IS THE PACE OF TECHNOLOGICAL PROGRESS DECELERATING?

Dumitru POSTORONCA*, Mohamed Dhiaeddine HASSINE, Nicolai PETCOV

Department of Software Engineering and Automation, group FAF-233, Faculty of Computers Informatics, and Microelectronics, Technical University of Moldova, Chisinau, Republic of Moldova

*Corresponding author: Dumitru Postoronca, dumitru.postoronca@isa.utm.md

Tutor/coordinator: **Elena GOGOI**, university lecturer

Abstract. *This article delves into the ongoing discourse surrounding the trajectory of technological progress, examining whether we are currently witnessing a slowdown or not. Through a comprehensive exploration, we have examined historical perspectives on technological advancement, contemporary trends, and challenges in innovation. At the same time, we have identified key factors shaping the rate of progress. We aimed to investigate how education and the development of the workforce are interconnected with the evolution of technology. We have identified that there is a complex relationship between these factors, and by studying them together, we hope to uncover and understand the complicated patterns and interactions involved in how technology advances. Drawing upon a diverse array of research and reliable evidence as scientific articles, statistics, and official data, this study aims to shed light on the nuances of the ongoing technological landscape. Ultimately, it endeavors to contribute to a deeper understanding of whether the perceived downturn in the rate of technological progress is a temporary phenomenon or an indication of broader systemic shifts.*

Keywords: *industry 4.0, innovation, patents, progress factors, revolution, technological progress*

Introduction

In the ever-evolving sphere of technology, a prevalent debate centers around the notion of a potential deceleration in innovation in our current era. This article embarks on a detailed exploration, delving into the annals of history, current trends, and the challenges that mold the path of technological progression. Through an all-encompassing perspective, we dissect the complex relationship between education, workforce development, and technological evolution, acknowledging the intricacies of their interconnections.

Our exploration into the historical backdrop aims to situate the present state of technological progress, providing insights into the patterns that have steered innovation over the centuries. Concurrently, scrutiny of modern trends and challenges offers a glimpse into the current landscape, pinpointing pivotal elements that dictate the speed of advancement. Importantly, we probe into the reciprocal relationship between education and technology, intending to decipher the complex patterns and interactions that characterize their mutual evolution.

This study leverages a wide spectrum of research and credible evidence, the main source being a similar study provided by Tyler Cowen “Is the Rate of Scientific Progress Slowing Down?” [1], aspiring to illuminate the subtle dynamics at play within the current technological panorama. In doing so, we aim to foster a deeper comprehension of whether the perceived deceleration in technological progress is a fleeting occurrence or a sign of more extensive systemic shifts. Essentially, this article strives to provide a thorough exploration that traverses the multifaceted aspects of the discourse on technological progress, aiming to demystify its complexities within a succinct framework.

Historical Perspective on Technological Progress

Throughout history, technological progress has been characterized by a series of transformative breakthroughs and innovations that have reshaped societies and propelled human civilization forward. From ancient times to the present day, humanity has continuously sought ways to overcome challenges, improve efficiency, and enhance quality of life through the application of technology.

One of the earliest examples of technological innovation can be found in the agricultural revolution, which occurred around 10,000 years ago. This period marked the transition from nomadic hunter-gatherer societies to settled agricultural communities, enabling humans to produce food more efficiently and sustain larger populations.

The subsequent centuries saw advancements in various fields, including transportation, communication, and manufacturing. The invention of the wheel, around 3500 BCE, revolutionized transportation and trade, allowing goods and ideas to be exchanged over longer distances. The development of writing systems, such as cuneiform in Mesopotamia and hieroglyphics in ancient Egypt, facilitated record-keeping, administration, and the spread of knowledge.

However, it was during the Industrial Revolution, known as Industrial Revolution 1.0, which began in the late 18th century, that technological progress accelerated dramatically. The harnessing of steam power, the invention of the spinning jenny and power loom in textiles, and the mechanization of agriculture transformed economies and societies. Factories emerged as centers of production, and urbanization accelerated as people migrated from rural areas to cities in search of employment.

In the 20th century, we witnessed even more rapid advancements in technology, particularly in the fields of transportation, communication, and computing. The invention of the automobile revolutionized personal transportation, while the development of the airplane enabled faster and more efficient travel over long distances. The invention of the telephone by Alexander Graham Bell and the subsequent expansion of telecommunications networks connected people across the globe, shrinking the world and facilitating the exchange of information.

The latter half of the 20th century saw the rise of the digital age, characterized by the invention of the transistor, the development of integrated circuits, and the advent of the personal computer. These breakthroughs laid the groundwork for the Information Age, marked by the proliferation of the Internet, mobile devices, and digital technologies. The digital revolution has transformed virtually every aspect of modern life, from communication and entertainment to commerce and healthcare.

Table 1

Key technological components of Industry 4.0 [1]

Technologies	Definition
Artificial intelligence	is an area of computer science that emphasizes the creation of intelligent machines that work and react like humans.
Blockchain	is a distributed database that maintains a completely, distributed and non-tampering continuously growing list of records using new encryption and authentication technology and network-wide consensus mechanism.
Cloud	refers to any IT services that are provisioned and accessed from a cloud computing provider.
Mobile Technology	is the wireless communication technology integration based on the wireless devices
Nanotechnology	also now referred to as molecular nanotechnology, is the particular technology to control individual atoms and molecules for fabrication of macroscale products.
Simulation	refers to technologies that use the computer for the imitation of a real-world process or system.

Today we are observing the development of Industrial Revolution 4.0 which is developed around the paradigm of replacing human work with automatic systems. This revolution can provide various economic benefits for businesses and firms. It is a relatively new trend that is still developing and people have established already the main resources and instruments that are creating the revolution (Tab. 1).

In order to highlight the frequency of innovations across time Bunch and Alexander Hellemans, science and technology writers and editors, have put on a timeline 8,583 most significant advancements in science and technology since the Dark Ages till 2005 when their work was published (Fig. 1). Points are an average over 10 years with the last point covering the period from 1990 to 1999. The smooth curve is the least squares fit of a modified Gaussian distribution to the data.

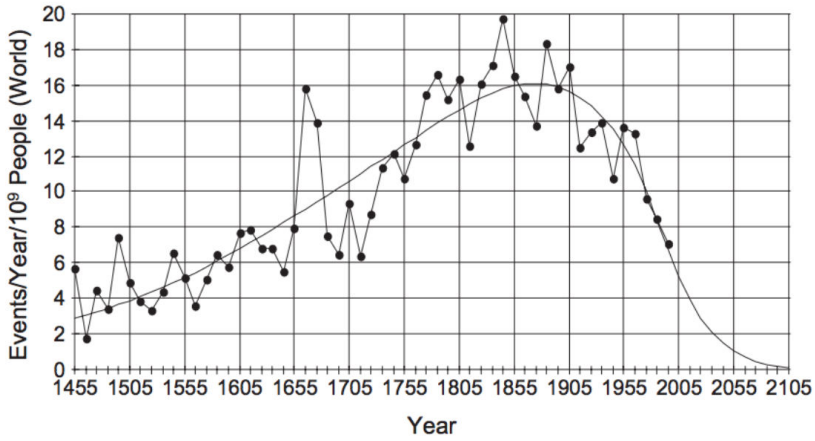

Figure 1. Rate of innovation since the end of the Dark Ages [2].

As we see the graph in Fig. 1 constructs a Gaussian distribution, where the number of new technological advancements is in decline even if we still have a positive rate. The peak decades are places between 1840-1905. Since then, we have been pushing against multiple limits, whatever their origins are. This is why Industry 4.0 can be treated as a result of the inertial force that remained after the technological boom of the 20th century and another one can be seen only after a few decades.

Trends and Challenges in Contemporary Technological Innovation

Contemporary technological advancements are reshaping societies at an unprecedented pace. This paper examines recent developments in key fields like artificial intelligence (AI), biotechnology, renewable energy, and space exploration while exploring the pace of innovation compared to previous decades. It then dives into the intricate tapestry of challenges and opportunities presented by these emerging technologies, including ethical considerations, regulatory hurdles, and the impact on employment and society.

Meanwhile, recent breakthroughs paint a captivating picture. From AI chatbots like ChatGPT crafting [3] human-quality text to CRISPR gene editing offering potential cures for genetic diseases, the boundaries of possibility seem to expand daily. Renewable energy sources like solar power are becoming increasingly cost-competitive, paving the way for a sustainable future. Meanwhile, space exploration ventures such as SpaceX's reusable rockets and the James Webb telescope propel our understanding of the universe to new heights.

Furthermore, arguments abound regarding the current pace of innovation. Some point to exponential growth in computing power (Moore's Law) [4] and increased global research collaboration as evidence of an accelerated revolution. Open-source platforms further democratize tools and resources, empowering diverse minds to contribute. However, not all sectors advance at the same rate. Fusion energy, for instance, still faces significant hurdles.

While exhilarating, this innovation surge presents formidable challenges. Ethical considerations around AI bias, gene editing, and autonomous weapons demand thoughtful approaches. Regulatory frameworks must adapt to keep pace with rapid development [5], balancing innovation with safety and ethical concerns. Automation threatens job displacement in various sectors, necessitating new skills and retraining programs. Additionally, widening access to technology can exacerbate inequality and societal disruption.

Despite the rapids, the potential benefits of responsible technological development are immense. Collaboration between researchers, policymakers, and the public is crucial [6]. Engaging in ethical discussions, fostering inclusive access, and investing in workforce development are essential steps. By navigating these challenges, we can harness the power of innovation to build a more equitable, sustainable, and prosperous future.

Factors Influencing the Rate of Technological Progress

In essence, the half-century from 1870 to 1920 was a whirlwind of innovation, with each industry experiencing transformative changes that would shape the course of the 20th century and beyond. But since the 1970's there has been great progress only in the field of information and communication technologies. The pace of progress in other areas seems to have been slowed significantly.

The Theorem of low-hanging fruit [7] is one of the slowdown arguments. As technology progresses, we solve the easy problems first and are left with the harder problems, making it exponentially harder to innovate and realize truly revolutionary things. As a result, many new technologies are optimizations, not revolutions.

A bit faster, a bit smaller, a bit cheaper, and maybe another feature or two. In fact, some key areas of technology appear to be in regression.

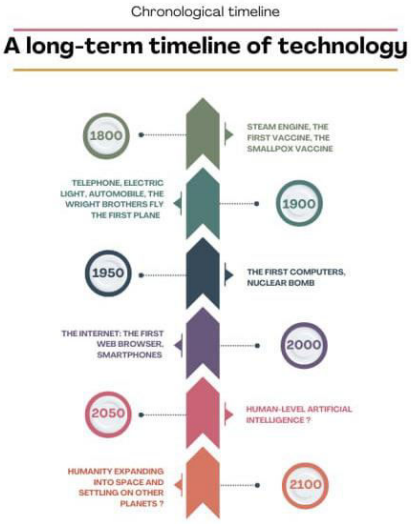

Figure 2. A long-term timeline of technology [8]

One solution to this problem is that government could try to get more people to become scientists and engineers. As the population grows, the sheer number of minds available to tackle complex problems multiplies. This crowdsourcing of intellectual capacity means that there are more individuals to think, debate, experiment, and innovate. with more people, there's a higher chance of having more geniuses. A vast population is more likely to produce individuals with the rare combinations of skills, talent, and intuition that lead to revolutionary breakthroughs.

Another possible solution to tackle the technological slowdown could be rapid advancements in artificial general intelligence and biotechnology [8]. The former could replace human worlds including engineers and researchers. This would allow to increase in the number of researchers working in state-of-the-art research [9].

Advancements in biotechnology could help us create genetically engineered human beings with greater research abilities.

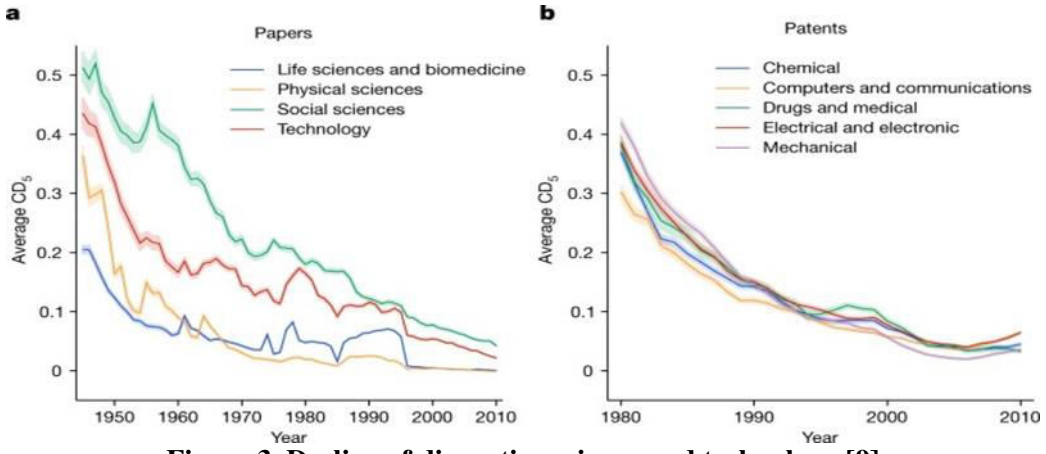

Figure 3. Decline of disruptive science and technology [9]

We know this is already within our technological reach but what about the ethical cause? this remains a controversial subject. The notion of creating a being for a predefined purpose challenges many ethical, philosophical, and religious beliefs about the sanctity and autonomy of individual life. So far, I believe as a global society we have made the right decision to not move forward with it which is for the best as it could create ethical, identity, economic, and political complexities.

The Impact of Education on Technological and Workforce Development

In an era marked by rapid technological advancements, global connectivity, and ever-evolving industries, the relationship between education and the workforce has emerged as a linchpin for societal progress. This compartment delves into the integral connection between education and the workforce environment, unraveling the profound impact of education in preparing individuals for the challenges and opportunities of the modern professional landscape. As we navigate an increasingly complex world, understanding the symbiotic interplay between education and the workforce becomes essential for fostering innovation, promoting social mobility, and driving sustained economic growth. Join us on a journey to explore how education serves as the cornerstone for building a skilled, adaptable, and empowered workforce poised to shape the future.

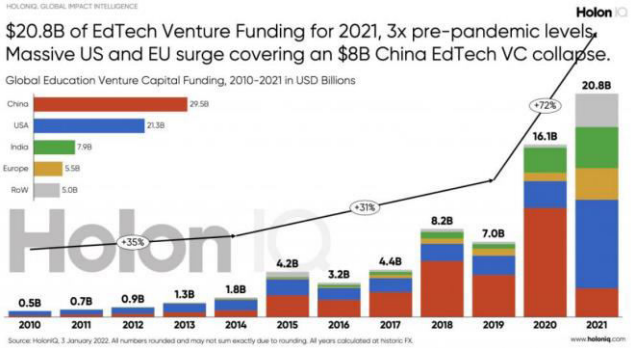

Figure 4. Venture Capital Investment in Technology [10]

Educational investments create a pool of researchers capable of catalyzing innovation and breakthroughs. A well-educated population becomes a catalyst for the adoption and growth of new technologies, fostering a market for innovation. The discourse emphasizes the connection between digital literacy, educational investments, and the widespread embrace of emerging technologies, showcasing how erudition manifests through online learning and open-source projects.

This graph above shows the amount of venture capital invested in technology companies globally over the past 10 years. As you can see, investment in technology has been growing rapidly in recent years.

In the face of accelerating technological change, continuous learning becomes essential. Education and workforce development programs, such as tech boot camps and upskilling initiatives, are vital in ensuring workforce adaptability. This adaptability not only guards against obsolescence but also cultivates a workforce ready to contribute to and embrace technological evolution.

In today's dynamic world, education is pivotal in cultivating adaptable problem-solvers. A curriculum that prioritizes critical thinking and creativity not only shapes well-rounded individuals but also fosters collaborative skills essential for success in an interconnected global landscape.

Moreover, educational initiatives that inspire interest in STEM (Science, Technology, Engineering and Mathematics) fields contribute significantly to nurturing the next generation of innovators. By providing hands-on experiences and fueling a passion for science, technology, engineering, and mathematics, educators play a vital role in driving progress and innovation.

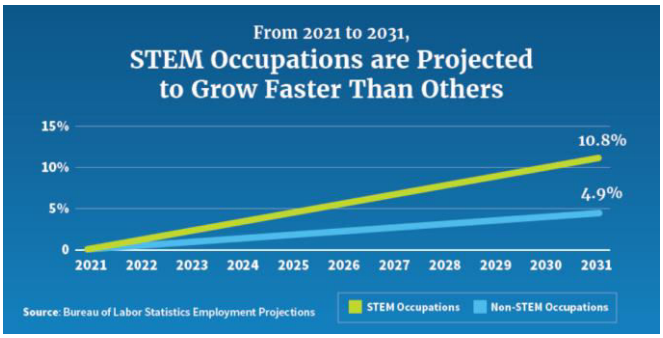

Figure 5. Growth of STEM Occupations [11]

This graph, from the US Bureau of Labor Statistics, shows the projected growth of STEM occupations in the US from 2021 to 2031. As you can see, STEM occupations are expected to grow much faster than all occupations, highlighting the increasing demand for STEM skills in the future job market.

In the rapidly evolving job market, lifelong learning is indispensable. Adapting to changing industry demands through continuous upskilling ensures professional viability and global competitiveness. Countries actively promoting continuous learning equip their workforce with in-demand skills, fostering personal fulfillment and enhancing their ability to navigate the complexities of the contemporary global landscape.

Government initiatives, including tax incentives and sector-specific programs, play a crucial role in fostering innovation and economic growth [12]. Tailored support for critical sectors encourages advancements and addresses industry-specific challenges, while digital literacy programs empower individuals to thrive in a technology-driven world.

In education, a shift towards modular learning allows customization of educational journeys, catering to diverse learner needs. Upskilling and reskilling courses support lifelong learning, and adapting to evolving industry demands. Recognizing the value of experiential learning, and acknowledgment of prior experience fosters inclusivity, creating a dynamic educational ecosystem tailored to the evolving workforce. Together, these initiatives contribute to a more responsive and adaptable economic and educational landscape.

In today's workforce landscape, employer-sponsored training programs play a pivotal role in skill development, offering continuous learning for professional growth. Online learning

platforms further democratize education, providing flexible opportunities for individuals to acquire and enhance skills. Industry partnerships strengthen the link between academia and real-world needs, ensuring a dynamic ecosystem that benefits both employers and learners. Together, these approaches create a responsive framework, meeting the evolving requirements of the modern workforce.

Conclusions

In the article, we reflect on the question: "Is technological progress slowing down?". We give different arguments, describe different periods of history, and show information from different graphs.

According to a study on the rate of innovation since the end of the Dark Ages, it is observed that a surge in technological progress occurred at the beginning of the 20th century, after which there was a slowdown. This phenomenon can be interpreted through the concept of "low-hanging fruit" - the idea that readily available or obvious opportunities for technological development have already been exhausted.

As the number of revolutionary patents declined over time, humanity turned its gaze to the development of artificial intelligence. This decision was aimed at increasing the likelihood of a new wave of technological revolution. On the other hand, the fact that progress has slowed down has led people to become more active in improving existing technologies, creating the illusion of continued progress. However, this may turn out to be only a temporary way to compensate for the slowdown rather than a real driver of innovation.

Humanity has created a sphere where they feel comfortable, and this is what is slowing down their development. Thus, we can say that at the moment all signs point to a slowdown in technological progress.

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