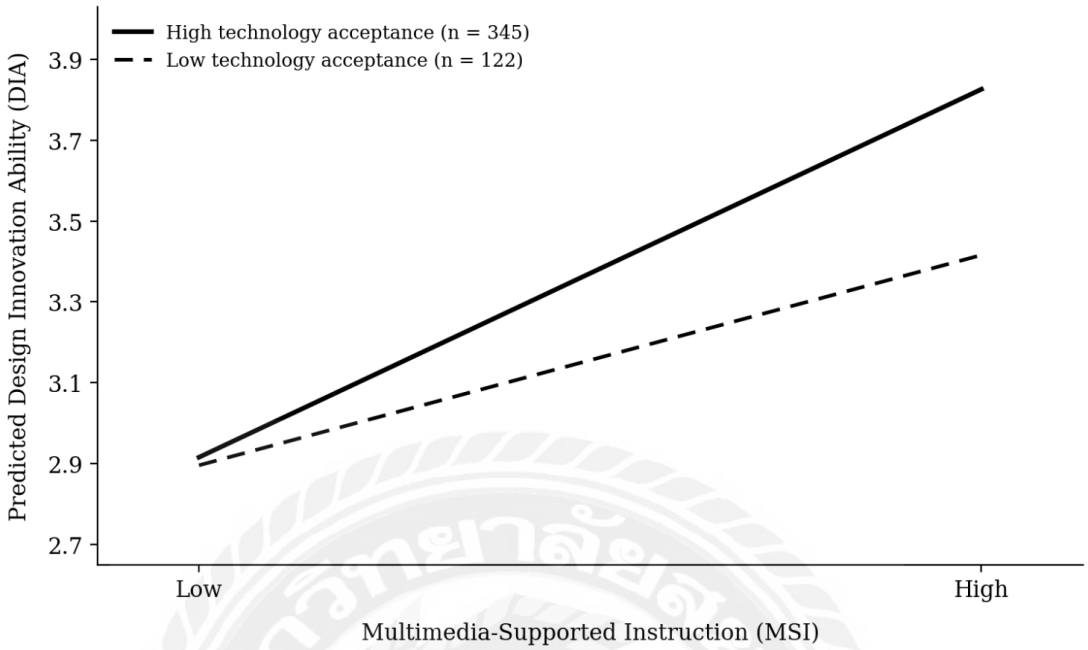


Figure 4.3 Moderating Effect of Technology Acceptance on the Relationship between MSI and DIA

4.2 Qualitative Analysis

4.2.1 Content Analysis

To extract key information from interview content, this study used NVivo 14 software for analysis. Developed by QSR International in the United States, this software specializes in qualitative analysis and mixed-methods research. Its application follows qualitative research principles, enabling simultaneous analysis, coding, and frequency statistics for multiple keywords in text. This study primarily relied on NVivo's text data processing and qualitative analysis features to improve data handling and enhance research accuracy. The focus group transcript and related interview notes were imported into NVivo 14. The researcher applied open coding to generate concepts, axial coding to develop a classification system, and selective coding to finalize the core categories.

Table 4.24 Interview Text Analysis Category System

Select Coding	Axial Coding	Open Coding	Reference Code Point	Description
CSE	Teaching Support	Teacher encouragement	7	Students feel motivated when teachers allow creative freedom and provide guidance.
	Assessment Constraints	Fear of failure; Rigid grading	5	Evaluation standards sometimes restrict risk-taking and experimentation.
DL	Software Competence	Use of Photoshop, CAD, and Procreate	6	Students frequently use digital tools but need training for advanced software.
	Information Evaluation	Comparing online tutorials	4	Students critically evaluate online information before applying it in design work.
IM	Career Relevance	Real-life project engagement	6	Students are more motivated when design tasks relate to real life or career goals.
KS	Peer Collaboration	Studio idea exchange	8	Collaboration in the studio encourages mutual learning and creativity.
	Sharing Barriers	Competition; Fear of idea theft	4	Some students are hesitant to share ideas due to competitive pressures.
MSI	E-learning Platform Use	Online tutorials and multimedia feedback	5	Multimedia resources enhance understanding and engagement.
	Teacher Digital Competence	Different levels of platform use among teachers	4	Some teachers fully utilize digital tools, while others use them minimally.
DIA	Cross-disciplinary Practice	Inspiration from other fields	6	Innovation emerges from integrating diverse disciplines and experimentation.
	Material Experimentation	Use of recycled or unconventional materials	5	Students who experiment with materials gain creative confidence.

Source: The Researcher (2025)

4.2.2 Analysis of Qualitative Research Results

Through coding analysis of focus group data, this study summarized students' core needs and experiences regarding Creative Self-Efficacy (CSE), Digital Literacy (DL), Intrinsic Motivation (IM), Knowledge Sharing (KS), and Multimedia-Supported Instruction (MSI) in the development of design innovation capabilities. Based on the open coding, axial coding, and selective coding of interview transcripts from eight design students, this study developed an integrated categorical framework encompassing seven core variables: Creative Self-Efficacy (CSE), Digital Literacy (DL), Intrinsic Motivation (IM), Knowledge Sharing (KS), Multimedia-Supported Instruction (MSI), Technology Acceptance (TA), and Design Innovation Ability (DIA).

The analysis reflects students' authentic learning experiences and reveals the behavioral mechanisms and contextual conditions underlying the quantitative model. Interview findings indicate that when instructors provide greater creative autonomy, timely feedback, and emotional support in the classroom, students' willingness to engage in innovative attempts significantly increases. All seven reference points consistently emphasized the crucial role of teacher support in encouraging students to take risks and tackle more complex creative tasks. Digital Literacy (DL) emerged as a three-dimensional construct consisting of assessment constraints, software competence, and information evaluation.

Digital Literacy extends beyond tool use; it also encompasses the ability to judge information quality. Together, these subdimensions shape students' capacity to translate conceptual ideas into innovative design outcomes. Regarding Intrinsic Motivation (IM), most students demonstrated higher levels of engagement and stronger motivation to refine their work when participating in real client projects, commercial design briefs, or public exhibitions. Knowledges Sharing (KS) formed two central categories: (a) peer collaboration and (b) sharing barriers. While KS can stimulate creative thinking, competitive learning environments may weaken its positive effects. Multimedia-Supported Instruction (MSI) plays a pivotal role in fostering design innovation; however, its effectiveness depends on instructors' digital teaching competence. Finally, with respect to Design Innovation Ability (DIA), students highlighted that cross-disciplinary knowledge inputs serve as an important source of design innovation, and that actively experimenting with new media and materials can enhance their confidence in creative expression.

4.2.3 Conclusion

The qualitative findings provided contextual support for the quantitative results and helped explain how CSE, DL, IM, KS, MSI, and TA contribute to the development of DIA. The focus group results further indicated that teacher support, digital tool use, intrinsic motivation, peer collaboration, multimedia-supported learning environments, and students' willingness to accept new technologies play important roles in shaping students' design innovation experiences.

4.3 Research Findings Validation

4.3.1 Expert Validation Procedure

To ensure the scientific rigor and practical relevance of the proposed Design Innovation Ability Enhancement Model, a model validation stage was conducted after

the completion of the quantitative and qualitative analyses. Unlike the IOC process, which involved five experts for validating the research instruments, this stage involved nine experts who evaluated the final proposed model. The purpose of this expert evaluation was to assess the propriety, feasibility, and utility of the model for improving the Design Innovation Ability of design students in universities in Shandong Province.

4.3.2 Expert Review Committee Information

Table 4.25 Expert Review Committee Information

No.	Expert Code	Institution	Title	Location	Participation
1	**E1**	Higher education institution	Principal, Professor	Jinan, Shandong Province	Online
2	**E2**	Higher education institution	Professor	Jinan, Shandong Province	Online
3	**E3**	Higher education institution	Professor	Binzhou, Shandong Province	Online
4	**E4**	Higher education institution	Professor	Jinan, Shandong Province	Offline
5	**E5**	Higher education institution	Professor	Jinan, Shandong Province	Online
6	**E6**	Higher education institution	Professor	Weihai, Shandong Province	Offline
7	**E7**	Higher education institution	Lecturer	Jinan, Shandong Province	Online
8	**E8**	Higher education institution	Lecturer	Jinan, Shandong Province	Offline
9	**E9**	Higher education institution	Professor	Jinan, Shandong Province	Offline

4.3.3 Evaluation Indicators

The nine experts independently evaluated the proposed model using a five-point Likert scale, where 1 represented “strongly disagree” and 5 represented “strongly agree.” The evaluation instrument included 12 indicators organized into three dimensions: Propriety, Feasibility, and Utility, with four indicators under each dimension. The collected data were analyzed using mean scores, standard deviations, and interquartile ranges. Mean scores were used to assess the overall evaluation level of each item, standard deviations were used to examine the dispersion of expert ratings, and interquartile ranges were used to assess the degree of expert consensus. The use of interquartile range is appropriate for examining consensus in expert evaluation and Delphi-type studies (von der Gracht, 2012).

Table 4.26 Evaluation Indicators of the Proposed Model

Dimension	No.	Item
Propriety	P1	Alignment with the theoretical framework
	P2	Construct validity
	P3	Research goal relevance
	P4	Suitability for the education context
Feasibility	F1	Practical implementation feasibility
	F2	Data collection and analysis feasibility
	F3	Time and resource manageability
	F4	Stakeholder collaboration feasibility
Utility	U1	Educational improvement value
	U2	Innovation cultivation effectiveness
	U3	Replicability and adaptability
	U4	Policy and management implications

Table 4.26 presents the 12 indicators used by the nine experts to evaluate the proposed model. These indicators were organized into three dimensions: Propriety, Feasibility, and Utility, with four indicators under each dimension.

4.3.4 Expert Evaluation Results

Table 4.27 Expert Evaluation Scores of the Proposed Model

Dimension	Code	E1	E2	E3	E4	E5	E6	E7	E8	E9	Mean Score	SD
Propriety	P1	5	4	4	5	5	4	5	4	4	4.44	0.53
	P2	4	4	4	4	5	4	4	5	5	4.33	0.50
	P3	4	4	4	4	5	4	4	5	5	4.33	0.50
	P4	5	4	4	4	5	4	5	5	4	4.44	0.53
Feasibility	F1	4	5	4	5	4	4	4	4	5	4.33	0.50
	F2	4	5	4	4	4	5	5	5	4	4.44	0.53
	F3	5	4	4	5	5	4	4	5	4	4.44	0.53
	F4	5	4	4	4	4	5	4	4	5	4.33	0.50

Dimension	Code	E1	E2	E3	E4	E5	E6	E7	E8	E9	Mean Score	SD
Utility	U1	5	4	4	5	5	4	5	4	5	4.56	0.53
	U2	5	4	4	5	5	4	4	5	4	4.44	0.53
	U3	5	4	4	4	4	5	5	5	5	4.56	0.53
	U4	4	4	4	5	5	4	4	4	4	4.22	0.44

As shown in Table 4.27, the mean scores of the 12 expert evaluation items ranged from 4.22 to 4.56, indicating that the proposed model was positively evaluated by the nine experts. The standard deviations ranged from 0.44 to 0.53, suggesting a relatively high level of agreement among the experts. Among the items, U4 obtained the lowest mean score, indicating that the policy and management implications of the model could be further refined.

4.3.5 Validation Conclusion

Based on the expert evaluation results, the proposed design innovation ability enhancement model demonstrated acceptable propriety, feasibility, and utility. The mean scores of all 12 evaluation items were above 4.00, indicating that the nine experts evaluated the model positively. The IQR results further showed that all items reached at least an acceptable level of consensus, with some items showing high or perfect consensus. These findings indicate that the proposed model is appropriate for the design education context, feasible for practical implementation, and useful for improving students' design innovation ability. Therefore, the model can serve as a practical reference for institutional planning, instructional improvement, and student-level innovation development in design education.

CHAPTER 5

DISCUSSION, CONCLUSION, AND RECOMMENDATION

This chapter systematically summarizes the data analysis and findings and proposes practical implementation strategies. The results reveal the interrelationships among the key variables, followed by a discussion of actionable pathways based on the empirical evidence. These insights provide recommendations for enhancing the design innovation ability of design students in Shandong Province. Finally, future research directions are proposed based on the study's outcomes. The chapter is organized into the following five sections:

5.1 Discussion
5.2 Conclusion
5.3 Recommendation
5.4 Research Limitation
5.5 Future Research Directions

5.1 Discussion

5.1.1 Discussion Related to the Research Questions

1) **What are the key factors that influence the design innovation ability of university design students?**

Based on the quantitative and qualitative findings presented in Chapter 4, this study concludes that the Design Innovation Ability (DIA) of university design students is primarily influenced by five major factors: Creative Self-Efficacy (CSE), Digital Literacy (DL), Intrinsic Motivation (IM), Knowledge Sharing (KS), and Multimedia-Supported Instruction (MSI). These findings are consistent with the theoretical foundations and empirical studies synthesized in Chapter 2, where each variable relationship was supported by relevant literature.

First, Creative Self-Efficacy (CSE) emerged as a core determinant of DIA. The mean score for CSE was 3.416, indicating that students reported a moderate to relatively high level of confidence in their creative capabilities. This aligns with Bandura's Social Cognitive Theory, which asserts that individuals with higher self-efficacy demonstrate greater persistence, stronger problem-solving tendencies, and improved creative performance in challenging tasks. The SEM results in Chapter 4 further confirmed that CSE exerts a significant and direct influence on DIA.

Second, Digital Literacy (DL) was found to play a substantial role in shaping DIA. The mean score of DL was 3.433, suggesting that students reported a moderate to relatively high level of digital literacy. This finding is consistent with the digital literacy frameworks discussed in Chapter 2 (Ng, 2012; Spante et al., 2018), which emphasize that digital skills are critical for enabling creative expression and facilitating design iteration. The results of this study revealed both direct and indirect effects of DL on DIA, reflecting its multi-layered influence through the enhancement of multimedia-supported learning environments and collaborative knowledge-sharing activities.

Third, Intrinsic Motivation (IM) was identified as an important psychological driver of design innovation. The mean score of IM was 3.361, suggesting that students reported a moderate level of intrinsic motivation in design learning. Consistent with Self-Determination Theory (Ryan & Deci, 2000), intrinsically motivated learners are more likely to demonstrate deeper cognitive engagement, sustained effort, and enhanced creative performance. As reviewed in Chapter 2, prior research (Amabile, 1996; Hennessey & Amabile, 2010) also affirms the central role of intrinsic motivation in promoting originality and innovation. The results of this study align closely with these theoretical expectations.

Fourth, Knowledge Sharing (KS) was shown to have a meaningful impact on DIA. With a mean score of 3.510, students reported a relatively high tendency toward collaborative learning, peer discussion, and idea exchange. This finding is consistent with Nonaka and Takeuchi's Knowledge Management Theory, which posits that the conversion and sharing of knowledge support new idea generation and innovation development. The qualitative findings from focus group interviews in Chapter 4 also indicated that peer collaboration and shared problem-solving experiences broaden students' creative perspectives and facilitate innovation.

Finally, Multimedia-Supported Instruction (MSI) was found to be a significant environmental factor enhancing DIA. MSI had the highest mean score among the core constructs (Mean = 3.555), suggesting that students generally perceived multimedia-supported learning resources positively. This result aligns with the Media Richness Theory and Mayer's Multimedia Learning Theory, both of which emphasize that rich and multimodal instructional environments enhance comprehension, cognitive engagement, and creative output. The SEM analysis confirmed MSI's direct positive influence on DIA, validating the theoretical arguments summarized in Chapter 2.

In conclusion, the findings of this study clearly demonstrate that the Design Innovation Ability of university design students is jointly shaped by creative self-efficacy (CSE), digital literacy (DL), Intrinsic Motivation (IM), knowledge sharing (KS), and multimedia-supported instructional environments (MSI). These variables interact to influence students' cognitive, behavioral, and social processes in design learning, highlighting the multifaceted nature of innovation development in design education. The strong consistency between the empirical results and the theoretical foundations presented in Chapter 2 provides solid evidence for the validity and robustness of the proposed research model. Collectively, these factors constitute a comprehensive and integrated explanatory framework for understanding how Design Innovation Ability is cultivated within higher education contexts, particularly in the rapidly evolving digital learning environment.

2) How does multimedia-supported instruction affect university students' design innovation ability?

The structural equation modeling results demonstrate that Multimedia-Supported Instruction (MSI) has a significant and positive influence on university students' Design Innovation Ability (DIA). MSI not only enhances DIA directly but also serves as a mediating instructional mechanism through which creative self-efficacy (CSE), digital literacy (DL), intrinsic motivation (IM), and knowledge sharing (KS) are

transformed into design innovation outcomes. These findings are consistent with the theoretical perspectives presented in Chapter 2.

From a theoretical standpoint, MSI provides a rich, multimodal learning environment that supports cognitive processing and creativity, consistent with Media Richness Theory (Daft & Lengel, 1986) and Mayer's Cognitive Theory of Multimedia Learning (2009). Through visual demonstrations, interactive tools, layered feedback, and platform-based communication, MSI increases students' cognitive engagement, enhances information integration, and encourages iterative experimentation—processes essential for innovation development.

The bootstrapped indirect effects further show that CSE, DL, IM, and KS influence DIA indirectly through MSI. This suggests that MSI functions as a pedagogical catalyst: it transforms students' confidence, technical skills, motivational states, and collaborative knowledge-building behaviors into tangible design outcomes. The use of structured digital platforms—featuring video-based explanations, annotated critiques, reusable demonstrations, and version-tracked submissions—ensures continuity of learning and supports iterative refinement of ideas. This instructional environment aligns with the literature reviewed in Chapter 2, which emphasizes that media-enhanced learning promotes deeper understanding, higher engagement, and stronger creative performance.

Overall, MSI plays a central role in shaping students' Design Innovation Ability by integrating technological affordances with psychological and social learning mechanisms. These results confirm MSI as a critical instructional factor in university-level design education.

3) To what extent does technology acceptance moderate the relationship between multimedia-supported instruction and design innovation ability?

The moderation analysis conducted in this study demonstrates that Technology Acceptance (TA) exerts a significant negative moderating effect on the relationship between Multimedia-Supported Instruction (MSI) and Design Innovation Ability (DIA). The interaction term (MSI × TA) yielded a regression coefficient of $B = -0.233$, with a standard error of 0.094, $t = -2.488$, and $p = 0.013$ ($n = 467$), indicating that the positive influence of MSI on DIA diminishes as students' levels of technology acceptance increase.

This finding diverges from the traditional assumptions of the Technology Acceptance Model (TAM), which typically posits that higher levels of perceived usefulness and perceived ease of use enhance the effectiveness of technology-integrated learning environments. However, within the context of design education, this negative moderation effect is theoretically plausible. Students with high levels of TA often possess stronger digital competence and greater autonomy in navigating technological tools; consequently, they rely more heavily on self-directed exploration rather than the structured guidance provided through MSI. When MSI offers standardized demonstrations, scaffolded learning materials, or platform-based resources, these students may perceive the additional support as redundant, yielding only limited incremental benefits in enhancing their creativity and innovation outcomes.

Conversely, students with lower levels of TA appear to benefit substantially more from MSI. Multimedia demonstrations, step-by-step visual explanations, replayable instructional content, and version-tracked feedback reduce cognitive load and mitigate technological barriers. These mechanisms align with Media Richness Theory and Mayer's Cognitive Theory of Multimedia Learning (2009), both of which emphasize that rich, multimodal instructional environments enhance comprehension, engagement, and creative performance. Therefore, MSI more effectively enhances DIA among students who lack confidence or fluency in navigating digital learning tools.

Qualitative evidence from the focus group interviews further supports this moderating mechanism. Participants with high TA reported a preference for independent exploration and were less reliant on multimedia-based scaffolding, whereas students with low TA expressed that MSI provided essential support for understanding design processes and overcoming technical difficulties. This divergence in learning strategies explains why MSI exhibits stronger effects on DIA among low-TA learners and weaker effects among their high-TA counterparts.

In summary, this study confirms that TA significantly moderates the relationship between MSI and DIA, operating through a negative moderation pattern:

Among students with low TA, MSI substantially enhances DIA by providing needed instructional structure and reducing technological barriers.

Among students with high TA, MSI offers limited additional benefit, resulting in a reduced marginal effect on DIA.

These findings extend the theoretical applications of TAM and media learning theories within design education and highlight the importance of considering individual differences in technology acceptance when integrating multimedia-supported instruction into university-level design programs.

4) What practical strategies can be proposed to enhance the design innovation ability of university design students based on empirical evidence?

Drawing on the empirical findings of this study—including structural equation modeling, qualitative interviews, and expert validation—this research concludes that enhancing university students' Design Innovation Ability (DIA) requires a comprehensive, multi-dimensional strategic framework. The development of DIA is not driven by a single factor; rather, it emerges from the coordinated interaction of individual competencies, motivational processes, social learning mechanisms, and media-supported instructional environments. Accordingly, several integrated practical strategies are proposed.

First, design education should prioritize strengthening students' creative self-efficacy (CSE) and digital literacy (DL), which constitute the foundational competencies for innovation. Among the direct predictors, Intrinsic Motivation (IM) demonstrated the strongest direct effect on DIA, while Creative Self-Efficacy (CSE) also showed an important positive effect. Therefore, instructional practices should incorporate project-based learning, scaffolded feedback cycles, and structured training in digital tools to enhance students' confidence, technical fluency, and ability to translate creative ideas into design outcomes.

Second, systematically cultivating Intrinsic Motivation (IM) is essential, as IM serves as a key psychological driver of sustained creative engagement. Consistent with Self-Determination Theory, students are more likely to produce innovative work when they perceive design tasks as meaningful, relevant, and autonomous. Real-world design briefs, interdisciplinary projects, client-based challenges, and public exhibitions can effectively strengthen students' sense of purpose, competence, and ownership.

Third, the study underscores the importance of fostering Knowledge Sharing (KS) environments. KS not only exerts a direct influence on DIA but also supports the cognitive diversity necessary for innovation. Strategies such as structured peer critique sessions, studio-based collaborative work, online resource-sharing platforms, and reflective dialogue activities can promote continuous knowledge exchange and broaden students' creative perspectives.

Fourth, Multimedia-Supported Instruction (MSI) should be systematically integrated into the curriculum. MSI demonstrated significant effects on DIA and its antecedent variables, underscoring its value as a media-rich instructional support. The use of video demonstrations, annotated feedback, interactive digital platforms, exemplar libraries, and version-tracked submissions enhances comprehension, reduces cognitive load, and supports iterative experimentation—as predicted by Mayer's Cognitive Theory of Multimedia Learning and Media Richness Theory.

Finally, instructional strategies must account for individual differences in Technology Acceptance (TA). The moderation analysis revealed a negative moderating effect: MSI produced stronger benefits for students with lower TA and diminishing marginal returns for those with higher TA. Consequently, differentiated instructional approaches are necessary—offering additional scaffolding and structured guidance for low-TA learners, while providing flexible, exploratory pathways for high-TA learners—to ensure that MSI is optimally effective across diverse student groups.

In sum, this study proposes a set of integrated practice-oriented strategies that operate across five domains: individual capability development, motivational enhancement, collaborative knowledge-building, media-supported instructional design, and technology-differentiated teaching support. These strategies collectively form a coherent learning ecosystem that promotes the development of Design Innovation Ability. Their strong alignment with the empirical findings reinforces both the robustness and educational relevance of the proposed DIA model.

5.1.2 Discussion on Creative Self-Efficacy (CSE)

Structural equation modeling revealed that Creative Self-Efficacy (CSE) had a statistically significant positive effect on Design Innovation Ability (DIA) ($\beta \approx 0.212$, $p < 0.001$), confirming Hypothesis 1. Mediation testing further showed that Multimedia-Supported Instruction (MSI) partially transmitted this effect, indicating that learners with higher self-efficacy tended to engage more actively with multimedia-based instructional resources, which subsequently enhanced their innovation outcomes. These quantitative findings establish CSE as a meaningful psychological antecedent of design innovation performance.

Qualitative evidence provides additional clarity regarding how CSE operates in real learning contexts. Students consistently reported that environments characterized by

"permission to try and fail," "step-by-step feedback," and "the ability to review earlier attempts" significantly strengthened their creative confidence. Interviewees described how specific visual feedback, annotated demonstrations, and replayable examples helped them sustain creative exploration, reduce fear of failure, and attempt more ambitious design solutions. These qualitative insights support and contextualize the quantitative mediation pathway (CSE → MSI → DIA), highlighting the instructional conditions under which self-efficacy translates into actual creative action.

Theoretically, these findings align with Bandura's Social Cognitive Theory (1997), which posits that self-efficacy shapes individuals' willingness to engage in challenging, uncertain, and exploratory tasks—behaviors central to design innovation. CSE supports creative persistence, encourages learners to tolerate ambiguity, and increases the likelihood that they will initiate independent experimentation.

Comparison with prior literature further reinforces this interpretation. Studies by Tierney & Farmer (2011), Puente-Díaz (2016), and Gong et al. (2009) consistently demonstrate that individuals with higher creative self-beliefs exhibit more originality, greater problem-solving flexibility, and more resilient creative behavior. The present findings align with these conclusions while expanding them into a multimedia-supported instructional context, which has received less empirical attention in design education research.

The mechanism underlying the CSE–DIA relationship appears to depend heavily on the instructional quality of feedback. While quantitative results establish statistical significance, qualitative evidence reveals a pedagogical nuance: when feedback is vague, non-visual, or lacks actionable specificity, heightened self-efficacy does not necessarily translate into improved design outcomes. In such cases, students may feel confident but remain unable to meaningfully refine or elevate their designs. Therefore, effective instructional design must ensure that feedback is specific, visual, traceable, and iterative—conditions that strengthen the functional coupling between CSE and actual innovation performance.

5.1.3 Discussion on Digital Literacy (DL)

The quantitative findings demonstrated that Digital Literacy (DL) exerted a significant positive effect on Design Innovation Ability (DIA) ($\beta = 0.136$, $p = 0.010$), supporting Hypothesis 2. Meanwhile, DL also significantly predicted students' utilization of Multimedia-Supported Instruction (MSI), and the mediation analysis confirmed that MSI partially transmitted the effect of DL on DIA. These results indicate that students' digital competency is not only directly related to their innovative performance but also indirectly enhances their creative outcomes through increased engagement with multimedia instructional resources.

Qualitative interview findings further clarified this relationship. Students repeatedly emphasized that digital skills—such as proficiency in design software, ability to evaluate online resources, and capacity to integrate multimodal information—enabled them to transform abstract ideas into actionable design outputs. Interviewee No. 2 noted, "Sometimes the idea is clear in my mind, but without knowing how to use software tools, I cannot produce the design I want." Similarly, interviewee No. 5 stated, "Watching tutorials and multimedia demonstrations helps me identify the right tools, steps, and design techniques to solve a problem." These insights illustrate how DL

shapes students' cognitive processing during design tasks and facilitates more precise and efficient execution.

Theoretically, these findings align with the Digital Literacy Framework proposed by Ng (2012), which conceptualizes DL as a multidimensional construct consisting of technological, cognitive, and critical evaluation skills. Students with higher DL can navigate digital environments more effectively, process complex information, and apply technological tools to express their creativity. This also reflects Mayer's Cognitive Theory of Multimedia Learning (2009), which argues that learners with stronger digital processing skills are better equipped to manage cognitive load and extract meaningful insights from multimedia representations.

A comparison with existing literature further supports the role of DL in innovation. Spante et al. (2018), Calvani et al. (2008), and Eshet-Alkalai (2012) have all emphasized that digital competence is foundational for enabling creative thinking, problem-solving, and design execution in contemporary learning environments. In creative disciplines, DL has been shown to influence not only the fluency of idea development but also the quality and originality of final design products.

5.1.4 Discussion on Intrinsic Motivation (IM)

The structural equation modeling results revealed that Intrinsic Motivation (IM) had a significant positive effect on Design Innovation Ability (DIA) ($\beta \approx 0.267$, $p < .001$), thereby supporting Hypothesis 3. Furthermore, IM significantly predicted students' engagement with Multimedia-Supported Instruction (MSI), and mediation analysis confirmed that MSI partially explained the relationship between IM and DIA. These quantitative findings suggest that students who perceive design learning as meaningful, enjoyable, or personally relevant are more likely to invest sustained cognitive effort, leading to enhanced innovation performance.

Qualitative findings complement these results by revealing how IM shapes students' actual learning behaviors. Interviewee No. 4 described that "When the design project is connected to real clients or authentic problems, I naturally want to refine my ideas again and again." Similarly, interviewee No. 7 shared that "I feel driven to explore new materials and design approaches when I find the topic interesting or inspiring." These reflections illustrate that IM fosters deeper engagement with both the design process and instructional materials, motivating students to seek additional resources, repeat demonstrations, and participate more actively in iterative design work. Students with high IM also reported greater willingness to overcome frustration and persist through difficult stages of the design process.

From a theoretical perspective, these findings align with Self-Determination Theory emphasizes that the satisfaction of autonomy, competence, and relatedness supports the development and maintenance of intrinsic motivation (Ryan & Deci, 2000). From this perspective, learning environments that support these psychological needs may encourage students' engagement, persistence, and willingness to explore challenging design tasks. When students feel self-directed and experience psychological meaningfulness in their tasks, they are more likely to engage in high-level cognitive processing, exploratory behavior, and creative experimentation. The current study extends these theoretical claims to the domain of multimedia-supported design education, showing that IM not only influences students' internal states but also shapes

their interaction with multimedia resources such as video demonstrations, annotated feedback, and digital exemplars.

Comparisons with prior literature further reinforce this interpretation. Amabile and Pratt (2016) and Hennessey & Amabile (2010) emphasized that intrinsic motivation is one of the strongest predictors of creative performance, as it stimulates curiosity, divergent thinking, and a willingness to take design risks. Studies in design education (e.g., Lau et al., 2020; Choi, 2022) similarly highlight that IM influences students' persistence in solving open-ended design problems and their initiative in exploring innovative techniques. The present findings are consistent with this body of research and add empirical evidence from the context of Chinese higher education in design.

The mechanism underlying IM's contribution to DIA can be understood as follows: intrinsic motivation energizes the design process, prompting students to allocate more cognitive resources to idea development, iteration, and refinement. This motivational energy translates into innovation when paired with instructional supports that offer clarity and direction. MSI enhances this process by providing structured demonstrations, feedback loops, and accessible resources that sustain students' engagement. In this regard, IM acts as a psychological driver, while MSI functions as a pedagogical amplifier that channels students' intrinsic motivation into concrete innovation outcomes.

5.1.5 Discussion on Knowledge Sharing (KS)

Quantitative analysis shows that knowledge sharing (KS) has a significant positive effect on Design Innovation Ability (DIA) ($\beta=0.124$, $p=0.021$), with multimedia-supported instruction (MSI) acting as a mediator. This result suggests that knowledge sharing not only directly promotes the development and integration of innovative thinking among students but also enhances the effectiveness of collective creation through the communication and collaboration features of the multimedia teaching environment. In other words, KS serves not just as an extension of individual abilities but also as a social mechanism that facilitates collaborative learning and the co-creation of innovative outcomes within the MSI setting.

Qualitative research further uncovered the behavioral mechanisms behind this effect. Focus group interviews showed that design students generally believed that peer critique, idea exchange, and co-creation discussions could inspire new ideas and lead to design breakthroughs. During open discussions and mutual evaluations, students often reexamined their own work from others' perspectives, encouraging diverse thinking and innovative solutions. However, interviews also revealed mixed feelings about knowledge sharing: some students worried about "idea theft" or "uncredited contributions," which limited their willingness to share. Active participation in collective innovation is more likely to occur when clear attribution and contribution mechanisms are in place. This shows that the positive impact of knowledge sharing depends on a safe, fair, and well-incentivized collaborative environment.

From a comparative perspective, quantitative analysis confirmed KS's significant positive effect on DIA, mediated through MSI's instructional support mechanisms. Qualitative findings further indicate that this process exhibits pronounced contextual dependence and psychological constraints. When teaching environments lack shared norms and incentive structures, knowledge sharing may weaken due to competitive

atmospheres or trust deficits, resulting in real-world classroom effects falling short of statistical predictions. In other words, while knowledge sharing has a significant positive effect in the model, its practical impact depends on whether schools and teachers can establish a collaborative culture characterized by transparency, fairness, and recognition mechanisms.

Therefore, this study argues that knowledge sharing should be integrated into instructional design and evaluation systems in design-focused higher education. Specifically, it recommends creating Co-creation Logs, Authorship Records, and Contribution Sheets as essential parts of the course grading process. This guarantees that students' collaborative efforts are clearly documented and academically recognized. At the same time, the MSI platform's data-tracking and version-control features should improve transparency in the sharing process, allowing instructors to better evaluate students' contributions to idea development, problem-solving, and teamwork. This institutionalized sharing system decreases students' concerns about knowledge security while strengthening the positive cycle between collaborative trust and innovative results.

In summary, knowledge sharing serves not only as an important antecedent factor in fostering design innovation ability but also as a foundational pillar for advanced creative learning environments. The knowledge exchange and collaboration mechanisms enabled by the MSI platform transform the learning process from individual exploration to collective co-creation, offering a new pathway for systematically enhancing design innovation competencies.

5.1.6 Discussion on Multimedia-Supported Instruction (MSI)

The structural equation modeling results indicated that Multimedia-Supported Instruction (MSI) had a significant positive effect on Design Innovation Ability (DIA) ($\beta = 0.130$, $p = 0.025$), supporting Hypothesis 9. Furthermore, MSI was found to partially mediate the effects of Creative Self-Efficacy (CSE), Digital Literacy (DL), Intrinsic Motivation (IM), and Knowledge Sharing (KS) on DIA, confirming Hypotheses 10 through 13. These findings highlight MSI as a central pedagogical mechanism that shapes how learner attributes translate into measurable innovation outcomes.

The qualitative evidence provides further insight into this instructional mechanism. Students consistently emphasized the value of replayable video demonstrations, step-by-step tutorials, annotated feedback, and version-tracking features integrated into multimedia platforms. Interviewee No. 5 shared, "Seeing the teacher's demonstration again and again helps me understand the hidden steps behind design decisions." Interviewee No. 8 stated, "Digital feedback allows me to compare different versions and see exactly how my design is improving." Such reflections demonstrate how MSI enhances transparency in the design process, supports iterative refinement, and reduces cognitive overload by providing multimodal instructional scaffolds.

From a theoretical standpoint, these findings align with Mayer's Cognitive Theory of Multimedia Learning (2009), which posits that learning is optimized when visual and verbal information are integrated in ways that reduce extraneous cognitive load and support schema construction. MSI provides exactly this type of multimodal input, enabling students to understand complex design procedures that cannot be fully

conveyed through text-based instruction alone. Additionally, Media Richness Theory (Daft & Lengel, 1986) supports the interpretation that rich, interactive media are particularly effective for tasks involving ambiguity and creative decision-making—conditions inherent to design innovation.

Comparison with existing literature further reinforces MSI's role. Research by Guo et al. (2014), Kay (2012), and Ibrahim et al. (2020) found that multimedia-supported environments enhance learners' comprehension, engagement, and creative performance by offering accessible, reusable, and visually explicit instructional content. In creative disciplines, studies by Choi & Kim (2021) and Lin (2020) demonstrate that multimedia tools improve ideation quality, prototyping accuracy, and iterative refinement, echoing the results of the present study. Specifically, MSI performs five major functions. First, it externalizes design thinking through visual demonstrations and annotations. Second, it enhances procedural understanding by making tacit design steps explicit. Third, it supports iterative learning through replayability, version comparison, and digital feedback loops. Fourth, it facilitates knowledge circulation through platform-based sharing and collaborative critique. Fifth, it amplifies the effects of CSE, DL, IM, and KS by providing the structural scaffolding that allows these learner attributes to influence actual design performance.

However, qualitative findings also indicate that MSI's effectiveness depends on instructional design quality. Some students expressed frustration when multimedia materials were unclear, outdated, or lacked alignment with learning objectives. This suggests that MSI is not inherently beneficial; rather, its impact relies heavily on thoughtful curation, consistent integration, and alignment with students' cognitive needs.

Overall, the results confirm that MSI is not merely a supplementary teaching tool but a core instructional mechanism that significantly enhances design learning processes and innovation outcomes. By making complex design processes visible, repeatable, and analyzable, MSI bridges the gap between learner potential and demonstrable Design Innovation Ability.

5.1.7 Discussion on Technology Acceptance (TA)

The moderation effect analysis revealed that Technology Acceptance (TA) significantly moderated the relationship between Multimedia-Supported Instruction (MSI) and Design Innovation Ability (DIA), with a negative interaction coefficient of $B = –0.233$, $SE = 0.094$, $t = –2.488$, and $p = 0.013$. Although H14 was supported in terms of statistical significance, the direction of the moderating effect was negative. This indicates that the positive effect of MSI on DIA became weaker as students' Technology Acceptance increased; in other words, MSI was more effective for students with low TA and less effective for students with high TA. These findings highlight the importance of providing additional technological training and instructional support to students with lower technology acceptance.

Qualitative interview data help explain this unexpected pattern. Students with lower technology acceptance frequently mentioned that MSI offered essential guidance, structure, and confidence. For example, interviewee No. 2 stated, "Without the multimedia demonstrations, I would not know where to start or how the design steps connect." Conversely, students with higher TA expressed a preference for autonomy

and flexibility. Interviewee No. 8 commented, “I already know how to navigate software and explore tools myself; sometimes the platform feels too restrictive or repetitive.” These contrasting perspectives demonstrate how learners' expectations and technology comfort levels fundamentally shape their responses to multimedia-supported instruction.

Theoretically, the findings correspond with the Media–Learner Fit Perspective, which argues that instructional media are most effective when they compensate for learners' weaknesses rather than duplicate existing strengths. While the original Technology Acceptance Model (TAM) (Davis, 1989; Venkatesh & Davis, 2000) suggests that perceived ease of use and perceived usefulness enhance technology engagement and outcomes, the current study extends this view by showing that effective learning also depends on whether the technology meaningfully adds value to learners’ pre-existing competencies. For learners already confident in digital tools, MSI provides limited marginal benefit and may even impede their preferred exploratory workflow.

Prior research offers partial support for this interpretation. Studies in educational technology (e.g., Park, 2009; Teo, 2011; Huang et al., 2020) highlight that high-TA learners often prefer flexible, non-linear learning environments, while structured multimedia paths benefit learners who lack technological confidence. Similarly, design education literature (e.g., Lin, 2020; Wu & Yu, 2021) suggests that novice learners rely heavily on demonstration-based instruction, whereas advanced learners thrive with greater experimental freedom. The present study reinforces these insights and provides empirical evidence of such dynamics within a university design context.

Overall, the moderating role of TA indicates that design education should shift toward precision and layered instruction. By implementing a progressive teaching framework of “low-TA support, medium-TA transition, and high-TA challenge,” universities and instructors can improve the efficiency of multimedia teaching resources and maximize the development of design innovation ability among students with different levels of technology acceptance.

5.2 Conclusion

This study aimed to develop a model for enhancing the Design Innovation Ability (DIA) of university design students in Shandong Province. Based on the quantitative analysis, qualitative findings, and expert validation, the study examined the direct effects of Creative Self-Efficacy (CSE), Digital Literacy (DL), Intrinsic Motivation (IM), Knowledge Sharing (KS), and Multimedia-Supported Instruction (MSI) on DIA. It also investigated the mediating role of MSI and the moderating role of Technology Acceptance (TA). The findings provide empirical support for the proposed Design Innovation Ability Enhancement Model.

5.2.1 Conclusion on the Direct Effects

The results confirmed that Creative Self-Efficacy, Digital Literacy, Intrinsic Motivation, and Knowledge Sharing all had significant positive effects on Design Innovation Ability. Among these antecedent variables, Intrinsic Motivation demonstrated the strongest direct effect on DIA, indicating that students’ internal interest, personal engagement, and willingness to explore design problems are essential

drivers of innovation performance. This suggests that design innovation depends not only on technical competence but also on students' sustained psychological engagement in the design process.

Creative Self-Efficacy also showed an important positive effect on DIA. Students who believe in their creative potential are more likely to tolerate uncertainty, take creative risks, revise their design works, and persist when facing design challenges. This confirms that confidence in one's creative ability is a key psychological foundation for design innovation.

Digital Literacy had a significant positive effect on DIA, showing that students' ability to use digital tools, evaluate online information, and transform digital resources into design outputs is increasingly important in contemporary design education. In the digital learning environment, design innovation requires not only creative ideas but also the ability to express, refine, and communicate those ideas through digital media.

Knowledge Sharing also contributed positively to DIA. This indicates that design innovation is not only an individual process but also a collaborative and social learning process. Peer discussion, idea exchange, resource sharing, and collaborative critique can broaden students' perspectives and support the generation of innovative design solutions.

In addition, Multimedia-Supported Instruction had a significant positive effect on DIA. This confirms that media-rich instructional environments, such as video demonstrations, digital platforms, visual feedback, and interactive learning resources, can directly enhance students' design learning and innovation performance.

5.2.2 Conclusion on the Mediating Effect of Multimedia-Supported Instruction

The results confirmed that Multimedia-Supported Instruction played a mediating role in the relationships between CSE, DL, IM, KS, and DIA. This means that students' psychological, digital, motivational, and social learning factors can influence design innovation ability not only directly but also indirectly through multimedia-supported instructional processes.

This finding highlights the central instructional role of MSI in design education. CSE, DL, IM, and KS provide important learner-level foundations, but these factors need an effective instructional environment to be transformed into visible design innovation outcomes. MSI functions as a pedagogical bridge by offering visualized demonstrations, structured learning resources, digital feedback, and opportunities for iterative design improvement.

Therefore, the development of DIA requires both student-level capability development and instructional support. It is not sufficient to cultivate students' creativity, digital skills, motivation, and collaboration alone. These factors should be activated and supported through well-designed multimedia-supported instruction.

5.2.3 Conclusion on the Moderating Effect of Technology Acceptance

The moderation analysis showed that Technology Acceptance significantly moderated the relationship between MSI and DIA. However, the direction of the moderation effect was negative. This indicates that the positive effect of MSI on DIA became weaker when students had higher levels of Technology Acceptance.

This finding suggests that students with high TA may already possess stronger digital confidence, technological autonomy, and self-directed learning ability. Therefore, they may rely less on structured multimedia-supported instructional resources. For these students, standard multimedia demonstrations or platform-based guidance may provide limited additional value.

By contrast, students with lower levels of TA may benefit more from MSI because multimedia demonstrations, step-by-step explanations, replayable resources, and digital feedback can reduce technological barriers and provide necessary learning structure. In this sense, MSI plays a compensatory role for students who are less confident in using digital technologies.

This conclusion provides an important implication for design education. Universities and instructors should not assume that all students benefit from MSI in the same way. Instead, instructional support should be differentiated according to students' levels of Technology Acceptance. Given the negative interaction effect, this interpretation should be regarded as a differentiated instructional implication rather than evidence that lower technology acceptance is inherently beneficial. Students with lower TA need more structured guidance and technical scaffolding, while students with higher TA need more flexible, exploratory, and self-directed learning opportunities.

5.2.4 Conclusion on the Design Innovation Ability Enhancement Model

Based on the empirical findings, this study developed the Design Innovation Ability Enhancement Model. The model includes five major components: learner-level antecedents, instructional process, learning outcome, boundary condition, and practical strategies.

The learner-level antecedents include Creative Self-Efficacy, Digital Literacy, Intrinsic Motivation, and Knowledge Sharing. These variables represent the psychological, digital, motivational, and social foundations of design innovation ability. The instructional process is represented by Multimedia-Supported Instruction, which functions as a key pedagogical mechanism that connects learner attributes with innovation outcomes. The learning outcome is Design Innovation Ability, which reflects students' capacity to generate creative design ideas, apply design knowledge, solve design problems, and produce innovative design works.

Technology Acceptance serves as a boundary condition in the model. It negatively moderates the relationship between MSI and DIA, suggesting that the effect of multimedia-supported instruction differs among students with different levels of technology acceptance.

The model also includes practical strategies at the institutional, instructional, and student levels. These strategies provide an applied pathway for improving DIA in university design education. Overall, the model demonstrates that the enhancement of design innovation ability requires the integrated development of students' internal capabilities, digital learning environments, collaborative learning mechanisms, and differentiated technology support.

5.2.5 Overall Conclusion

In conclusion, this study provides empirical evidence that Design Innovation Ability is shaped by multiple interconnected factors. CSE, DL, IM, and KS are

important antecedents of DIA, while MSI serves as both a direct instructional factor and a mediating mechanism. TA further influences the effectiveness of MSI through a significant negative moderating effect.

The findings suggest that improving students' design innovation ability should not rely on a single intervention. Instead, universities should adopt a systematic approach that integrates creative confidence, digital literacy, intrinsic motivation, knowledge sharing, multimedia-supported instruction, and differentiated technological support. The Design Innovation Ability Enhancement Model developed in this study offers both theoretical explanation and practical guidance for strengthening design education in the digital era.

5.3 Recommendation

Based on the findings and conclusions of this study, several recommendations are proposed for enhancing the design innovation ability of university design students in Shandong Province. These recommendations are organized into theoretical implications, practical implications, institutional-level strategies, instructional-level strategies, and student-level strategies.

5.3.1 Theoretical Implications

First, this study extends the application of Social Cognitive Theory in the field of design education. The significant positive effect of Creative Self-Efficacy on Design Innovation Ability confirms that students' beliefs in their own creative capability play an important role in shaping their innovative performance. This finding supports Bandura's (1997) view that self-efficacy influences individuals' motivation, persistence, and performance in complex tasks. Therefore, self-efficacy should be regarded as a key psychological foundation in the development of design innovation ability.

Second, this study enriches the understanding of digital literacy in innovation-oriented design learning. The significant effect of Digital Literacy on DIA indicates that digital competence is not limited to technical operation. It also includes information evaluation, digital expression, resource integration, and critical use of digital tools. This is consistent with Ng's (2012) digital literacy framework, which emphasizes the technical, cognitive, and socio-emotional dimensions of digital competence.

Third, this study supports the relevance of Self-Determination Theory in design education. Intrinsic Motivation was found to be the strongest direct predictor of DIA among the antecedent variables. This finding is consistent with Self-Determination Theory, which highlights the importance of basic psychological need satisfaction in supporting intrinsic motivation (Ryan & Deci, 2000). The positive relationship between Intrinsic Motivation and Design Innovation Ability observed in the present study provides further support for considering students' motivational experiences when designing innovation-oriented learning activities.It also supports creativity research showing that intrinsic motivation is closely related to originality, persistence, and creative performance (Amabile, 1996; Hennessey & Amabile, 2010).

Fourth, this study contributes to knowledge management and social learning perspectives by confirming the role of Knowledge Sharing in design innovation. The results suggest that design innovation ability can be strengthened through peer

discussion, collaborative critique, and shared problem-solving. This demonstrates that innovation in design education is both an individual and collective learning process, which is consistent with the knowledge creation perspective proposed by Nonaka and Takeuchi (1995).

Fifth, this study contributes to multimedia learning theory by identifying MSI as a mediating instructional mechanism. MSI helps transform students' psychological, digital, motivational, and social learning factors into measurable design innovation outcomes. This finding highlights the importance of instructional design in explaining how learner characteristics become actual innovation performance. It also supports Mayer's (2009) argument that multimedia learning can improve learning outcomes when visual and verbal information are effectively integrated.

Finally, this study extends the application of the Technology Acceptance Model by identifying a negative moderating effect of TA. The findings suggest that higher technology acceptance does not always strengthen the effect of multimedia-supported instruction. Instead, students with high TA may already possess strong technological autonomy, which reduces the marginal effect of structured MSI. This provides a more nuanced understanding of technology-supported learning in design education and extends the traditional assumptions of TAM (Davis, 1989; Venkatesh & Davis, 2000).

5.3.2 Practical Implications for Design Education

The findings of this study provide several practical implications for design education.

First, instructors should strengthen students' creative self-efficacy by creating a supportive learning environment. Design courses should allow trial and error, encourage experimentation, and provide constructive feedback. Students should be guided to view design failure as part of the creative process rather than as a negative outcome. This recommendation is consistent with the role of mastery experience and feedback in strengthening self-efficacy (Bandura, 1997).

Second, digital literacy should be systematically embedded into design curricula. In addition to teaching software operation, instructors should guide students in searching for design references, evaluating digital resources, integrating multimodal information, and using digital tools to express and refine creative ideas. Such activities are consistent with the Digital Literacy Framework, which emphasizes the integration of technical, cognitive, and socio-emotional competencies in digital learning environments (Ng, 2012).

Third, intrinsic motivation should be cultivated through meaningful and authentic design tasks. Real-world design briefs, project-based assignments, design competitions, public exhibitions, and client-based challenges can increase students' sense of relevance, autonomy, and ownership. Such activities are consistent with Self-Determination Theory, which emphasizes autonomy, competence, and relatedness as important conditions for intrinsic motivation (Ryan & Deci, 2000).

Fourth, knowledge sharing should become a regular part of design learning. Peer critique, group discussion, studio-based collaboration, online sharing platforms, and reflective dialogue can help students exchange ideas and improve their design thinking.

Instructors should establish clear rules for contribution recognition to reduce students' concerns about idea ownership and unfair participation.

Fifth, multimedia-supported instruction should be improved and integrated into design teaching. Instructors can use video demonstrations, visual case analysis, annotated feedback, process recording, digital portfolios, and version-tracking tools to make design processes more visible, repeatable, and analyzable. These practices are consistent with multimedia learning principles that emphasize cognitive load management and the effective integration of visual and verbal information (Mayer, 2009; Clark & Mayer, 2016).

Sixth, instruction should be differentiated according to students' levels of Technology Acceptance. Since students with low TA reported comparatively lower levels of Design Innovation Ability, universities and instructors should provide targeted support to improve their willingness and confidence in using new technologies. This may include introductory digital skills training, step-by-step multimedia demonstrations, technical assistance, and structured opportunities to practice using digital learning tools. For students with high TA, instructors can offer more advanced, flexible, and exploratory design activities. These differentiated approaches aim to strengthen technological readiness and create supportive conditions for developing students' design innovation ability.

5.3.3 Institutional-Level Recommendations

Universities should establish a supportive institutional environment for developing students' Design Innovation Ability.

First, universities should build digital design learning platforms. These platforms should include teaching materials, design case libraries, software tutorials, student work archives, feedback records, and collaborative learning spaces. Such platforms can support both classroom teaching and students' independent learning.

Second, universities should strengthen teacher training in multimedia-supported design instruction. Teachers need professional development opportunities to improve their ability to design multimedia materials, use digital feedback tools, manage online learning platforms, and integrate technology with studio-based teaching.

Third, universities should establish a design innovation ability evaluation system. Evaluation should not focus only on final design products. It should also consider design process, creativity, digital application, collaboration, iteration, and reflection. This can encourage students to pay more attention to the development process of innovation.

Fourth, universities should support interdisciplinary design projects. Cross-disciplinary cooperation can expose students to more complex and authentic design problems. This can stimulate creativity and improve students' ability to solve real-world problems through design.

Fifth, universities should provide differentiated technology support. Students with weaker technology acceptance or digital competence should have access to basic digital training, technical workshops, and learning support services. Students with stronger digital ability should be encouraged to explore advanced design tools, AI-supported design methods, and independent innovation projects.

5.3.4 Instructional-Level Recommendations

Instructors should improve classroom teaching by integrating multimedia-supported instruction with design practice.

First, instructors should use visual demonstrations to explain complex design processes. Since many design skills are procedural and tacit, video demonstrations, screen recordings, step-by-step tutorials, and case analysis can help students understand how design ideas are developed and refined.

Second, instructors should provide iterative and traceable feedback. Annotated feedback, version comparison, and digital portfolios can help students understand how their work changes over time. This can strengthen students' reflection and improve the quality of design revision.

Third, instructors should organize structured peer critique. Peer critique should not be casual or unregulated. Teachers should provide clear criteria, critique procedures, and contribution records so that students can learn from one another in a fair and productive environment.

Fourth, instructors should design authentic and open-ended tasks. Design assignments should be connected to real social, cultural, commercial, or technological problems. Open-ended tasks can stimulate intrinsic motivation and provide space for creative exploration.

Fifth, instructors should guide students to combine digital tools with creative thinking. Technology should not be used only for presentation or production. It should support idea generation, problem analysis, visual exploration, prototyping, and reflective improvement.

Sixth, instructors should adopt differentiated teaching strategies based on students' Technology Acceptance. For low-TA students, teachers should provide more scaffolding and technical support. For high-TA students, teachers should offer more autonomy, exploratory tasks, and advanced digital challenges.

5.3.5 Student-Level Recommendations

Students should also take active responsibility for improving their own Design Innovation Ability.

First, students should strengthen their creative self-efficacy by actively participating in design tasks, accepting challenges, and learning from failure. They should understand that creative ability can be developed through practice, feedback, and repeated revision.

Second, students should continuously improve their digital literacy. They should learn not only how to use design software but also how to search for useful information, evaluate digital resources, organize visual references, and apply digital tools to solve design problems.

Third, students should cultivate intrinsic motivation by connecting design learning with personal interests, social needs, and future career goals. When students understand the meaning and value of design tasks, they are more likely to engage deeply in the creative process.

Fourth, students should actively participate in knowledge sharing. They should share design references, discuss problems with peers, give constructive feedback, and learn from others' ideas. Knowledge sharing can help them broaden their thinking and improve the originality of their design work.

Fifth, students should make full use of multimedia-supported learning resources. They should review video demonstrations, compare feedback records, use online platforms, and document their design process. These practices can help students develop stronger reflective and iterative design habits.

Sixth, students should develop a balanced attitude toward technology. Students with low Technology Acceptance should gradually build confidence through basic practice and guided learning. Students with high Technology Acceptance should avoid over-reliance on tools and focus on using technology to support originality, critical thinking, and meaningful design expression.

5.4 Research Limitations

Although this study provides meaningful findings, several limitations should be acknowledged.

First, the sample was limited to design students from universities in Shandong Province. Therefore, the findings may not be fully generalizable to other provinces, regions, educational levels, or non-design majors.

Second, this study adopted a cross-sectional survey design. Although the hypothesized relationships were supported by statistical analysis, the study cannot fully explain long-term causal changes in students' design innovation ability.

Third, the measurement of Design Innovation Ability was mainly based on questionnaire data. Future studies may combine self-reported data with teacher evaluation, portfolio assessment, competition results, expert scoring, or other objective indicators.

Fourth, Technology Acceptance was treated as a moderating variable in the study. However, TA is a complex construct that may include perceived usefulness, perceived ease of use, attitude toward technology, and behavioral intention. Future research may examine these dimensions separately.

Fifth, although qualitative focus group data were used to support the quantitative findings, the number of interview participants was relatively limited. Future studies may include more students, teachers, administrators, and industry experts to obtain richer qualitative evidence.

5.5 Future Research Directions

Future research can be further developed in several directions.

First, future studies can expand the research sample to universities in different provinces and regions to test whether the Design Innovation Ability Enhancement Model is applicable in broader educational contexts.

Second, future research can compare different design majors, such as visual communication design, product design, industrial design, environmental design,

fashion design, and digital media design. Such comparisons may reveal differences in how design innovation ability is developed across disciplines.

Third, longitudinal research can be conducted to examine how students' design innovation ability changes over time under multimedia-supported instruction. This would provide stronger evidence of developmental trends and causal relationships.

Fourth, future studies can include objective indicators of design innovation ability, such as portfolio quality, design competition performance, teacher ratings, expert evaluation, patent applications, or project outcomes.

Fifth, future research can further explore the role of artificial intelligence in design education. AI-supported design tools may influence students' digital literacy, multimedia learning experience, creative self-efficacy, and design innovation outcomes.

Sixth, future research can further investigate the negative moderating effect of Technology Acceptance. This finding should be tested in other educational contexts to determine whether similar patterns exist among students in different disciplines or learning environments.

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APPENDIX

APPENDIX A: English-Chinese Questionnaire

Questionnaire

A Model for Improving the Design Innovation Ability of Design Students in Universities in Shandong Province

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Dear Students:

Hello! Thank you very much for taking part in this research.

This study is anonymous and will be used for academic research only, and the data will be kept strictly confidential. Meanwhile, the second part of this questionnaire uses a five-point Likert scale, which is divided into 1-5 points, from 1 to 5: Strongly disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly agree (5). Please choose the number that is closest to your actual situation. There are a total of 36 questions, The options themselves are not right or wrong, so please fill them out fairly and objectively, as your thoughts will provide important help to my research. Thanks again!

Mrs. Sun Mengqi, Ph.D. Student

Siam University

Part I: Demographic Information of Participants

Instructions: Please select the appropriate information in the boxes.

1. Gender

☐ Male ☐ Female

2. Grade Level

☐ Freshman year ☐ Sophomore year

☐ Third year ☐ Fourth year

3. Learning Platform

☐ Super star learning ☐ Tencent Conference

☐Other

4. Technology Acceptance

☐ Like to try to accept new technology

☐ Dislike to try to accept new technology

5. Type of your major

☐ Design majors ☐ Non-design majors

6. Which university do you attend?

☐ Shandong Normal University

☐ Shandong Vocational and Technical University of Engineering

☐ Dezhou College

☐ Shandong University of Art & Design

☐ Qingdao University of Science and Technology

Part II Relational factors

The questionnaire of this part used a Likert scale, Please choose one of the options tick √ in each question that is closer to your feelings.
5 = Strongly Agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly Disagree
Please choose the number that is closest to your actual situation.

Thank you very much for your cooperation!

ON.	question	Degree of agreement				
		5	4	3	2	1
Creative Self-Efficacy(CSE)						
CSE1	I am confident in my ability to solve problems.					
CSE2	I have the ability to come up with innovative design ideas					
CSE3	I have the ability to further develop the design ideas of others.					
CSE4	I can effectively persuade teammates to consider my design ideas.					
CSE5	I am confident in my ability to come up with innovative design ideas.					
Digital Literacy (DL)						
DL1	I am proficient in using digital tools (e.g., design software, course platforms).					
DL2	I can effectively access and filter learning resources through the Internet.					
DL3	I am able to collaborate and communicate using digital tools.					
DL4	I am able to use digital tools to solve learning difficulties.					
DL5	I can evaluate the reliability of online information and use it to my advantage.					
Intrinsic Motivation (IM)						
IM1	I am full of curiosity about the design courses I am studying.					
IM2	I believe that difficulties in design projects can be overcome through hard work.					
IM3	I feel happy and satisfied when studying design courses.					
IM4	I studied design because it brings me satisfaction.					

IM5	Learning the design course content has made my life more meaningful.					
Knowledge Sharing (KS)						
KS1	I am happy to share my knowledge and experience with my classmates.					
KS2	When participating in discussions, I will try to offer my input whenever possible.					
KS3	I am willing to answer questions raised by my classmates.					
KS4	When my classmates encounter learning difficulties, I am willing to provide help.					
KS5	I think sharing knowledge and experience with others is a very fulfilling thing.					
Multimedia-Supported Instruction (MSI)						
MSI1	The multimedia teaching platform provides clear learning guidance and helps me complete my learning tasks.					
MSI2	Multimedia presentations (e.g., videos, visualizations, etc.) can stimulate my creativity in design learning.					
MSI3	Using the multimedia-assisted teaching system allows me to understand design knowledge more intuitively.					
MSI4	The multimedia-assisted teaching system has enhanced my interaction with teachers and classmates.					
MSI5	I feel satisfied and comfortable with the multimedia teaching platform experience.					
Design Innovation Ability (DIA)						
DIA1	When faced with a problem, I am able to come up with new design solutions.					
DIA2	I can clearly express my innovative design ideas through sketches, models or presentations.					
DIA3	I am able to integrate knowledge and ideas from different fields into practical design.					
DIA4	I have the ability to translate innovative design ideas into practical results.					
DIA5	I have confidence in continuously improving my design and innovation capabilities.					

You have completed this questionnaire. Thank you for your support. I wish you a smooth work and a happy life!

Chinese Questionnaire

调查问卷

山东省高校设计学生设计创新能力提升模型

亲爱的同学们：你好！非常感谢你们参与这项研究。这项研究是匿名的，仅用于学术研究，数据将严格保密。同时，本问卷的第二部分使用5点李克特量表，分为1-5分，从1到5：强烈不同意（1），不同意（2），中立（3），同意（4），强烈同意（5）。请选出最接近您实际情况的数字。总共有30个问题，选项本身没有对错之分，因此请公平、客观地填写，因为您的想法将对我的研究提供重要的帮助。再次感谢!

第一部分：参与者的人口统计学信息

说明：请在方框中选择适当的信息。

1.性别

☐ 男　　☐ 女

2. 年级

☐ 大一　　☐ 大二

☐ 大三　　☐ 大四

3. 学习平台

☐学习通　　☐ 腾讯会议

☐其他

4. 技术接受度

☐ 愿意尝试接受新技术　　☐ 不愿意尝试接受新技术

5. 专业类型

☐ 设计专业　　☐ 非设计类专业

6. 您就读的大学是哪所？（仅选择一个）

☐ 山东师范大学

☐ 山东工程职业技术大学

☐ 德州学院

☐ 山东工艺美术学院

☐ 青岛科技大学

第二部分关系因素

本部分的问卷采用李克特量表，每个问题中请勾选√最接近您感受的选项。

5=非常同意，4=同意，3=中立，2=不同意，1=非常不同意

序号	问题	答案				
		5	4	3	2	1
创造性自我效能感						
CSE1	我对自己解决问题的能力充满信心。					
CSE2	我具备提出新颖设计想法的能力					
CSE3	我有能力进一步发展他人的设计想法。					
CSE4	我总能成功说服他人采纳我的建议。					
CSE5	我自己能够提出创新的设计想法。					
数字素养						
DL1	我能够熟练地使用数字工具（如设计软件、课程平台）。					
DL2	我能够通过互联网有效获取和筛选学习资源。					
DL3	我能够使用数字工具进行合作和交流。					
DL4	我能够运用数字工具解决学习中的困难。					
DL5	我能够评估网络信息的可靠性并加以利用。					
内在动机						
IM1	我对所学设计课程的学习充满好奇心。					
IM2	我相信通过努力能够克服设计项目中的困难。					
IM3	我认为设计课程学习让我感到愉快。					
IM4	我学习设计是因为它能带给我满足感。					

IM5	设计课程内容的学习让我的生活更有意义。					
知识分享						
KS1	我乐意与同学分享自己的知识与经验。					
KS2	参与讨论时，我会尽可能提供自己的意见。					
KS3	我愿意回答同学们提出的问题。					
KS4	当同学遇到学习困难时，我愿意提供帮助。					
KS5	我认为与他人分享知识经验是一件很有成就感的事情。					
多媒体辅助教学						
MSI1	多媒体教学平台提供了清晰的学习指导，帮助我完成学习任务。					
MSI2	多媒体展示（如视频、可视化等）能够激发我在设计学习中的创造力。					
MSI3	使用多媒体辅助教学系统让我能够更直观地理解设计知识。					
MSI4	多媒体辅助教学平台提升了我与教师同学的互动交流。					
MSI5	我对多媒体教学平台的使用体验感到满意且舒适。					
设计创新能力						
DIA1	在遇到问题时，我能够提出新的设计解决方案。					
DIA2	我能够通过草图、模型或演示清晰表达我的创新设计想法。					
DIA3	我能够将不同领域的知识与理念融入实际设计中。					
DIA4	我有能力将创新设计想法落实为实际成果。					
DIA5	我有信心不断提升自己的设计创新能力。					

您已经完成了这份问卷。感谢您的支持。祝您工作顺利，生活愉快！

APPENDIX B: English-Chinese Interview Outline

Part I. Introduction

Interview Topic: A Model for Improving the Design Innovation Ability of Design Students in Universities in Shandong Province

Interview Duration: 90 minutes

Interview Participants: A design major student

Thank you for joining this interview. Your insights will be invaluable to our research. Please be assured that all information provided will remain confidential and be used solely for academic purposes.

Part II. Questions by Variable

1. Creative Self-Efficacy (CSE)

• Do you believe you can demonstrate creativity in your design courses or projects? Why or why not?

• Could you describe an experience where you successfully produced an innovative design? What do you think contributed to that success?

• When facing design challenges, how do you usually approach problem-solving? Do you feel confident about finding unique solutions?

2. Digital Literacy (DL)

• Which digital tools or software do you frequently use in your design learning (e.g., Photoshop, CAD)? Do you find them easy to use?

• How do you judge whether online design-related information or resources are of high quality?

• Are you aware of any codes of conduct or ethical standards related to digital design? How do you understand them?

• When you need to gather information from multiple sources, how do you integrate and apply it in your work?

3. Intrinsic Motivation (IM)

•In what ways do you feel the content of your design courses is relevant to your life or future career?

•Which parts of the course or projects do you find most interesting? Why?

•Do you feel that studying design makes your life more meaningful? Could you share an example?

•Are you curious about innovations or emerging trends in your field of study? Can you elaborate?

4. Knowledge Sharing (KS)

• Do you usually share design ideas or learning experiences with your classmates? Why or why not?

• How do you feel during the process of knowledge sharing—positive, neutral, or pressured?

• Have you ever helped classmates solve a design problem? Could you describe that experience?

• Would you like to share your expertise and experiences more frequently in the future? Why or why not?

5. Multimedia-Supported Instruction (MSI)

• Which teaching platforms (e.g., Learning Access or similar e-learning tools) do you often use in your design learning? How do you feel about them?

• Do you think these platforms have supported you in accessing resources, interacting with peers, or improving your learning experience?

• In what ways have these platforms enhanced your design learning abilities?

• Have you encountered any challenges while using these platforms? How did you address them?

6. Technology Acceptance (TA)

• When you encounter a new learning technology or platform, do you feel it is easy or difficult to learn? Could you give an example?

• Do you believe using new digital tools or multimedia platforms really improves your design learning outcomes? Why or why not?

• Would you be willing to continue using multimedia-supported instruction in the future? What motivates your decision?

7. Design Innovation Ability (DIA)

• In your courses or projects, do you often try to come up with new and unique design solutions? Can you give an example?

• Do you incorporate ideas from other fields into your design work? If yes, could you share an example?

• Have you experimented with using new materials or techniques in your design? What was the outcome?

• What do you see as your greatest strength and biggest challenge when transforming creative ideas into actual design results?

Part III. Conclusion

1. In your opinion, what is the most important factor influencing your ability to innovate in design?

2. If you could propose one improvement, what kind of support from your school or teachers would best help you enhance your design innovation ability?

3. Is there anything else you would like to add—something not covered in the questionnaire but that you feel is important for your learning and innovation

Chinese Interview Outline

第一部分. 介绍

采访主题：研究提升设计专业学生的设计创新能力

面试时长：90 分钟

面试参与者：设计专业的学生

谢谢你参加这次采访。你的见解对我们的研究非常宝贵。请放心，所有提供的信息都会保密，并且只会用于学术目的。

第二部分：按变量分类的问题

1. 创造性自我效能

.• 你觉得自己能在设计课程或项目中展现创意吗？为什么或为什么不呢？

• 你能描述一次成功完成创新设计的经历吗？你认为是什么促成了那次成功？

• 遇到设计挑战时，你通常是如何解决问题的？你对找到独特的解决方案有信心吗？

2. 数字素养

• 在你的设计学习中，你经常使用哪些数字工具或软件（例如 Photoshop、CAD）？你觉得它们好用吗？

• 你如何判断网上与设计相关的信息或资源质量是否高？

• 你是否了解任何与数字设计相关的行为准则或道德标准？你是怎么理解它们的？

• 当你需要从多个来源收集信息时，你是如何整合并应用到你的作品中的？

3. 内在动机

• 你觉得你的设计课程内容在哪些方面与你的生活或未来职业相关？

• 你觉得课程或项目中哪些部分最有趣？为什么？

• 你觉得学习设计让你的生活更有意义吗？能举个例子吗？

• 你对你专业领域的创新或新兴趋势感到好奇吗？能具体说明一下吗？

4. 知识分享

• 你平时会和同学分享设计想法或学习经验吗？为什么会或不会？

• 在知识分享的过程中，你的感受如何——积极、中立，还是有压力？

• 你有没有曾帮同学解决过设计问题？能描述一下那个经历吗？

• 你以后想更频繁地分享你的专业知识和经验吗？为什么会或不会？

5. 多媒体支持教学

• 在学习设计的过程中，你通常使用哪些教学平台（例如学习通或类似的在线学习工具）？你对它们感觉如何？

• 你认为这些平台在获取资源、与同学互动或提升学习体验方面对你有帮助吗？

• 这些平台以何种方式增强了你的设计学习能力？

• 在使用这些平台时，你遇到过哪些挑战？你是如何解决的？

6. 技术接受度

• 当你接触到新的学习技术或平台时，你觉得它容易学习还是困难？你能举个例子吗？

• 你认为使用新的数字工具或多媒体平台真的能提升你的设计学习效果吗？为什么或者为什么不？

• 你愿意在未来继续使用多媒体支持的教学吗？是什么驱动了你的决定？

7. 设计创新能力

• 在你的课程或项目中，你是否经常尝试提出新的独特设计方案？能举个例子吗？

• 你会在设计工作中融入其他领域的想法吗？如果会，可以分享一个例子吗？

• 你有尝试过在设计中使用新材料或新技术吗？结果如何？

• 在将创意想法转化为实际设计成果时，你认为自己最大的优势和最大挑战是什么？

第三部分 结论

1. 在你看来，影响你设计创新能力的最重要因素是什么？

2. 如果你可以提出一个改进建议，你觉得学校或老师提供什么样的支持最能帮助你提升设计创新能力？

3. 你还有什么想补充的内容吗——一些问卷里没有涉及，但你觉得对你的学习和创新很重要的东西？

APPENDIX C: Index of Item-Objective Congruence

A Model for Improving the Design Innovation Ability of Design Students in Universities in Shandong Province

Research Questions

1) What are the key factors that influence the Design Innovation Ability of university design students?

2) How does Multimedia-Supported Instruction affect university students' Design Innovation Ability?

3) To what extent does technology acceptance moderate the relationship between Multimedia-Supported Instruction and Design Innovation Ability?

4) What practical strategies can be proposed to enhance the Design Innovation Ability of university design students based on empirical evidence?

Research Objectives

1) To identify key factors influencing the Design Innovation Ability of university design students.

2)To examine the impact of Multimedia-Supported Instruction on students' Design Innovation Ability.

3)To analyze the moderating effect of technology acceptance on the relationship between Multimedia-Supported Instruction and Design Innovation Ability.

4)To formulate and validate model improving the Design Innovation Ability of university design students.

Instruction

The questionnaire is divided into two parts: the first part is basic information (demographic) questions, and the second part is about the measurement items related to "Design Innovation Ability".

This study aims to identify and verify the key factors affecting the Design Innovation Ability of design college students and to construct a theoretical-practical path to improve students' innovation ability.

The variables involved in the questionnaire include: knowledge sharing, digital literacy, intrinsic motivation, creative self-efficacy, teaching medium, moderating variables, and technology acceptance.

Please judge and score whether each item accurately measures the variables it represents according to the following scoring criteria:

The scoring criteria are as follows:

Rating = +1: If you are confident that the item accurately measures the corresponding study characteristics.

Score = 0: If you are not sure whether the item measures the corresponding study characteristics;

Score = -1: If you are confident that the item failed to measure the study feature.

NO	Creative Self-Efficacy	Expert Opinion			Remarks
		1	0	-1	
CSE1	I am confident in my ability to solve problems.				
CSE2	I have the ability to come up with innovative design ideas				
CSE3	I have the ability to further develop the design ideas of others.				
CSE4	I can effectively persuade teammates to consider my design ideas.				
CSE5	I am confident in my ability to come up with innovative design ideas.				
NO	**Digital literacy**	**1**	**0**	**-1**	**Remarks**
DL1	I am proficient in using digital tools (e.g., design software, course platforms).				
DL2	I can effectively access and filter learning resources through the Internet.				
DL3	I am able to collaborate and communicate using digital tools.				
DL4	I am able to use digital tools to solve learning difficulties.				
DL5	I can evaluate the reliability of online information and use it to my advantage.				
NO	**Intrinsic Motivation (IM)**	**1**	**0**	**-1**	**Remarks**
IM1	I am full of curiosity about the design courses I am studying.				
IM2	I believe that difficulties in design projects can be overcome through hard work.				

IM3	I feel happy and satisfied when studying design courses.				
IM4	I studied design because it brings me satisfaction.				
IM5	Learning the design course content has made my life more meaningful.				
NO	**Knowledge Sharing**	**1**	**0**	**-1**	**Remarks**
KS1	I am happy to share my knowledge and experience with my classmates.				
KS2	When participating in discussions, I will try to offer my input whenever possible.				
KS3	I am willing to answer questions raised by my classmates.				
KS4	When my classmates encounter learning difficulties, I am willing to provide help.				
KS5	I think sharing knowledge and experience with others is a very fulfilling thing.				
NO	**Multimedia-Supported Instruction**	**1**	**0**	**-1**	**Remarks**
MSI1	The multimedia teaching platform provides clear learning guidance and helps me complete my learning tasks.				
MSI2	Multimedia presentations (e.g., videos, visualizations, etc.) can stimulate my creativity in design learning.				
MSI3	Using the multimedia-assisted teaching system allows me to understand design knowledge more intuitively.				
MSI4	The multimedia-assisted teaching system has enhanced my interaction with teachers and classmates.				

MSI5	I feel satisfied and comfortable with the multimedia teaching platform experience.				
NO	**Design Innovation Ability**	**1**	**0**	**-1**	**Remarks**
DIA1	When faced with a problem, I am able to come up with new design solutions.				
DIA2	I can clearly express my innovative design ideas through sketches, models or presentations.				
DIA3	I am able to integrate knowledge and ideas from different fields into practical design.				
DIA4	I have the ability to translate innovative design ideas into practical results.				
DIA5	I have confidence in continuously improving my design and innovation capabilities.				

Result of the Index of Item-Objective Congruence (IOC) Rating

Construct No.	Item No.	Rating from experts					∑R	$\frac{\sum R}{N}$	Result
		Dr. P1	Dr.P2	Dr.P3	Dr.P4	Dr.P5			
I Creative Self-Efficacy	1	1	1	1	1	1	5	1	Pass
	2	1	0	1	1	1	4	0.8	Pass
	3	1	1	1	1	1	5	1	Pass
	4	1	1	1	1	1	5	1	Pass
	5	1	1	0	1	1	4	0.8	Pass
II Digital literacy	1	1	1	1	1	1	5	1	Pass
	2	0	1	1	1	1	4	0.8	Pass
	3	1	1	1	1	1	5	1	Pass
	4	1	1	1	0	1	4	0.8	Pass
	5	1	1	1	1	1	5	1	Pass
III Intrinsic Motivation	1	1	1	1	1	1	5	1	Pass
	2	1	1	1	1	1	5	1	Pass
	3	1	1	1	1	1	5	1	Pass
	4	1	1	1	1	0	4	0.8	Pass
	5	1	0	1	1	1	4	0.8	Pass
IV Knowledge Sharing	1	1	1	1	1	1	5	1	Pass
	2	1	0	1	1	1	4	0.8	Pass
	3	1	0	1	1	1	4	0.8	Pass
	4	0	1	1	1	1	4	0.8	Pass
	5	1	1	1	1	1	5	1	Pass
V Multimedia-Supported Instruction	1	1	1	1	1	1	5	1	Pass
	2	1	1	1	1	1	5	1	Pass
	3	1	1	1	1	1	5	1	Pass
	4	1	1	1	1	1	5	1	Pass
	5	0	1	1	1	1	4	0.8	Pass
VI Technology Acceptance	1	1	1	1	1	1	5	1	Pass
	2	1	1	0	1	1	4	0.8	Pass
VII Design Innovation Ability	1	1	1	1	1	1	5	1	Pass
	2	1	1	1	0	1	4	0.8	Pass
	3	1	1	1	1	1	5	1	Pass
	4	0	1	1	1	1	4	0.8	Pass
	5	1	1	1	1	1	5	1	Pass

Note: The expert invitation letters were issued during the early stage of the research when the dissertation title was still being refined. After feedback from the dissertation committee, the title was revised. However, the research focus and expert evaluation procedure remained consistent with the final research design.

SU. 0210.04/ 22

Graduate School of Education
38 Siam University
Petchkasem Bangwa,
Phasicharoan Bangkok 10160

January 2025

Dear: Si Hongshen, Ph.D
Texas State College Lecturer
Subject: Invitation to be an expert to examine research tools

Since Miss. Sun Mengqi, student ID 6319002021, a doctoral student in English program, Graduate School of Education works on dissertation: " Research and Strategy Exploration on the Model of Enhancing College Students' Innovation Ability in Shandong Province Universities " with Assoc. Prof. Dr. Boonmee Nenyod (an advisor) and Assistant Professor Dr. Leehsing Lu (a co-advisor), the Graduate School of Education would like to invite you to be an expert to examine the research tools.

Questionnaire regarding current circumstances is a significant tool of the research which is needed to be considered and examined including suggestion for research tools. Miss. Sun Mengqi will contact and coordinate all details by himself.

We really appreciate your help.

Best regards

Professor Emeritus Dr.Chanita Rukspollmuang
Dean of Graduate School of Education

SU. 0210.04/ 18

Graduate School of Education
38 Siam University
Petchkasem Bangwa,
Phasicharoan Bangkok 10160

January 2025

Dear: Professor Dai Gang

Shandong Normal University, Ph. D. adviser

Subject: Invitation to be an expert to examine research tools.

Since Miss. Sun Mengqi, student ID 6319002021, a doctoral student in English program, Graduate School of Education works on dissertation: "A Teacher Training Model for Enhancing Students' Innovation Abilities in Private Undergraduate Universities in Shandong Province." with Assoc. Prof. Dr. Boonmee Nenyod (an advisor) and Assistant Professor Dr. Leehsing Lu (a co-advisor), the Graduate School of Education would like to invite you to be an expert to examine the research tools.

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We really appreciate your help.

Best regards

Professor Emeritus Dr.Chanita Rukspollmuang
Dean of Graduate School of Education

SU. 0210.04/ 21

Graduate School of Education 20
38 Siam University
Petchkasem Bangwa,
Phasicharoan Bangkok 10160

January 2025

Dear: Fu Jun, Ph.D

Shandong Agricultural Engineering College Lecturer

Subject: Invitation to be an expert to examine research tools

Since Miss. Sun Mengqi, student ID 6319002021, a doctoral student in English program, Graduate School of Education works on dissertation: "A Teacher Training Model for Enhancing Students' Innovation Abilities in Private Undergraduate Universities in Shandong Province." with Assoc. Prof. Dr. Boonmee Nenyod (an advisor) and Assistant Professor Dr. Leehsing Lu (a co-advisor), the Graduate School of Education would like to invite you to be an expert to examine the research tools.

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We really appreciate your help.

Best regards

Professor Emeritus Dr.Chanita Rukspollmuang
Dean of Graduate School of Education

SU. 0210.04/ 19

Graduate School of Education
38 Siam University
Petchkasem Bangwa,
Phasicharoan Bangkok 10160

January 2025

Dear: Professor Li Gang

Dean, School of Physical Education, Shandong University of Finance and Economics

Subject: Invitation to be an expert to examine research tools.

Since Miss. Sun Mengqi, student ID 6319002021, a doctoral student in English program, Graduate School of Education works on dissertation: "A Teacher Training Model for Enhancing Students' Innovation Abilities in Private Undergraduate Universities in Shandong Province." with Assoc. Prof. Dr. Boonmee Nenyod (an advisor) and Assistant Professor Dr. Leehsing Lu (a co-advisor), the Graduate School of Education would like to invite you to be an expert to examine the research tools.

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Best regards

Professor Emeritus Dr.Chanita Rukspollmuang
Dean of Graduate School of Education

SU. 0210.04/ 20

Graduate School of Education
38 Siam University
Petchkasem Bangwa
Phasicharoan Bangkok 10160

January 2025

Dear: Assoc. Prof. Qin Xiaonan
Ocean University of China, Ph.D. adviser
Subject: Invitation to be an expert to examine research tools

Since Miss. Sun Mengqi, student ID 6319002021, a doctoral student in English program, Graduate School of Education works on dissertation: "A Teacher Training Model for Enhancing Students' Innovation Abilities in Private Undergraduate Universities in Shandong Province." with Assoc. Prof. Dr. Boonmee Nenyod (an advisor) and Assistant Professor Dr. Leehsing Lu (a co-advisor), the Graduate School of Education would like to invite you to be an expert to examine the research tools.

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Miss. Sun Mengqi will contact and coordinate all details by himself.

We really appreciate your help.

Best regards

Professor Emeritus Dr.Chanita Rukspollmuang
Dean of Graduate School of Education

APPENDIX D: PIM



ใบรับรองจริยธรรมการวิจัยในมนุษย์
สถาบันการจัดการปัญญาภิวัฒน์

หมายเลขใบรับรอง: PIM-REC 026/2568

ข้อเสนอการวิจัยนี้ และเอกสารประกอบของข้อเสนอการวิจัยตามรายการแสดงด้านล่าง ได้รับการพิจารณาจากคณะกรรมการจริยธรรมการวิจัยในมนุษย์ สถาบันการจัดการปัญญาภิวัฒน์แล้ว คณะกรรมการฯ มีความเห็นว่าข้อเสนอการวิจัยที่จะดำเนินการมีความสอดคล้องกับหลักจริยธรรมสากล ตลอดจนกฎหมายข้อบังคับและข้อกำหนดภายในประเทศ จึงเห็นสมควรให้ดำเนินการตามข้อเสนอการวิจัยนี้ได้

ชื่อข้อเสนอโครงการ: A model study to improve the design innovation ability of design students in colleges and universities in Shandong Province

รหัสข้อเสนอการวิจัย (ถ้ามี): -

หน่วยงาน: Faculty of Education, Siam University

ผู้วิจัยหลัก: Mrs. Sun Mengqi

ลงนาม.....

(อาจารย์ ดร.พิเชษฐ์ มุสิกะโปดก)
ประธานคณะกรรมการจริยธรรมการวิจัยในมนุษย์
สถาบันการจัดการปัญญาภิวัฒน์

วันที่รับรอง: 20 พฤศจิกายน 2568 **วันหมดอายุ:** 20 พฤศจิกายน 2569

เอกสารที่คณะกรรมการรับรอง
1. โครงร่างการวิจัย
2. ข้อมูลสำหรับชี้แจงกลุ่มประชากรหรือผู้มีส่วนร่วมในการวิจัย และ ใบแสดงความยินยอมจากกลุ่มประชากรหรือผู้มีส่วนร่วมในการวิจัย
3. เครื่องมือที่ใช้ในการวิจัย/เก็บรวบรวมข้อมูล เช่น แบบสอบถาม แบบสัมภาษณ์ ประเด็นในการสนทนากลุ่ม เป็นต้น

เงื่อนไขการรับรอง
1. นักวิจัยดำเนินการวิจัยตามที่ระบุไว้ในโครงร่างการวิจัยอย่างเคร่งครัด
2. นักวิจัยรายงานเหตุการณ์ไม่พึงประสงค์ร้ายแรงที่เกิดขึ้นหรือเปลี่ยนแปลงกิจกรรมวิจัยใดๆ ต่อคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ภายในกำหนด
3. นักวิจัยส่งรายงานความก้าวหน้าต่อคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ตามเวลาที่กำหนดหรือเมื่อได้รับการร้องขอจากคณะกรรมการฯ
4. หากการวิจัยไม่สามารถดำเนินการเสร็จสิ้นภายในกำหนด ผู้วิจัยต้องยื่นขออนุมัติใหม่ก่อนอย่างน้อย 1 เดือน
5. หากการวิจัยเสร็จสมบูรณ์ ผู้วิจัยต้องแจ้งปิดโครงการตามแบบฟอร์มที่กำหนด

APPENDIX E : Expert Evaluation Invitation Letter



SU.0210.14/ 22

Graduate School of Education
Siam University
38 Phet Kasem Rd., Bang Wa,
Phasi Charoen, Bangkok 10160

31 March 2025

Dear Professor Wu Mengjun,
Principal, Shandong University of Engineering and Technology

Subject: Invitation to be an expert to evaluate the results.

Since Ms. Sun Mengqi, student ID 6319002021, a doctoral student in English program, Graduate School of Education, works on a dissertation *"A model study to improve the design innovation ability of design students in colleges and universities in Shandong Province."* with Assoc. Prof. Dr. Boonmee Nenyod (the advisor) and Dr. LeeHsing Lu (the co-advisor), the Graduate School of Education would like to invite you to be an expert to evaluate the results. Ms. Sun Mengqi will contact you and coordinate all details herself.

We really appreciate your help.

Yours sincerely,

Professor Emeritus Dr. Chanita Rukspollmuang
Dean of Graduate School of Education

SU.0210.14/ 22

Graduate School of Education
Siam University
38 Phet Kasem Rd., Bang Wa,
Phasi Charoen, Bangkok 10160

31 March 2025

Dear Professor Zhou Changlinag,
Shandong Normal University

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Professor Emeritus Dr. Chanita Rukspollmuang
Dean of Graduate School of Education

SU.0210.14/ 22

Graduate School of Education
Siam University
38 Phet Kasem Rd., Bang Wa,
Phasi Charoen, Bangkok 10160

31 March 2025

Dear Professor Zhang Wei,
Shandong University of Art & Design

Subject: Invitation to be an expert to evaluate the results.

Since Ms. Sun Mengqi, student ID 6319002021, a doctoral student in English program, Graduate School of Education, works on a dissertation *"A model study to improve the design innovation ability of design students in colleges and universities in Shandong Province."* with Assoc. Prof. Dr. Boonmee Nenyod (the advisor) and Dr. LeeHsing Lu (the co-advisor), the Graduate School of Education would like to invite you to be an expert to evaluate the results. Ms. Sun Mengqi will contact you and coordinate all details herself.

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Professor Emeritus Dr. Chanita Rukspollmuang
Dean of Graduate School of Education

SU.0210.14/

Graduate School of Education
Siam University
38 Phet Kasem Rd., Bang Wa,
Phasi Charoen, Bangkok 10160

March 2025

Dear Dr. Dai Gang,
Advisor, Shandong Normal University

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Professor Emeritus Dr. Chanita Rukspollmuang
Dean of Graduate School of Education

SU.0210.14/ 22

Graduate School of Education
Siam University
38 Phet Kasem Rd., Bang Wa,
Phasi Charoen, Bangkok 10160

31 March 2025

Dear Dr. Fu Jun,
Lecturer, Shandong Agricultural Engeering College

Subject: Invitation to be an expert to evaluate the results.

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Dean of Graduate School of Education

SU.0210.14/ 22

Graduate School of Education
Siam University
38 Phet Kasem Rd., Bang Wa,
Phasi Charoen, Bangkok 10160

31 March 2025

Dear Assoc. Prof. Dr. Qin Xiaonan,
Advisor, Ocean University of China

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Dean of Graduate School of Education



SU.0210.14/ 22

Graduate School of Education
Siam University
38 Phet Kasem Rd., Bang Wa,
Phasi Charoen, Bangkok 10160

31 March 2025

Dear Dr. Si Hingshen,
Lecturer, Texas State College

Subject: Invitation to be an expert to evaluate the results.

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Dean of Graduate School of Education

SU.0210.14/ 22

Graduate School of Education
Siam University
38 Phet Kasem Rd., Bang Wa,
Phasi Charoen, Bangkok 10160

31 March 2025

Dear Professor Ma Li,
Shandong University of Engineering and Technology

Subject: Invitation to be an expert to evaluate the results.

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Dean of Graduate School of Education

SU.0210.14/ 22

Graduate School of Education
Siam University
38 Phet Kasem Rd., Bang Wa,
Phasi Charoen, Bangkok 10160

31 March 2025

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Dean, School of Physical Education, Shandong University of Finance and Economics

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Dean of Graduate School of Education

AUTHOR'S BIOGRAPHY

Name and Surname:	Sun Mengqi
Date of Birth:	14/3/1993
Nationality:	Chinese
Birth of Place:	China Shandong Province
E-Mail:	Lisa20212022@163.com
Work Position:	Student
Workplace:	Siam University
Address:	38 Petkasem Road, Bangwa Phasicharoen,Bangkok,10160.

Bachelor's Degree

Degree:	Bachelor
Major:	Landscape Architecture
Institution:	Lijiang College of Guangxi Normal University
Country:	China
Year:	2012

Master's Degree

Degree:	Master
Major:	Agronomy
Institution:	Jiangsu University of Science and Technology
Country:	China
Year:	2017