

Schumpeter's Innovation Theory and Technopreneurial Character Development Among Industrial Electrical Engineering Graduates in the Age of Automation

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Abstract

The rapid development of automation, artificial intelligence, the Internet of Things, and smart manufacturing has transformed the competency requirements for Industrial Electrical Engineering graduates. Technical proficiency alone is increasingly insufficient, as graduates are also expected to identify technological opportunities, develop innovative solutions, and create economic value. This study aims to examine the integration of Joseph Schumpeter's Innovation Theory into the development of technopreneurial character among Industrial Electrical Engineering graduates in the automation era. A descriptive qualitative literature review was employed by synthesizing scholarly literature on Schumpeterian innovation, creative destruction, technopreneurship, automation, and engineering education. The analysis focused on translating Schumpeter's five forms of innovation into the context of electrical engineering and examining their implications for technopreneurial character development. The findings indicate that Schumpeter's innovation framework provides a relevant conceptual foundation for transforming technical competencies into entrepreneurial value creation. The five forms of innovation new products, new production methods, new markets, new sources of supply, and new forms of industrial organization can be applied to electrical engineering through the development of smart monitoring systems, efficient engineering processes, affordable automation solutions, alternative technology resources, and technology-based service models. This study proposes an integrative pathway from technical competence to problem identification, innovative recombination, prototyping, market validation, commercialization, and value creation. The study contributes a Schumpeterian perspective for strengthening technopreneurship education and repositioning Industrial

Electrical Engineering graduates as technology creators and value creators in the era of automation.

Keywords: automation; creative destruction; engineering education; electrical engineering; schumpeter; technopreneurship

INTRODUCTION

Advances in digital technology, automation, the Internet of Things (IoT), artificial intelligence (AI), robotics, and intelligent control systems have fundamentally transformed the structure and operational mechanisms of industry. These changes are not limited to the use of more automated machinery; they also affect how organizations produce goods, manage resources, control processes, interact with customers, and create economic value. In the context of the Fourth Industrial Revolution, production systems are increasingly moving toward the integration of physical devices, software, communication networks, data, and decision-making systems. Consequently, the competencies required of the workforce are also changing. Routine and repetitive tasks are becoming increasingly easy to automate, while the demand for workers capable of system integration, complex problem-solving, innovation, technology development, and value creation is on the rise. These changes place vocational education in a strategic position, as vocational education graduates occupy a pivotal role at the intersection of education, technology, and industry needs.

These changes have specific implications for Industrial Electrical Engineering graduates. Competencies that have long formed the foundation of electrical engineering education

such as circuit design, control systems, power electronics, microcontroller programming, electrical installations, sensors, actuators, and industrial automation remain core competencies. However, mastery of these technical competencies is increasingly insufficient if not accompanied by the ability to understand user needs and transform technical solutions into valuable innovations. A graduate may be able to design monitoring systems, develop control devices, or create microcontroller based prototypes, but these abilities do not automatically make them an innovator or a technopreneur. The challenge lies in the ability to bring technology out of the laboratory and apply it to the real-world problems faced by industry and society. This article highlights a gap between mastery of electrical hard skills and the ability to commercialize solutions and respond to market needs.

This shift in orientation requires the field of Industrial Electrical Engineering education to move from an approach that is purely technology-centered toward one that is more problem-centered and value-centered. Students should not merely be guided to answer the question, What technology can be developed?, but must be trained to address questions such as What problems need to be solved? Who is facing these problems? What technology is most appropriate? And what value can be created

through these solutions? This orientation transforms the project development process from a simple design build test sequence into a broader process: problem identification opportunity recognition technology development prototyping validation commercialization. In this process, the success of an innovation is determined not only by technical feasibility but also by its relevance to users and its economic viability.

The need to cultivate this mindset can be explained more fundamentally through Joseph A. Schumpeter's Theory of Innovation. Schumpeter identifies innovation as the primary driving force in economic dynamics and views entrepreneurs as actors who create new combinations of available resources. Thus, entrepreneurs are not merely business owners or managers but agents of change who introduce new combinations into economic activity. Schumpeter identified five forms of innovation: the introduction of new products or improvements in product quality, the adoption of new production methods, the opening of new markets, the mastery of new sources of supply, and the creation of new organizational or industrial structures. These five forms of innovation are highly relevant to the field of Industrial Electrical Engineering, as each can be applied to product development processes, engineering efficiency, the creation of technology markets, the use of alternative resources, and the development of new business models.

A number of studies on engineering and entrepreneurship education have highlighted the

importance of developing entrepreneurial competencies among engineering students. However, there is still room to explore in greater depth how Schumpeter's theory of innovation can be specifically applied as a conceptual framework for transforming engineering competencies into technopreneurial capabilities in the field of industrial electrical engineering. Most studies on technopreneurship focus primarily on entrepreneurship education, digital entrepreneurial intent, digital literacy, or the development of entrepreneurial skills in general. Meanwhile, a more systematic relationship between Schumpeter's five forms of innovation, electrical engineering competencies, changes resulting from automation, and the creation of economic value has not yet been extensively explained as a unified framework. It is this gap that serves as the focus of this article's contribution.

Based on this gap, this article positions Schumpeter's Theory of Innovation not merely as a classical economic theory, but as an analytical lens for understanding the development of technopreneurship in Industrial Electrical Engineering education. Schumpeter's five forms of innovation are used to map how engineering competencies can be translated into innovations in products, production methods, markets, supply sources, and new organizational structures. Furthermore, the concept of creative destruction is used to explain how such innovations can transform established industrial practices while simultaneously opening new

opportunities for engineering graduates in the era of automation. Within this framework, technopreneurship is understood as a process of transformation from technical competence toward innovation capability and ultimately toward value creation.

The research question in this article is how Joseph A. Schumpeter's Theory of Innovation can be used to explain the transformation of Industrial Electrical Engineering students' competencies into technopreneurship skills in the era of automation, particularly through the five forms of innovation and the concept of creative destruction. In line with this issue, this article aims to analyze and formulate a Schumpeterian perspective that explains how technical competencies in Industrial Electrical Engineering can be transformed into the ability to identify opportunities, develop innovations, solve industrial problems, create economic value, and build technopreneurship capacity amid technological change and industrial automation.

This study aims to develop a Schumpeterian perspective in the context of Industrial Electrical Engineering education. This article proposes that the transformation of graduates from technicians into problem solvers, innovators, and ultimately technopreneurs can be fostered through experiences that intentionally link engineering competencies with Schumpeter's five forms of innovation. Within this framework, automation is not viewed as a force that merely replaces human

labor, but rather as an environment of change that opens up new needs, markets, technologies, and business models. This perspective is expected to provide a conceptual foundation for the development of vocational learning that is more oriented toward innovation and value creation, while also strengthening the readiness of Industrial Electrical Engineering graduates to serve not only as users of technology but as creators of technology and value in the era of automation.

METHOD

This study employs a descriptive qualitative method using a literature review approach. According to Zed (2014), a literature review is not merely a matter of reading and recording data, but rather a series of activities related to collecting literature, reading, and thoroughly analyzing research materials. This approach was chosen because the primary objective of the study is to synthesize classical theoretical concepts of entrepreneurship with applied phenomena in the field of modern electrical engineering.

Data collection focused on secondary data obtained from various scientific literature, including basic entrepreneurship textbooks, national and international journal articles, and conference proceedings relevant to the topics of technopreneurship and technical vocational education. The literature search focused on specific keywords such as Schumpeter's Theory, Creative Destruction, Technopreneurship, and Industrial Automation. The literature selection

process was conducted using inclusion criteria, namely articles published within the last 10 years to ensure the relevance of industrial automation trends, combined with references to Schumpeter's classical theory as the foundation for the analysis (Snyder, 2019).

The data analysis technique used was descriptive and interpretive content analysis (Sugiyono, 2016). The analysis process was conducted in three stages: first, a conceptual examination of the five forms of innovation proposed by Joseph Schumpeter; second, identifying the technical capabilities of Industrial Electrical Engineering graduates (such as circuit design, sensor integration, and microcontroller control engineering); and third, synthesizing these two elements to formulate a commercialization strategy for hardware products with economic value in the era of the Fourth Industrial Revolution.

RESULT AND DISCUSSION

Entrepreneurship and Technopreneurship

Entrepreneurship is fundamentally defined as the ability and courage to create something new and different through creative thinking and innovative actions to generate business opportunities. According to Suryana (2014), the essence of entrepreneurship lies not only in commercial activities but also in the ability to identify market opportunities, assess risks, and organize resources to generate economic value. Entrepreneurs are driving forces that transform abstract

ideas into commercial realities capable of solving societal problems.

Over time, the strong intersection between business and engineering has given rise to the concept of technopreneurship. Wibowo (2017) defines technopreneurship as an entrepreneurial process that integrates a strong command of technology as the primary instrument for producing innovative products, processes, or services. Unlike conventional entrepreneurs, who may focus on service innovations or distribution models, a technopreneur relies on in-depth research, engineering, and technology implementation to create a competitive advantage that is difficult for competitors to replicate.

Therefore, technopreneurship requires a balanced blend of two mindsets: technical analytical acumen and managerial sensitivity. On the one hand, a technopreneur must understand the complexities of systems engineering; on the other hand, they must also be able to formulate monetization strategies. This approach ensures that the technology developed does not merely remain a laboratory artifact, but rather becomes a highly effective commercial solution for the broader public. It is this fundamental understanding of the integration of engineering and business that serves as a strong foundation when we narrow this concept down to more specific engineering fields, particularly electrical engineering.

The Concept of Technopreneurship in the Electrical Field

Based on this general understanding of technopreneurship, in the field of electrical engineering and control systems, there is a clear distinction between a conventional entrepreneur and a technopreneur. Conventional electrical entrepreneurs generally operate in the standard service sector or pure trade, such as installing electrical panels in buildings, maintaining induction motors, or simply acting as distributors of electronic components. Although profitable, this business model offers stagnant value-added because it relies on technology created by others (Yuliansyah & Pratama, 2021). In contrast, electrical technopreneurs act directly as value creators. They leverage their deep understanding of power electronics, feedback control theory, and automation to design original solutions. Rather than merely assembling commercially available components (COTS), technopreneurs in this field are capable of performing advanced technical analyses such as calculating settling time and overshoot in second order systems, designing multilayer printed circuit boards (PCBs), and developing intelligent control algorithms that can be patented as intellectual property (IPR).

Technopreneurship in electrical engineering should be understood as a competency framework that integrates engineering skills, technological innovation, opportunity identification, and the creation of economic value (Jonathan, 2020). This concept differs from conventional entrepreneurship,

which generally stems from existing commercial, service, or business management activities. In technopreneurship, technology is not merely a tool to support business activities but serves as the primary source of innovation, competitive advantage, and the creation of new opportunities. The literature on technological entrepreneurship education indicates that the interdisciplinary nature of technology means that developing technopreneurship requires a combination of technical and managerial skills; an education that is overly fragmented along disciplinary lines risks producing engineers who are technically strong but lack entrepreneurial skills or vice versa. In the context of Industrial Electrical Engineering education, this concept has become increasingly important because advancements in automation, the Internet of Things (IoT), control systems, artificial intelligence, and industrial digitization have transformed the economic value of technical competencies (Thanh Huong et al., 2024). It is no longer sufficient to measure students' abilities solely by whether they can design circuits, program microcontrollers, integrate sensors, or operate control systems. These competencies must be expanded to include the ability to address more strategic questions: what problems can this technology solve, which users need these solutions, how much value is created, and how can these solutions be developed into sustainable products or services. Thus, the focus of engineering education needs to shift from technology development to

technology-enabled value creation. Findings regarding engineering students indicate that knowledge of digital entrepreneurship and digital entrepreneurship education contribute to the development of digital entrepreneurial self-efficacy and attitudes toward digital entrepreneurship, which in turn are related to digital entrepreneurial intentions.

Conceptually, technopreneurship can be situated at the intersection of engineering capability and entrepreneurial capability. Engineering capability enables

students to develop functional technical solutions, while entrepreneurial capability enables them to identify needs, evaluate opportunities, understand users, make decisions under conditions of uncertainty, and transform those technical solutions into economic value. Therefore, a technopreneur must not only be someone capable of creating technology but must also be able to connect that technology to real-world problems and market needs. This framework can be formulated as follows:



Figure 1. The concept of technopreneurship in the electrical field

This sequence demonstrates that technological products are not the ultimate goal. Products are a medium for creating value. An energy monitoring system, for example, may technically be capable of reading electricity consumption in real time. However, technopreneurial value only emerges when students are able to identify that industries or SMEs face energy cost issues, and then develop a system capable of providing information to reduce energy waste, determine user segments, calculate production costs, establish pricing models, and design service mechanisms. In this context, engineering skills serve as the foundation, while entrepreneurial skills act as the mechanism that brings technology out of the laboratory and into the hands of users. Findings by

Shekhar and Huang Saad indicate that the involvement of engineering students in entrepreneurship education programs is a critical issue in the professional development of engineering students. This reinforces the argument that engineering education should not rigidly separate engineering competencies from entrepreneurial competencies (Shekhar et al., 2021).

Another fundamental difference lies in the concept of value creation. Innovative technology products do not necessarily have economic value if they do not solve users' problems or lack a clear utilization model. Therefore, Industrial Electrical Engineering students need to be guided to understand that the success of an innovation is determined not only by technical feasibility, but also

by user desirability and economic viability. This concept can be illustrated through three dimensions:

Table 1. The concept of value creation

Dimension	Question	Competency
Technical Feasibility	Can technology work?	Engineering & Problem solving
User desirability	Do users need this solution?	Opportunity recognition & costumer understanding
Economic viability	Can the Solution Generate Sustainable Value?	Business model & commercialization

Technopreneurship also cannot be reduced to a set of technical and business skills. It involves a shift in mindset. Students need to view technological change not merely as something they must keep up with, but as a source of opportunities to be explored. In this context, there are several key traits: Opportunity recognition the ability to see needs as opportunities for innovation; Innovative thinking the ability to create new combinations of technologies or solutions; Problem-solving orientation a focus on solving real-world problems; Risk awareness the ability to account for technological and market uncertainties; Adaptability the ability to respond to technological changes; Value orientation the ability to link solutions to user benefits; and Commercial orientation the ability to bring innovations to market. A recent study on engineering students found

that an entrepreneurial mindset influences attitudes toward digital entrepreneurship, while digital skills increase students' openness to innovation (Ganefri, et al., 2025). This reinforces the view that technopreneurship in engineering education is not merely an additional entrepreneurship course, but rather a process of shaping a mindset that enables technological competencies to be translated into innovation opportunities.

Based on the above discussion, technopreneurship in Industrial Electrical Engineering education can be conceptualized as an integrative competency, rather than a standalone, supplementary competency. This competency consists of at least four layers. First, technological competence: at this stage, students master electrical technology, electronics, control systems, sensors, microcontrollers, automation, IoT, and digital technology. Second, innovation competence: at this stage, students are able to develop new combinations of technologies, improve existing products, discover new methods, and generate innovative solutions. Third, entrepreneurial competence: at this stage, students are able to recognize opportunities, understand the market, identify users, manage resources, calculate costs, and develop business models. Fourth, commercialization competence: at this stage, students are able to take innovations from the prototype stage to products or services that can be used and developed sustainably. Conceptually:

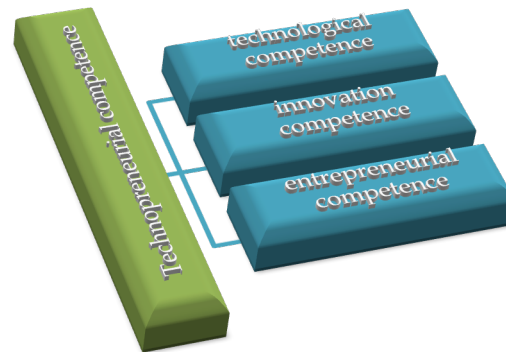


Figure 2. Technological competence

This conceptualization aligns with recent research that identifies technopreneurship as a combination of technological and entrepreneurial competencies. A 2025 study on measuring students' technopreneurship skills, for example, identified dimensions such as opportunity recognition, digital competence, innovation, risk management, and leadership (Mashudi et al., 2025).

For Industrial Electrical Engineering education, this conceptualization has important implications. Learning should not be directed solely toward producing students who can build devices, but also students who can identify problems, develop technological solutions, test user needs, and create value through those solutions. At the technician stage, students are able to operate and develop systems. At the problem-solver stage, students are

able to use technology to solve problems. At the innovator stage, students generate new solutions or combinations of technologies. At the technopreneur stage, students are able to connect these innovations with user needs and build mechanisms for sustainable value creation. This shift in orientation is increasingly relevant because recent research on vocational students shows that entrepreneurship education is associated with technopreneurship intentions, while digital business literacy and digital financial literacy strengthen that association (Hasan, et al., 2025). In other words, vocational students need not only technological literacy but also business literacy that enables them to understand how technology can be developed into economic activities. Thus, the transformation of competencies can be formulated as follows:

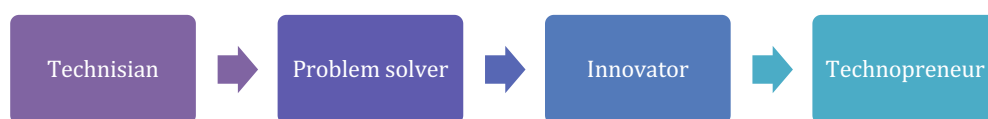


Figure 3. transformation of competencies

This transformation from technician to technopreneur has shifted the position of electrical engineering graduates within the industrial supply chain. They no longer compete on the basis of low installation service rates, but rather on the quality of product innovation. The ability to identify specific problems in the industry and then formulate solutions based on microcontrollers and customized automation systems is the key strength of the electrical engineering technopreneurship concept. However, to realize this strength and transform a mere technical idea into a commercial product that disrupts the market, an electrical engineering technopreneur needs a structured innovation framework.

Implementation of Schumpeter's Five Innovations in the Electricity Sector

Joseph A. Schumpeter's theory of innovation provides a highly relevant framework for explaining how technical competencies can be developed into technopreneurial capacity. For Schumpeter, innovation is not limited to scientific discoveries that are entirely new, but rather is a process of new combinations, that is, new combinations of products, production methods, markets, resources, and economic organizations. From this perspective, an entrepreneur acts not only as an inventor but also as an agent who introduces these new combinations into economic activity and brings about changes in market structure. Contemporary neo-Schumpeterian

literature also affirms that these five forms remain relevant for understanding how innovation creates structural change and creative destruction in the economy (Henrekson, et al., 2024). In Industrial Electrical Engineering education, these five forms of innovation can be translated into a more operational context. Students are not only guided to be able to design and operate electrical systems but are also trained to recognize that every technical competency can be a source of innovation if it can generate new solutions, new efficiencies, new markets, new resource configurations, or new business organizational models. Thus, Schumpeter's theory provides a conceptual bridge between engineering competence and technopreneurial value creation that can be explained in the following steps:

First, the primary form of innovation within Schumpeter's framework is the introduction of a new product or a substantial improvement in product quality. In the context of industrial electrical engineering, product innovation does not necessarily mean creating a device that has never existed before. Innovation can take the form of creating a product with new functions, improving the performance of an existing product, integrating multiple technologies into a single system, or developing a product better suited to the needs of a specific user segment. From a technopreneurship perspective, a key difference lies in the starting point of product development. Conventional academic projects often begin with the

question: What kind of device can be built using a specific microcontroller or sensor? In contrast, a Schumpeterian approach should begin with the question: What problem has not yet been effectively solved, and what technological product could provide a better solution? For example, students might develop a temperature monitoring system based on sensors and a microcontroller. In the context of conventional engineering education, the success of a project might be determined by the sensor's ability to accurately read temperature and display the data on a screen. However, from a technopreneurship perspective, this development must be taken further to

create a product with use value: the sensor is housed in a casing suitable for an industrial environment, data can be monitored via a dashboard, the system triggers an alarm when the temperature exceeds a certain threshold, and the device is designed to be easy to install and maintain. Thus, the value of the innovation lies not solely in the sensor, but in a new combination of the sensor, control system, data communication, product design, and user needs. This is what enables engineering competencies to be transformed into technopreneurship. Conceptually, it can be illustrated as follows:



Figure 4. The first of schumpeter's five innovations in the electricity sector

Students thus learn that open-source technology can still lead to innovation when combined in new ways and tailored to specific needs. This aligns with the literature on engineering technopreneurship, which identifies the development of technological products or services as one of the core competencies of technopreneurship (Helman, Joanna, et al., 2025). Engineering education needs to provide students with the opportunity to move from technical prototypes toward innovations that are relevant to users and have commercial potential.

Second, the second form involves the introduction of new production methods or work methods. In the field of electrical engineering, this form of

innovation is often overlooked because students' attention is primarily focused on the final product. However, from a Schumpeterian perspective, the way a product is produced or a service is delivered is also a source of innovation. In Industrial Electrical Engineering education, new methods can include changes in design processes, programming, testing, hardware and software integration, and even device production processes. In other words, innovation occurs not only in what is created but also in how things are made more effectively. For example, students who previously developed embedded systems individually—writing the same code repeatedly for each project—can now create reusable

software libraries. The use of professional development environments, version control systems, modular programming, automated testing, and code documentation can reduce development time and improve product consistency. From Schumpeter's perspective, these changes are crucial because productivity is determined not only by product quality but also by the ability to produce products more efficiently in terms of time, cost, and resources. For tech entrepreneurs in the electrical sector, the implications are significant. If it takes 10 days to manufacture a product and that process can be reduced to 4 days through design standardization and modularization, then production capacity increases without having to proportionally increase resources. This relationship can be illustrated as follows:

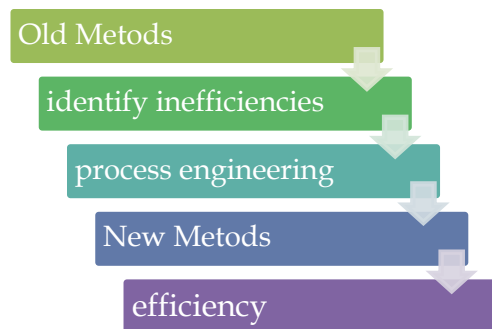


Figure 5. The second of schumpeter's five innovations in the electricity sector

Therefore, students need to understand that process innovation is part of creating economic value. Studies on the integration of Industry 4.0 into engineering education also highlight the importance of developing competencies in systems

integration, data, and interdisciplinary skills to meet the demands of the digital industry (Khan, S.H. & Mourad, A.H., 2025). In the context of education, this means that student projects should not only evaluate the output of a device but also the efficiency of the device's development process.

Third, the third form of innovation is the opening of new markets. This concept is crucial for distinguishing an engineer from a technopreneur. Engineers can develop good technology, but technopreneurs are required to identify who needs that technology and in what market context it can create value. In the field of Industrial Electrical Engineering, new market opportunities can arise when technologies previously available only to large industries are made simpler, more affordable, and more accessible to user groups that were previously unable to use them. An example is automation for small and medium-sized enterprises (SMEs). Complex PLC and industrial automation systems are often designed for large-scale manufacturing companies. However, SMEs may have simpler needs: temperature monitoring, motor control, energy logging, machine monitoring, or automatic alarm systems. This is where students can identify a market gap:

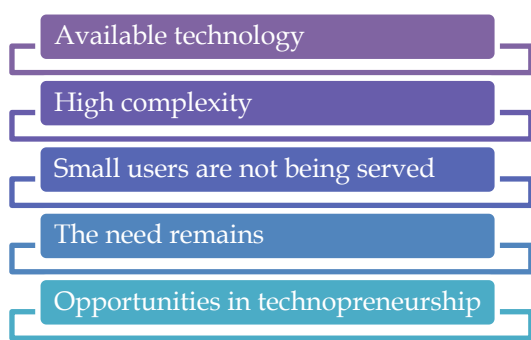


Figure 6. The third of schumpeter's five innovations in the electricity sector

Opening up new markets doesn't simply mean selling products to more people; rather, it means creating or identifying user segments that the technology hadn't previously targeted for example:



Figure 7. Strategy selling products

Thus, technopreneurs do not merely follow existing markets but identify market gaps that have not yet been adequately addressed. This concept is closely linked to opportunity recognition. In technopreneurship education, students need to learn how to conduct customer discovery, field observations, user interviews, pain point identification, and needs validation before determining which technology to develop. Recent literature on technopreneurship education in engineering criticizes learning that is overly focused on business plans and emphasizes the importance of prototyping, customer discovery, and feasibility validation. Thus, the market is no longer viewed as a place to sell products after they are completed, but as an integral part of the innovation process from the very beginning.

Fourth, the fourth form involves the use of new sources of supply whether raw materials, components,

technologies, or other resources required in the production process. In electrical engineering, this innovation can emerge through students' ability to identify alternative components, technologies, suppliers, platforms, or system architectures that deliver similar functionality at a lower cost or with more suitable characteristics. An example is the use of open-source hardware-based microcontrollers, such as the Arduino or ESP32 families, to build specific automation systems. In certain contexts, such technology can serve as an alternative to more expensive conventional automation systems if user requirements do not demand the full capabilities of premium industrial systems. However, innovation in sourcing should not be interpreted as merely replacing expensive components with cheaper ones. In the context of technopreneurship, what is more important is the ability to perform resource recombination. Students need to consider cost, quality,

availability, reliability, compatibility, security, ease of maintenance, scalability, and supply sustainability, thus:



Figure 8. The fourth of schumpeter's five innovations in the electricity sector

This concept highlights a key trait of technopreneurs: resourcefulness the ability to creatively identify and combine available resources to generate previously unthought-of solutions (Beniamino C., 2022). In a vocational

education setting, this ability is particularly relevant because students do not always have access to high-value industrial equipment. Resource constraints can, in fact, serve as a learning context for fostering creativity, frugal innovation, and needs-based engineering skills.

Fifth, the fifth form is the most strategic because it relates to changes in how industries or businesses are organized. While the previous four forms can produce new products, methods, markets, or resources, organizational innovation changes how value is created, delivered, and obtained within a business ecosystem. In the field of electrical engineering, traditional business models often take the form of:

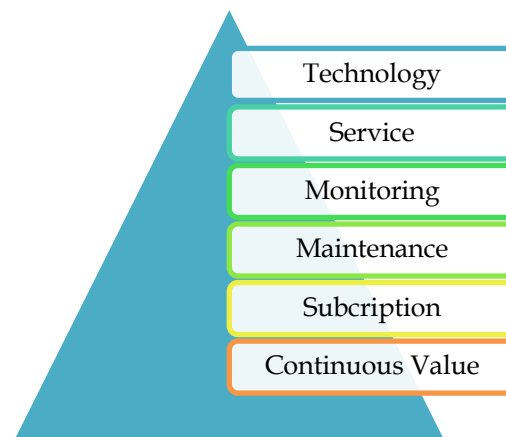


Figure 9. The fifth of schumpeter's five innovations in the electricity sector

An example is the shift from a company that merely sells and installs automation devices to one that provides Automation as a Service or Hardware as a Service. In this model, users do not have to purchase all the devices at once but can pay based on usage or subscribe to monitoring and maintenance services. This shift

represents a more profound innovation than simply creating new devices. What has changed is the business logic it has shifted from the customer buys hardware to the customer buys an outcome or service. For example, customers no longer purchase an energy monitoring device but instead buy an energy

consumption optimization service. Sensors and cloud systems merely serve as the infrastructure to deliver that service. This is where electrical engineering students need to be introduced to the concept that technology can serve as a platform for building business models, not just as a product to be sold. Recent studies on technopreneurship education in engineering highlight the importance of linking technological competencies with entrepreneurial and strategic skills, as well as a real world innovation ecosystem.

These five forms of innovation should not be understood merely as five distinct categories. Rather, the strength of Schumpeter's perspective lies in the possibility of combining all five within a single innovation process. For example, students develop an energy automation system for MSMEs

Table 2. Schumpeter's five innovations in the electricity sector

Schumpeter's Form	Implementation
New Product	Energy Monitoring and Control System
New Production Method	Modular development and installation process
New Market	MSMEs that previously did not use automation
New Source of Supply	IoT components that are easier to obtain
New Organization	Automation as a Service Models

Creative Destruction in the Age of Automation

The concept of creative destruction is one of the central ideas in Joseph A. Schumpeter's thinking on the dynamics of capitalism and innovation. For Schumpeter, economic development does not primarily occur through slow, linear changes, but through the emergence of new combinations that transform the existing economic structure. Innovation enables economic actors to introduce new products, new production methods, new markets, new sources of inputs, and new forms of organization. When these new combinations succeed, old technologies, products, processes, or organizations may lose their relevance. The term destruction in creative destruction does not imply aimless ruin. Destruction refers to the displacement of old configurations, while creative indicates that this shift simultaneously generates new configurations that possess economic or social value (Ramazan Uctu, et al., 2024). In a contemporary context, research on creative destruction shows that innovation can transform industrial structures through the emergence of new technologies and business models while rendering old technologies or practices obsolete.

This perspective is highly relevant to the development of automation. Automated control systems, robotics, the Internet of Things (IoT), artificial intelligence (AI), smart sensors, cloud computing, and cyber physical systems are not merely add ons to legacy industrial systems. These technologies can transform the

way production, monitoring, and maintenance are carried out, the way companies interact with customers, and even the way economic value is created. Recent studies on Industry 4.0 integration show that these changes

are both technological and organizational in nature and require changes in workforce competencies. In the era of automation, the process of creative destruction can be explained through three main stages:



Figure 10. Development of automation.

In the first stage, new technologies are introduced to solve specific problems. For example, sensor-based and IoT monitoring systems are developed to reduce the need for manual inspections of machine conditions. In the second stage, activities that were previously performed manually begin to be reduced, integrated, or even eliminated. In the third stage, new needs emerge, such as the development of IoT systems, sensor integration, data analysis, digital system maintenance, cybersecurity, software development, and automation consulting. Therefore, automation should not be viewed solely in terms of which jobs are lost, but also in terms of which activities emerge as a result of the technology. Research on AI and creative destruction shows that new technologies can render old business practices obsolete while simultaneously opening up new cycles of innovation and economic renewal. This is crucial for Industrial Electrical Engineering education. If students are prepared only to operate existing technologies, they risk becoming mere

users of technology. Conversely, if students are trained to view technological change as an opportunity to create new solutions, they can take on roles as innovators and technopreneurs.

One conceptual error in understanding automation is assuming that technology has only a negative relationship with the workforce. The relationship is more complex. Automation can indeed reduce the need for routine, repetitive, and structured jobs. However, at the same time, automation increases the demand for competencies related to design, integration, programming, maintenance, data analysis, product development, and systems management. In engineering education, these changes have led to a shift in competency profiles. A systematic review by Khan and Mourad of 178 Industry 4.0 studies identified gaps in competencies related to systems integration, data analytics, cybersecurity, interdisciplinary collaboration, human-machine interaction, and an understanding of business model innovation. Thus, creative destruction

can be interpreted as a process of job transformation, not merely the elimination of jobs.

Table 3. Process of job transformation

Old Model	Creative Destruction Proses	New Model
Manual engine inspection	Replacement sensor	Condition monitoring (IoT)
Conventional panel	Digital control system	Smart control system
Repairs when damaged	Data for predicting conditions	Predictive maintenance
Single-transaction sales	Cloud-Connected Technology	Monitoring as a Service
Conventional installation	Integration of sensors, controls, and data	Smart automation service

What has changed is not just the tools, but the value structure offered to users. A crucial aspect of this research is that creative destruction does not stop at technological innovation. New technologies can force changes in business models. For example, a conventional electrical engineering company may generate revenue from the installation of panels and devices. In that model, customers purchase products or installation services. As IoT technology advances, the company can offer online connected monitoring systems. Customers no longer simply buy devices; instead, they buy functions and outcomes such as continuous monitoring of machine conditions.

In this context, creative destruction can also serve as the

foundation for defining the characteristics of a technopreneur. Students need to be developed not only into individuals capable of mastering technology, but also into individuals who can anticipate change and take innovative action. These characteristics encompass at least five competencies. *First*, technological sensitivity, the ability to track technological developments and understand their potential applications. *Second*, opportunity recognition, the ability to identify opportunities arising from technological changes and user needs. *Third*, innovative recombination, the ability to combine technology, resources, knowledge, and market needs into new solutions. *Fourth*, market orientation, the ability to ensure that innovations have users and solve real problems. Research findings on technology companies highlight the importance of the relationship between technical opportunities and market orientation in driving entrepreneurial action. *Fifth*, adaptive action, the courage to change designs, business models, or strategies when the technological environment and user needs change. Therefore, a technopreneur is not merely someone capable of creating technology, but someone capable of transforming technological change into opportunities for value creation.

The most important implication of this perspective is the need for a shift in the orientation of engineering education, particularly in vocational education. Education must not only teach students how to make a system work, but also why such a system

needs to be created, who needs it, and how it creates value. Recent studies on engineering education for Industry 4.0 indicate that industry demands are increasingly focused on interdisciplinary competencies, including systems integration, data, multidisciplinary collaboration, human-machine interaction, and business model innovation. Therefore, the final projects of Industrial Electrical Engineering students can be reoriented:

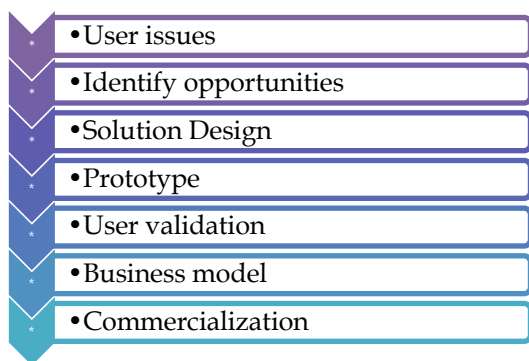


Figure 11. Business model innovation

This change is crucial because it transforms engineering projects into a space for developing the character of technopreneurs, rather than merely a space for demonstrating technical competence.

CONCLUSION

Automation, AI, IoT, and smart manufacturing require Industrial Electrical Engineering graduates to go beyond technical competence: they must anticipate technological change, identify problems and opportunities, and turn technical solutions into economic and social value. Technopreneurship, grounded in Schumpeter's theory of innovation,

bridges engineering competencies and these capabilities.

Schumpeter sees innovation as new combinations of resources, technologies, and organizational forms, in five types: new products, production methods, markets, supply sources, and industrial organization. In electrical engineering and automation, these appear as smart monitoring and control systems, modular engineering processes, solutions for underserved segments, alternative technologies and components, and solution-based services such as Automation-as-a-Service. Creative destruction shows that automation reduces routine work but creates new demands, skills, and business models, so graduates should be active agents of change.

Students must ask not only whether a system works, but what problem it solves, for whom, and how it becomes a sustainable business. The framework runs from technical competence through problem identification, recombination, prototyping, market validation, and commercialization to value creation. Technopreneurship is integrated with engineering education, and projects should be judged on relevance, novelty, manufacturability, and market viability, not just function. Graduates must shift from technology users to technology and value creators.

REFERENCES

- Armika, M., Situmeang, Y., & Sihotang, H. (2026). Peran inovasi dalam kewirausahaan: Kajian literatur berdasarkan teori schumpeter.

- Jurnal Penelitian Ilmiah Interdisipliner*, 10(6), 719-727.
- Beniamino C., Erlend N. (2022) Schumpeterian theory and research on forestry innovation and entrepreneurship: The state of the art, issues and an agenda. *Forest Policy and Economics*, 138, 102720. <https://doi.org/10.1016/j.forpol.2022.102720>
- Blank, S., & Dorf, B. (2012). *The startup owner's manual: The step-by-step guide for building a great company*. K&S Ranch.
- Drucker, P. F. (1985). *Innovation and entrepreneurship: Practice and principles*. Harper & Row.
- Fayolle, A., & Gailly, A. (2015). The impact of entrepreneurship education on entrepreneurial attitudes and intention: Hysteresis and persistence. *Journal of Small Business Management*, 53(1), 75-93.
- Ganefri, Waras, Trisno, B., Mohd Nordin, N., Hidayat, H., Rahmawati, Y., & Nurhidayatulloh. (2024). Cultivating digital entrepreneurs: Unravelling factors shaping digital entrepreneurship intention among engineering students in higher education. *International Journal of Management Education*, 23(2). <https://doi.org/10.1016/j.ijme.2024.101100>
- Habiburrahman, Sediya S., Ilham K., (2024). Product Innovation and Digital Marketing Strategies: Key to Small Business Success in the Creative Economy Era. *Jurnal Kewirausahaan dan Bisnis*, 29 (2), 103-113. DOI: 10.20961/jkb.v29i2.96868
- Hasan, M., Tahir, T., Nurjannah, Aeni, N., & Kang, H. (2025). Investigating the role of entrepreneurship education on the technopreneurship intention of Generation Z vocational students: Why do digital business literacy and digital financial literacy matter? *Journal of Technical Education and Training*, 17 (3), 25-42
- Henrekson, M., Johansson, D., & Karlsson, J. (2024). To be or not to be: The entrepreneur in neo-schumpeterian growth theory. entrepreneurship theory and practice. *Entrepreneurship Theory and Practice*, 48(1), 104-140. <https://doi.org/10.1177/10422587221141679>
- Helman, J., et.al., (2025). Technopreneurship in engineering education: synthesizing pedagogical approaches for sustainable competency development. *Sustainability*, 17 (2), 11228. <https://doi.org/10.3390/su172411228>
- Hidayat, M., & Susanto, A. (2020). Pengembangan karakter technopreneurship mahasiswa vokasi melalui pembelajaran berbasis proyek. *Jurnal Pendidikan Vokasi*, 10(2), 145-156.
- Jonathan, D. Linton (2020, *Research on Science and Technological Entrepreneurship Education: What*

- Needs to Happen Next ?*, J. *Technol Transf* 46, 393–406 (2021). <https://doi.org/10.1007/s10961-020-09786-6>
- Khan, S. H., & Mourad, A. H. I. (2025). Integrating Industry 4.0 in engineering education: implementation patterns, pedagogical strategies, and industry alignment. *Cogent Education*, 12 (1), <https://doi.org/10.1080/2331186X.2025.2588010>
- Kusuma, B. A., & Raharjo, S. (2022). Implementasi Internet of Things (IoT) pada sistem otomasi industri skala menengah. *Jurnal Teknik Elektro dan Kendali Terapan*, 4(1), 12–21.
- Marwan, E., Yuliani. (2015). Entrepreneurial strategy of pastry msme: the effect of product, price, and promotion on sales performance. *Jurnal Kewirausahaan dan Bisnis* 30 (2), DOI: 10.20961/jkb.v30i2.114376
- Mashudi, I., Darman, D., & Djafri, N. (2025). Developing an instrument to measure students' technopreneurship skill levels in starting new businesses using the Rasch model. *International Journal of Innovative Research and Scientific Studies*, 8(7). <https://doi.org/10.53894/ijirss.v8i7.10408>
- McClelland, D. C. (1961). *The achieving society*. Van Nostrand.
- Mubarak, A. (2019). Desain dan implementasi sistem kendali cerdas berbasis mikrokontroler untuk efisiensi energi industri. *Jurnal Rekayasa Elektrika*, 16(3), 112–120.
- Schumpeter, J. A. (1934). *The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle*. Harvard University Press.
- Schwab, K. (2016). *The fourth industrial revolution*. World Economic Forum.
- Shekhar, P., & Huang-Saad, A. (2021). Examining engineering students' participation in entrepreneurship education programs: Implications for practice. *International Journal of STEM Education*, 8(4). <https://link.springer.com/article/10.1186/s40594-021-00298-9>
- Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333–339.
- Sudira, P. (2012). *TVET abad XXI: Filosofi, teori, konsep, dan strategi pembelajaran vokasional*. UNY Press.
- Thanh, H., et.al. (2024). Antecedents of digital entrepreneurial intention among engineering students. *International Journal of Information Management Data insights*, 4(1). DOI. <https://doi.org/10.1016/j.jjime.2024.100233>
- Uctu, R., Nadide S.H.T., Mustafa A. (2024). Creative destruction and artificial intelligence: The transformation of industries during the sixth wave. *Journal of Economy and Technology*, 2, 296–

- 309,
<https://www.sciencedirect.com/science/article/pii/S294994882400043X>
- Wibowo, A. (2017). *Pendidikan kewirausahaan: Konsep dan strategi membangun karakter technopreneurship*. Pustaka Pelajar.
- Yuliansyah, H., & Pratama, R. (2021). Peluang komersialisasi sistem otomasi industri berbasis Internet of Things (IoT) pada sektor UMKM. *Jurnal Inovasi dan Kewirausahaan Teknologi*, 5(1), 32–44.
- Zed, M. (2014). *Metode penelitian kepustakaan* (Ed. ke-3). Yayasan Pustaka Obor Indonesia.