HUMAN RESOURCE TRAINING FOR THE SEMICONDUCTOR INDUSTRY IN DIGITAL TRANSFORMATION: NEEDS AND CHALLENGES

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ARTICLE INFO
Received: 25/10/2024
Revised: 17/02/2025
Accepted: 19/02/2025

Keywords: *Digital transformation, semiconductor design, human resource training, high-tech industry, workforce development, educational collaboration.*

ABSTRACT

The development of the semiconductor industry is becoming a significant revolution to promote the country's growth and enhance its global standing. Vietnam currently holds a valuable opportunity to integrate more deeply into the global semiconductor supply chain by fostering collaborations with multinational corporations, investing in advanced manufacturing capabilities, and enhancing workforce training to meet global standards. These steps are pivotal to leveraging Vietnam's potential as a competitive player in the industry. With an annual growth rate of 7-9%, semiconductor chips are regarded as the foundation of modern computing and play a critical role as the world advances into an era of burgeoning research and the application of emerging technologies like AI, IoT, 5G, and Big Data.

The demand for materials and technology during the digital transformation process includes sensor systems, the Internet of Things (IoT), Artificial Intelligence of Things (AIoT), broadband communication, high-speed computing, and more. These technologies are necessary for data collection, storage, processing, and analysis, forming the backbone of digital communication networks and supporting the evolution of a digital society. Applications of Fourth Industrial Revolution technologies will be implemented in fields such as industrial production monitoring, remote control of agricultural processes, education, and more to foster digital transformation across multiple sectors.

1. INTRODUCTION

Semiconductors, or "chips," are vital components powering the advanced digital devices integral to modern life. From smartphones and pacemakers to the internet, airplanes, and hypersonic weapons, semiconductors are integral to nearly every industry. They play a central role in economic growth, security, and technological innovation, driving advancements in communication, healthcare, military systems, transportation, clean energy, and many other applications (Morris, 1990).

The semiconductor industry plays a vital role in shaping and driving the development of various sectors in the global economy, contributing over $620 billion in revenue as of 2024, with projections to reach $1 trillion by 2030. It underpins advancements in key industries such as telecommunications, clean

energy, healthcare, and transportation, making it a cornerstone of modern innovation. As one of the backbone industries for economic growth, it provides the foundation for other fields like electricity, electronics, automation, and telecommunications. Often referred to as the "lifeline" of the digital economy, semiconductors are pivotal and are projected to generate over $620 billion in revenue by 2024, escalating to $1 trillion by 2030. This industry also forms the core of the technological competition among global powers in the 21st century (Chung, 2021).

According to the Industrial Policy and Strategy Research Institute, 2024 marks the first year of Vietnam's national strategy for developing the semiconductor industry. This foundational and critical sector is expected to remain a national priority for the next 30-50 years, presenting Vietnam with a chance to bolster its domestic electronics industry.

Vietnam's rapidly growing economy has achieved significant milestones and accomplishments. In the semiconductor sector, numerous collaboration agreements and investment projects have emerged. For instance, Intel has expanded phase two of its chip testing factory in Ho Chi Minh City with a total investment of $4 billion. Amkor Semiconductor plans to inaugurate its factory in Bac Ninh in October 2023, with an investment of approximately $1.6 billion. Most recently, on September 16, 2023, Hana Micron (South Korea) opened its semiconductor manufacturing facility in the Van Trung Industrial Park (Bac Giang), marking the first semiconductor production project in northern Vietnam. The company aims to achieve $300 million in revenue this year and plans to increase its total investment to over $1 billion by 2025, generating $800 million in revenue and creating approximately 4,000 jobs (Anh V., 2024).

Aligned with global trends, Associate Professor Dr. Tran Xuan Tu, Director of the Institute of Information Technology at Vietnam National University, Hanoi, emphasized that Vietnam has a young and abundant workforce with strong mathematical thinking capabilities. The country's pool of highly skilled talent continues to grow. Fields like IT, automation, electronics, and computer engineering all related to different stages of the semiconductor industry are garnering substantial interest from the younger generation. Domestic educational institutions need to develop comprehensive training plans to further enhance workforce quality and leverage this advantage.

Semiconductors, chip design, and related fields have garnered considerable attention from various nations. Experts and managers worldwide recently convened to discuss these topics at the "SEMI SEA TalentConnect" forum. This event, organized by the Global Semiconductor Industry Association (SEMI) in collaboration with Vietnam National University, Hanoi, was a part of the 2023 Vietnam Business Summit. The forum aimed to connect talent, offering Vietnamese students and youth a deeper understanding of the semiconductor industry in Southeast Asia and globally. Discussions also focused on opportunities for collaboration between SEMI and Vietnamese universities to develop human resources in semiconductor chip design. Mr. Scott Nguyen, Director of Customer Support at Kulicke & Soffa, remarked, "We are surrounded by semiconductors. These tiny chips power everything from mobile phones to cars. It can be said that semiconductors play a crucial role in shaping the world" (Minh, 2023).

According to Tuan (2023), within Vietnam's semiconductor market, power management integrated circuits (PMICs) dominate with a market share of approximately 68%, followed by microchips at 29%, while the remaining segment is attributed to radio-frequency identification (RFID) technology. The revenue of PMICs

and microchips is projected to grow by 40% between 2020 and 2025

From an application perspective, consumer electronics lead with a market share of around 62%, followed by information and communication technology (ICT) at 21%, and the automotive sector at approximately 10%. The ICT product market size is expected to grow by 45% during 2020–2025, while consumer electronics and automotive segments are anticipated to expand by 32% over the same period (Tuan, 2023).

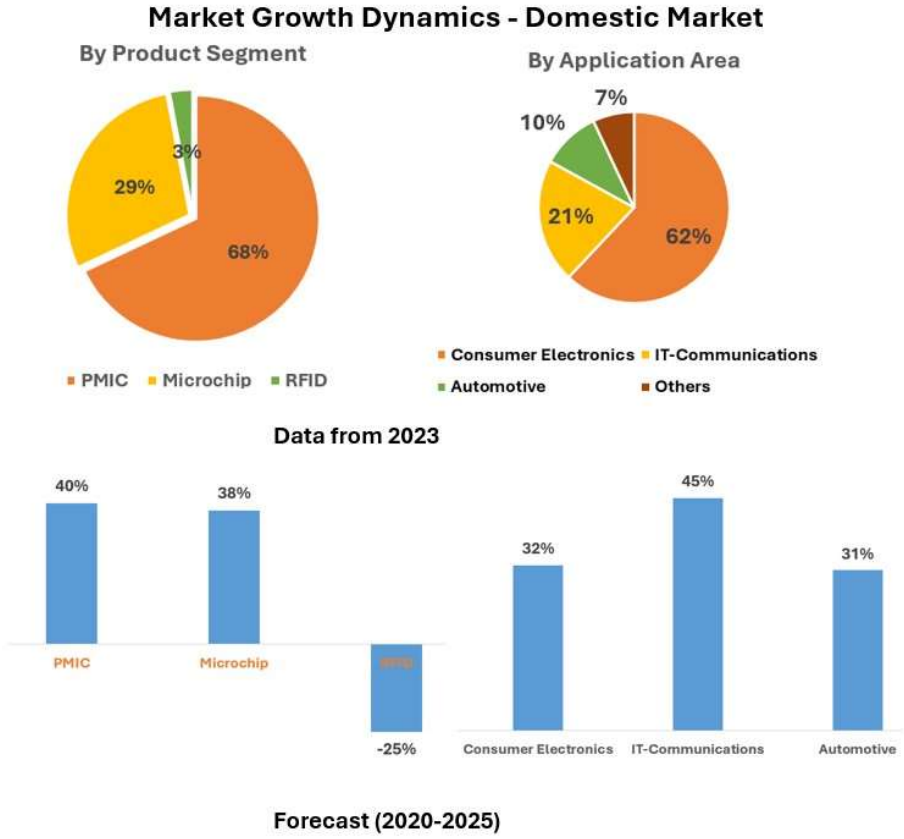

Figure 1. Projected Growth Rate of Semiconductor Product Segments

Source: Tuan, (2023).

Information Technology (IT) would not exist without microchips. Over a decade ago, mobile phones and computers were considered luxury items in Vietnam, accessible only to a small demographic with substantial economic means. Today, technology has become an indispensable part of life. From university students and high schoolers to primary school children, owning a mobile phone or laptop is almost ubiquitous. Even preschoolers are familiar with iPads and smartphones, adeptly using them as a part of their natural development. This transformation illustrates that technology has evolved beyond being a mere tool; it has become a fundamental factor reshaping the way we live and work. Businesses of all sizes rely on computers for data processing and operations management. Technology has permeated both domestic life and revolutionized core industrial sectors, transforming everything from manufacturing facilities to service providers, educational institutions to communication networks. The semiconductor revolution has not only broadened access to information and

knowledge but has also created a connected society where people can learn and grow.

While the aforementioned points highlight the impact of semiconductors on the electronics industry, this influence extends across various other industries. Today, virtually every modern industrial product contains semiconductors. In critical products like smartphones and automobiles, the value of semiconductors constitutes an increasingly significant proportion of the overall product cost. For instance, a smartphone typically contains around 20 chips, accounting for 60% of its total value. In luxury cars, the number of chips required is estimated to be ten times that of a smartphone (KH&CN, 2023), resulting in a far higher chip value proportion for high-end vehicles than ever before. Moreover, as discussed earlier, the emergence of semiconductors has made IT a reality, revolutionizing economic, cultural, and social activities on a global scale

2. LITERATURE REVIEW

Globally, the semiconductor industry is projected to face a labor shortage of 70,000 to 90,000 workers in the United States over the coming years. In Japan, the Semiconductor Industry Association forecasts an annual deficit of approximately 1,000 high-quality personnel over the next decade. This shortage is further exacerbated by Japan's "race" to establish new semiconductor manufacturing facilities, which demands an increasingly skilled workforce. To address this challenge, the South Korean Ministry of Education has launched a "10-year roadmap" aimed at training 150,000 semiconductor graduates. Selected universities are being designated as "semiconductor universities," with each region establishing dedicated semiconductor research centers integrated into a national network (Anh V., 2024).

During the 2024 "Semiconductor Day" event held on August 30 at the Ariyana International Convention Center in Da Nang, Deputy Minister of Information and Communications Bui Hoang Phuong emphasized that the Internet of Things (IoT) and Artificial Intelligence (AI) are core technologies of the Fourth Industrial Revolution (Industry 4.0). At the heart of IoT and AI are semiconductor chips. Semiconductor technology is embedded in almost all devices and facets of daily life, shaping and redefining the world with profound impacts on economic and national security. Developing the semiconductor industry must be coupled with advancements in the electronics sector to create sustainable markets for semiconductor chips. Vietnam should also focus on building a highly skilled workforce to position itself as a global human resource hub for the semiconductor industry (TT&TT, 2024)

According to Nguyen (2023), the growing demand for skilled labor in the semiconductor technology sector has made it an attractive field in the 2024 university admissions cycle. The Ministry of Information and Communications reported that Vietnam requires 5,000 to 10,000 semiconductor engineers annually, yet current output meets less than 20% of this demand. Data from the National Portal on Science and Technology reveals that Vietnam currently has 5,575 chip design engineers. Economic experts forecast that over the next five years, the demand for semiconductor professionals will rise to 20,000, and to 50,000 within the next decade (KH&CN, 2023). Developing the workforce requires a collaborative effort between the government, academia, and industry. This tripartite partnership helps students gain practical experience in chip design and testing while learning to address technical challenges in production processes. Training programs at Vietnam National University, Hanoi; Vietnam National University, Ho Chi Minh City; and FPT University, in collaboration with industry

partners, are actively contributing to creating an environment conducive to talent development in this field.

Vietnam's semiconductor industry is experiencing a significant growth, attracting numerous large-scale projects. Approximately 80% of enterprises in the sector focus on final-stage chip design, leveraging low investment costs and simplified training requirements. However, the majority of these designs are outsourced to foreign partners, accounting for over 80% of the industry's total value. Despite the growing number of enterprises, Vietnam's contribution to the global value chain remains modest, primarily limited to assembly, testing, and packaging stages segments dominated by major corporations such as Samsung, Intel, and Foxconn (Dai Nam University, 2024)

According to research conducted by Long and Linh (2024), Vietnam currently has over 5,500 chip design engineers, with more than 76% based in Ho Chi Minh City. Workforce projections indicate that by 2030, Vietnam will require approximately 15,000 engineers for chip design and 35,000 personnel for production, testing, and packaging stages. However, current capacity is estimated to meet only about 20% of this demand (Figure 2).

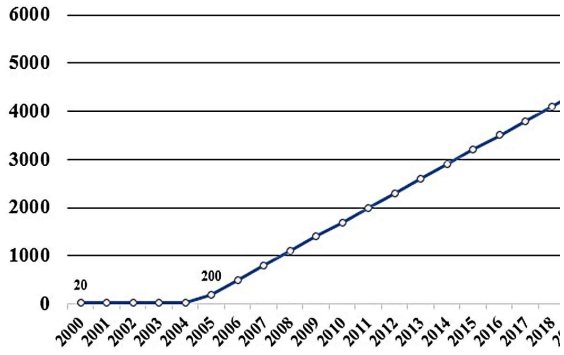

Figure 2. Estimated Number of Chip Design Engineers in Vietnam 2000–2021

Source: Yen, (2021).

The advancement of digital transformation necessitates the development of systems such as sensors, the Internet of Things (IoT), Artificial Intelligence of Things (AIoT), broadband communication, and high-speed computing. These systems are essential for collecting, storing, accumulating, processing, and analyzing data, forming the foundation for implementing digital communication networks. Such technologies support the functionality of a digital society, enabling remote monitoring, control, and inspection of activities related to industrial and agricultural production, among others. These applications leverage the technologies of the Fourth Industrial Revolution.

From Figure 3, it is evident that testing (27.5%) and physical design (16.8%) represent the largest proportions of workforce demand, underscoring the critical need for specialized talent in these fields.

In the face of significant opportunities for the country, the Government has promptly recognized emerging trends and leveraged its role through diplomatic channels and the implementation of policy tools to attract investors. However, one of the major concerns for investors is the readiness of Vietnam's workforce in the semiconductor sector, both in terms of quantity and quality.

Regarding the workforce, Minister of Information and Communications - Nguyễn Mạnh Hùng stated in a working session with the two national universities on September 6, 2023, Vietnam needs 10,000 engineers annually to meet the labor demand for the semiconductor industry. However, the current supply meets less than 20% of this need (KH&CN, 2023). In reality, the semiconductor industry must compete for talent with other rapidly developing high-tech sectors such as electronics, automation, artificial intelligence, and more.

According to a survey conducted by the Institute of Economic and Business Policy (IBEP), approximately 60% of universities across the country offer programs that support the semiconductor sector, such as Information

Technology, Control and Automation, Data Science and Artificial Intelligence, Electrical-Electronic Engineering, Telecommunications, etc. These programs provide a workforce that is largely concentrated in the southern region. As a result, in terms of human resources, the southern region holds a competitive advantage in the development of semiconductor design. In fact, many semiconductor design companies are located in Ho Chi Minh City, such as Marvell, Renesas, Applied Micro, and Ampere (Tuan, 2023).

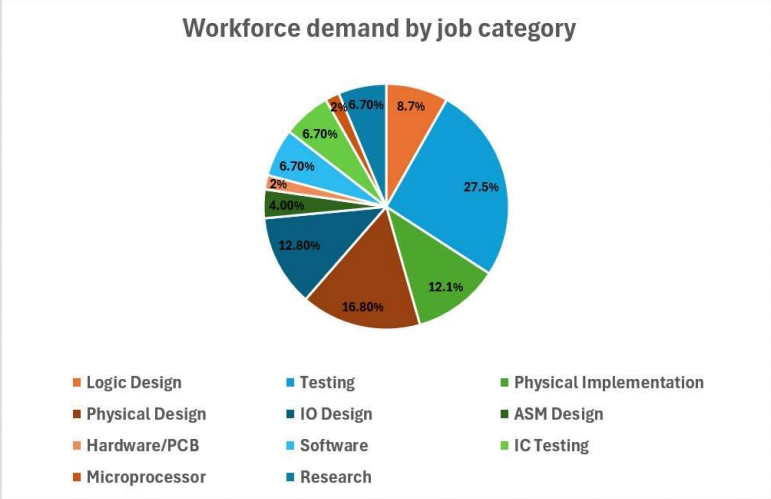

Figure 3. Workforce demand by job category

Source: Yen, (2021).

Regarding the quality of human resources, most universities currently lack specialized programs in integrated circuit/semiconductor design, instead offering related fields. The main reason is the limited availability of experts in integrated circuit/semiconductor design to meet the staffing standards at universities, as well as the high costs associated with investing in software systems and laboratories for training purposes.

3. PROPOSED SOLUTIONS

Given these challenges, the training of semiconductor human resources must now be regarded as a "national strategic mission". Vietnam needs to implement the following strategic solutions simultaneously:

- The Government should play a pivotal role in attracting foreign investors and leveraging policies to establish a robust industry ecosystem. It should also strengthen cooperation with countries and territories excelling in semiconductor production

- Explore opportunities to participate deeply in the semiconductor production chains of advanced countries, initially focusing on widely-used chip fabrication technologies. This approach will enable gradual acquisition and mastery of semiconductor production technologies.

- Foster a startup and innovation ecosystem in the electronics and semiconductor sectors. This includes investing in the upgrading of technical infrastructure within high-tech zones an essential component of the startup and innovation ecosystem. Such efforts will support the growth of electronics and semiconductor enterprises while concentrating on attracting investment projects aligned with Vietnam's strengths. These initiatives aim to enhance Vietnam's technological capabilities, particularly in technology adoption, application, and innovation.

- Educational and training orientation at educational institutions should focus on state-

directed training and research programs while accommodating business demands through targeted funding and commissioned training. Collaboration with businesses to align training with industry practices is essential to ensure quality education, particularly for postgraduate-level human resources. Concurrently, attention and investment must be directed toward research and development activities. Upgrading specialized research institutes in electronics and semiconductors under relevant ministries is necessary to enhance Vietnam's technological capabilities.

- Educational institutions serve as key contributors to the training of semiconductor and microchip professionals, addressing the needs of both domestic and international enterprises. Close collaboration with countries such as the Netherlands, Japan, and South Korea in semiconductor education is vital. Regularly sending students to participate in international training, research exchange programs, and faculty-student exchange initiatives contributes to the development of thousands of high-quality professionals capable of engaging in various stages of the semiconductor design industry

- Promote connectivity in science by fostering collaboration among outstanding researchers who are recognized not only for their expertise but also for their integrity. Expand the scale and improve the quality of human resources in the fields of semiconductors and AIoT, while increasing investment in education, science, and technology. Additionally, attract Vietnamese experts and scientists from advanced countries to return and contribute to the development of the electronics, semiconductor, and artificial intelligence sectors. In human resource training, apart from expanding the scale and introducing new training programs in electronics and semiconductors at major technical universities nationwide, efforts should focus on establishing specialized universities and academies dedicated to electronics and semiconductors to meet the rapid development demands of these industries

- Enterprises should closely collaborate with universities by commissioning training programs, co-conducting research, sponsoring equipment and software, and providing financial support. Such collaboration will enable universities to foster domestic companies capable of developing electronic and semiconductor products manufactured in Vietnam to serve local markets, with a gradual transition toward exports.

4. CONCLUSION

With the increasing presence of research and development centers established by semiconductor corporations in the near future, Vietnam will build a core workforce of semiconductor design engineers and a steady stream of newly trained young engineers annually. The challenge of human resources in the semiconductor industry can be addressed in the near future through the determination and cooperation of all stakeholders. With a high-skilled labor force, low labor costs, an available domestic market, the participation of major investors, and private companies heavily investing in research, development, and equipment manufacturing, coupled with government support for workforce training and research, collaboration among enterprises will create significant opportunities in the semiconductor field.

Educational institutions continue to expand their training capacity, focus on specialized research, and collaborate with domestic and international enterprises to better meet economic demands. These efforts contribute to advancing the semiconductor industry and fostering a new generation of talent for the future. Vietnam needs more “bright spots” to address the labor shortage issue promptly and position itself as a critical link in the global semiconductor supply chain.

Sensor systems, IoT systems, AIoT systems, and communication systems supporting the digital transformation process will be built using large-scale materials, components, machinery, and equipment. These systems require continuous maintenance, upgrading, and expansion. The financial resources required for such a nationwide digital transformation system will be substantial and long-term. For a populous nation like Vietnam, it is essential to develop a robust electronics and semiconductor industry to meet the critical demands of digital transformation, particularly in ensuring the domestic production of semiconductor devices. This effort not only reduces dependence on imports but also establishes a strong technological foundation, supporting the construction of a digital society and fostering technological innovation. Semiconductors, as core components of IoT and AIoT systems, play a pivotal role in optimizing performance, conserving energy, and enhancing the security of smart devices, which are essential for nationwide digitization (Long & Linh, 2024). Critical factors such as hard infrastructure, soft infrastructure, policy mechanisms, research and development, strategies, and particularly human resources are being prioritized and prepared, reflecting the Vietnamese Government's strong and timely commitment. This commitment positions Vietnam's semiconductor industry to take control and participate more deeply in the global semiconductor value chain.

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ĐÀO TẠO NGUỒN NHÂN LỰC NGÀNH VI MẠCH BÁN DẪN TRONG CHUYỂN ĐỔI SỐ: NHU CẦU VÀ THÁCH THỨC

TÓM TẮT

Việc phát triển ngành công nghiệp bán dẫn đang trở thành một cuộc cách mạng quan trọng để thúc đẩy sự phát triển và nâng cao vị thế của đất nước. Việt Nam hiện có cơ hội quý báu để tham gia sâu hơn vào chuỗi cung ứng bán dẫn toàn cầu. Với tốc độ tăng trưởng 7 - 9% mỗi năm, vi mạch bán dẫn được coi là nền tảng của tính toán hiện đại và đóng vai trò thiết yếu trong bối cảnh thế giới đang bước vào giai đoạn bùng nổ nghiên cứu, ứng dụng các công nghệ mới như AI, IoT, 5G, Big Data,... Nhu cầu về vật tư và công nghệ trong quá trình chuyển đổi số bao gồm các hệ thống cảm biến, Internet vạn vật (IoT), trí tuệ nhân tạo vạn vật (AIoT), truyền thông băng rộng, tính toán tốc độ cao... để thu thập, lưu trữ, xử lý và phân tích dữ liệu, tạo nền tảng cho mạng truyền thông chuyển đổi số, đồng thời phục vụ đời sống của xã hội số. Các ứng dụng công nghệ từ Cuộc cách mạng công nghiệp lần thứ tư sẽ được triển khai trong các lĩnh vực như giám sát, điều khiển từ xa các hoạt động liên quan đến sản xuất công nghiệp, nông nghiệp, giáo dục,... nhằm thúc đẩy quá trình chuyển đổi số trên các lĩnh vực.

Từ khóa: *Chuyển đổi số, công nghiệp công nghệ cao, đào tạo nguồn nhân lực, hợp tác giáo dục, phát triển nguồn nhân lực, thiết kế vi mạch.*