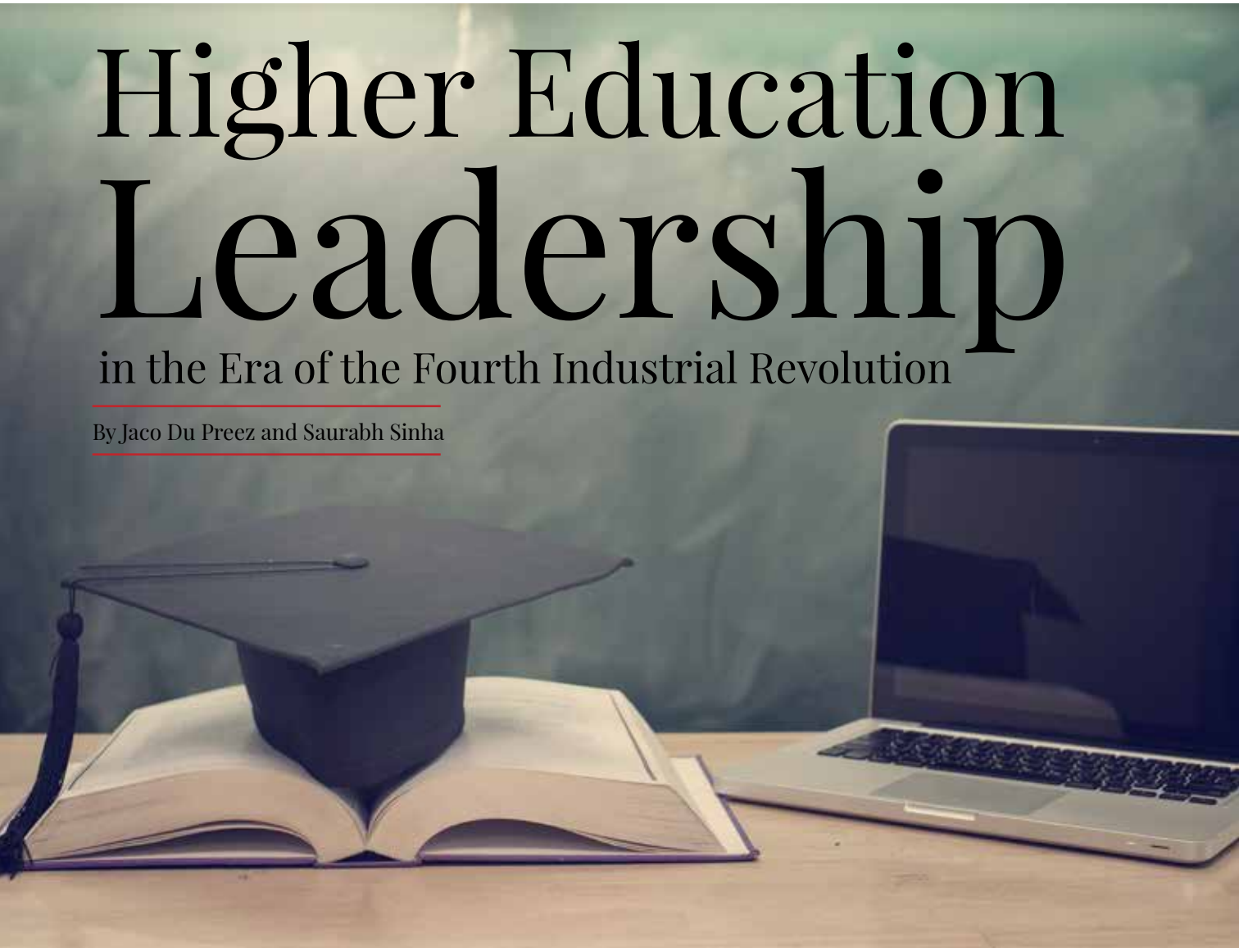

Higher Education Leadership

in the Era of the Fourth Industrial Revolution

By Jaco Du Preez and Saurabh Sinha

Introduction

A number of universities in South Africa have taken up the quest for the Fourth Industrial Revolution (4IR). Universities like the University of Johannesburg (UJ) aspire to "dynamically shape the future", and the 4IR provides a perfect segue for this – the university's approach towards the 4IR catalyses us to shape graduates who are able to think differently and to distinguish themselves in this way. In particular, our focus has been on learning. Learning encompasses a blend of teaching, research and innovation in an era where even the fundamentals are shifting.

Through a considered process that took almost a year, UJ decided to contextualise its 2025 strategy for Global Excellence and Stature (GES) for the 4IR. This strategic or catalytic initiative has wide implications for the university's business, and in particular for the research-innovation nexus. The quest is to graduate students who are able to access and define new economic zones. South Africa's current focus is not only on the physical and urban economies, but also on the digital economy and the oceans economy, through Operation Phakisa ("hurry up"). The South African government has more recently extended these initiatives to the basic education sector. The digital economy brings about opportunities for creating jobs in a virtual environment, as well as new ways of combatting poverty. While it may be tempting to point out that one of the main culprits

behind the rise in income inequality worldwide is technology, this conclusion does not do the complexity of the problem any justice. Technology improves efficiency and creates avenues for wealth creation. The methods by which we utilise the benefits of these improvements can play a vital role in income disparity, as reported in an in-depth analysis of countries throughout Western and Eastern Europe with respect to technological change (Kharlamova et al., 2018).

The digital economy has, however, been around for some time. One could visualise the oceans and digital/data economy in an analogous way. In the ocean, for instance, there is much water, but most of this is not accessible for (say) drinking. The digital economy similarly has much data, but there are limitations that prevent making use of all this data in a meaningful way – as computing and communication technologies (wired and wireless) have yet to converge in a sophisticated way. Sophistication refers to the inclusion of advanced artificial intelligence (AI) systems utilising machine and, in particular, deep learning. The latter includes data fusion from various man-machine sources, and this will have privacy, security and other secondary implications. Advanced systems, such as traffic networks, may face the complication of a hijack and individual data breaches would routinely occur. Using technologies such as AI in a multipronged way refers to the 4IR and would allow for accessing and utilising data beyond offerings of the "traditional" digital economy (the Third Industrial Revolution). In the analogy of the oceans, it would be like accessing water (data) or aspects of the ocean (digital economy) that are yet to be harvested in a sustainable way. With that said, the importance of curbing the hype behind the alleged powers of big data and seriously taking into account its real world implications, such as privacy and information security, should not be brushed aside.

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It is important to note that the digital economy has the potential of deepening inequality, unless a consideration of digital equity and equality is included as an "initial specification" in education and economic scenarios related to the 4IR. In the education scenario, inclusiveness must be a central focus in project and programme initiatives. Fortunately, younger generations (millennials and beyond) are a majority in the "Global South" and their energy, combined with the 4IR, could bring about a new kind of global renewal for equality. In the economic scenario, government must play a role in encouraging entrepreneurship by assisting start-up companies, supporting Small, Medium & Micro Enterprises (SMMEs), encouraging and driving investment in digital infrastructure, and guiding the adaptation of primary and secondary education to the new digital landscape. An example of such initiatives would be to incentivise the 4IR as an economic stimulus, with productivity gains gradually being taxed. The nature of start-up companies operating in highly competitive markets requires government to lower the barrier to entry and loosen the regulatory burden for small businesses. The situation is worsened in the case of the digital economy. The World Bank notes that it takes an average of 40 days to start a business in South Africa, compared to four days in the U.S. and five days in the U.K. As initiatives progress in parallel, education-economic thinking for inclusiveness would need to be central to the graduate's paradigm of thinking, as it would encourage economic participation and would enable previously unexplored horizons.

University students therefore have to be trained to reach a new level of digital astuteness, to access multiple thought domains through interdisciplinary activity, and to develop a mindset that aspires beyond the ordinary. The 4IR provides a perfect platform for this new model of education. A distinguishing characteristic of the 4IR is the effort expended to ensure sustainability, and an acute awareness of the social change that accompanies technological revolution. It can be argued that these changes occurred rather organically in the past, and were in part also a product of the rapidly varying geopolitical situation across the world (prime examples are the two World Wars, which accelerated technological and

scientific development in addition to drastically altering global economic activity). In today's world, broadly speaking, things are more stable, and new technologies need time to be fully adapted and to produce their full effect.

It is by no means far-fetched to consider the higher education system as an industry in itself, given that it records about $380 billion worth of economic activity in the U.S. (Penprase, 2018). To this extent, the analysis of the education system in the context of the 4IR can be performed. This article first analyses the education paradigm in a historical context, given that there is much to learn from the joint advancement and interaction of technology and higher education, as evidenced in the previous three industrial revolutions. With the background established, we zero in on the unique situation in South Africa and discuss various opportunities where 4IR technology could be adopted in the process of propelling higher education into the next age.

The Effect of the First Three Industrial Revolutions on the Education Paradigm

Figure 1 provides a brief, visualised summary of the move towards Industry 4.0 and highlights some of the pertinent technologies that have come along with it. The utilisation of the 4IR technologies outlined in Figure 1 has been studied extensively for industrial and manufacturing applications (Perera et al., 2015), but recent efforts in the education industry have also been promising.

The First Industrial Revolution abruptly highlighted the limitations of the educational system at the time, and it opened up a diverse array of new disciplines that could be pursued in educational programs. The New Education, as described by Charles Eliot (President of Harvard at the time), details a dramatic shift in the education paradigm, and universities across the world adopted the German model of postgraduate research (Hawkins, 1964). As a result, dozens of research-focused universities started to appear in the United States, and this model is still influential to how universities are operated today (Watson, 2010). The second half of the 19th century, a time period commonly associated with the Second Industrial Revolution, saw the emergence of electrically driven manufacturing technologies, leading to what was known at the time as a "new economy".

Significant improvements in access to higher education were achieved, which in turn produced a genuine leap in discovery by harnessing the possibilities brought about by technological revolution. The United States in particular saw a drastic increase in innovative institutions of higher education, driven by a combination of private and public funding (Penprase, 2018). Moreover, the Morrill Act of 1862 expanded the options for further study to agriculture, mechanical arts and

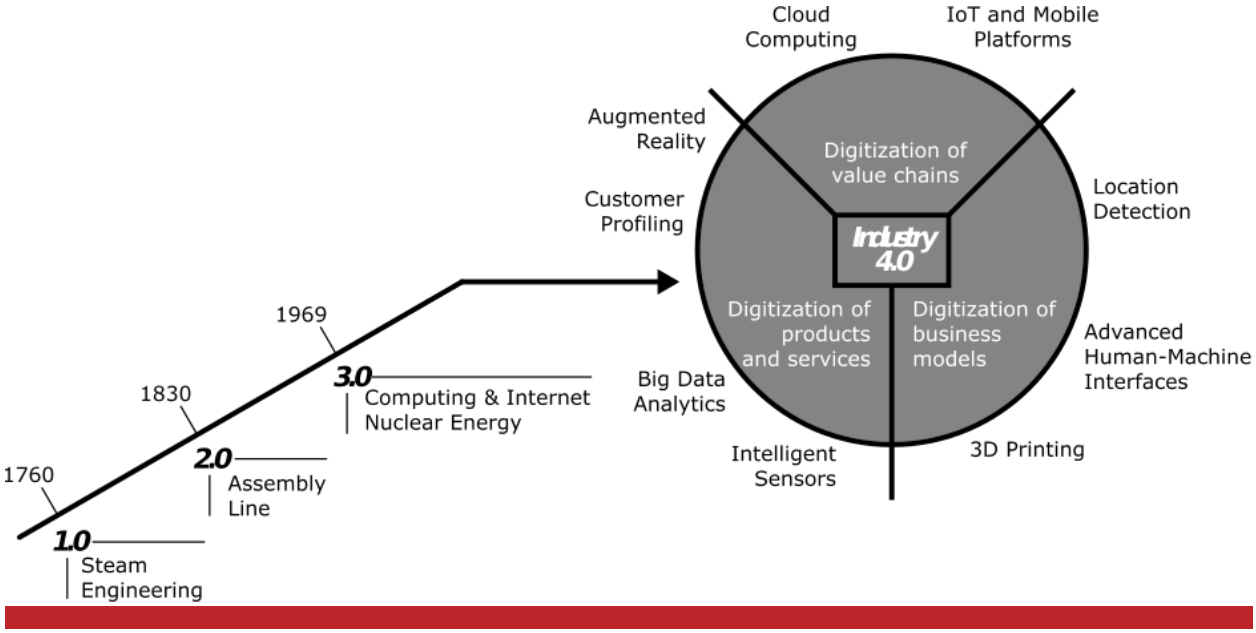

Figure 1. Pathway to the Fourth Industrial Revolution across time.

science and engineering, with the intention of opening up educational opportunities to the industrial class (Jolly, 2009). As a result of this and the previously-unseen profitability of new industries brought about by the revolution, institutions such as Stanford University and the University of Chicago were founded (in 1885 and 1890, respectively). Smaller colleges such as the Throop College (Caltech as it is known today) were also established during this time. The societal and economic changes were both a product of the revolution and a response to it. A role for women as an integral part of the academy and industry was cultivated by the prominence of co-educational institutions.

Given the recent emergence of the Third Industrial Revolution (which will loosely be described as the computer revolution of the later decades of the 20th century), the effect that it has had on higher education has arguably only been truly felt in the past couple of years. Countries across the world have been exhibiting increasing participation rates to higher education programs, and the globalisation of research efforts has further added to this effect. Moreover, the prominence of remote learning has increased substantially due to the availability of online courses – many of which are available from highly reputable institutions, such as the Open CourseWare (OCW) initiative from the Massachusetts Institute of Technology (MIT).

Education in South Africa

The problems facing our education system in South Africa are multi-faceted and should be approached as such. Among age groups from 15 to 64 years, the youth (15-24 years) bracket boasts the highest unemployment for all educational

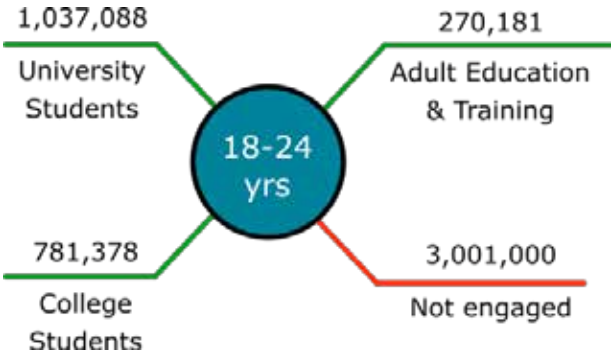

Figure 2. Summary of individual engagement in higher education for persons between 18 and 24.

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levels (Stats SA, 2019). More than 30% of graduates of some or other form of tertiary education are not employed, while close to 60% of young people that did not graduate from high school are in the same boat. A breakdown of educational engagement for 18 to 24 year olds as measured in 2014 is shown in Figure 2 (Stats SA, 2019).

Figure 2 shows that 58.9% of our youth are neither employed nor engaged in any form of tertiary training, educational or otherwise. There are plenty of factors that contribute to these alarmingly high rates – resource availability and utilisation in primary and secondary schools, access to mother-tongue education, administrative and policy issues, and school infrastructure problems, to name but a few, and limiting the discussion to but a few paragraphs is nowhere near enough to do the issue justice (Legotlo and Wilfred, 2014). About half of individuals between 18 to 24 state that a lack of funding is the reason behind their inability to attend further education, compared to about 18% that indicated insufficient academic performance. The solutions that the 4IR could bring to problems such as accessibility to education could be significant, but they would rely on harnessing the many aspects of current and future generations of intelligent systems. A handful of initiatives are discussed in the succeeding section.

One of the primary challenges of the 4IR is the scarcity of qualified, trained personnel to spearhead the movement, especially in higher education (Baygin et al., 2016). As such, the importance of improving access to online resources, training material, courses and remote instruction cannot be overstated, as it will facilitate greater enrolment. Online universities, for example, are not burdened by the need for physical proximity and the maintenance of campus

infrastructure, although they do come with their own challenges with regards to infrastructure upkeep. The upcoming section will highlight some aspects of the 4IR that could greatly benefit young people who are eager to learn.

Applications and Educational Improvements Inspired by the 4IR

The subtle entry of machine learning techniques into our daily lives in recent years has truly enabled connected devices to operate as extensions of people, augmenting many ways in which they operate at home and at work. A new era of augmented intelligence is bound to drastically change current educational systems, and the success of the transition relies on efficiently manoeuvring technological changes. The trend of augmentation (as opposed to automation) will most likely continue in the education industry, considering the importance of human interaction and relationships during development. Higher Education (HE) forms an integral part of the 4IR, and HE4.0 (as it is occasionally referred to) will no doubt transform the education system for the better (Xing and Marwala, 2017).

An effective educational plan to cope with the 4IR must follow the example of the Third Industrial Revolution, which took a more hybrid approach to instruction and made a vast array of resources available on demand, even outside of scheduled hours.

Massive Open Online Courses

Massive Open Online Courses (MOOC) are a departure from the classical lecturing paradigm, where students are gathered in a classroom run by one or more lecturers. Removing the need for physical proximity to a lecturer and significantly expanding the reach of lectures presented are two primary positives offered by MOOC. The success of online training services such as Udemy, Coursera, Udacity and Skillshare (to name but a fraction of the selection available) clearly highlights the efficacy of these platforms. Courses are rated by users, but are generally not presented and evaluated according to any particular standard – an issue that should be addressed if such platforms are to be expanded to university- and graduate-level training. The Open University is an example of a successful online educational platform that offers degrees accredited by both the Middle States Commission on Higher Education and the Mid-Atlantic Region Commission on Higher Education.

Perhaps one of the greatest advantages of the online university, and for selected academic programmes, is the sizeable reduction in infrastructure and upkeep costs. With South Africa's higher education institutions reporting a reduction in capital expenditure of about 6% between 2015 and 2017, reducing the cost of providing tertiary education is crucial (Stats SA, 2018).

Remote Learning, Tutoring and Support

An integral part of MOOC, remote tutoring and support can also be leveraged in traditional teaching environments. Moreover, access to online discussion boards and remote support from tutors is, for the most part, significantly more efficient compared to traditional teaching environments. The online interface between students and facilitators opens up additional possibilities, such as translating written material into different languages. Natural language processing (NLP) can greatly assist in this regard, especially considering the amount of algorithm training material available. An extension of this is the translation of speech material into a suitable language. The usefulness of such an approach is of course subject to the characteristics of each particular language, but in many cases portions of the material that have considerable overlap between languages could be translated, whereas more technical aspects may not be translatable to begin with. With that said, NLP as a field is not mature enough to handle such complex tasks, seeing that lexical, syntactic, referential and pragmatic ambiguities – fundamental characteristics of language – are not yet properly defined within the framework in which NLP interprets language.

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Automated Administration

Administrative tasks – such as grading, the collection and analysis of historical data, student administration and feedback – could benefit from the adoption of several machine learning paradigms. Tools such as *nbgrader* offer a standard interface through *Jupyter* notebooks that guide instructors through the grading process of a particular notebook. The tool is an example of an integrated grading solution that is used to release assignments to students, analyse results, collect submissions and provide a combination of automated and manual grading options. Another example is *Gradescope*, which is currently used in at least 500 universities worldwide. This service is capable of grading just about any subject (computer science, math, engineering, economics, etc.), regardless of whether the assignment is paper-based (i.e. with handwritten answers). In-depth analyses of each student, as well as the class as a whole, throughout the course of a semester can be generated easily. *Gradescope* also automatically groups similar answers, allowing instructors to grade multiple papers simultaneously.

Individualised and Adaptive Learning

Data collected from online portals, mobile learning applications, student assignments and other sources opens the door to a long-term analysis of each individual student that can be produced without much involvement from an instructor. All of this data documents the journey of each student, which allows the instructor to access key insights that almost certainly would not be available if such a task were to be approached manually. Like augmenting administrative tasks, this could allow institutions to service a larger number of students with critical instructive tasks. In an environment where outstanding instructors are limited, this could significantly improve the student intake without necessarily sacrificing quality. Furthermore, online material could be tailored to each student: by giving a proficiency goal at the end of a course, a customised pathway through the coursework can be recommended to ensure that students can progress at their own pace.

Improved Connectivity and Accessibility

The profound proliferation of connected and affordable mobile devices, the widely available infrastructure for high-speed internet, and the abundance of quality educational content available online has drastically altered the delivery of educational services for the foreseeable future. With mobile providers investing in 5G infrastructure, and the Department of Communications and Digital Technologies giving the go-ahead on initiating the rollout, internet access is bound to improve even further. Providers could partner up with universities (physical and online) to offer educational packages that would further improve connectivity for students. Collaboration between institutions in different hemispheres has become a reality with the support of the education cloud, which not only improves the quality of teaching but benefits research efforts in multiple different ways. In the 4IR paradigm, the student is seen as a customer who buys into a service with an envisioned outcome, and the service is designed to meet this outcome within certain restrictions – much like universities are accountable to accrediting agencies. Providing students with practical content outside of their normal framework greatly improves long-term understanding, and this is possible now more than ever with the connected nature of our lives. Independent online communities of academics, researchers and students have emerged, facilitating the exchange of experiences, findings and material.

Platforms have become a truly dominant approach to delivering services. They act as mediators between various groups (such as between users and advertisers, as is the case for most free-to-use platforms available today), providing the owners with vast information about user trends and habits. This, in turn, enables the continuous improvement of services and the

expansion of the target audience. The demand for enhanced performance measurement, internationalisation, competition, marketisation and innovation is driving universities towards an unbundling into multiple discrete services (Galbraith, 2018). These services can be catered for by a range of providers, and institutions can then package these services as needed. This creates an education-on-demand paradigm, which can be accessed (and accordingly monetised) by the student as required.

Conclusion

Accessibility to tertiary education remains a central problem in South Africa, from the perspective of students as well as instructors. Limited and expensive infrastructure, practical limitations in terms of classroom size and instructor workload, as well as the limited availability of quality personnel are some of the major problems that must be overcome. The somewhat rudimentary requirements for beginning to harness the educational benefits of the 4IR – such as low-cost smartphones and widely-available broadband internet – are readily available, and online learning is challenging the traditional notion of reliance on a campus-based university education in order to access higher learning opportunities. For us to realise the true potential of the technologies that have taken the world by storm in the 4IR, a new generation of trained and capable instructors must play their part in transforming institutions of higher education through a multi-disciplinary approach. The 4IR is changing every aspect of our lives and is transforming the world into a connected, augmented marketplace of ideas. As industries are gradually reacting and adapting to the 4IR, it is safe to say that the best is undoubtedly yet to come, and the opportunities for growth are up for the taking. It is, however, naive to ignore the challenges – technological and societal – that the new revolution poses, and we should be careful to not sacrifice hard-earned freedoms in the name of progress. An equally sophisticated effort must be directed at maintaining privacy, information security and freedom from tyranny. In Solzhenitsyn's address to the International Academy of Philosophy in Lichtenstein, he famously stated "No, all hope cannot be pinned on science, technology, or economic growth. The victory of technological civilization has also instilled in us a spiritual insecurity. Its gifts enrich, but enslave us as well. All is interests, we must not neglect our interests, all is a struggle for material things; but an inner voice tells us that we have lost something pure, elevated, and fragile. We have ceased to see the purpose" (1993). ■

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