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Regeneration of industrial heritage: A study on the feasibility of expanding into campus space

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Abstract: With the rapid pace of urbanization, campuses are confronted with the challenge of increasingly limited land resources. Traditional campus planning has proven inadequate in meeting the growing educational demands. In this context, exploring the feasibility of repurposing industrial heritage sites for campus space has emerged as a crucial research topic, offering valuable opportunities to expand campus facilities. This paper takes the regeneration design of industrial heritage along the Jiangsu Canal as an illustrative example and analyzes its potential value, modes of reuse, and design strategies. It further investigates how these sites can be transformed into educational spaces within a campus setting. Through practical applications in industrial heritage regeneration design, this paper explores three dimensions: adaptive integration with external spatial environments, functional replacement within internal structures, adaptive reconstruction of space layouts, and renewal of architectural forms. Ultimately, feasible strategies for regenerating and expanding industrial heritage into campus spaces are summarized herein, providing novel ideas and methodologies for future campus expansion endeavors. Concurrently, we hope to raise awareness among all sectors of society regarding the protection and reuse of industrial heritage while collectively promoting sustainable development in this field.

Keywords: *Campus spaces, Feasibility studies, Industrial heritage, Regenerative design.*

1. Introduction

Urban cultural heritage refers to significant elements of historical, cultural, artistic, architectural, or social value in a city. These encompass architectures, districts, landscapes, ruins, traditional crafts, and cultural spaces. These invaluable heritage components not only preserve the historical memory of urban development but also showcase the traditional legacy of societal culture, the evolution of artistic styles, and the trajectory of human activities. As an integral part of urban progress, urban cultural heritage plays an indispensable role in maintaining the distinctiveness of a city while promoting cultural inheritance and enhancing its image. They are not merely valuable assets but also bridges connecting the past with the future by allowing individuals to deeply comprehend a city's history and culture while experiencing its unique allure. The Sustainable Development Goals for Heritage aim to ensure proper protection, effective transmission, and scientific management of this cultural and natural heritage while fostering social,economic,and environmental sustainability. This implies that we should cherish these heritages and maximize their value through protection so that they may shine even brighter in this new era.

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As a novel form of cultural heritage, industrial heritage has undergone a gradual and continuous process of promotion, evolving from being gradually comprehended to actively protected. Presently, there is a shift in attitudes towards industrial heritage, as it is no longer perceived merely as an artifact of the past but rather recognized as an integral component of cultural heritage. It encapsulates significant historical memories pertaining to the development of human society and encompasses abundant values in terms of history, society, science and technology, economy, and aesthetics. Moreover, it serves as invaluable material evidence tracing the trajectory of social progress. Protecting industrial heritage not only fulfills the mission of preserving our cultural inheritance but also plays a pivotal role in maintaining cultural diversity and fostering creativity; thus becoming an essential measure for promoting sustainable social advancement. With the growing demand for spiritual fulfillment among individuals today, the outdated approach solely driven by economic interests that involved demolition and reconstruction has been gradually phased out. Instead, emphasis is placed on preserving, safeguarding repairing and regenerating industrial heritage within new environments to achieve harmonious coexistence between culture and economy[1]. In The Life and Death of American Big Cities, Jane Jacob emphasized that we should not solely rely on age and value to determine the objects of preservation while disregarding other historic structures. The transformation of old architectures should consider social benefits, with design and research centered around human activities. Rational space utilization must adhere to sustainability principles, which constitute the core focus of reuse. [2]. Therefore, in the process of urban construction, industrial heritage cannot be simply dismantled in a conventional manner. On the contrary, it is essential to intelligently integrate industrial heritage into the new environment through meticulous screening, preservation, renovation, and reorganization. This will create a spatial form that caters to modern needs while accentuating the past's industrial grandeur. The approach of adaptive reuse not only safeguards the historical characteristics of industrial heritage but also endows it with renewed functionality through renovation, thereby extending its architecture life cycle and enhancing its adaptability to contemporary demands [3-4].

The objective of this study is to analyze the value composition and reuse modes of industrial heritage along the Jiangsu Canal and propose corresponding strategies for regeneration design. To achieve this aim, qualitative research methods are employed to uncover issues, comprehend event phenomena, analyze human behavior and perspectives, and address inquiries in order to obtain relevant information. At the methodological level, this study extensively examines theories related to the protection and development of industrial cultural heritage, applying these theories to practical cases of adaptive reuse where industrial heritage is transformed into campus spaces. Through a thorough analysis of the feasibility of protecting industrial heritage and designing its regeneration process, researchers present a series of targeted suggestions and countermeasures with the goal of assisting fellow scholars in defining problems more accurately while promoting profound advancements in industrial heritage preservation. Specific research methods include: first, the literature research method. By collecting relevant information on industrial heritage research, we can gain an in-depth understanding of the connotation, characteristics, classification and value composition of industrial heritage. In addition, an in-depth analysis of the development history, basic composition, and current status of protection and adaptive reuse of industrial heritage is conducted. Second, case study method. Through analyzing design cases concerning the adaptive reuse of industrial heritage within campus spaces, this approach discusses the feasibility and suitability of transforming industrial heritage sites into expanded campus areas from three perspectives: integrating external spatial environments adaptively, replacing internal functions effectively, and adapting space through reconstruction while considering architectural form renewal. This methodology aims to provide researchers with practical experiences and successful practices by conducting in-depth studies on specific cases so as to enhance their understanding of the process involved in reusing industrial heritage sites within campus spaces.

2. Review on the Development of Industrial Heritage Protection

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Since the grand inception of the Industrial Revolution in England around 1750, approximately 274 years have passed. This revolution not only profoundly changed people's way of life but also reshaped the landscape of cities and countryside. The rapid advancement of technology led to the proliferation of industrial facilities, sparking jubilation for the flourishing industrial development. However, as we entered the 1960s and 1970s, resources gradually depleted, and the pace of economic transition hastened, leading to the closure of traditional industries. Once bustling industrial sites, towering architectures, advanced facilities, and equipment gradually fell into disuse, leaving a multitude of industrial workers unemployed, while environmental and social issues became increasingly prominent. Faced with all this, people began to deeply reflect on the negative impacts brought about by the process of industrialization, paying more attention to the issues of protecting and reusing industrial heritage.

As time passes and history accumulates, industrial relics increasingly reveal their unique value, akin to "fossil specimens," gradually integrating into the rich fabric of industrialized nations' historical and cultural heritage. Since 1986, the United Nations Educational, Scientific and Cultural Organization (UNESCO) has taken proactive steps to include these industrial relics in the World Heritage List alongside canals, railways, bridges, transportation, and power facilities that demonstrate outstanding engineering technology of the time. Industrial relics, as vivid witnesses to human civilization and urban development, resemble ancient palaces and temples, carrying the historical memory of cities. They have become indispensable cultural landscapes in the long river of human history, showcasing the splendor and vicissitudes of the industrial era to the world.

2.1. Characteristics of China's Industrial Heritage

1) Ancient Industrial Heritage (before 1840)

China has a long history and a splendid culture. Since ancient times, handicrafts have been highly developed, and the level of scientific and technological achievement has reached a considerable height. Over the years, we have left behind a rich ancient industrial heritage, primarily concentrated in mining and metallurgy, kiln sites, brewing, hydraulic engineering, and other broad categories of industrial architectural domains. For example, the Linxi Dajing Ancient Copper Mine in Inner Mongolia bears witness to the wisdom and hard work of ancient people in metal smelting. The Jun Tai Jun Porcelain in Weixian County, Henan Province, with its unique glaze colors and shapes, showcases the superb craftsmanship of ancient handicrafts. Moreover, ancient industrial heritage in places like Chengdu and Sichuan is equally diverse, encompassing masterpieces of hydraulic engineering or the inheritance of brewing techniques, all revealing the splendid chapter of ancient industrial civilization.

2) Modern Industrial Heritage (1840-1949)

Under the unique historical context of semi-feudal and semi-colonial China, Chinese industry emerged from a state of poverty and backwardness. During the Westernization movement in the late Qing Dynasty, government-run enterprises and government-business joint ventures played a pivotal role in driving this process, thereby laying an initial foundation for China's industrialization. Subsequently, during the late Qing Dynasty and early Republic periods, national capitalism and industrialists actively engaged in industrial development by establishing a series of enterprises that further propelled Chinese industry forward. Concurrently, as China gradually transformed into a semi-feudal and semi-colonial nation, foreign-funded enterprises entered the Chinese market, bringing advanced technology and management expertise that had a significant impact on China's industrial progress. Among these enterprises are notable examples such as Nanjing Jinling Arsenal, Fuzhou Mawei Shipyard, and Shanghai Yangshupu Waterworks; they not only represent important milestones in China's industrial history but also serve as symbols of the unwavering determination and hard work exhibited by the Chinese nation.

3) Contemporary Industrial Heritage (After 1949)

The development of China's industry can be divided into four distinct stages: the period of national economic recovery (1949–1953), the "First Five-Year Plan" period (1953–1966), the tumultuous period

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of the Cultural Revolution (1966–1976), and the period of industrial structural adjustment and upgrading since the beginning of the reform and opening-up policy. During the period of national economic recovery, 156 key industrial projects aided by the Soviet Union served as a beacon for China's industrialization. Meanwhile, military-industrial enterprises emerged rapidly under the Third Front Construction policy, demonstrating the vitality of China's socialist economy. Representative enterprises like Changchun First Automobile Works and Shenyang Foundry became shining stars in industrial construction during this period. With the advent of the First Five-Year Plan period, China's industry entered a phase of rapid development. During this time, the government increased investment in industry and promoted the construction of major industrial projects, laying a solid foundation for China's industrialization process. However, during the Cultural Revolution, the development of China's industry encountered obstacles. Despite facing numerous challenges, industrial construction continued to advance, showcasing the tenacious vitality of China's industry. Since the reform and opening-up policy, China's industry has encountered unprecedented development opportunities. With adjustments and upgrades in industrial structure, China's industry has gradually moved towards high-end, intelligent, and green development, contributing Chinese wisdom and strength to the world's industrial development.

2.2. Survey, Planning and Development of Industrial Heritage in China

In October 1986, Mr. Wang Tan of Tsinghua University in China chaired the inaugural seminar on the history of modern Chinese architecture, signifying the official commencement of a new era in the study of this field. Subsequently, there has been an extensive surge in nationwide research dedicated to modern architectural exploration, with particular emphasis on public architectures, religious structures, and residential edifices. While modern industrial architecture is also encompassed within the scope of investigation and research as a vital component of the contemporary architectural system, it regrettably fails to assume a central focus in terms of research and preservation efforts concerning modern architecture in China.

1) Survey on the Protection of Industrial Heritage in China

Since 1961, the State Council of the People's Republic of China has attached great importance to the protection of cultural heritage. As of the announcement of the eighth batch of national key cultural relics protection units in 2019, there are a total of 5058 key cultural relics protection units nationwide, with 453 industrial heritage sites accounting for 8.96% of the total, an increase from 7.75% in the previous seven batches. Due to the need for a further unified understanding of the scope of industrial heritage, there are some differences in the numbers reported by different scholars. However, it is certain that industrial heritage still requires stronger research and protection compared to other types of heritage. These industrial heritage sites mainly include smelting sites, mining sites, kiln sites, bridges, brewing facilities, and water conservancy projects. Industrial heritage is an important carrier of industrial culture, recording significant information about the different stages of China's industrial development and witnessing the historical process of national and industrial development. It holds important historical, technological, socio-cultural, and artistic value. They are not only important physical materials for studying the history of China's industrial development but also important mediums for inheriting and promoting excellent traditional Chinese culture.

2) Planning for the Protection of Industrial Heritage in China

The protection planning and management system for industrial heritage is essentially evolving along two main directions: one influenced by the declaration of World Heritage sites, which prompts the formulation of heritage protection plans and applications for World Heritage status; the other led by the Ministry of Housing and Urban-Rural Development, encompassing urban special planning, historical district preservation planning, historical building conservation planning, and general industrial heritage protection planning systems. In terms of formulation requirements, urban special planning can be seen as an innovation in the development of China's industrial heritage protection planning. At the urban level, protection of industrial heritage tends to lean towards comprehensive planning, with cultural

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relics primarily categorized by scale and in alignment with regulatoryly detailed planning. In contrast, historical building preservation planning involves more detailed planning or construction project management. The emergence of industrial heritage protection planning signifies the diversification of China's cultural heritage protection planning. Since the standardization of two important planning systems—the National Key Cultural Relics Protection Unit Protection Planning in 2004 and the Historical and Cultural City Protection Planning in 2005—the Ministry of Housing and Urban-Rural Development and the State Administration of Cultural Heritage issued the "Requirements for the Preparation of Protection Plans for Historical and Cultural Cities, Towns, and Villages (Trial)" in 2012 and the "Basic Requirements for the Preparation of Traditional Village Protection and Development Plans (Trial)" in 2013. In 2015, the State Administration of Cultural Heritage issued the "Regulations on the Protection Planning of Major Sites" and the "Guidelines for the Preparation of Great Wall Protection Plans (Draft for Solicitation of Comments)," and in 2017, it also issued the "Requirements for the Preparation of Protection Plans for National Key Cultural Relics Protection Units (Revised Draft)". The development process of protection planning indicates that China's cultural heritage protection planning is gradually becoming more refined and beginning to research protection planning for different types of cultural heritage [5].

3) The development of the protection of industrial heritage in China

The main historical period of industrial heritage encompasses the industrial revolution from the latter half of the 18th century to the present day, while also acknowledging pre-industrial and embryonic industrial activities. China's industrial heritage primarily consists of modern factories established by foreign capital, industrial development propelled by westernized officials, private capitalist ventures in Chinese national industry, and socialist industry during New China. These distinct legacies constitute the core of China's industrial heritage. Despite having a relatively short history spanning only a few decades or nearly a century, they serve as indispensable physical evidence of social progress. Industrial heritage carries vital information regarding China's societal advancement and exerts an even more profound influence on population, economy, and society than cultural heritage in other historical periods. Consequently, safeguarding industrial heritage holds immense significance. In urban construction within China, numerous instances of factory closures and relocations followed by real estate development have resulted in the irreversible demolition of valuable industrial heritage sites and the substantial loss of invaluable archives. Therefore, expeditiously conducting identification and salvage arrangements for industrial heritage is particularly crucial.

Since 2001, the relevant functional departments of the Chinese government have initiated the formulation and issuance of a series of significant documents in the field of industrial heritage. Among them, in April 2006, the China Association for the Protection of Monuments and Sites (ICOMOS CHINA) organized the China Industrial Heritage Protection Forum in Wuxi and adopted the "Wuxi Proposal: Emphasizing Industrial Heritage Preservation during Rapid Economic Development." In that same month, the State Administration of Cultural Heritage held its own China Industrial Heritage Protection Forum in Wuxi and endorsed the Wuxi Proposal. In May of that year, recognizing both the importance and urgency of industrial heritage preservation within China's cultural heritage protection framework, the State Administration of Cultural Heritage issued a notice titled "Strengthening Industrial Heritage Preservation," officially commencing nationwide efforts to safeguard industrial heritage. This initiative propelled comprehensive development within China's industrial heritage protection domain while igniting an upsurge in preservation endeavors. In 2007, as part of its third national survey on cultural relics, China included industrial heritage for investigation purposes for the first time ever, thereby elevating it to one of their primary areas for newly discovered heritages. This endeavor not only underscores industrial heritage's crucial role within cultural preservation but also establishes a solid foundation for excavation, identification, and protection measures concerning China's industrial legacy.

In 2019, the State Administration of Cultural Heritage officially initiated the application and evaluation process for the eighth batch of key national cultural relic protection units. Within this

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evaluation, a comprehensive review was conducted on 49 industrial heritage sites, thereby not only emphasizing the significant status of industrial heritage in cultural heritage preservation but also highlighting its increasing recognition and concern across various sectors of society. The thorough development of this assessment holds immense significance in further advancing the safeguarding and inheritance of industrial heritage while promoting the integration between cultural diversity and sustainable development. However, despite certain industrial heritage sites being included in the protected list, their legal protection merely represents a small fraction compared to what should be encompassed within such preservation efforts. Since 2006, several cities have commenced general identification procedures for industrial heritage along with formulating protective plans; however, most cities, particularly traditional industrial ones, have yet to incorporate industrial heritage protection into their scope of cultural heritage preservation while lacking an overall evaluation framework for such assets.

3. The Relevance of Adaptive Reuse of Industrial Heritage and Campus Space

The idle industrial heritage in the city, due to its advantageous location and low density as well as a low plot ratio, often becomes an ideal site for educational buildings. Moreover, the diverse interior spaces it offers also cater to various activity venues on campus. The transformation of abandoned industrial heritage into flexible campus space and its adaptive reuse not only effectively enhances the functional space of regional urban areas under the backdrop of advocating a low-carbon economy and promoting green buildings, but also serves as a valuable means to preserve historical context and place spirit. This transformation has rendered it environmentally friendly, resource-efficient, and economically advantageous, thus becoming an effective approach to urban renewal within the framework of sustainable development. Numerous exemplary cases exist in both domestic and international practice where industrial heritage sites have been successfully repurposed into educational buildings, fully showcasing the potential of transforming abandoned industrial heritage into vibrant and innovative educational spaces. By preserving historical context while incorporating innovative design elements, these adaptive renovation projects have emerged as beneficial practices for urban renewal and sustainable development that warrant our attention and consideration.

Overseas, the University of Nottingham Juliby in the UK has successfully repurposed a derelict bicycle factory into a verdant campus that exudes natural vitality. The design concept emphasizes ecological principles by transforming the former industrial heritage within the factory into a hub for campus information, central teaching and service facilities, dining establishments, versatile halls, and other educational and support functions catering to 2,500 students. In addition, Dan Mroskeeler Music Festival High School has implemented a blend of preservation and contemporary construction techniques, which collectively constitute the school complex. Drawing inspiration from the Roskilde Music Festival, the design ingeniously amalgamates "joyful moments" and "unrestrained freedom" to evoke a psychological sense of liberation. The teaching building preserves the original concrete facade, columns, and roof while reconfiguring and optimizing the internal space. The renovated area now functions as a dynamic creative hub and community, fostering individual potential across various disciplines such as music, media, contemporary art, architecture, and design (Figure 1).

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a. Nottingham Juluby Campus in the UK

b. Roskilde Music Festival High School inDenmark

Figure 1.
Cases of foreign industrial heritage being expanded into campus space.

The focus of industrial heritage transformation in China primarily lies in the preservation of urban industrial heritage, with the primary objective being commercial profitability. This emphasis on profit limits the potential for diversified development within industrial heritage transformation. While there are relatively few instances of transforming industrial heritage into university buildings in China, there are still some noteworthy cases (Table 1). For instance, the Wuchuan Road Campus of Shanghai University of Finance and Economics has repurposed the seven-floor workshop of the former Phoenix Bicycle Factory into the Yingxian Library, encompassing a construction area of 30,677 square meters and accommodating over 3,000 reading seats. This transformation aims to establish a new spatial order and communication space within the building while simultaneously fulfilling the functional requirements for school operations. Furthermore, it successfully preserves the historical memory and context associated with its previous use. The process of renovation design emphasizes the shaping of architectural quality with a humanistic touch, the creation of an open and communicative spatial atmosphere, the adoption of adaptive ecological strategies, and the highlighting of the design concept prioritizing space. The former site of Huaqing College, Xi'an University of Architecture and Technology, was previously occupied by the Shaanxi Steel Plant. Through a methodical approach involving preservation, demolition, and new construction, we have meticulously respected the architectural style of the original factory. Consequently, we have successfully transformed this space into a sprawling campus spanning 500,000 square meters. This campus now comprises state-of-the-art teaching buildings, comprehensive service facilities, computer network centers, and research buildings, as well as an extensive library, laboratory complex, student activity center, and dining hall. These enhancements aim to provide both teachers and students with an exceptional learning environment while ensuring their comfort in daily living.

Table 1.
Typical cases of domestic industrial heritage transformed into campus space

No.	Current name	Original use	Year of construction	Reuse time	Photograph
1	The library of Shanghai University of finance and economics	The third factory of phoenix bicycles	1988	2006	

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No.	Current name	Original use	Year of construction	Reuse time	Photograph
2	The department of construction, Inner Mongolia university of technology	Shan'xi steel factory	1968	2008	
3	Huaqing College, Xi'an University of architecture and technology	Iron and steel factory	1958	2002	
4	Jia Pingwa literature art museum	Printshop	unknown	2006	

Table 2.
(Cont.) Typical cases of domestic industrial heritage transformed into campus space.

No.	Current name	Original use	Year of construction	Reuse time	Photograph
5	The library of Shanghai University of finance and economics	The third factory of Phoenix bicycles	1988	2006	

4 Industrial Heritage Extends the Fundamental Principles of Campus Space

4.1. Preservation and Regeneration of Architectural Authenticity

The first principle of adaptive reuse of industrial heritage is authenticity, which can be observed in renowned cases of industrial heritage renovation. These cases demonstrate that architectural structures, materials, sites, and industrial equipment possess significant historical, cultural, artistic, scientific, social,

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and economic value. By appropriately transforming and renewing the original architectural features to accommodate new functions while preserving their unique characteristics and artistic charm. The industrial heritage, simultaneously, is the outcome of the process of human industrialization, bearing witness to the advancement of large-scale industrial production and serving as a vessel for historical recollection and emotional sustenance. When converting the industrial heritage into an educational facility, it is possible to harness the potential of the original building space and structure, including the architectural form, internal building height, lighting conditions, and color scheme. The design direction for extending industrial heritage to campus space is sought through functional replacement of internal spaces, preservation of the original space, and reorganization and addition.

4.2 Shaping the Openness and Flexibility of Space

The continuous development of education will lead to a greater diversity in course offerings and teaching methods, necessitating the adoption of openness and flexibility as important principles to adapt to future changes in education. The spatial characteristics of openness and flexibility reflect their inherent adaptability and external relevance, highlighting the organic interaction between spatial functionality and human behavior[5]. The characteristics of the main structure of industrial heritage, such as its robust construction, lofty and adaptable space, and substantial building volume, align with this observation. Primarily leveraging the open external spaces and towering internal areas within industrial heritage sites enables the convergence and intermingling of multiple functional zones, facilitates seamless integration between interior and exterior spaces, and also allows for flexible spatial transformations. This approach enhances spatial inclusivity and effectively fosters student engagement in teaching activities. Secondly, communication spaces, gray spaces, and composite spaces are extensively utilized in educational buildings. By employing open and flexible spatial design, they have the potential to influence the behavior of both teachers and students, stimulate critical thinking among students, enhance campus activity venues for students' enrichment, facilitate spontaneous communication between teachers and students, as well as foster diversity and the extension of campus culture. Finally, the change in teaching and learning breaks the traditional closed and conservative model, and the continuous development of education itself provides a driving force for the innovation of teaching space, which helps to change the single campus space and provides multiple possibilities for the expansion of campus space. The evolution of educational concepts and needs will lead to the emergence of open and flexible spaces as a significant trend in future educational architecture. The characteristics of industrial heritage perfectly align with this trend, offering new opportunities for innovation and progress in educational spaces.

4.3. The Integration of Industrial Historical Memory and Campus Culture

Chinese architect Wu Liangyong once stated: "Culture is the accumulation of history, preserved within architectural structures, and integrated into daily life." As two distinct forms of architecture, industrial heritage and educational architecture possess distinctive functional characteristics, cultural attributes, and temporal qualities. The industrial heritage, as a crucial component of urban development, embodies the historical evolution and cultural value orientation of both industrial and post-industrial societies, along with the political, economic, cultural, and technological advancements during the industrial era. These remnants serve as tangible manifestations of a city's history while also serving as significant testaments for future generations to comprehend their past [3]. The educational building, bearing a long cultural context and academic atmosphere, is an important place for teaching and educating people and also the cradle of cultivating innovative talents. Through the adaptive reuse of industrial heritage, it can better continue its place spirit, penetrate industrial history culture and campus culture into each other, and form a situation of mutual darning. By incorporating industrial heritage into the design of educational architecture, the campus not only serves as a hub for teaching and learning but also serves as a tangible representation of the city's historical context. This integration creates a harmonious entity that seamlessly blends history with future aspirations.

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4.4. Creation of Low-Carbon and Ecological Campuses

In the context of promoting the implementation of sustainable development strategies and green design, global adoption of green building standards aims to minimize energy consumption and carbon emissions within the construction industry. Environmental sustainability, energy efficiency, emission reduction, low-carbon, and ecological considerations have become pivotal factors in educational building design. First and foremost, the material lifespan of a building always exceeds its functional lifespan, particularly in the case of industrial buildings, which often undergo multiple changes in function throughout their existence. Preserving the structure and aesthetics of existing buildings through adaptive reuse is not only an effective means to achieve new functionalities but also serves as a cost-saving measure by eliminating the need for extensive construction. Additionally, this approach ensures the continuation of historical heritage within the physical environment. Secondly, transforming industrial heritage typically involves shorter cycles and lower costs compared to constructing new building structures and infrastructure. The original buildings and corresponding infrastructure can often be partially retained for continued use. Compared to demolition and reconstruction, adaptive reuse offers the advantage of reducing additional transportation and disassembly costs associated with building materials, as well as minimizing the release of toxic gases from solid waste and building materials. Moreover, the reuse of industrial heritage can alleviate pressure on urban transportation and energy resources (such as water and electricity consumption) while also mitigating CO2 emissions generated during the transportation of building materials. Simultaneously, it avoids significant environmental pollution caused by dust and noise during the demolition process. By embracing low-carbon recycling practices for old facilities and materials, this approach aligns with the development needs of sustainable cities focused on low-carbon initiatives.

5. Design Practice of Regenerating Industrial Heritage into Campus Space

5.1. Project Background

With the expansion of school enrollment, the existing campus area has become insufficient to meet the growing demand for learning and the increasing student population. Given limited resources in old urban areas, it has become an urgent challenge for education, planning, and construction management departments to effectively expand the current campus space, modernize and update the campus environment to cater to evolving learning needs, and create a contemporary campus environment that aligns with the requirements of this new era. Addressing this issue will have a profound impact on schools, communities, and the future of education. Addressing this issue will have a profound impact on schools, communities, and the future of education. Gongdao Middle School in Yangzhou, Jiangsu Province, China, has been faced with this contradiction since it expanded its enrollment scale. Located in Hanjiang District, Yangzhou, a canal city in Jiangsu Province, GongdaoTown has rich natural resources, a solid industrial foundation, obvious ecological agriculture features, and great leisure tourism potential. After many discussions between the leaders in charge and experts, it was decided to transform the idle old industrial plant area on the east side of the school into an education park to realize the revitalization of the regional environment of the ancient town of the canal.

The Yangzhou Zhongjiang Machine Tool Factory, constructed in the 1980s and once an emblem of Gongdao Town, stands to the east of the school, encapsulating a generation's memories. Currently designated as Yangzhou City's general industrial heritage, this factory has remained closed for numerous years and now lies abandoned. The plant exhibits a relatively orderly layout, with buildings dispersed throughout the premises, creating an external space shaped like an L shape. The factory consists of two rows with a total of seven plants, each exhibiting unique shapes. Among them, Buildings A and B are single-story, multi-span workshops that were originally used as machining facilities and boast high ceilings. The remaining buildings are single-story, single-span structures housing machine repair workshops, finished product workshops, and warehouses. All the buildings feature concrete frame structures, providing an open space with a simple yet elegant design. The primary structure and

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maintenance walls have been well preserved, truly reflecting the characteristics of the industrial era while also possessing potential for retention and reconstruction (Figure 2).

5.2. Design Concept

1) The concept of integration - incorporation of urban context and texture

Under the premise of respecting the historical context of the city, by emphasizing the characteristics of the site and preserving the historical context and cultural memory of the original building, the goal is to inherit the spirit of the campus. Relying on the existing urban structure, we attach importance to the transformation characteristics of the existing buildings and extend their sense of scale to the urban environment. The reshaped campus is integrated into the urban fabric, injecting new urban vitality and reinterpreting its historical value.

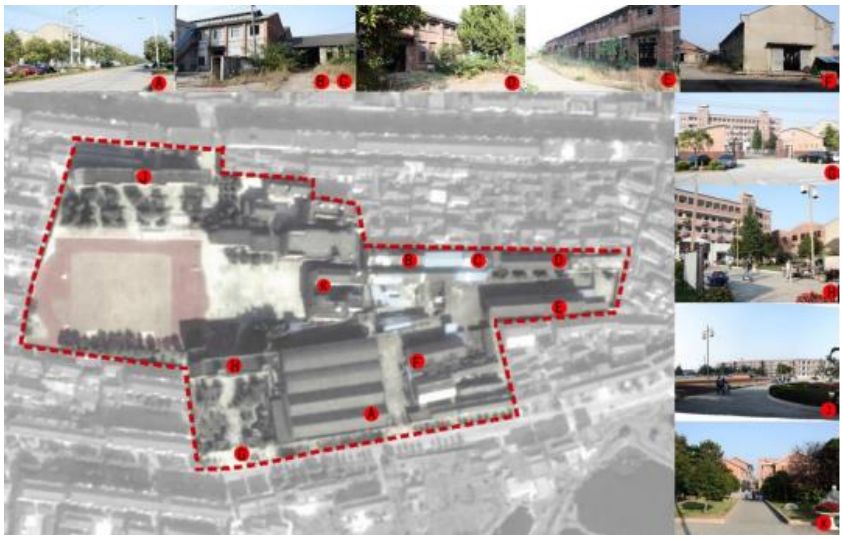

Figure 2.
Base status.

2) The concept of humanistic - expanding campus cultural blocks

The campus expansion focuses on cultural and sports buildings, transforming industrial plants of different sizes into multi-functional venues such as indoor gymnasiums, lecture halls, graphic information centers, and art and music classrooms, creating a communication space with creative culture and student activities as the core, and building an adaptable, demanding, and vibrant campus cultural area.

3) The concept of symbiosis - symbiosis between old and new buildings and the Environment

Use the idea of symbiosis to deal with the diverse and heterogeneous problems in the transformation of industrial heritage, and fully respect the balanced integration of various elements of the architectural history, campus internal environment, and the building itself. Reorganization and reconstruction of educational buildings, the environment, and old factory spaces aim to create an ecological campus that not only has modern cultural characteristics but also reflects the historical context of the site and achieves the integration of new and old buildings and the campus environment.

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5.3. Design Strategies

1) Integrated into the overall layout of the urban space texture

In order to enhance the connection between the campus and the city and present a coherent and comprehensive urban image, disorderly areas that do not conform to the overall spatial pattern are reasonably demolished, constructed and integrated in the external design. At the same time, the distinctive spatial structural characteristics of the original school and factory are retained and extended, while the adjacent east-west interfaces are connected to establish an overall framework of "one street and two axes". The streets within the campus serve as the layout framework, establishing a cohesive structure and facilitating convenient and efficient connectivity between the functional courtyards of both the new and old campus spaces. The two axes are referred to as the "campus memory axis" and the "industrial memory axis." The original entrance of the old factory has been transformed into the main entrance, serving as a prominent feature of the campus. Additionally, by preserving Etiquette Square, which retains its industrial heritage from when it was part of the original factory area, it becomes an integral component of the "industrial memory axis." Furthermore, in order to maintain continuity with regards to spatial sequence and important landscape nodes, we have preserved the north-south traffic main axis of the original campus to form what is now known as our "campus memory axis."

2) Construction of campus space structure and order

A well-designed campus spatial structure can effectively connect different functional areas, enhance the utilization efficiency of campus resources, facilitate the development of teaching activities, and also influence the communication environment and the construction of a vibrant campus atmosphere. In terms of design, it is important to adhere to the principle of "respect" in order to optimize and integrate the existing spatial layout on campus. The overall flow line for pedestrian traffic within the campus should be planned as "school entrance, ceremonial square, cultural district, sports area, and teaching zone," while students' outdoor activity paths should alternate between the original teaching area and an expanded cultural block, creating two mutually beneficial spaces. In order to enhance the overall experience of the old and new spatial orders, the public space was reorganized around the tall chimney. The researchers planned the square, the multiple paths connecting the square, the appropriate viewing scale, and the orderly interface enclosure, positioning it as an important element in the entire spatial order and becoming a turning point and guiding mark on the entire campus movement line. Contribute to the natural transition of people between old and new spaces. In the design of the campus cultural block, the combination form of neighborhood courtyards is adopted, the original factory buildings are retained, and an irregular U-shaped structure is formed by adding connectors and corridors. This design creates an open public space on campus and uses the turning openings between the old and new buildings to create a pleasant semi-open courtyard space (Figure 3).

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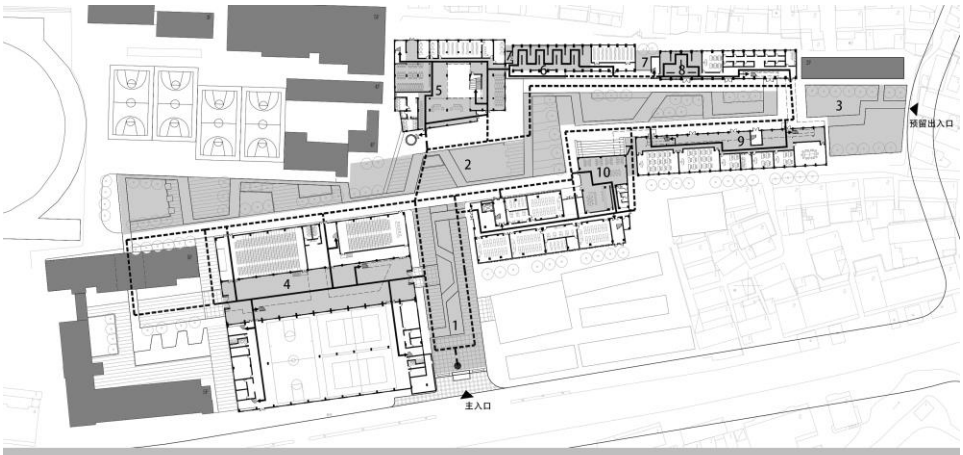

Figure 3.
Spatial fluidity

3) Replacement of internal functions and adaptive reconstruction of space

The process of spatial reconstruction involves breaking the original spatial relationship and integrating new and old media systems to reconstruct the spatial order. The industrial heritage's large, tall spaces and exposed structural components align with contemporary teaching philosophy that emphasizes communication, experience, and practice. To meet teaching needs, a functional adaptability-based scheme for spatial reconstruction is proposed to assign appropriate functions, diversify the teaching space, and promote the integrated development of teachers and students.

(1) From single space to multiple space modes

In the process of industrial heritage renewal, people's spatial experience and enjoyment are met through the protection and restoration of buildings, as well as the preservation of historical pictures and scenes.

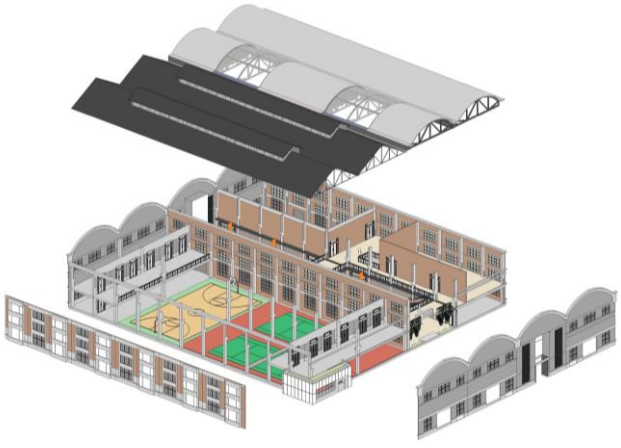

Figure 4.
Activity center model.

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The repurposed industrial heritage assumes a more inclusive nature by integrating diverse behaviors, thereby promoting new spatial experiences and enhancing the vitality of the place. In view of the location of Factory Building A on the campus, in order to facilitate direct access to the teaching area on the west side from the campus entrance square, a "building inner street" renovation strategy was adopted. This strategy transformed the one-span column space inside the main factory building into a complete inner street and, at the same time, demolished part of the gable walls on the east and west sides to clearly mark the location of the entrance and exit. The inner street connects the campus entrance plaza, the teaching area, and the north and south venues inside the building (Figure 4). The four-span space is transformed into a behavioral space of varying scales, encompassing a sports experiential zone (wind and rain playground), an educational and training facility (lecture hall, multifunctional classroom), as well as an entertainment experience area (small theater, activity room).In an 8,000 m^2 space, various functions such as a small theater, exhibition area, bookstore, lecture hall, and fitness center are combined. These functions complement and integrate with each other, organically organizing students engaging in different activities around a vibrant street-like space.

(2) From spatial openness of functional openness

The design of building B focuses on strengthening its structure and defining its functions while adhering to the principle of openness by incorporating layered spaces. These additional layers are strategically placed within the line of sight, creating a continuous transverse layout that connects the upper and lower levels, resulting in an open book reading space. This innovative design transforms modern learning from paper-based to digital platforms, making the reading room a versatile space for reading, discussions, and knowledge exchange. Instead of using walls to enclose specific functional areas, they are utilized to create flexible spaces that cater to different privacy requirements. Movable bookshelf walls divide the space into distinct reading zones while maintaining transparency and reflecting the overall openness of the area. To mitigate any sense of detachment caused by the lofty ceiling height, exhibition platforms are seamlessly integrated with stairs, steps, and ramps to establish organic connections between different floor levels (Figure 5).

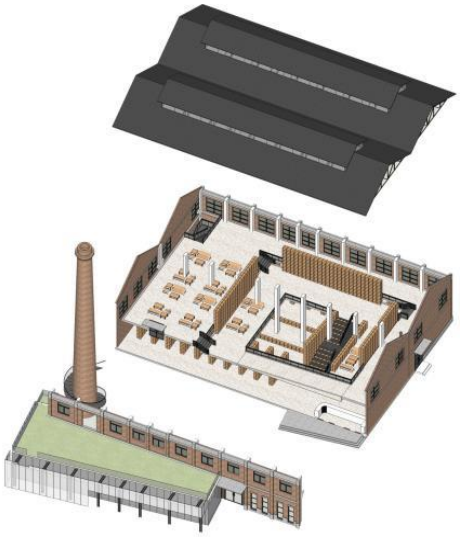

Figure 5.
Information graphic center.

(3) From Spatial Expansion to Spatial Interaction

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As the core spiritual space of educational buildings, public interaction spaces expand diverse levels of communication spaces within the campus, creating a harmonious atmosphere for knowledge exchange, which is particularly important for improving the quality of campus space. By expanding the traffic space and incorporating interaction functions, the utilization rate of communication space can be effectively improved, and intensive and composite use of public space can be achieved. For example, in the design of entrance space, walkways and stairway platforms can be appropriately enlarged and widened, and shared atrium spaces can be set up. According to the scale, virtual reality, brightness, and atmosphere of the space, exhibition, reading, and art salons can be arranged to maintain the flow and transparency of the space. This priority strategy for creating public interaction spaces is not only reflected in the "adaptation" of industrial plant spaces to functional changes but also in the "induction" of communication activities. For instance, according to the functional replacement and streamline of space, Building A is divided into three functional zones: the wind and rain playground, the lecture hall, and the activity corridor. One of the tall spaces of the factory building is reserved to form an interaction place (atrium space) between the wind and rain playground and the lecture hall. The space is divided and separated by some displays and landscape greening related to industrial history. Based on the open characteristics of interaction space, it is positioned as a student activity corridor that emphasizes communication, experience, and practice. The atrium space is a versatile indoor space that looks like a street. The wind and rain playground and lecture hall are unfolded along the "street." Through overhead structures, corridors, passages, bridges, stairs, etc., the interaction space is interconnected and accessible, forming a multi-dimensional sense of public space and demonstrating the street form of a miniature city (Figure 6).

Figure 6.
Atrium space.

4) Adaptive Redevelopment and Renovation of Architectural Forms

Zhang Yonghe and Zhang Lufeng wrote in "Learning from Industrial Buildings"[6]: "Important Formula 11: Industrial Buildings = Civil Buildings = Basic Buildings. Regardless of any type of building, if architects devote themselves to the connection of materials, the logic of construction, the

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quality of construction, the relationship with the site, and the human experience of space, they are creating basic buildings."In the process of reusing industrial heritage as civil buildings, emphasis is placed on the construction of architecture and spatial experience. The interfaces created by materials and construction are integrated into the human experience of space, allowing the industrial building environment to possess both continuity and a renewed sense of perception.

(1) Re-composition and detailed design of old and new materials

(2) In order to fully enhance the regional character, the facade was meticulously designed to reflect the juxtaposition between preservation and new construction. By incorporating innovative materials and structures, we seamlessly integrate the old with the new, blending ancient elements with contemporary architecture in a harmonious manner. In the design of the activity center, gable hollow tile masonry replaces traditional ventilation louvers and is applied throughout public corridors, stairwells, toilets, and other areas requiring ventilation and lighting. This not only improves indoor natural lighting but also creates an environment with a dynamic interplay of light and shadow (Figure 7). Regarding facade materials and color scheme, we maintain an industrial style by utilizing red brick veneer, dry hanging cement board, and cement-colored exterior paint. To distinguish the new section from the old one while establishing a contrast between virtuality and reality, dark metal-framed glass is employed, which adds lightness to the building while enhancing the internal-external communication atmosphere. In terms of detailed design aspects such as doors, windows, and walls, the existing structure is reinforced using new metal frames that enrich the facade shape while increasing visual interest without compromising the overall integrity of the building (Figure 8).

Figure 7.
The reconstitution of bricks.

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Figure 8.
Architectural exterior design.

(3) Redesign of Industrial Architectural Elements

In the revitalization of industrial heritage, our commitment lies in preserving its industrial essence and providing students with a seamless experience of industrial architectural spaces, enabling them to truly appreciate the allure of reborn industrial architecture (Figure 9). The building retains its inherent features, such as exposed concrete structural elements, steel staircases, and unapologetic structural details that serve as a testament to advanced industrial technology. The juxtaposition between new and old structural components is clearly visible, effectively conveying the construction logic and transformation approach: the added and reinforced floor structure system reflects the adaptive process of transforming cultural and architectural spaces alongside plant structures; the interior function layout exemplifies how building functions are harmoniously integrated with workshop spaces through meticulous construction planning. Furthermore, the interior space decoration showcases an innovative fusion of green technology with plant equipment and installations, while the architectural details and external envelope demonstrate a creative blend of traditional materials with contemporary ones.

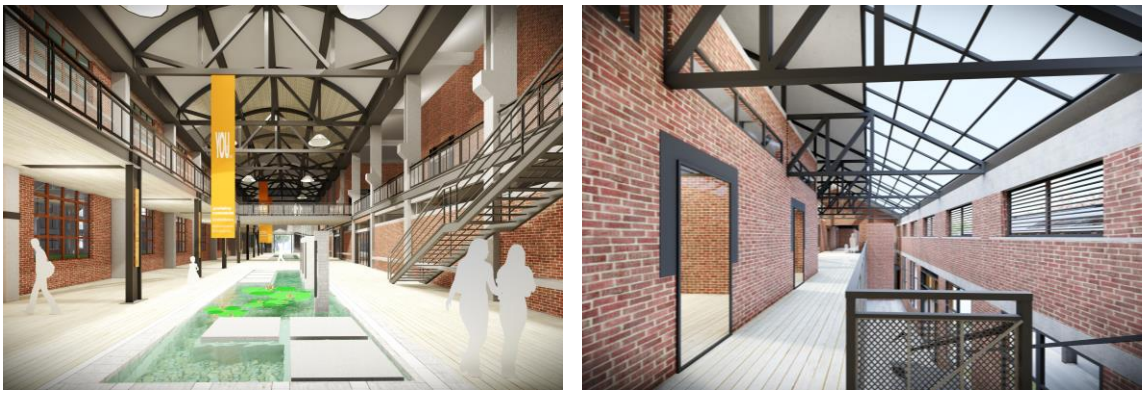

Figure 9.
Interior space construction experience.

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5) Integration of industrial landscape and campus environment

In his book "External Space Design," Yoshinobu Ashihara [7], a contemporary Japanese architect, argues that the external space of architecture originates from the essence of nature. It is a defined space within nature's framework, distinct from its infinite expanse. The external space represents a purposefully created environment by humans and holds more significance than nature itself. This exterior space is characterized by two elements: the ground and walls, as it can be seen as a "roofless building." In the context of transforming an educational park with industrial heritage, the external space serves as an extension of the internal spaces. However, due to changes in architectural functions, the original external space no longer meets the functional requirements of educational buildings. Therefore, renovating this external space becomes crucial for integrating newly reconstructed buildings with urban surroundings and traffic flow through urban design principles. Simultaneously, these renovated outdoor areas can better fulfill the functional needs of educational structures while considering factors such as building facades and landscapes.

(1) Enclosure of the courtyard

The courtyard space between the original buildings of industrial heritage is extensive, simplistic, and predominantly constructed with hard materials. It lacks landscape design and is primarily utilized for machine and material storage. Conversely, in educational buildings, the courtyard space is frequently employed as it serves as the central area of the school where individuals can observe, sit and converse, engage in entertainment activities, and partake in social interactions. The existing courtyard characteristics of industrial buildings no longer align with the requirements of campus structures for such spaces. Therefore, during the transformation process, it becomes imperative to enclose and segregate the initial courtyard area while incorporating landscape design elements to establish an enjoyable scale and foster diverse layers of communication spaces. Yangzhou Gongdao Middle School's external landscape space exhibits a segmented layout wherein each section forms a small enclosed courtyard equipped with leisure amenities like seating areas. This arrangement provides teachers and students with a post-class venue for communication and interaction (Figure 10).

Figure 10.
Rest area landscape design.

(2) Square setting

The campus plaza plays a pivotal role in the external environment of the building and serves as an essential element of the school landscape, providing students and faculty with a conducive space for learning, socializing, and functioning. The exterior spaces of industrial heritage buildings possess distinctive characteristics. In terms of design, an excessive scale would result in emptiness and monotony, lacking affinity and attraction overall. Appropriate scaling creates a comfortable and friendly atmosphere while fostering effective communication through elements such as enclosure, ground paving, and level treatment. The establishment of the square not only fulfills the functional

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requirements of external space for educational buildings but also enhances the quality of the surrounding environment. At Yangzhou Gongdao Middle School's entrance, a waterscape design has been incorporated to embellish the campus gateway with a touch of vitality. Students pause at the school gate to appreciate this splendid scenery that exudes energy and liveliness on campus. This water feature design has become a prominent highlight within the campus premises, attracting teachers and students to gather together during their leisure time to relish nature's beauty while unwinding (Figure 11).

Figure 11.
Entrance waterscape design.

(3) Landscape reshaping

Landscape shaping involves the preservation, transformation, and planning of industrial heritage architectural landscapes, as well as the incorporation of new landscape elements such as greenery, sculptures, and water features to infuse fresh characteristics into the industrial heritage. The specific approach is outlined below: firstly, it is essential to retain the industrial elements. Industrial buildings and their surrounding areas often possess unique historical production equipment and features that reflect their respective eras. In the renovation project of Yangzhou Gongdao Middle School's industrial heritage site, certain industrial elements with cultural significance were preserved.

Figure 12.
Reuse of water towers in industrial structure.

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Figure 13.
Integrating industrial elements into campus landscape design.

This not only maintains the historical context of the industrial heritage but also adds an artistic ambiance to the external environment. For instance, during renovations, the iconic water tower was preserved on campus and repurposed as an entrance to an infographic center, enhancing visual interest while becoming a prominent symbol (Figure 12). Secondly, landscape sketches are introduced for embellishment purposes. These decorative landscape pieces serve to beautify public spaces by showcasing aspects of urban history or social spirit through sculptures or frames. In transforming industrial heritage buildings at Yangzhou Gongdao Middle School's campus design project, old buildings along with machinery and equipment possessing historical value were retained and transformed into captivating landscape pieces that seamlessly integrate with their surroundings (Figure 13).

6. Conclusion

In the project of industrial heritage regeneration design, whether industrial heritage, as an important component that is well preserved and carries collective memory, can go beyond the era's demise and find paths of protection and reuse, thus exploring and presenting its practical significance to the city, is the core of this study. The research findings indicate: Firstly, regional culture serves as the starting point for the reuse of industrial heritage, symbolizing the beginning of the transition of abandoned industrial heritage towards new land use stages. The historical, artistic, social, and economic values carried by abandoned spaces provide rich possibilities for the protection and reuse of industrial heritage. Secondly, with the rapid expansion of Chinese cities, new urban problems continue to emerge, prompting more diversified trends in the protection and reuse of industrial heritage. Proper protection and effective utilization of industrial heritage are of great significance for promoting sustainable urban development. Thirdly, in the case of industrial heritage regeneration design, there are relatively few practices that transform industrial heritage into campus spaces. However, through in-depth interviews with government agencies, educators, students, and parents, it was found that representative industrial heritage campus spaces can effectively meet the contemporary societal demand for diverse educational cultures. Meanwhile, more and more architects are committed to creating personalized campus spaces through diversified educational concepts and strategies to stimulate children's creativity. Fourthly, through the implementation of appropriate renewal strategies and design practices, feasible approaches for the transformation of industrial heritage into campus spaces have been summarized. These

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approaches include adaptive integration of external spatial environments, internal functional replacements, spatial reconstruction, and adaptive transformation and renewal of architectural forms. These practices not only make positive contributions to ecological environments, economic development, and urban renewal but also provide valuable opportunities for shaping local characteristics and creating urban images.

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