ASEAN Journal for Science Education

Journal homepage: https://ejournal.bumipublikasinusantara.id/index.php/ajsed

General Theory of Post-Industrial Services (Servicology): A Conceptual Framework for Educational Services and Science Development

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ABSTRACT

The development of the post-industrial economy increases the importance of services, including education, science, information, and other knowledge-based activities. This study develops the methodological foundations of a general theory of the service sector, referred to as servicology, to improve the socio-economic efficiency of post-industrial services. The study applies philosophy and methodology of science, historical analysis, logical analysis, system analysis, and the theory of technological structures. The framework defines the object, subject, functions, roles, and laws of servicology and examines the influence of scientific, technological, information, and communication development on services. A four-level service model is proposed for analyzing service design, positioning, competitiveness, and efficiency. The framework also considers educational services as mechanisms for knowledge formation, accumulation, transfer, professional culture development, and research and innovation training. The proposed servicology framework provides a methodological basis for analyzing and developing educational and other post-industrial services.

ARTICLE INFO

Article History:
Submitted/Received 02 Jan 2026
First Revised 18 Apr 2026
Accepted 27 Jul 2026
First Available online 22 Aug 2026
Publication Date 01 Sep 2027

Keyword:
Educational services;
Post-industrial services;
Science development;
Service sector;
Servicology;
Technological development.

1. INTRODUCTION

The service sector has become an increasingly important component of post-industrial economies as economic activity shifts from predominantly material production toward knowledge-intensive, technological, educational, informational, and professional services. Services influence economic productivity, social development, technological adaptation, and the quality of human life. Their increasing diversity and complexity have also created a need for a more systematic theoretical framework capable of explaining how services are designed, delivered, evaluated, and developed [1-5].

Service science has emerged as an interdisciplinary field integrating concepts from economics, management, technology, operations, and social sciences [1, 2]. However, several conceptual issues concerning the nature, classification, structure, and management of services remain unresolved [3, 5]. The heterogeneous and often intangible characteristics of services make it difficult to apply models originally developed for conventional manufacturing and tangible products. This challenge becomes more important in post-industrial society, where technological and social development continuously generates new forms of services.

Scientific and technological progress further changes the structure of the service economy. Digitalization, artificial intelligence, automation, network technologies, and advanced engineering systems increasingly influence how services are created and delivered. The growing convergence between production and service systems is also reflected in the extension of lean-production principles from manufacturing to the management of goods and services [6]. These developments also affect education because educational institutions simultaneously function as knowledge-producing organizations and service providers. In this context, education involves not only knowledge transfer but also professional preparation, innovation, research training, technological competence, and the development of values and professional culture.

The relationship between technological transformation and education has become increasingly important. Engineering education is required to respond to emerging technologies, industrial transformation, sustainability, and changing professional competencies [7-11]. Current educational research also emphasizes methodological improvement, curriculum development, technological integration, and stronger connections among education, research, and industrial needs [8-11]. These developments indicate that educational services should not be examined independently from broader technological and socio-economic changes.

Post-industrial education also requires institutions capable of integrating teaching, research, innovation, and interaction with industry. Advanced engineering schools, for example, can operate as innovation hubs connecting education with technological development and new institutional and business models [7]. Similarly, competency requirements in technical and vocational education are changing in response to industrial transformation and Industry 4.0 [12, 13]. These developments support the need for a broader theoretical framework that can explain educational services as part of an evolving post-industrial service system.

The original concept developed in this study is servicology, understood as a general scientific theory of services. Servicology considers services not only as economic transactions but also as complex systems involving producers, consumers, technologies, resources, management mechanisms, social objectives, and long-term effects. Such a perspective is

relevant to education because educational services involve multidimensional relationships among students, educators, institutions, industries, governments, and society.

The study is also connected with the concept of technological structures or technological orders. Changes in dominant technologies influence production, communication, social organization, education, and the demand for different types of services. The contemporary technological stage is characterized by rapid development of digital technologies, automation, intelligent systems, advanced communication, and knowledge-based activities. These transformations increase the role of the service sector and create new requirements for scientific and educational systems.

Despite the growing importance of service science, a comprehensive theoretical framework integrating economic, technological, managerial, social, and educational dimensions remains insufficiently developed [1-5]. This gap is particularly relevant for education because educational services increasingly interact with engineering, innovation, technological development, and industrial transformation.

Therefore, this study aims to develop the methodological foundations of a general theory of the post-industrial service sector, referred to as servicology, and to examine its relevance to educational and knowledge-based services. Specifically, the study seeks to: (i) clarify the characteristics and methodological foundations of the service sector; (ii) define the object, subject, functions, roles, and laws of servicology; (iii) examine the influence of scientific and technological development on post-industrial services; (iv) conceptualize educational services within the servicology framework; and (v) develop a four-level model for analyzing the design, positioning, competitiveness, and effectiveness of services.

2. LITERATURE REVIEW

2.1. Service Science and the Post-Industrial Service Sector

The service sector includes commercial and non-commercial activities designed to satisfy individual, organizational, technological, economic, and social needs. Unlike conventional tangible products, services are frequently characterized by intangibility, variability, inseparability of production and consumption, and limited storability. These characteristics make the analysis and management of services fundamentally different from conventional manufacturing activities.

Theoretical studies of the service economy have long identified unresolved problems concerning the definition, classification, measurement, and economic contribution of services [3, 5]. Service management research has consequently developed as a multidisciplinary field involving operations, marketing, management, information systems, and organizational studies [1, 2]. The development of service science further reflects an attempt to integrate these perspectives into a systematic framework for understanding the design and delivery of services [1].

The importance of services becomes particularly evident in post-industrial economies. Service-sector development is associated with changes in employment structures, technological systems, consumption patterns, urban economies, and knowledge-intensive economic activities [4, 5]. Sustainable development also increasingly depends on services that support education, innovation, health, communication, environmental management, and technological systems [4].

A general theory of services should therefore move beyond a narrow interpretation of services as market transactions. It should include technological processes, organizational structures, management systems, stakeholder interactions, resource utilization, social consequences, and long-term development. Such an approach provides the conceptual basis for servicology.

2.2. Servicology as a General Theory of Services

Servicology can be defined as an interdisciplinary scientific framework for studying the creation, provision, development, management, and effects of services. Its object is the service sector and individual services, while its subject includes economic, managerial, technological, organizational, financial, social, and professional relationships arising during service production and consumption.

The need for such a framework is reinforced by the increasing complexity of service systems. Modern services often integrate physical infrastructure, digital technologies, professional competencies, information processing, and continuous interaction among multiple stakeholders. Lean approaches have also been extended from manufacturing to goods and service systems, indicating increasing convergence between production and service-management concepts [6].

Within servicology, several functions can be identified. These include methodological, cognitive, instrumental, legislative, optimization, predictive, preventive, psychological, knowledge-socialization, risk-management, and system-forming functions. These functions reflect the broad role of services in contemporary socio-economic and technological development.

Servicology also considers relationships between technological progress and service-sector transformation. The theory of technological orders describes long-term stages of technological change in which new technological systems modify production structures, economic organization, and social activities. The contemporary technological stage involves advanced digital systems, automation, network technologies, intelligent management, and increasingly complex interactions between technology and society.

These changes are directly relevant to education. Education itself can be conceptualized as a post-industrial service that develops human capital, transfers knowledge, builds competencies, and supports innovation. From this perspective, educational development represents an integral part of service-sector transformation rather than an isolated social activity.

2.3. Educational Services in Post-Industrial Development

Educational services differ from many conventional services because their outputs include knowledge, competencies, professional values, intellectual development, research capabilities, and long-term social effects. Educational services therefore have both immediate and strategic dimensions.

Recent developments in engineering and science education demonstrate this multidimensional character. Engineering education increasingly incorporates sustainability, green engineering, advanced technologies, and interdisciplinary competencies [11, 14]. Research trends in engineering and materials education also demonstrate growing attention to curriculum development, technological integration, and educational innovation [8, 9].

Methodological quality is another important element of educational services. Effective science and engineering education requires appropriate research design, systematic evaluation, and recognition of methodological limitations and common research failures [10]. Consequently, educational services should include not only teaching activities but also research preparation and scientific competency development.

Technological transformation creates additional requirements for professional education. Industry 4.0 has changed the competency profiles expected from technical and vocational instructors and engineering students [12, 13, 15]. Emerging technologies in industrial sectors also require educational institutions to continuously adapt learning content and instructional approaches [16]. These trends demonstrate that educational services are strongly connected to technological evolution.

Higher education institutions can therefore be viewed as complex service systems involving teaching, research, innovation, professional training, and interaction with industrial and social stakeholders. Post-industrial educational institutions increasingly perform innovation functions in addition to conventional teaching functions [7].

Within the servicology perspective, educational services can be interpreted as systems for the formation, accumulation, and transfer of knowledge. They can include the educational process itself, professional cultural development, scientific research and innovation training, and preparation for interaction within professional environments. These components were explicitly identified in the original conceptual framework of this study.

Thus, servicology provides a framework for linking educational activities with technological, economic, managerial, and social development. This perspective is especially relevant to science and engineering education because these fields are directly affected by technological change and industrial transformation.

3. METHOD

3.1. Research Design

This study used a conceptual and theoretical research design to develop the methodological foundations of servicology as a general theory of post-industrial services. The study did not employ experimental or survey data. Instead, it synthesized theoretical concepts concerning the service sector, technological development, management, education, and post-industrial transformation. The methodological approach combined the philosophy and methodology of science, historical analysis, logical analysis, system analysis, and the theory of technological structures. These methods were specified in the original study as the principal tools for constructing the general theory of the service sector.

3.2. Analytical Framework

Historical analysis was used to examine technological development and changes in the relationship between production, services, technology, and society. The original framework divides technological development into 22 technological orders, ranging from early human technological development to the contemporary stage characterized by nanotechnology, robotics, the Internet of Things, digital systems, and other advanced technologies. Logical analysis was applied to clarify the concepts, characteristics, object, subject, functions, roles, and proposed laws of servicology. System analysis was used to examine the service sector as an interconnected system involving service providers, consumers, technologies,

resources, institutions, management mechanisms, and socio-economic environments. The analysis also considered educational services as part of the post-industrial service sector. Particular attention was directed to their roles in knowledge formation, knowledge transfer, professional development, scientific research, innovation training, and interaction with technological and industrial transformation.

3.3. Conceptual Development Procedure

The conceptual development was conducted in four stages. First, the characteristics and theoretical problems of services were identified from the existing literature and the original servicology framework. Second, the object, subject, functions, roles, and laws of servicology were systematized. Third, the relationship between scientific-technological development and post-industrial services was examined using the technological-order perspective. Fourth, the framework was applied to educational and knowledge-based services. The study subsequently developed a four-level service model. The first level represents the principal benefit or need addressed by the service. The second represents the actual service and its properties, quality, reliability, safety, and other characteristics. The third includes supporting elements such as availability, financing, guarantees, and follow-up services. The fourth represents strategic, socio-economic, and environmental effects. This four-level structure is intended for service design, positioning, comparison, competitiveness assessment, and evaluation of long-term effects. The model was also applied to a vehicle-maintenance service as an illustrative case. The same conceptual structure provides a basis for analyzing educational services as multidimensional post-industrial services. No new empirical data were generated, and the study remains a conceptual development based on theoretical synthesis and system analysis.

4. RESULTS AND DISCUSSION

4.1. Conceptual Structure of Post-Industrial Services

Services should be considered as a distinct component of post-industrial economic and social systems. Their characteristics differ from those of conventional material products and influence how services are designed, delivered, evaluated, and managed. **Table 1** summarizes the principal characteristics identified in the servicology framework. The characteristics in **Table 1** explain why service activities require a theoretical framework that extends beyond conventional product-based analysis. Intangibility, variability, and non-preservation complicate standardization and quality assessment, while increasing technological dependence connects services directly with scientific and technological development. These unresolved conceptual characteristics have long been recognized in service-sector research [1-5].

The post-industrial context further increases this complexity. Modern services increasingly combine professional competencies, information, technologies, infrastructure, and interactions among stakeholders. Consequently, servicology is proposed as an integrated framework for analyzing these relationships rather than treating individual service sectors independently.

Table 1. Principal characteristics of services within the servicology framework.

CHARACTERISTIC	DESCRIPTION	IMPLICATION FOR SERVICE MANAGEMENT
Intangibility	A service is primarily an activity or benefit rather than a physical product.	Evaluation requires indicators beyond physical product characteristics.
Inseparability	Production, distribution, and consumption can occur simultaneously.	Provider-consumer interaction becomes an important component of service quality.
Variability	Service quality can vary according to personnel, conditions, time, and consumer requirements.	Standardization and quality management become more difficult.
Non-preservation	Many services cannot be stored for future consumption.	Capacity and demand must be coordinated during service delivery.
Consumer orientation	Services are directed toward satisfying specific economic, social, or technical needs.	Consumer requirements should influence service design and evaluation.
Technological dependence	Service provision increasingly involves technologies, technical systems, and information infrastructure.	Technological development continuously changes service delivery mechanisms.
Socio-economic function	Services influence individuals, organizations, the economy, and society.	Effectiveness should include economic and social outcomes.

4.2. Servicology as a General Scientific Framework

The analysis resulted in the formulation of servicology as a general scientific theory of services. Its object, subject, stakeholders, method, and intended outcomes are summarized in **Table 2**. Servicology integrates several dimensions that are frequently studied separately. This multidisciplinary character is consistent with service-science research emphasizing the need to integrate management, operations, technology, and customer-related perspectives [1, 2]. It also responds to unresolved theoretical issues surrounding service-sector development [3, 5]. The framework extends these perspectives by considering technological change and long-term socio-economic effects as integral components of service analysis. This is particularly important under post-industrial conditions, in which service systems increasingly depend on advanced technologies and knowledge-intensive activities.

Table 2. Conceptual structure of servicology.

COMPONENT	CONCEPTUAL DEFINITION
Object	The service sector and individual services considered as specific products and objects of economic activity.
Subject	Economic, managerial, organizational, financial, social, and professional relationships arising during the production, promotion, provision, and consumption of services.
Main stakeholders	Service producers, consumers, customers, intermediaries, individuals, organizations, and other entities participating in service-related socio-economic relationships.
Scientific method	A system of principles and techniques for obtaining objective knowledge about the design, creation, provision, modernization, and effects of services.
Main orientation	Scientific support for the development and management of services.
Expected contribution	Improved effectiveness, reduced risks, and stronger scientific and innovative development of the service sector.

4.3. Functions of Servicology

Table 3 summarizes the principal functions of servicology identified through the conceptual analysis. The functions in **Table 3** demonstrate that servicology is intended to serve both theoretical and practical purposes. Its methodological and cognitive functions support knowledge development, while its instrumental and optimization functions connect theory with service management. Predictive and preventive functions are particularly relevant under rapid technological change because emerging technologies can simultaneously create opportunities and new risks. The knowledge-socialization function is especially relevant to education. Education provides mechanisms through which scientific and technological knowledge is transferred to individuals and society. Thus, educational services are not peripheral to servicology; they contribute directly to the accumulation, dissemination, and application of knowledge.

Table 3. Functions of servicology in post-industrial development.

FUNCTION	PRINCIPAL ROLE
Methodological	Develops concepts, theoretical foundations, research methods, and service-management approaches.
Cognitive	Accumulates and systematizes knowledge concerning services, technologies, innovation, and service development.
Instrumental	Develops practical tools for research, innovation projects, lifecycle management, and service modernization.
Legislative	Supports the development of legal norms related to services, innovation, safety, and responsibility.
Optimization	Identifies effective service technologies and methods while considering costs, safety, and environmental conditions.
Predictive	Examines future development of services under scientific and technological change.
Preventive	Supports proactive measures for reducing technological, economic, and social risks.
Psychological	Supports understanding of the importance of scientific and technological development in services.
Knowledge socialization	Disseminates knowledge concerning science, technology, and service-sector development.
Risk minimization	Addresses technological, environmental, and social risks associated with service activities.
System-forming	Integrates knowledge and management processes required for comprehensive service development.

4.4. Proposed Laws of Servicology

Table 4 presents the proposed laws of servicology, which describe relationships between service-sector development and technological, economic, and social complexity. The propositions in **Table 4** connect service-sector growth with increasing technological and socio-economic complexity. This relationship is relevant to post-industrial development, where services increasingly support sophisticated industrial, technological, educational, financial, and social systems [4, 5]. This framework is also compatible with the changing requirements of education. Technological transformation creates new competencies, occupations, and learning requirements. Engineering and technical education must therefore

continuously respond to industrial and technological developments [12, 13, 15, 16]. The increasing complexity described in servicology can consequently be observed in educational services through curriculum adaptation, technological integration, professional competency development, and research training.

Table 4. Proposed laws of servicology.

NO	PROPOSED LAW
1	The service sector is simultaneously a segment of the real economy and public life.
2	Increasing complexity of the technosphere and social life promotes intensive development of the service sector.
3	Increasing complexity of economic and social activities leads to greater differentiation and specialization of services.
4	Services develop as mechanisms for adaptation to changing technological and social conditions.
5	Service effectiveness has economic, social, and temporal dimensions.
6	Increasing complexity of financial, economic, and social activities increases the future importance of the service sector.
7	Increasing complexity of these activities also increases the complexity and comprehensiveness of services.

4.5. Educational Services within the Servicology Framework

Education is included among the principal types of post-industrial services considered within the servicology framework. Educational services have distinctive characteristics because their outputs extend beyond immediate service consumption. They contribute to knowledge, competencies, professional culture, research capacity, and long-term socio-economic development. **Table 5** summarizes the principal components of educational services identified within the servicology framework. This conceptualization is particularly relevant to science and engineering education. Contemporary engineering education increasingly incorporates sustainability, technological change, research competencies, and new professional requirements [8-11, 14].

Table 5. Educational services within the post-industrial servicology framework.

COMPONENT	ROLE IN EDUCATIONAL SERVICES	RELEVANCE TO POST-INDUSTRIAL DEVELOPMENT
Knowledge formation and transfer	Develops and communicates knowledge to learners.	Supports knowledge-based economic and social activities.
Educational process	Organizes systematic teaching and learning.	Provides structured human-capital development.
Transfer of values and professional culture	Develops professional norms and values.	Supports professional and institutional development.
Research training	Develops the ability to conduct scientific investigation.	Strengthens scientific capacity and knowledge production.
Innovation training	Prepares learners to participate in innovation.	Connects education with technological and industrial development.
Self-presentation preparation	Develops professional communication and presentation capabilities.	Supports participation in professional environments.

Industrial transformation also requires continuous adaptation of educational competencies. Industry 4.0 affects the competencies expected from TVET instructors and students [12, 13, 15], while emerging industrial technologies create additional challenges and opportunities for technical education [16]. Consequently, educational services cannot remain static when technological systems evolve.

Higher education may also function as an innovation-oriented service system. Advanced engineering schools illustrate how teaching, research, innovation, industry interaction, and institutional development can be integrated within post-industrial higher education [7]. This strengthens the conceptual relationship between servicology and science and engineering education.

4.6. Four-Level Model for Service Analysis

One of the principal outputs of the study is a four-level service model that extends service analysis to include a fourth strategic and socio-environmental level. The model is summarized in **Table 6**. The model expands service assessment beyond immediate service delivery. The fourth level is particularly important because it introduces long-term socio-economic and environmental consequences into service analysis. The model is illustrated using vehicle maintenance, ranging from the core benefit of maintaining vehicle operability and safety to long-term effects such as extending vehicle life and reducing resource requirements.

Table 6. Four-level model for analyzing post-industrial services.

LEVEL	MAIN CONTENT	ANALYTICAL PURPOSE
Level 1: Core benefit	Main technical, economic, or social need satisfied by the service.	Identifies the fundamental purpose of the service.
Level 2: Actual service	Properties, quality, reliability, safety, price, and external characteristics of service provision.	Evaluates the actual characteristics and performance of the service.
Level 3: Augmented service	Availability, financing or credit, guarantees, and follow-up service.	Examines additional mechanisms supporting service accessibility and value.
Level 4: Strategic and socio-environmental effects	Long-term socio-economic, environmental, resource, and market effects.	Evaluates broader and longer-term consequences of the service.

For educational services, the framework provides a conceptual basis for examining not only immediate teaching and learning but also professional development, research, innovation, and technological adaptation. This perspective is consistent with discussions on sustainability and technological integration in engineering education [11, 14].

5. CONCLUSION

This study developed the conceptual foundations of servicology as a general theory for understanding post-industrial services. The framework integrates economic, technological, managerial, social, and educational dimensions through the proposed functions and laws of servicology. Educational services are positioned as an important component of post-industrial development by supporting knowledge formation and transfer, professional culture, research, and innovation. The proposed four-level service model provides a systematic framework for examining core benefits, actual service characteristics, supporting elements, and strategic socio-economic and environmental effects. Servicology can therefore provide a

methodological basis for developing educational and other knowledge-intensive services under continuing scientific and technological transformation.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper is free from plagiarism.

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