

Review of the Research on the Influence of Digital Infrastructure on Student-led Innovation in Shandong Province, China

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Abstract—In the context of digital economy and educational digitization, digital infrastructure in higher education institutions has become a critical foundation for talent cultivation and innovation activities. Student-led innovation, as a vital component of university innovation systems, largely depends on robust digital environments. Based on reviewing domestic and international research, this paper systematically examines the connotation of digital infrastructure in universities, the key characteristics of student-led innovation, and their theoretical connections. It focuses on analyzing how digital infrastructure positively impacts student-led innovation through enhancing resource accessibility, optimizing learning and practice environments, fostering student autonomy, and promoting the development of university innovation ecosystems. Furthermore, by evaluating the current status of digital construction and innovation education in Shandong Province, the study identifies gaps in existing research regarding student perspectives, operational mechanisms, and regional holistic analysis. The findings suggest that digital infrastructure plays a crucial supporting role in student-led innovation, and future efforts should emphasize deeper integration between digital development and innovation capability cultivation. These conclusions provide theoretical references for optimizing digital infrastructure and innovating talent development practices in higher education institutions.

Keywords— Digital infrastructure; university digitization; student-led innovation; innovative talent cultivation; Shandong Province universities.

I. INTRODUCTION

With the rapid development of the digital economy and the deepening of the new round of technological revolution, higher education is undergoing profound transformation from informatization to digitalization and intelligence. As a critical foundation supporting teaching, research innovation, and talent cultivation, university digital infrastructure has become a key factor in enhancing institutions' core competitiveness and innovation capabilities. Meanwhile, under the innovation-driven development strategy, students are no longer passive participants in innovation activities but increasingly become active agents in innovation practices. The role of student-led innovation in university innovation systems is becoming increasingly prominent.

As a leading province in China's higher education sector, Shandong boasts a comprehensive range of universities and

institutions, making it a representative case in advancing educational digitalization and cultivating innovative talents. In recent years, Shandong's universities have consistently strengthened smart campus development, built online learning platforms, and established digital platforms for innovation and entrepreneurship, providing students with richer digital support for creative activities. However, existing research primarily focuses on how digital infrastructure impacts teaching quality, learning outcomes, or teaching methodologies, while paying relatively less attention to student-led innovation. Particularly, there is a notable lack of systematic provincial-level studies addressing this issue.

Based on this, this paper reviews and comments the related researches of Shandong Province on the promotion of student-led innovation in digital infrastructure of colleges and universities, which is based on the systematic review of the related researches at home and abroad, focusing on the connotation of digital infrastructure of colleges and universities, the characteristics of student-led innovation and the mechanism of the interaction between the two.

II. DEFINITION OF CORE CONCEPTS

(1) Digital Infrastructure of Universities

Digital infrastructure is widely recognized as the essential foundation supporting digital technology operations, data processing, and information services, primarily comprising hardware facilities, software systems, and related service environments. In higher education contexts, the concept of digital infrastructure has evolved beyond basic IT conditions like network bandwidth and servers to form a comprehensive digital support system covering teaching, management, and innovation activities. Research indicates that such infrastructure serves as both a material basis for educational digital transformation and a critical driver for advancing teaching methodologies and innovation capabilities (Selwyn, 2016; Wang Zhuli, 2020). With the ongoing development of smart campuses and educational informatization, university digital infrastructure now exhibits distinct systemic and platform-oriented characteristics in its functional and operational aspects.

From a functional perspective, digital infrastructure in higher education institutions primarily manifests in three key areas: teaching and learning support, innovation and entrepreneurship services, and information resource sharing. Firstly, in terms of teaching support, digital learning platforms, learning management systems, online course platforms, and virtual laboratories provide students with more flexible and diverse learning environments. These tools effectively overcome the time and space constraints of traditional classrooms, fostering students' self-directed learning and inquiry-based learning capabilities (Means et al., 2014).

Secondly, regarding innovation services, universities leverage project management platforms, innovation information systems, and competition service platforms to offer digital support for student initiatives. This includes project application, process management, and outcome presentation, thereby reducing institutional and technical barriers to innovation participation and enhancing the sustainability of creative activities (OECD, 2019). Thirdly, in information resource sharing, digital libraries, research databases, and campus-internationally connected resource systems facilitate efficient integration and sharing of educational and innovative resources. This expands students' creative horizons and promotes interdisciplinary and cross-organizational collaborative innovation. Collectively, these functional elements form the essential foundation for digital teaching and innovation activities in higher education, providing the necessary environmental support for student-led innovation development.

(2) Student-led innovation

Student-led innovation refers to creative practices where students serve as the central actors in innovation activities, operating within environments with high autonomy and relative openness. Its core lies in emphasizing students' active participation and central role in the innovation process. Unlike teacher-led or goal-oriented embedded innovation activities, student-led innovation places greater emphasis on students' autonomous decision-making and practical leadership in areas such as topic selection, project design, team organization, resource integration, and outcome presentation. This innovation model not only focuses on results but also values the process-oriented significance of students building competencies through real-world practical activities. Existing research suggests that in higher education innovation systems, student-led innovation helps transform students from "learners" into "problem solvers" and "innovative practitioners," serving as a crucial pathway to cultivate innovative awareness and comprehensive abilities (Lackeus, 2015; Etkowitz & Zhou, 2017).

In terms of concrete manifestations, student-led innovation typically takes the form of entrepreneurial projects, science and technology competitions, interdisciplinary practices, and solutions to real-world social challenges. These initiatives often transcend traditional disciplinary boundaries, emphasizing problem-solving and hands-on approaches that require students to collaborate across fields and engage in

continuous exploration within complex contexts. Research indicates that student-led innovation demonstrates distinct characteristics of autonomy, practicality, and openness. It effectively stimulates students' learning motivation and innovative potential while fostering knowledge integration, teamwork, and social responsibility awareness during the process (Boud & Feletti, 1997; Zhou et al., 2020). Consequently, student-led innovation has become an integral component of higher education's innovation talent development framework, serving as a key indicator of the transition from knowledge transmission to competency cultivation in academic education.

III. THEORETICAL BASIS OF HOW DIGITAL INFRASTRUCTURE IN UNIVERSITIES AFFECTS STUDENT-LED INNOVATION

(1) From the Perspective of Human Capital Theory

Human capital theory posits that education and training constitute a vital form of investment, which enhances individuals' knowledge, skill sets, and overall competencies to yield long-term benefits for both personal and societal development (Schultz, 1961; Becker, 1964). In higher education, this theory underscores that the educational resources and learning environments provided by universities during talent cultivation serve as fundamental conditions for fostering students' skill accumulation and unleashing their innovative potential. With the ongoing advancement of educational digitalization, university digital infrastructure has evolved into a crucial vehicle for human capital formation, transitioning from a mere information transmission tool to a platform for capability development and innovation support.

Supported by digital infrastructure, students can more easily access diverse learning resources and engage in interdisciplinary and cross-contextual practical activities, thereby continuously enhancing their information acquisition, analytical, and innovative capabilities through real-world problem-solving. Research indicates that digital learning environments expand students' opportunities for innovative practice by reducing learning costs and lowering innovation barriers, which contributes to the sustained accumulation of human capital (Psacharopoulos & Patrinos, 2018). From the perspective of human capital theory, university digital infrastructure serves not only as a crucial component of educational investment but also as a key condition for fostering student-led innovative capabilities.

(2) The Perspective of Resource-Based Theory

Resource-based theory posits that organizational performance and competitive advantage stem from scarce, irreplaceable, and hard-to-imitate resources (Wernerfelt, 1984; Barney, 1991). In higher education, digital infrastructure serves as a strategic organizational asset, whose value extends beyond enhancing administrative and teaching efficiency to sustaining innovation activities. As universities increasingly prioritize innovation, digital infrastructure plays a pivotal role in integrating resources and optimizing the innovation ecosystem.

Specifically, universities integrate digital platforms to consolidate both internal and external innovation resources—including research data, competition projects, corporate partnerships, and social service demands—providing systematic and sustained support for student-led innovation. This resource integration capability helps mitigate information asymmetry and resource shortages students encounter during innovation processes, thereby enhancing the sustainability and success rate of innovation activities. Research indicates that when universities effectively allocate and utilize digital resources, their innovation support capacity significantly improves, creating a more conducive organizational environment for student-led innovation (Grant, 1996; OECD, 2019). Thus, the resource-based theory provides a crucial organizational framework for understanding how university digital infrastructure facilitates student-led innovation.

(3) From the Perspective of Constructivist Learning Theory

Constructivist learning theory posits that knowledge is not unidirectionally transmitted by teachers, but rather a dynamic process of continuous construction by learners through active exploration, reflection, and social interaction within specific contexts (Piaget, 1972; Vygotsky, 1978). From this theoretical perspective, the design of learning environments plays a decisive role in learning outcomes. By creating open, diverse, and highly interactive learning environments, university digital infrastructure provides crucial support for students to engage in self-directed inquiry-based learning and collaborative innovative practices.

Digital learning platforms, virtual laboratories, and online collaboration tools provide students with real or simulated problem scenarios, enabling them to continuously refine cognitive structures and generate new knowledge through practice. Research indicates that digital-based learning models enhance student engagement and learning investment, while fostering their sense of agency and practical skills in innovative activities (Jonassen, 1999; Selwyn, 2016). From the perspective of constructivist learning theory, university digital infrastructure not only transforms learning methods but also provides crucial environmental support for students' transition from passive knowledge recipients to active innovators.

IV. THE ROLE MECHANISM OF DIGITAL INFRASTRUCTURE IN UNIVERSITIES IN PROMOTING STUDENT-LED INNOVATION

(1) Improving the availability of innovation resources

Digital infrastructure in higher education serves not only as a technological backbone but also as a strategic mechanism for integrating and mobilizing diverse innovation resources. Through online platforms, information management systems, and digital collaboration tools, students gain streamlined access to a wide range of innovation projects, competitive events, and research materials that were previously fragmented or difficult to obtain. This enhanced accessibility significantly reduces structural and informational barriers that often limit student engagement in innovation activities, thereby enabling a broader and more diverse cohort of students to participate actively in creative and entrepreneurial

endeavors. By facilitating timely access to relevant resources, digital infrastructure not only supports students' ability to identify, plan, and execute innovative initiatives but also fosters a more inclusive and participatory innovation culture within the university. Consequently, such resource integration creates a fertile environment in which student-led innovation can flourish, promoting both individual skill development and collective problem-solving capacities (OECD, 2019; Zhou et al., 2020). In this sense, digital infrastructure functions as a critical enabler that bridges the gap between students' innovative potential and the practical opportunities to apply it.

(2) Optimize the Learning and Practice Environment for Innovation

Digital technologies offer students a highly flexible and multifaceted environment for engaging in innovative practice, extending well beyond the constraints of traditional classrooms. Tools such as virtual laboratories, online collaboration platforms, and cross-institutional digital networks allow students to participate in innovation activities that transcend temporal and spatial limitations, facilitating collaborative projects across disciplines and even between universities. This digitally mediated environment not only enables real-time interaction, resource sharing, and joint problem-solving but also encourages students to approach challenges from multiple perspectives, thereby fostering interdisciplinary thinking and enhancing creative capacity. Moreover, by providing opportunities for iterative experimentation and reflective practice in virtual or hybrid contexts, digital technologies deepen students' engagement in innovation processes and broaden the scope of practical innovation activities in which they can participate (Jonassen, 1999; Selwyn, 2016). Consequently, such open and flexible digital environments play a pivotal role in stimulating students' innovative thinking, promoting autonomy and initiative in creative endeavors, and cultivating the skills necessary to navigate complex, real-world problems effectively.

(3) Enhancing Students' Participation and Autonomy

Digital platforms emphasize user engagement and autonomous decision-making, providing students with platforms to showcase creativity, organize teams, and manage projects. Supported by digital infrastructure, students can actively participate in innovation processes, fostering a stronger sense of agency and responsibility in creative endeavors, thereby driving the development of student-led innovation.

(4) Promoting the Construction of Innovation Ecosystem in Universities

The digital infrastructure in universities plays a vital role in connecting students, teachers, enterprises, and social resources. Through innovation and entrepreneurship platforms and information systems, universities can establish a multi-stakeholder innovation ecosystem, providing a more comprehensive external support environment for student-led innovation.

V. REVIEW OF THE CURRENT STATUS OF RESEARCH ON HIGHER EDUCATION INSTITUTIONS IN SHANDONG PROVINCE

Current research consensus indicates that Shandong's higher education institutions have achieved significant progress in digital infrastructure development. The continuous improvement of smart campus construction, online teaching platform deployment, and innovation and entrepreneurship service systems has established a robust digital foundation for academic operations and student development. Studies demonstrate that through policy support and technological advancement, these institutions have progressively developed a digital infrastructure framework centered on campus networks, digital teaching platforms, and information management systems. This framework has proven instrumental in enhancing teaching efficiency, expanding educational resource availability, and improving learning environments (Wang Zhuli, 2020; Liu Xiaodong et al., 2021). These findings provide critical insights into the functional value of digital infrastructure in higher education.

The current literature predominantly examines how digital infrastructure impacts teaching quality, learning outcomes, and educational equity. For instance, numerous studies have analyzed the role of digital platforms in enhancing student learning performance, transforming teaching methodologies, and narrowing educational resource disparities through perspectives like online education, blended learning, and educational technology applications (Means et al., 2014; Selwyn, 2016). In contrast, research on digital infrastructure's influence on students' innovative capabilities—particularly student-led innovation—remains limited. Existing studies often provide general descriptions of innovation capacity or awareness, lacking in-depth analysis of the underlying processes and mechanisms.

In studies examining innovation-related themes, scholars have acknowledged the positive role of digital environments in stimulating students' innovative awareness, enhancing practical skills, and promoting participation in creative activities. They argue that digital platforms provide students with more open and diverse innovation spaces, which helps boost their enthusiasm for engaging in creative practices (OECD, 2019; Zhou et al., 2020). However, existing research predominantly analyzes the impact of digital technologies or platforms from a single perspective, lacking systematic exploration of the mechanisms behind student-led innovation. Current studies have yet to fully reveal how university digital infrastructure influences students' innovative behaviors through pathways such as resource allocation, environmental support, and institutional safeguards. Additionally, systematic reviews examining the relationship between university digital infrastructure and student innovation at the provincial level remain relatively scarce. The lack of a clear and unified analytical framework in related research has, to some extent, limited the generalizability and explanatory power of research conclusions.

VI. RESEARCH IMPLICATIONS AND FUTURE RESEARCH DIRECTIONS

Current research indicates that digital infrastructure in higher education institutions has emerged as a crucial enabler of student-led innovation, providing both the technological tools and the resource environments necessary for fostering creative and entrepreneurial activities. Digital platforms, virtual laboratories, online collaboration tools, and information management systems collectively contribute to enhancing students' access to knowledge, supporting interdisciplinary problem-solving, and facilitating engagement in authentic innovation practices. Despite the increasing attention to digital infrastructure in higher education, existing studies have primarily focused on its effects on teaching quality, learning efficiency, and educational equity, with comparatively fewer investigations systematically examining how digital infrastructure directly influences student-led innovation or the mechanisms through which this influence occurs (Zhou et al., 2020; OECD, 2019).

Moving forward, universities should explicitly recognize and prioritize the role of digital infrastructure as a support system that empowers students to act as primary innovators, rather than merely functioning as a technical or administrative facility. This requires a strategic shift from traditional infrastructure development toward the cultivation of service-oriented innovation capabilities, including fostering students' autonomy, creativity, collaborative problem-solving skills, and access to integrated innovation resources. From a theoretical perspective, future research should aim to strengthen conceptual frameworks that explain student-led innovation in the context of digitalized higher education, particularly focusing on the pathways, processes, and mediating factors by which digital infrastructure affects students' innovative behaviors.

Furthermore, comparative studies that incorporate diverse institutional types, program structures, and regional characteristics are likely to provide more nuanced insights into how contextual factors interact with digital infrastructure to influence innovation outcomes. Such investigations could enrich theoretical understanding and inform practical strategies for integrating digitalization with innovation-oriented education, ultimately supporting the development of high-quality, student-centered innovation ecosystems within universities. By advancing both theoretical and empirical knowledge in this area, higher education institutions can more effectively leverage digital infrastructure to cultivate students' innovative capacity, thereby contributing to broader goals of educational excellence, societal innovation, and regional development.

VII. CONCLUSION

In conclusion, existing research generally indicates that digital infrastructure in higher education institutions positively impacts student-led innovation. By enhancing resource accessibility, optimizing the innovation environment, fostering student autonomy, and building an innovation ecosystem, digital infrastructure provides crucial support for student-led

innovation. Shandong Province's universities have established a solid foundation in digital infrastructure development, and it is essential to further strengthen the deep integration of digitalization with innovative talent cultivation in the future. The review analysis in this paper can provide theoretical references for relevant empirical research and policy formulation.

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