Adnan Badran *Chief Editor*
Elias Baydoun · John R. Hillman
Editors

Higher Education in the Arab World: Research and Development

جامعة البترا

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Dedicated to Professor John R. Hillman BSc, PhD, FLS, CBiol, FRSB, FRSE (1944–2021)

John Hillman was born in Farnborough, Kent, educated at Chislehurst and Sidcup Grammar School, and obtained his BSc (1965) and PhD (1968) from the Botany Department at the University College of Wales, Aberystwyth. He was especially interested in the physiology and biochemistry of plants, and the mechanisms involved in plant flowering at the protein and molecular levels. He was invited to do a BSc in zoology, at which he excelled, but declined. Nevertheless, having worked on a local farm during his school years, the interactions between plants and animals did not go unnoticed, thus sparking a passion for agriculture and the environment that influenced his subsequent academic career, which started in 1968 at Nottingham University's School of Agriculture.

In 1971, John moved to Glasgow University as a lecturer in the Department of Botany. At this time, the department had only one final-honours student. During his tenure *and promotion to senior lecturer (1977), reader (1980), and professor and head of botany (1982), he worked tirelessly to stimulate the interest of first-year students in plant science. By the time he left Glasgow in 1986, the Botany Department was the largest in the UK, had 50 research students and was producing up to 50 honours graduates each year, all of whom found jobs.*

In 1986 Professor Hillman took up the directorship in Dundee of the Scottish Crop Research Institute (SCRI), which as an organisation was largely unknown outside Scotland and specialised in breeding new crop varieties, especially barley, potatoes, and soft fruits, by traditional methods. By the time that he retired in 2005, the institute had doubled in size, and had been transformed into an internationally recognised centre for modern research into biotechnology, genomics, metabolomics, bioinformatics, recombinant-antibody diagnostics, and non-linear mathematics, among other things, while still maintaining the conventional plant breeding programme. The expansion and modernisation of SCRI was partially financed by Mylnefield Research Services (MRS) Ltd., which was founded by Professor Hillman who was deputy chairman from 1989 to 2005. MRS was one of the first technology-transfer companies to be created in the UK in the public-sector research establishment and, unlike any other, had no subsidies from the public or private sectors or from trusts.

During his academic life, John was a member/chairman/president of nearly 100 committees and organisations, including *chairman of the Agriculture, Natural Resources and Environment Sector Panel of the UK Technology Foresight programme (1994–1995) and the Agriculture, Horticulture and Forestry Sector Panel (1995–1997). He also wrote many reviews, in particular, one of the 1987–1989 Global Climate Change reviews, perhaps ahead of its time.*

As a result of collaborations with colleagues at The American University of Beirut, Professor Hillman became interested in Middle East affairs, and he pursued this interest after retirement, culminating in his contributions to this book series on Higher Education in the Arab World, drawing inspiration from his experience of the deficits he could see in the UK education sector.

Above all, Professor Hillman was unstinting in the time he gave to his students, encouraging them to complete their degrees when they wanted to give up. He had an open-door policy for academic and non-academic colleagues to discuss their concerns and supported them in advancing their careers. He was never afraid to speak his mind and stand up for what he believed was right, even when that meant arguing his case with civil servants and officials. In all, he had great humanity and a wonderful sense of humour; he will be missed.

Sandy K Hillman

"One always measures friendships by how they show up in bad weather" (Winston Churchill)

Professor John Hillman was more than a friend. He was the family I could choose. In

1979, in the city of Glasgow in the United Kingdom, I met Prof Hillman in the Department of Botany at the University of Glasgow, where I used to visit as a research fellow. He was a renowned scientist, scholar and academician, with a long list of achievements and awards; everyone knew him as the ultimate polymath, a walking encyclopaedia, and his essays were described as masterpieces. In fact, Prof Hillman's dedication to work was obvious to everyone around him. He never took a vacation and, although he thought he would never work after retirement, he never stopped and maintained his involvement in various areas.

Our relationship evolved beyond science and research. He joined us at the Arab Academy of Sciences in Beirut and has been involved in its activities since its inception in 2002, to which he showed unrivalled commitment. He attended all the conferences organized by the Academy and was involved in every detail. He was the driving force behind the Academy's projects on energy, water and food security as well as higher education in the Arab world.

As editor of this book, Prof Hillman was eager to read the work of the authors. He said, "it will be a substantial book". Accordingly, I have requested the authors to be prompt with their submissions. "If I am alive, I would like to go through as many as I can", he added. Unfortunately, he didn't have the energy to do everything he wanted to for the last volume. A survivor of non-Hodgkin lymphoma, he had to face cancer again. In 2019, during the conference of the

Arab Academy of Sciences on research and development, part of the Higher Education in the Arab World series, he was already suffering from abdominal pain. Sadly, by the time he was diagnosed with cancer, the tumour had spread. He fought hard and kept his good sense of humour all along his battle. He continued working and writing and reviewing his chapter for as long as he could. He never surrendered to weakness or pessimism. His passion and courage are unmatched.

We are grateful for all he did for us, for his knowledge, ethics and wisdom. He will be greatly missed.

Elias Baydoun

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Introduction

Adnan Badran, Elias Baydoun, Joelle Mesmar, and John R. Hillman

Abstract This book follows up on our previous reviews on higher education in the Arab world, underpinning research at the heart of a modern university in its pursuit of the advancement of knowledge and understanding. Research is the basis of the global knowledge-based economy, innovation, creativity, aiming to improve the quality of life and build wealth. In this issue, 29 eminent authors review the concepts and classifications of the different types of research. They scrutinize the position and performance of research and development in the Arab world from the perspective of higher education institutions, and examine the reasons behind their underperformance. Recommendations and advice on the roles that the universities, governments and the private sector should play to foster the connectivity of research with the subsequent development phase and enhance the economic productivity of Arab countries to become global players, are also addressed.

Keywords Arab universities · Research · Development · Innovation · Indicators · Technology transfer · Knowledge economy

With only a few notable exceptions, the Arab world has failed to capitalize on its intellectual potential enabling it to participate properly in the global knowledge economy. Its research and development (R&D) activities in both the private and public sector are failing to deliver social and economic improvement despite substantial expansion in the numbers of young people and in the numbers of institutions

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of higher education. Confirmation of the underperformance of Arab universities in their research mandate is seen in the international university ranking tables. No Arab university is considered in the top 100 global universities, despite some having received massive financial inputs and others among some of the oldest institutions of higher education in the world.

Four recent Springer Nature books sponsored by the University of Petra and organized by the Arab Academy of Sciences have reviewed in detail key aspects of higher education in the Arab world: *Universities in Arab Countries: An Urgent Need for Change* (2018); *Major Challenges Facing Higher Education in the Arab World: Quality Assurance and Relevance* (2019); *Higher Education in the Arab World: Building a Culture of Innovation and Entrepreneurship* (2020); and *Higher Education in the Arab World: Government and Governance* (2020).

In this fifth book of 17 chapters, 31 eminent authors examine the concepts and classification of different types of R&D, and scrutinize the current position of university R&D globally and then in the Arab region, noting the main themes, their international impact, and propose new directions. Crucially, it examines the underlying reasons for the underperformance, including specific government research policies, university appointment-and-governance processes to stimulate research, funding assessment and allocation processes, resource limitations, and public attitudes. By substantially upgrading the research component of Arab universities along with the quality of education generally, the Arab world will have the vehicle to transition into peaceful and stable members of leading global economies. There are opportunities for inter-university cooperation and the establishment of regional university-linked research institutes with specialist facilities.

Never has there been so much R&D carried out in the world by so many people in an expanding number of organizations, supplemented by an array of associated industries and professional organizations. However in many countries, despite substantial direct and indirect investments in the university sector and in R&D more widely, there have not been significant increases in economic productivity and gross domestic product properly to justify these investments in the short to medium term without a thorough scrutiny of the effectiveness of the spend in all its sectors. This book offers possible solutions to this dilemma.

We begin with an overview on R&D in Academia in chapter "An Overview of Research and Development in Academia" (*Baydoun* et al.), which starts with a definition of research, its different types and classifications, and its impact on development. Research is often divided into two general categories: (1) Basic research is inquiry aimed at acquiring new knowledge, and (2) Applied research is effort directed towards solving problems or developing new processes, products, or techniques. In fact, research is a fundamental feature of humans, which favors the seeking of knowledge and understanding, devising ways of utilizing knowledge, and meeting the needs of societies. In the modern era, research is carried out by governments, higher education institutions, organizations in the private sector, charities and individuals, focused on building a knowledge-based economy. Research lies at the heart of a modern concept university, and government policies that promote higher education and research are associated with economic and social progress.

Having dysfunctional higher education systems, under-developed countries are unable to participate in the global knowledge-based economy. The rationale for modern governments and private sector institutions to invest in R&D is addressed, focusing on meeting the needs of modern societies, and ensuring their long-term sustainability and competitiveness, respectively. A vast array of rapidly expanding transformative technologies is not only modifying human behavior, but also revolutionizing R&D and the operation of modern societies by affecting economic and social conditions, the private sector, and the functioning of the government. More specifically, the role and implications of how these technologies influence academia are addressed, such as creating new activities and melding others. The authors also reflect on the actuality of academic R&D, including both good practice and deleterious effects of poor management. They describe what success of the university and success at R&D entail. They also take a critical view on the effects of university rankings on the behavior and expectations of universities, the growing competition for funding as well as the problems related to careers in R&D. The wide-ranging roles of governments in R&D is then explored, reflecting on the position of governments in developing countries. The main impedances to successful R&D in both the public and private sectors are also described. This overview then gives an outlook on the future of R&D, emphasizing on the major impact of the COVID-19 pandemic and potential future pandemics on the functioning of universities. Academia is already changing, involving the re-shaping of universities, the establishment of institutions to concentrate expertise, and the re-shaping of the publishing industry. Finally, recommendations on R&D policies for the Arab world are considered based on the global analysis of R&D presented in this chapter.

In the next chapter "Reflections on Research" (*McKellar*), the author reflects more broadly on research and its impact on various fields discussing the good, the beneficial and the bad contributions, focusing on seven themes. When it comes to (a) economic productivity, there is a clear link between research spend, innovation and productivity, "supporting but not resolving the chicken and egg relationship between R&D and Gross Domestic Product (GDP)". (b) On health and welfare of mankind looking, historic breakthroughs in medical research are enumerated, noting that the pace of discoveries in the pharmaceutical industry for instance has been slower in the modern era, mainly due to increased competition and regulatory burden. And like other pandemics, research will help control COVID-19. The importance of research on (c) setting and influencing policy, and to (d) education and stimulation of critical thinking is also addressed. As for research in the areas of history, culture and philosophy, the author describes how it contributes to the (e) fulfilment and happiness of society. The importance of research on (f) the environment and climate change is then discussed in the sense that although research contributes significantly to help the betterment of the environment, if left unchecked, it could lead to negative and even cataclysmic impact. Research has also undoubtedly played a major role in the enhancement of (g) communication through the internet and the power of computing. Finally, the author answers questions related to the efficiency and value research, as to where research should be carried out, and addresses the debate between applied and basic research, and the effect of competition on research outputs.

In chapter "The Future of Science in the 21st Century: Towards a New Paradigm" (*Serageldin*), the author challenges readers to look at the future of science and research in the twenty-first century. Recently the world has witnessed major transformations, mainly due to "the most transformative of all inventions: The Internet". Five profound changes are described and include: (1) The way we acquire knowledge, (2) The expansion of the scope of information available through the information and communications technology revolution and "Big Data Analytics", (3) The rapidly growing importance of social connectivity and mobile telephony, (4) The rapid expansion of the interaction of humans with machines, creating a new era of artificial intelligence, and (5) The rapidly evolving interaction of machines without further human intervention, known as the "Internet of Things". These transformations have influenced the way science and research is being done by changing practices of science, increasing the centrality of data science and providing a capacity for openness and working by putting emphasis on cross-disciplinary and specialists teams for example, and enhancing information sharing through the adoption of the "Open Science" movement. The author argues that this fast-paced evolution needs to be accompanied with wisdom and good ethics. He then provides recommendations on what should change in teaching, highlighting the reforms needed in the content, the methods of delivery, the participants involved in the education process, the venues, the role of libraries, and links to society, making the education system an incubator of effective citizens.

The benefits that universities contribute to economy and the society is the focus of chapter "The Opportunities and Challenges Facing Arab Universities as Part of the International Community of Higher Education that Supports Economic Development" (*Parry*). The author provides an overview on the critical roles of the stakeholders involved – universities, governments and businesses – and the challenges in linking them to drive innovation-led economic and social development. The characteristics of research universities as "as central institutions of the 21st century" are first addressed, in addition to trends in investments in research, noting that the development and support of these institutions is expensive and competitive. Arab research-based universities are rare, despite the huge expansion in the number and capacity of Arab universities in recent years. However there is growing regional recognition on the importance of knowledge as a driver of economic growth and expansion, as witnessed by a series of investments and programs, and the publication of national innovation strategies in several countries. Today, several critical factors still impede research universities to have the right impact on social and economic development. These are addressed in detail in this chapter. Drawing on examples from the developed world, and particularly the University of Surrey in the UK, the author provides a perspective on the critical factors needed to face these challenges. These are centered around: university curricula; student enterprise strategies; programs for enhancing the experience of post-graduate students, such as Doctoral colleges; science and technology parks; and the collaboration with the government and industry, among others.

The ups and downs of science and technology indicators in Arab countries is discussed in chapter "Ups and Downs of Science and Technology Indicators in Arab Countries" (*Badran & Badran*), covering in great detail the ranking of Arab countries compared to the world in terms of GDP per capita, global competitiveness, expenditure in R&D, number of researchers in R&D, number of scientific research papers published, density of indexed publications, high-tech export ratios and patents. The authors further describe who conducts research in the Arab world and presents an overview of the leaders in world productivity, emphasizing on the growing gap in science, technology and innovation between the Arab world and the developed countries, and between the rich and poor in most countries of the world. In order to bridge this knowledge gap and to fuel innovation through R&D, the Arab world should not only increase its investments in R&D but also empower its students, scientists and researchers by providing a stimulating environment and enhancing their communication with the industry, and understanding of technology transfer. The Arab world have so far failed on building the human capital needed for a knowledge-based economy and achieving economic self-reliance.

Performance measures of research using bibliometric indicators have been gaining strong interest, taking on different forms and complexities with the aim to measure the trends of knowledge and compare the different producers of knowledge. In chapter "Measuring Knowledge Production in Arabic Using Arcif: Statistical Indicators and Impact Factor" (*Al-Shorbaji*), the author starts with a definition of "statistical bibliography" and presents "citation analysis" as the most common bibliometric tool, describing who it is used by and why, before embarking on a detailed overview of the different citation databases in the world and the roles of citation analysis, the impact factor and the h-index in the ranking of research, universities, and authors. The issue of science publishing in the Arab world is then addressed, highlighting the reliance of Arab researchers on publishing mainly in international journals and in the English language. In recent years, several initiatives have been taken to encourage Arab universities and researchers to publish their work in Arab journals and to contribute to the dissemination of knowledge in local contexts. From there comes the vision of e-Marefa as a database for Arabic knowledge products "to promote the relationship between the use of the national language with scientific research production and socioeconomic development". Also covered in the scope of this chapter is the Arab Citation and Impact Factor (Arcif), which is a product of e-Marefa, as an Arabic citation analysis system. The author then concludes with an analysis of the results of the Arcif reports for the year 2020 and provides recommendations for further improving e-Marefa and Arcif.

Unfortunately, R&D efforts in the Arab world have not reached the required level to support local industries and contribute to real local and regional economic growth. In chapter "Bolstering Economic Growth in the Arab Region through Commercialization of Research Outcomes" (*Khasawneh* et al.), the authors provide an assessment of the performance of R&D in the Arab world, describing the current barriers and challenges that have been impacting industrial pursuits and real economic growth. R&D carried out in Arab higher education institutions have failed to address immediate community concerns and the society's needs, as researchers are often engaged in the research end of R&D cycle, failing to reach the development side, and institutions are “unprepared to handle effectively the process of turning technology leads into viable and approved seed products”. Universities need to connect with society and maximize the notion of knowledge-based value. Based on that, the current barriers, challenges and difficulties faced by higher education institutions are addressed and a roadmap for research commercialization is presented, emphasizing on the importance of technology transfer through industry liaison offices. Building knowledge translation and transfer is essential to develop self-reliance, provide employment opportunities, overcome poverty, and catalyze real economic growth of the Arab countries.

Researchers in the developing countries often complain of the lack of resources and experimental equipment for conducting state of the art research. In chapter “Research Possibilities in Computational Modeling as a Low Cost Alternative to Traditional Experimental Research” (*Murad*), examples of research based on computational molecular modelling, requiring a small fraction of resources while still being very impactful, are presented. Topics and matters of importance and relevance to the Arab world can be tackled and include: overcoming the shortage of water through desalination of brackish water, enhancing the separation of petroleum-derived gases, making use of solar energy by developing new generation of batteries, among others. Such research not only provides a low cost alternative to expensive and elusive experimental research, but also allow for the investigation of a wide range of scientific problems.

Chapter “Contemporary Challenges Confronting Scientific Research in Humanities within Higher Education Institutions in the Arab World” (*Hamaidi* et al.) provides a perspective from higher education institutions in the Arab world on the reality of scientific research in the field of humanities. The authors argue the importance of research in the humanities and discuss the financial, administrative and personnel obstacles facing colleges in the humanities. They address the difficulties faced by faculty including: weak publishing of their research in prestigious journals, mainly due to language barriers and lack of adequate references; inadequate financial support; lack of attributes needed to be successful researchers due to lack of training and teamwork spirit; and heavy administrative commitments. Finally they provide recommendations to universities for fostering a supportive and encouraging climate to conduct research addressing the communities’ needs.

In chapter “Innovation and Scientific Research at Jordanian Universities: The University of Petra as a Case Study” (*El-Muwalla*), the University of Petra (UOP) is used as a case study of the promotion of scientific research and innovation in facing competition, securing the university’s academic development and sustainability, and ultimately contributing to national progress. Although higher education institutions in the Arab world have made progress in research and innovation, they still lag behind their international counterparts, as evidenced by limited citations and low h-index. This chapter showcases the efforts made at UOP with regards to scientific research, such as increasing expenditure on research and research-related activities and policies. Then it sheds light on the measures taken to promote a culture of innovation at the university, in line with the Jordanian innovation strategy, which involves the setting up of specialized centers for driving technology transfer projects, funding patents, and organizing conferences.

Morocco's research policy measures and impact on national development are outlined in chapter "Research Policy in Morocco and the Impact on National Development" (*Benjelloun*). Efforts to restructure and mobilize national research initiatives in Morocco have been taking place since 2000. The Moroccan research environment is centered around the Ministry of Higher Education and consists of a system managed by public and independent institutions in charge of: setting legislation, planning, funding and evaluating research activities (Permanent Interministerial Committee for Scientific Research and Technological Development); offering funding opportunities and access to advanced laboratories (National Center for Scientific and Technical Research); evaluating research projects (National Agency for Evaluation and Quality Assurance); proposing new initiatives and orientations in line with the national plan (Higher Council for Education, Training and Scientific Research); prioritizing research efforts (Hassan II Academy for Science and Techniques); and ensuring cooperation between university-led research efforts and the public and private efforts (Research and Development Foundation). The author presents the country's research strategies and orientations, highlighting the national development priority areas and the roles played by the different actors. Instruments for encouraging innovation in Morocco are also addressed; these are centered around financial incentives, technology transfer and innovation-based entrepreneurship. Although Morocco has made huge progress in its research and innovation endeavors, especially in the energy field, and the textile and pharmaceutical industries, the R&D system remains modest and fragile. The strategic research plan for 2025 sets policy measures meant to improve research governance and align research activities and innovations with the needs of the economy. Finally, the author recommends establishing a national dashboard allowing for the transparent evaluation of progress made by all actors involved.

In chapter "Research, Development, and Local Impact: A Case Study of the Australian College of Kuwait" (*Zabalawi* et al.), the Australian College of Kuwait (ACK) is used as a case study showcasing the R&D reforms needed in the higher education sector to establish a sustainable research ecosystem that contributes to building sustainable economies. This chapter highlights first the position of R&D in the Arab world and describes the general challenges in the higher education sector hindering the progression of R&D. The authors argue that with the right reform, R&D in the Arab universities can make an impact. This should start with the government setting clear national development plans for a knowledge-based economy (the "New Kuwait Vision 2035" in the case of Kuwait). From there, higher education institutions redesign their strategies and governance framework, in alignment with the national vision. This chapter presents an adaptable framework developed by ACK that seeks to integrate R&D as a critical pillar in the college's strategic planning to establish a solid foundation for research, development and innovation serving the needs of the nation. The four main dimensions of this framework are addressed: (1) Teaching and learning, which aims at integrating research into teaching and training students to become critical thinkers and in touch with local workplaces and research organizations; (2) Service to the community through research projects that serve the needs of the community and technology transfer, in order to maximize local impact; (3) Innovation and entrepreneurship, which aims at engaging students to become entrepreneurs through the Innovation and Entrepreneurship Center of ACK; (4) R&D strategy with clear goals and effective and efficient research systems, overseen by the Research Council and a Research Center. Finally drawing on the experience of ACK, the authors provide recommendations for R&D reform for institutions of higher education to create a sustainable research ecosystem.

Strategic planning in R&D institutions is an important dynamic process to determine the institution's long-term goals, improve operational management, allocate the necessary resources to achieve these goals, and maximize output and productivity. It involves a culture of open communication and dialogue across all stages of the process and include feedback and monitoring tools to inform the next round of strategic planning. In chapter "Three Decades and Beyond of Strategic Planning for Research and Development in Kuwait: The Case of Kuwait Institute for Scientific Research" (*Omar*), the Kuwait Institute for Scientific Research (KISR) is used as a case study for the importance of strategic planning in R&D institutions. The author provides an overview of the strategic planning process the institution has been conducting since its inception in 1967, transforming KISR from a small research institute into a pioneering national institute of scientific excellence, which aims to become an international center of excellence in science, technology and innovation for the benefit of Kuwait and in line with "Kuwait's Vision 2035". The stages of evolution and transformation of KISR are described through its five-year strategic plans, presenting KISR as model in strategic planning for R&D institutions in the Arab world.

In chapter "Higher Education in the Arab World: Research and Development from the Perspective of Oman and Sohar University" (*Al-Fazari*), Sohar University in Oman is used as a case study for the contribution of university-led R&D initiatives to national development and growth. As part of the restructuring and modernization process to support Oman's Vision 2040 and recognizing the important role of higher education and research in social and economic development and addressing current and emerging challenges, the government recently established the Ministry of Higher Education, Research, and Innovation to supervise the R&D sector and drive research and innovation. Accordingly, higher education institutions in Oman have established research programs and centers focused on strategically important fields. In this chapter, the author draws the attention on R&D initiatives by Sohar University, emphasizing on the role of the university in "conducting research with impact". Finally realistic and implementable recommendations for developing the R&D sector in the Arab region are proposed based on the author's R&D Welfare Model, which focuses on bridging the gap between academia, industry and the government to drive R&D, innovation and investments for the welfare of the society and country as a whole.

Is research in a developing country worthwhile? In chapter "Managing Creativity on a Budget: The Future of Academic Research and Development in Lebanon" (*El-Chaer*) the author takes a critical view of the role of R&D in the Arab world, placing Lebanon and Lebanese academics research institutions as an example of the challenges faced by developing countries and academic centers. Such challenges include: the lack of national research strategies focused on national needs that promote research universities; the scarcity of human and material resources; the complexity of the research management system, which is ill-equipped to keep up with the economic, social and technical changes; the lack of academic research freedom, mainly due to limited funding and ethical considerations, and which often stunts creativity; the lack of meaningful performance assessment metrics and the inappropriate use of key performance indicators such as the impact factor; and the lack of capabilities to manage research compliance and reporting requirements, which increase administrative costs and divert faculty time from research and innovation. Once these challenges are addressed, a national roadmap can be developed to draw types of strategies: (1) local research to address societal problems that are based on national strategic priorities; (2) international research to address more advanced global problems that require regional and international collaborations.

The status of R&D in a post-war Syria is addressed in chapter "Academic Research in Support of Post-Conflict Recovery in Syria" (*Mualla*). The author first presents the landscape of research institutions in Syria and highlights the impact of the war on research facilities and research output. In fact, Syria is lagging way behind other countries in the region in terms of research and innovation; this is due to a lack of a national research strategy linking research institutions to the industry, lack of coordination between the various research institutions, poor financing of research projects, and economic sanctions. The different areas that higher education institutions and academic research can contribute to the recovery process of the country are addressed, such as providing the human capital and expertise needed for reconstruction and state-building, supporting peace-building, and driving the rehabilitation and restoration of national heritage. Finally, recommendations for enabling academics and research to contribute to this recovery process are suggested.

At a time when the Arab world faces an existential threat from the effects of climate change, the advent of the era of COVID-19 and its long-term effects are modifying the functioning of R&D in universities as well as research institutes, charities, and industry. In fact, there are ongoing international reviews of the potential roles of universities in delivering economically and societally worthy outputs, unconstrained by previous higher-education models and oftentimes reputation. The international education of foreign undergraduate and postgraduate students is also threatened, further imperiling the financial viability of numerous institutions. The robustness of governance processes will be tested alongside the ability to establish appropriate educational and R&D priorities relevant to Industry 4.0 in a period of harsh financial constraints.

Traditional disciplinary-oriented approaches to research, where each discipline uses its methodological paradigms in a self-contained manner to address its own objectives, have contributed to advancing knowledge and strengthening professional practices. However, the need to explore and understand complex phenomena and to develop new ideas, calls for the involvement of multiple disciplines and relies on collaborative teams of researchers. Hence the emergence of multi-, inter- and trans-disciplinary research approaches to fuel research, development and innovation. In chapter "Challenges and Opportunities of Multi-Disciplinary, Inter-Disciplinary and Trans-Disciplinary Research" (*Shanableh* et al.), the different types of research approaches are defined, highlighting the opportunities and challenges associated with each type, drawing on the University of Sharjah's experience. Since 2014, the latter has re-structured research around three research institutes, with the aim to encourage cross-disciplinary collaboration: The Medical and Health Sciences Research Institute, the Research Institute of Sciences and Engineering, and the Humanities and Social Sciences Institute, which serve the various colleges of the university.

Given the severity of the COVID-19 effects globally on academic life in all its aspects, preparations are in hand to hold a conference of the Arab Academy of Sciences as a prelude to publishing a book on Arab universities in the COVID-19 era and thereafter. This will examine the effects of the pandemic on the functioning of the higher-education sector, online education, societal effects that impinge on the universities, R&D priority setting in a period of harsh financial constraints, dealing with future pandemics and existential threats, upgrading undergraduate and post-graduate curricula to bolster national economies, and advice to governments and higher-education governing bodies.

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An Overview of Research and Development in Academia

Elias Baydoun, Joelle Mesmar, Abdul Rahman Beydoun, and John R. Hillman

Abstract This overview chapter encompasses the main underpinning themes of research and development (R&D) of universities around the world. Our observations and opinions apply equally to public-sector university-linked research institutes that conduct mainly original research as opposed to policy research. After an Introduction that includes defining the terms used in the chapter and scoping the topic, the main 13 sections of the chapter cover (a) R&D as a fundamental feature of human development reflecting the inherent curiosity of humans and their ability to learn and implement their knowledge. (b) The rationale for modern governments to invest in R&D, referring to the New Growth Theory and meeting the needs of modern societies. (c) The rationale for private-sector organisations to invest in R&D to ensure their long-term sustainability and competitiveness. (d) The various definitions and concepts of R&D. and Research & Experimental Development. (e) The roles and implications of the rapidly expanding number of transformative technologies that are not only profoundly transforming virtually all R&D but also the operation of modern societies including universities. (f) The need for specialist facilities, staffing, and learned societies for R&D to thrive. (g) The importance of international collaboration. (h) Funding sources for R&D. (i) The actuality of academic R&D, including both good practice and deleterious effects of poor management. (j) The pivotal wide-ranging roles of governments. (k) Impediments to successful R&D in both the public and private sectors. (l) Geopolitical aspects of R&D, and (m) Future of R&D. The Conclusions Section considers recommendations on R&D policies for the Arab world as well as for developing economies based on our global analysis of R&D.

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1 Introduction

Research and development (R&D) have been variously defined individually and in their conjoined form. For example, the Organization for Economic Co-operation and Development (OECD) refers to any creative systematic activity undertaken to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to devise new applications [1]. The US National Science Foundation has helpfully provided an annotated compilation of concepts and definitions for identifying definitions of R&D drawn from international sources [2]. Businessdictionary.com defines research as a systematic investigative process employed to increase or revise current knowledge by discovering new facts [3]. With its focus on business, the website defines research methodology as the process(es) used to collect information and data for the purpose of making business decisions; the methodology may include publication research, interviews, surveys, and other research techniques, and could include both current and historical information [4]. There are numerous other definitions, categories, and sub-sections depending on bureaucratic requirements [5, 6].

Research is often divided into two general categories: (1) Basic Research is inquiry aimed at increasing scientific knowledge, and (2) Applied Research is effort aimed at using basic research for solving problems or developing new processes, products, or techniques. In its broadest sense, though, research includes any gathering of data, information, and facts for the advancement of knowledge. It extends beyond the STEMM subjects (science, technology, engineering, mathematics, and medicine) into the arts, social sciences, and humanities. Here, we consider facts to be statements of epistemological quality founded on and consistent with objective reality, and proven to be so by evidence, i.e. they can be verifiable and regarded as true. Facts differ from opinions and interpretations and are not irrevocable – they can change with greater knowledge.

As we have noted in our previous reviews [7–10], research is at the heart of a modern concept of a university in its pursuit of the advancement of knowledge and understanding. It underpins teaching and other forms of education. Public-sector university-linked research institutes that conduct mainly original research as opposed to policy studies have research at their heart, too. It is the basis of the global knowledge economy, innovation, creativity, and improving the quality of life, including wealth creation. Within universities, research can be categorised as basic (fundamental or blue skies), applied, development-oriented, original, scientific, humanities-based, and artistic. Accompanying development work is becoming increasingly important to improve societal impact as well as the funding base.

Contrary to general opinion, "curiosity-led" does not only apply to basic research. Funding mechanisms usually reflect these classifications and shape, possibly constrain, R&D output. Universities should in any case be dynamic intellectual repositories if governed properly, capable of conducting all types of R&D.

Nevertheless, in the current COVID-19 (SARS-CoV-2) pandemic, economic realities are such that there are ongoing urgent national and international reviews of the potential roles of universities in delivering economically and societally worthy outputs, unconstrained by previous higher-education models and oftentimes grandiose reputations. Prospects of other pandemics and other economic and healthcare shocks indicate the necessity of improving the university sector to address profound changes in their modus operandi. In addition to being funded for home-produced students, the hitherto lucrative international-education market for foreign undergraduate and postgraduate students is also threatened, further imperilling the financial viability of numerous institutions. Existential threats of climate-change weather perturbations afflict all Arab countries, and their universities should be at the forefront of providing answers to provide mitigating effects and solving problems [11].

There are many other classifications of research that impact on development**.** In our view, Original Research is essentially the production of new knowledge, not the re-presentation or repackaging of existing knowledge in a new form. It is the pursuit of original creativity and innovation. In experimental work, it typically involves direct or indirect observation of the researched subject(s), carefully documents the methodology, results, and conclusions of one but usually more experiments to ensure statistical robustness to any conclusions. In some circumstances, original research offers novel interpretations of previous results. In formal advanced analytical work, entirely new results are produced, or there could be a new way of approaching an existing problem. In non-experimental and non-analytical subjects, the originality resides in the particular way existing understanding is changed or re-interpreted, based on the outcome of the work of the researcher. The degree of originality and quality of the research are assumed to be the major criteria for articles to be published in independently refereed academic journals.

Scientific Research is universally accepted as a systematic way of gathering, ordering, and analysing data, describing them, and thereafter reaching conclusions. It is undoubtedly the most effective way of harnessing curiosity and discovery constructively. In general, it seeks to explain the nature and the properties of the world and universe, as well as making discoveries of varying types of utility to the development of humanity. It makes practical applications possible. Scientific research is a widely used criterion for judging the standing of an academic institution in the international ranking tables. Scientific research is properly based on the Scientific Method that typically follows an orderly type of protocol in both pure and applied research. For example: (a) description, observations, and formation of the topic; (b) creation of one or more hypotheses – testable predictions that designate the relationship between two or more variables – these hypotheses do not have to be immediately logical or overtly apparent; (c) description of one or more concepts by relating it/them to other concepts; (d) defining all the known variables and how they will be assessed in the study; (e) meticulously gathering/collecting and recording data often by identifying and sampling a population using valid, reliable research systems and by thorough use of controls; (f) data analysis using appropriate statistical methods; (g) data interpretation: this can be represented through tables, figures, histograms, pictures, and more modern forms of visual presentation – then described in words; (h) tests are then conducted, preferably by independent scientists to see if the hypothesis/hypotheses are consistent with or are odds with the results – a revision of the hypothesis/hypotheses may be needed; (i) conclusion(s). Much depends on the quality and completeness of the research description to ensure the exact original protocol can be followed and preferentially supplemented with different and even better methodology.

Research in the Humanities often uses different methods such as hermeneutics and semiotics [7]. Humanities scholars usually do not search for the ultimate correct answer to a question but explore the issues and details that surround it. Context is always important, and context can be social, historical, political, cultural, or ethnic. Historical research embodied in historical method uses primary sources and other evidence to systematically investigate a topic, and then to write histories in the form of accounts of the past allowing for the appropriate behavioural context of the time. Other studies aim to merely examine the occurrence of behaviours in societies and communities, without particularly looking for or commenting on reasons or motivations to explain them. These studies may be qualitative or quantitative, and can use a variety of approaches.

Artistic Research, also referred to as "non-scientific practice-based research", includes the situation when creative works are considered both the research and the object of research itself. It is the debatable body of thought replete with opinions that change with fashion and public moods which offer an alternative to purely scientific methods in its particular search for knowledge and truth.

All types of research are carried out in the Arab world, some of it extremely competently, other types requiring much-better quality control. Few Arab journals are highly regarded internationally. Although it seems as if most research in Arab countries is applied, it suffers from poor connectivity with the subsequent development phase.

Worldwide, there is a pressing need to bridge the gulf between scientific research and the research in the arts, social sciences, and humanities in order to release new areas of symbiotic creativity.

In the university system in general, there appears to be a hierarchy of research esteem that favours basic research over applied research. This view is reinforced by the university rankings system, citation analyses, the popularity of certain journals that specialise in basic research, and bureaucratic naïveté. Many applied journals have a low ranking because their research community is smaller although their economic role is arguably much larger, enabling the basic research to be funded. Moreover, much basic research is dependent on technological advancements and thus the division of esteem is unjustified.

The terms Research and Development are both often and justifiably conjoined. In essence, the concepts and products of research innovation are surely meant ultimately to flow seamlessly into society, implementing new products and services improving both efficiency and productivity. Otherwise, the inputs into research would be for self-satisfaction and pointless for the rest of society. Most frequently, the R&D phase is really a prelude to full market introduction.

Indicators of Development include economic and social measurements, and can extend into issues such as human rights, equality, and freedom of expression. The World Bank has assembled a massive database on virtually all aspects of development [12]. Common indicators [13, 14] studied even at the pre-university-entry level include (a) Gross Domestic Product (GDP) – how much money a country makes from its products over the course of a year, as well as the sum of gross value added by all resident producers in the economy plus product taxes and minus any subsidies not included in the value of the products. (b) Gross National Product (GNP) is the GDP of a nation together with any money that has been earned by investment abroad minus the income earned by non-nationals within the nation. (c) GNP per capita is calculated as GNP divided by population; but is imperfect as the calculation doesn't take into account certain forms of production, such as subsistence production. (d) Crude Birth and Death rates (per 1000) can be used as an overall measure of the state of healthcare and education in a country, though these numbers do not give a full picture of a nation's situation. (e) The Human Development Index (HDI) is a composite statistic calculated from the Life expectancy index, Education index, Mean years of schooling index, Expected years of schooling index, and Income index. Countries are ranked based on their score and split into categories that suggest how well developed they are. (f) Infant mortality rate is the number of infants dying before reaching 1 year of age per 1000 live births in a given year. (g) Literacy rate is the rate, or percentage, of people who are able to read. High female literacy rates generally correspond with an increase in the knowledge of contraception and a falling birth rate. (h) Life expectancy can be used as an indicator of the healthcare quality in a country or province, level of sanitation, and provision of care for the elderly. Many of these indicators are subject to retrospective revision but collectively they reveal the extent to which an economy is linked into the global knowledge economy.

Our observations and opinions on R&D in this chapter have been shaped by our conducting and publishing original R&D papers and reviews, and holding grants, contracts, and awards, for a combined period of over 100 years.

2 A Fundamental Feature of Human Development

The ascent of humans as the dominant animal on Earth, able to modify the global environment, cause the extinction of other life forms, modify the genetics of all life forms, create a new geological era (Anthropocene), and start to explore the universe, is a manifestation of the ability to seek and apply knowledge. An unrelenting quest for knowledge and understanding along with the advancement of civilisation constitute a fundamental defining characteristic of humans. In evolutionary terms, the profundity of the transition between a simple hunter-gatherer existence to the current nature of modern human existence has been remarkably fast, again revealing the adaptability of humans and the ability to have its destiny shaped by R&D.

The human condition favours the seeking of knowledge and understanding, the keeping of records of achievements and events, appreciation of the joy of learning and creativity, planning for the future, and devising ways of utilising knowledge. Recognition of the concepts of beauty and design, economic advancement through the knowledge economy, modification of lifestyles, and improved human interconnectivity point to further human evolutionary changes, regardless of the essentially anti-Darwinian nature of modern medicine. On the downside, certain superpowers have the means to render part or even the whole of Earth devoid of advances life forms through the deployment of nuclear weapons.

In the modern era, economic and social progress is closely aligned with government policies that promote higher education and research. Underdeveloped countries have dysfunctional higher-education systems, are unable to participate in the global knowledge-based economy, and tend to rely on their natural resources and cheap labour.

Also, in the modern era, research and development activities are conducted by governments, higher-education institutions (predominantly universities), individuals, organisations in the private sector, and charities. This effort is accompanied by specialisation in the publishing industry; legal processes to try and safeguard intellectual property; marketing; manufacturing industries for R&D equipment; and suppliers of other goods and services. Research intensity varies around the world with geopolitical forces and government involvement leading to major shifts in locating centre of excellence and the competition to acquire intellectual property (IP) rights, and even economic and military superiority.

3 The Rationale for Governments Investing Public Spending in Research and Development

Reference to the New Growth (Endogenous Growth) theory should be unnecessary to emphasise the critical roles of government investments in R&D in any modern advanced economy [9]. Governments have no option at present other than to invest in knowledge in all its forms mainly because both individuals and organisations do not necessarily have endogenous incentives to do so. Knowledge is undervalued and its acquisition does not deny others from also acquiring knowledge. The desperate need for countries, especially developing countries, to benefit from socio-economic advancement and participation in the modern global knowledge economy should makes government involvement inevitable. Yet many governments fail to have coherent long-term strategies. Governments can work closely in conjunction with the private sector to support R&D that helps deliver public goods and even military defensive and offensive equipment and systems

Oppressive government or religious interference in controlling R&D (as well as education more generally) has a pronounced negative effect on innovation and creativity. Governments (i.e. politicians) often attempt to pick "winners" and discover they rarely understand the complexities of the rapidly evolving marketplace, the benefits of competition, the type of people needed to organise and run the programmes, and the need for freedom to pursue the most promising lines. Yet governments can actively encourage an R&D culture, even with modest investments, given appropriate forward-looking policies (see **Sect. 11. The Role of Governments in Research and Development**).

4 The Rationale for Private-Sector Investments in Research and Development

The private sector in democratic countries operates in a mixed market (mainly but not exclusively free market) [10] and to survive let alone thrive have little medium-to-long-term option other than gain competitiveness in a rapidly changing world by conducting R&D programmes directly or indirectly. From this approach is gained greater operational efficiency, ownership of valuable IP, longer-term sustainability and adaptability, and possession of many of the attributes of corporate social responsibility (e.g. help maintain the educational and research base, gain access to potential employees, build relationships with civic society etc.). In general, though, the private sector collectively is heavily criticised for short-term thinking and planning (e.g. terminating its R&D programmes prematurely) and failing to align itself with modern R&D. Many companies can only grow by mergers and/or acquisition rather than rely on in-house innovation.

For academic staff, patents and other forms of IP should be regarded as much more important than most publications in openly available journals. There is in any case an explosion in the number of journals, increasingly online, and the publication system is starting to be overwhelming without analyses using artificial intelligence. Academics must improve their relationships with the private sector so as to attract additional resources, contacts, and different forms of expertise, not least in experimental development.

5 Definitions and Concepts of Research and Development

Quick Google searches of the term "classification of research" yield a plethora of schemes. Many are based on the Frascati system [e.g. 15], but many have doubtful utility in the funding and actuality of R&D, and many try to explain the basis of their classifications without offering potential benefits. Classification schemes tend to become more complex with time.

Clear and agreed definitions of research and development are obligatory requirements of many statistical reporting systems of government and funding and monitoring agencies around the world. The widely accepted internationally recognised definition is taken from the Frascati Manual, an OECD publication which has become a standard reference for R&D surveys and data collection in the 37 OECD member states, the European Union (EU), United Nations organisations, and beyond [16]. Its origins go back to 1963 when a group of OECD experts met with the NESTI (National Experts on Science and Technology Indicators) group in Frascati, Italy. Based on a document by the eminent British economist Christopher Freeman (1921–2010) [17] they drafted the first version of the Frascati Manual.

Subsequently, the NESTI group have developed the Frascati Family" of documents including the Frascati Manual on R&ED, the Oslo manual on innovation, The Canberra Manual on human resources, and documents on technology, balance of payments, and patents as indicators of science and technology [18].

The Frascati definition of research and experimental development (R&ED) comprises creative and systematic work undertaken in order to increase the stock of knowledge (including knowledge of humankind, culture, and society) and to devise new applications of available knowledge. The term R&(E)D covers three activities: basic research, applied research, and experimental development (see **Sect**. **1. Introduction**). Basic or fundamental research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products, or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. R&(E)D covers both formal full-time and occasional R&D in R&D units.

R&(E)D must be distinguished from a wider range of activities relating to R&D with a scientific and technological basis; such activities are excluded from the definition of R&(E)D unless they are carried out solely or primarily for R&D purposes. Pure R&D activities should have an element of novelty and the resolution of scientific and/or technological uncertainty, i.e. when the solution to a problem is not readily apparent to someone familiar with the basic stock of common knowledge and techniques for the area concerned. There are several general exclusions and reference to the Frascati Manual should be made for detailed analysis of exclusions, but general exclusions include: (a) education and training other than PhD research – thereby omitting Master's level research by thesis; (b) general purpose data collection (such as recording weather statistics); (c) routine testing and analysis of materials, components, products, processes, etc.; (d) feasibility studies; (e) policy-related studies; (f) phase IV of clinical trials unless they result in a further scientific or technological advance.

There are clear differences between the general wide-ranging definitions of R&D with its broad coverage, and the tighter definition of the Frascati Manual, where perhaps reference should be made not to R&D but to R&ED.

The UK, EU, and the USA share similarities and differences in their attitudes to the many roles and funding criteria of R&D, and the roles of government.

For many senior scientists, engineers, and technologists the various classifications can be a significant bureaucratic imposition of little functional merit other than for bureaucrats. The various systems often expose the stupidity of failing to understand the continuity between the various categories and the necessity of as much freedom to operate as possible. Differences in approach to R&D between all the STEMM subjects in particular and the arts, social sciences, and humanities need to be bridged to introduce new forms of creativity that in themselves will introduce even more classification complexities.

Indicators of development described in **Sect. 1. Introduction** indirectly point to the sort of activities that can be classified under development in R&D. For Research and Experimental Development, however, the range of accepted activities is narrowed. In essence, the concepts and products of innovation are meant to flow seamlessly into implementing new products and services improving both efficiency and productivity. Most frequently, the R&D phase is envisaged as a prelude to full market introduction.

Further elaboration of the classification and taxonomy of research, for purposes that seem to many scientists to lack real-life usefulness although might have taxation implications for the private sector, have been published and/or placed on the internet by a wide range of organisations. Using a framework based on the Frascati Manual 2015 of basic research, applied research, and experimental development, one proposal is to have six classification criteria, namely (a) the nature of the research (different forms of pure research, oriented types, detailed, and various types of specialised research); (b) form of cognition (various types of theoretical, empirical, and practical studies); (c) the research procedure (various types of exploratory, descriptive, explanatory, and technical research); (d) data analysed (various types of qualitative and quantitative research); (e) areas of knowledge (various types of monodisciplinary and multidisciplinary research); and (f)scale of cognition (elementary at micro level, system at the macro level, both elementary and system level, case studies, unique, and prototype) [19].

Another source [20] points out other criteria. Research can be mixed quantitative and qualitative, exploratory, descriptive, explanatory, longitudinal (data from multiple points in time with trend, cohort, and panel studies), cross-sectional research, action research in the social world, classification research, comparative research, causal research to look at cause and effect when using variables, theory-testing research, and theory-building research.

In our view, the greater utility of R&D classifications comes less from their ex ante (before starting the R&D) applications than from their ex post (after the R&D has been completed) analytical role. All too often, there are also obligations to submit detailed progress reports of increasing complexity including detailed accountancy data and “milestones”, as well as impositions of formal visiting-group reviews that could modify future work even if the visiting group bears no liabilities for incorrect advice [see sections on Visiting Groups or Teams and Peer Evaluation in 8]. All too often, projects have been curtailed prematurely, equivalent to “pulling a seedling up by its roots to see how it is growing". STEMM R&D desperately need long-term data sets. Of course, if the R&D is meeting unsurmountable barriers to progress then it should be curtailed. Just brief progress reports should be sufficient, raising then the question of what to do with the personnel and assets (see **Sect. 10. The Actuality of University Research and Development**).

Common sense dictates that there should not be an insistence on research to be naïvely hypothesis-driven that can impede progress if imposed with little flexibility and adaptation leading to a narrowing of design and ignoring other productive approaches e.g. the "suck it and see" or casual observations. In any case, constructing hypotheses of minor utility can be relatively easy in most instances. Grander hypotheses are best achieved if they also reveal possible routes to test them.

The importance of detailed confidential (unmodified) record keeping and its release by publishing in independently refereed journals (best achieved by firstly obtaining IP protection) is paramount to provide confidence to those that follow in the footsteps of the original R&D. As life scientists, we recommend the use of blockchain technologies when different individuals, technologies, and sources are used in large-scale experiments in order to strengthen the veracity of much research. In carrying out research, we also recommend (a) careful statistically robust designs, (b) detailed descriptions of the materials and methods, (c) detailed analyses of the potential and actual variables such that there a full range of controls is deployed, (d) comprehensive description of the results, and (e) a set of conclusions, all five recommendations noted in independently vetted records as described in our previous review [9]. Proper validation of the work comes with independent repetition of the work that yields the same results, even if there is disagreement over the conclusions. Further validation could come from the use of different methods or using from data sets from different sources.

In our previous review [9], we noted that IP protection processes vary between countries, and care needs to be taken over selecting the most appropriate country or countries to submit applications for protection. Applying for IP protection merely delays publication, and if desired, the IP can be made freely available and not circumvented by parasitical organisations that prosper on the back of openly published material lacking protection in the simplistic view held by many in the public sector especially that it should be freely available or they can ignore the basic obligation owed to the taxpayer.

6 The Roles and Implications of Transformative Technologies

Since the start of the millennium, a vast, ever-expanding array of technologies is modifying human behaviour, economic and social conditions, the private sector, and the functioning of the entire public sector including governments. Hitherto, we attempted to provide examples from a wide range of activities that can be justifiably described as transformative technologies [see Table 2, pp. 40–45 in 8]. The pace of change is such that the tabled listing urgently requires to be updated, preferably by a panel off state-of-the-art STEMM personnel. As we stated, nearly all the technologies influence and advance all academic disciplines including the arts and humanities, as well as modifying and even transforming national and regional economies and societies. Many technologies interact with other technologies and are cross-disciplinary and underpin virtually all modern entrepreneurial initiatives. Many pose regulatory challenges to governments and civil society. Trade bodies, imperilled older industries and commercial interests, and all levels of education are encountering challenges in the way they function. The nature and breadth of R&D is being revolutionised. The pace of change is accelerating. Crucially in the context of this publication, the entire spectrum of education must be revised and upgraded; long-established practices will be discarded, and those responsible for teaching will demand new skill sets.

In planning for the future, R&D bodies will find it essential to carry out regular preparations include SWOT (strengths, weaknesses, opportunities, and threats), horizon scanning, trend impact analysis, scenario method, Delphi, and Foresight exercises that will enable the organisation to keep abreast of the latest developments and identify areas of activity in decline [8]. The team members must be open-minded, up to date in their knowledge, and opportunistic.

Even reviewing a small sample of the transformative technologies starkly exposes the vulnerability of existing teaching curricula and administrative structures in higher education. It is not just a matter of reconfiguring R&D. Staff competencies will need to be constantly kept under review and refreshed where necessary. The COVID-19 pandemic is already accelerating academic transformation at a time when there exists a strong focus on quality assurance, relevance of the teaching and research, the extent of creativity, and the need to encourage entrepreneurship at a time of climate-change vulnerabilities. University governance practices are under stress and clearly require massive reshaping and rejuvenation. Universities have no option other than to consider two major reports. Firstly, the Fourth Industrial Revolution (Industry 4.0) first published in *Foreign Affairs* by Klaus Schwab of the World Economic Forum [21, 22] in which the reality and prospects are considered of the ongoing automation of traditional manufacturing and service industries using modern smart technologies. Second, a related report from the World Economic Forum on the future of jobs [23] and its subsequent updates in 2018 [24] and in 2020 [25] highlight skill sets needed in the present day and the future. These reports collate well with the earlier Organization for Economic Co-operation and Development Centre for Research and Innovation report by Charles Fadel on twenty-first century skills and preparing students to meet the needs of the global economy [26]. People, not just students, are needed with skills and attitudes to populate modern knowledge-based, rapidly evolving manufacturing and service industries. The share of manual and routine cognitive labour is declining rapidly as is evident by the rising levels of unemployment of unqualified males, whereas the share of non-routine cognitive labour is increasing, as is employer expectations. The realities of the modern knowledge-based economy encompass global awareness;

financial, economic, business, and entrepreneurial literacy; civic literacy and awareness; health literacy; creativity and innovation; critical thinking and problem solving; communication abilities in various media and ability to collaborate; information literacy; media literacy; ICT literacy; flexibility and adaptability; initiative and self-direction; cultural and cross-social skills; productivity and accountability; leadership and responsibility; and, last but not least, environmental literacy. This is a formidable listing, and we do not know of any higher-education institution that has reconfigured its various curricula to address more than a few of these realities. Yet these are the topics that will be needed for "future-proofing" curricula. Thus, talk of "future-proofing" curricula must be integrated with a broad appreciation of the role of transformative technologies, learning the basic vocabulary and concepts of selected subjects, and accepting the need for lifelong learning and career changes.

7 Need for Specialist Facilities, Staffing, and Learned Societies

Modern R&D institutions, depending on their specialisations, must have access to advanced computing, libraries, studios, properly categorised collections, biosecurity systems, robust cybersecurity, advanced analytical equipment, etc., all requiring servicing and updating even in financially constrained times Thus, prioritisation is needed as well as cross-organisation and international collaboration not least when access is needed to major hugely expensive facilities (e.g. nuclear reactors, light sources, astronomical telescopes, satellites etc.).

Dedicated public-sector research institutes generally find it easier to provide adequate staffing (teams of support scientists, technicians, and assistants). They are usually able to have statistical, biomathematical, contract administration and guidance, and secretarial support. Leading university R&D groups nowadays include project administrators and those preparing grant and contract applications. Some senior academic leaders seem unaware that we are in the era of consortium STEMM R&D, where lone investigators are greatly in the minority except in under-resourced institutions.

As stressed in our previous review [8], R&D must follow strict independently vetted quality-assurance guidelines (i.e. ISI) with certified monitored instrumentation, careful record keeping, and regular reviews. Ready access to the information gives reassurance to the R&D sponsors.

The Arab world is deficient in internationally highly regarded learned societies free from government, political, powerful individual, and religious involvement. Learned societies when functioning properly have at least seven invaluable attributes: (a) demonstrate that academics are a part of a global community with shared values of integrity and commitment; (b) they act as a vehicle for meetings and dialogue to refine technologies and interpretations; (c) provide directly or through guidelines mentoring of students and younger members of staff; (d) have a young members section of prospective leaders of the future; (e) organise publications; (f) interface with other organisations and governments (national and international) and offer independent advice; (g) highlight opportunities and issues of concern e.g. biosecurity, cybersecurity, priority areas of R&D, changes in the post-pandemic world etc.; and (h) maintain a database of skills and specialist expertise. Most democratic governments actively support their leading learned societies.

The growth of R&D activity in recent years has highlighted the pivotal role of university-linked science parks, technology parks, and business-incubator facilities for both universities and the private sector [9]. Their ability to exploit IP in all its forms reflects the presence of critical masses of specialist skills (negotiations, legal issues, technical issues, marketing, new contacts, meeting places, etc.) and access to specialist facilities.

8 International Collaboration

There are numerous reasons for encouraging international collaboration in R&D. These include (a) accessing foreign talented individuals and their teams; (b) accessing specialist facilities; (c) accessing high-level training; (d) establishing a new institution able to share costs and liabilities; (e) provide a regional facility to tackle cross-country R&D priorities; and (f) stimulate national R&D leaders and the academic community. At the outset of negotiations, clear pre-agreements are essential on IP processes, payment and employment arrangements, and disposal of assets. It is important to stress that such collaborations should apply to both the public and private sectors, including charities. International collaboration is an essential component of peaceful co-existence.

9 Sources of Research and Development Funding

At a global level, financial support comes from both national and international sources. These include national and international agencies, local and national government, companies, charities, and all-too-rarely, wealthy individuals. Most sources apply strict conditions to the application process, assessments, and monitoring how the money is spent. There may be conditions imposed on IP ownership. The outcome of the research may determine whether there would be repeat funding to the same applicant. Many R&D applicants in developing countries are not eligible for much international funding unless they are able to access limited specific funding earmarked for developing countries.

Estimates of global spend on R&D come from a variety of sources, e.g. *R&D World* [27], Taylor & Francis [28], Statista [29], UNESCO [30], OECD [31], and the Central Intelligence Agency [32]. Significant changes are taking place in where the spend is occurring, and the nature of the spend in line with the COVID-19 pandemic. The data do not provide information on the effectiveness of the spend. China shows a steady increase in spend whereas there is a decline in the USA such that both countries are approaching parity in their percentage R&D share with Europe close behind. The Middle East only accounts for less than 3% of global R&D spend.

In our experience, most academics need continual guidance on the vast array of public and private R&D sources but rarely is this advice available. Likewise, many young academics need assistance in submitting applications and rely on an ad hoc system of advice from immediate colleagues. Universities should be prepared to give expert advice and encouragement as well as have a reputation for integrity and comprehensive record-keeping in the eyes of sponsors.

Public-sector grants for postgraduate studentships and competitive scholarships, assistanceships, equipment, buildings, general awards, and recurrent spend tend to be bureaucratic but more straightforward than some of the complexities of private-sector funding that can impose onerous obligations on IP and publishing. Some universities have sufficient resources to fund their own grant system. This enables them to focus on priority areas including essential skill sets and sustain funding for projects that suffer short-term gaps in external funding.

A perpetual challenge is for the university to receive full economic costs for externally funded projects – the perpetual problem of overheads for institutions to pay for essential running costs (e.g. energy, libraries, computing, maintenance, cleaning, administration etc.). Over the years, we have heard of overheads calculated to be well in excess of 60% of the funding for the work itself. This problem illustrates the continual need for institutions to drive down overhead costs by improving efficiency and eliminating waste. By and large, public-sector sponsors are often more understanding of the overhead problem than the private sector that usually expects to see efficiency gains in running the institution although it is in reality seeking a subsidy.

Irrespective of the debate about overheads, private-sector (including those from charities and wealthy individuals) grants and donations must still be pursued in order to contribute to the institutional R&D portfolio, and institutional engagement with civil society.

10 The Actuality of University Research and Development

Recent years have witnessed a massive expansion worldwide with increased numbers of universities, faculty staff, students, administrators, and support staff. Unsurprisingly, there has been a concomitant increase in competition for resources. Clearly, there has been inadequate collaboration and the present COVID-19 pandemic has exposed the inadequacies and economic precariousness of numerous institutions.

The University International Rankings system is modifying behaviour of universities and expectations of their staff, students, sponsors, and governments. Although the veracity of the rankings data needs to be vetted and confirmed, and their true relevance assessed, it is a fact that R&D performance is a critical factor in achieving international recognition. In the background, there is a scramble to attract leading STEMM teams to boost ranking position. So-called universities lacking R&D will scrape the barrel of rankings or, more usually, be ignored.

Within universities, those involved in R&D are dependent on imposed performance indicators and ever-increasing bureaucratically imposed targets (e.g. publication citations and impact, patents, social-media impacts etc.). These impositions often fail to assess the real value of any IP, the fact that progress can be variable, and a bureaucratically hostile working environment is an unproductive and unstable one.

Success for the university (if not for the individuals involved) with regard to both financial and reputational factors is ultimately dependent on both the quality of university governance and institutional leadership, and thus the quality of the appointments policies to select the most appropriate individuals. Building a culture of innovation, creativity, and entrepreneurship as well as wholehearted commitment to the institution takes time and is a two-way process but is essential. Success at R&D is also dependent on the quality of team leadership – reflecting an ability to (a) pursue productive lines of R&D, publishing and gaining IP, and maintaining a high profile with sponsors; and (b) ability to synthesise a productive team with adequate resources – nowadays the team will include administrators and grant/contract writers as well as highly trained and experienced technical and support staff. Attracting a high-profile R&D team is an expensive and far from straightforward business. Poaching is becoming commonplace of successful leaders and some if not all their teams to other institutions offering better rewards, particularly to the leader. Those staff members that remain (perhaps impeded by family commitments, schooling, cost of housing, etc.) may actually be disadvantaged and suffer unemployment. Institutions have a moral obligation to offer support for team members that have been deserted by their team leaders. Redeployment, assisting with job seeking, alerting other institutions of the availability of these people, and retraining offer best practice, but is an all-too-rare feature of most universities and research institutes.

Growing competition for funding that is becoming increasingly short term, admirable perhaps for bureaucratic monitors and generating frequent performance assessments, but the phenomenon is the cause of deflecting even the most talented people to perpetual grant seeking and increasing the insecurity of employment for team members. Important R&D continuity can be broken. The best situation is where the host institution provides core funding to sustain employment of the support staff and some recurrent spend at the very least. Very often team members are on short-term contracts. In some institutions, the combination of enforcing detailed R&D classifications, overly detailed risk assessments, and over-the-top health and safety regulations may be seen as legal protection for the institution but can be used as a reason not to do R&D, i.e. the Precautionary Principle [33, 34] in extremis. Although widely deployed in health, safety, and environmental cases, the Precautionary Principle has been widely criticised for its one-sided nature in its quest for absolute certainty and absence of risk [9, 33]. In reality, both aims are impossible to achieve, despite the prompting of certain activist groups, without stifling R&D, creativity, innovation, entrepreneurship, and human progress. Rather, the correct approach for universities, government regulators, and agencies is one that incorporates a combination of risk management based on evidence, cost-benefit analyses, best practice, and integrity in association with robust laws.

Confidentiality and security of R&D activities are becoming a serious issues worldwide with competitors and even state actors involved in the theft of potential and actual IP by a combination of scams, deliberate breaches of seemingly secure computing networks, direct robbery, stealing by visiting students and staff, and bribery of staff. Many universities have relatively weak cybersecurity and other security systems and urgently need to upgrade them. Team members may have to sign confidentiality agreements with the host institution. One important area that needs to be reviewed is the maintenance of records. Laboratory notebooks must be upgraded, overseen independently, and logged as property of the institution with due recognition to the author and associates [9]. Functional asset registers are required to optimise use of facilities; maintenance costs of redundant equipment & other facilities must be culled.

For those wanting to spend their careers in R&D, there are worrisome problems of working in mediocre and/or under-resourced universities and research institutes. They all-to -frequently suffer the well-known problem of the lone academic lacking financial and facilities support, or even colleagues to collaborate with – they need either to move or seek inter-institutional collaboration. They often lack statistical and computing advice, and sometimes lack guidance over publishing and conducting meetings. Centres of excellence are inevitable to overcome this problem of the lone academic. By and large, the tradition R&D team in a university comprises an academic member of staff with short-term-funded research students, postdoctoral assistants, and ancillary technical support; as such, the team structure is inherently fragile unless there is institutional core funding for staff and recurrent spend. All to often, the host department does not supervise the supervisor, fails to ensure best practice in supervision, fails to maintain an oversight of career progression, fails to ensure adequacy of resources to complete postgraduate degrees, and fails to ensure that the grant or contract meets the legal terms and conditions. In this regard, the wide adoption of "lowest-common-denominator" circulating headships of sections and departments can reveal leadership deficiencies.

Lack of career progression is often seen in team members who may be highly skilled, qualified, and experienced but unwittingly sacrifice the potential of an independent career to be part of a successful team. Some team leaders exploit their staff and offer little advice or encouragement especially if it means depleting the team of one or more key members.

Unemployed and underemployed graduates and postgraduates are testament to irrelevant education and R&D, as well as to grade inflation, lack of ambition and entrepreneurship, and poor career advice. Graduates are sometimes reluctant to move from their alma mater or change R&D direction; these are surprising and depressing types of inflexibility for young people. There is now an expanding number of post-doctoral workers ("re-treads") in universities and institutes working on a series of short-term contracts in highly specialised areas, often lacking self-confidence to change career until forced to by becoming outdated or becoming too expensive to employ. Another serious issue is the nature of postgraduate supervision when students are expected to be part of a team such that they act essentially as technicians, unable to publish their research in their own right. They might even be expected to receive much of their guidance and supervision from other team members, commonplace in large teams and consortium STEMM R&D. As a consequence, it is becoming difficult to assess the true capabilities of newly graduated PhDs if their publications are just a minor part of multi-authored works. We recommend that these people should be encouraged by their supervisors to publish single-author reviews or short papers and make presentations at conferences. Merely assisting a postgraduate to construct a thesis is not a justification for a supervisor insisting on joint authorship of a paper; that is one of the basic roles of being a supervisor.

We see a major opportunity for development of Diploma Supplements [35] at both the PhD and postdoctoral levels. All PhDs should attend and pass formal lecture and laboratory courses to provide evidence of accumulating a body of skills that should include statistics and experimental design, computing and word processing, keeping laboratory notebooks, language proficiency, range of relevant techniques and technologies (e.g. molecular biology), and presenting seminars and lectures. These formal courses if authenticated by independently assessed quality assurance and relevance reviews should be added as an official supplement to the PhD degree certificate. This should lessen the chance of being deceived by inaccurate references. For postdoctoral staff, a similar system could operate with formal training and competences independently assessed, sometimes by manufacturers of sophisticated instrumentation, so that Diploma Supplements can be added to their curricula vitae. We believe that such systems demonstrate a care of duty by the university or research institute to postgraduates and postdoctoral staff.

Finally, there are too many outdated and incompetent, mainly very old, people in charge of R&D especially in universities and public-sector research institutes. They continue to seek the accolades and rewards of past achievements but are outmoded and unaware of the potential and developing reality of transformative technologies nor have the ability to integrate with other disciplines. The lack of enforced retirement by governing bodies and senior staff (sometimes reflecting cowardice to avoid legal challenge and/or sour personal relationships) is clogging up the system and reducing opportunities for appointing and promoting young talented people. By all means allow such a person to become an éminence grise with an advisory role.

11 The Roles of Governments in Research and Development

Governments should be an important source of funding, providing grants, loans, and contracts (capital and recurrent), scholarships, special awards that favour R&D, buildings, land, and links to international organisations. Funding is best provided through intermediary bodies and agencies that have independent overseers and long-term budgets, thereby cushioning short-term political and even civil-service interference.

Carefully crafted policies are essential to (a) foster independent quality-assurance and relevance assessments of education and research in both state-funded and private higher-education institutions (no country should host inferior institutions); (b) encourage entrepreneurship and risk-taking, inward investments, and protection of intellectual property; (c) combat corruption in all its forms [10]; (d) promote participation in the global knowledge economy; (e) assist in the development of close links with national and international industry and commerce; (f) promote participation in international bodies (e.g. World Trade Organization, United Nations Educational, Scientific and Cultural Organization etc.); (g) aid in participation in transnational R&D programmes; and (h) help sustain national asset and skills registers. Many governments in developing countries fail to utilise their institutions of higher education to provide advice and guidance, especially in policy-making exercises. Nevertheless, most governments around the world claim to develop and implement evidence-based policies but this is rarely the case as political realities and activist groups have disproportionate influences. Our observations are that governments including the civil service can find rapidly developing R&D unsettling as existing policies and systems are disrupted, but few senior politicians and senior civil servants have an up-to-date scientific and technological knowledge. That point alone is a reason why governments should consult their universities more often.

Senior politicians as well as government advisors and regulators must understand the limits of algorithms and computer models. The current COVID-19 pandemic illustrates the tendency of governments and select groups of advisors to base society-modifying decisions on flawed evidence associated with a lack of transparency. Instead of careful assessments of published papers, press releases have become commonplace. Bodies akin to the UK Centre for Data Ethics and Innovation [36] need to be formed globally.

Nationalised bodies such as occurs in health systems, transport systems, infrastructure systems, certain types of manufacturing, agencies etc. should be involved in R&D (independently and collaboratively) to ensure the most-efficient and cost-effective practices are adopted, prevent intellectual stagnation in the organisation, and contribute to the national R&D effort. In fact, an R&D culture should permeate the whole of society.

12 Impediments to Successful Research and Development

The main impediments to successful R&D are as follows:

- The resource conundrum – inadequate financial support and facilities leading to an inability to plan and complete programmes. Fast-moving R&D can be resource demanding and flexible budgeting is needed
- Incompetent staff sometimes happens especially in appointing people based on overly optimistic references; poor supervision and leadership

- Poor experimental design
- Cheating
- Irresponsible and dangerous R&D
- Suppressive government and institutional policies failing to understand the need for managed risk and uncertainty
- Over-interpretation of the Precautionary Principle e.g. excessive risk appraisals and over-the-top health-and-safety demands, bans on R&D of certain technologies, failure to distinguish between R&D and entry into the market – they are not the same – in fact, the R&D could show the reason why entry should be prevented or why the ban is irrational and damaging
- Actions of aggressive pressure groups and organisations (e.g. destruction of field trials, vilification of scientists, incessant lobbying, malevolent advertising etc.)
- Failure to publish or exploit the results of the R&D. Too much time, money, and resource have been wasted on R&D by students and professionals whose results and conclusions are not openly available despite access to the internet, annual reports, and online listings of theses and project reports
- Effects of external factors e.g. withdrawal of a sponsor, death or departure of key individuals (not only the team leader but certain technical and administrative support), pandemics, natural disasters, and civil disturbances and conflicts (e.g. Syria, Libya etc.)

13 Geopolitical Aspect of Research and Development

Military and key economically strategic industries attract a considerable portion of global R&D spend (see **Sect. 9 Sources of R&D Funding**). Often, this support can be disguised as funding of innocent-sounding projects. Importance of secrecy is paramount until the military release facilities and capabilities of considerable benefit to civil society (e.g. GPS, satellites, drones etc.).

IP ownership of equipment and software as well as near-absolute as possible secrecy are needed for the most advanced R&D and international competitiveness.

Key to continuing productive R&D is the regaining control of single-source supply chains for essential components (e.g. rare earths; compounds; solvents; metals; consumables; sophisticated analytical and communication equipment with its associated software etc.), as has been highlighted by the COVID-19 pandemic. Even close allies placed export restrictions on health-related products as they addressed national requirements irrespective of importing countries having accepted the loss of their own manufacturing capability in the pursuit of low costs and greater overall efficiency. The vulnerability of having a single source of essential supplies is leading to large-scale repatriation of manufacturing industry and seeking new sources of other supplies.

Establishing international R&D consortia favours a relatively narrow group of certain nations, with only limited opportunities available for developing countries. Governments from developing countries should endeavour to promote formal R&D

links with leading countries and specific R&D groups, at least equivalent to the efforts they make in encouraging international links between universities at the undergraduate and postgraduate levels.

14 Future of Research and Development

The COVID-19 pandemic and potential for other pandemics are already affecting the functioning of universities and society in general as well as causing a reappraisal of national and regional R&D and industrial priorities. It is not all bad news if old inefficient working practices and institutions are abandoned and new wealth-creating opportunities arise.

R&D activities reflect the complexities of modern societies, political and geopolitical instability, and the influence of the major technology and manufacturing companies, in addition to a rapidly reshaping international academic system where the already strong and powerful institutions will grow in influence. Huge changes are currently taking place in academia with the culling or merger of inferior institutions able to be replaced by institutions with more competent staff and modern methods of education and lifelong learning. Some of the inadequate institutions could be merged to form transformative-technologies hubs. The traditional undergraduate and postgraduate degree course structures have to be constantly revised as a result of technological advances. With the responsibility for conducting most basic research, universities must be able to identify talented creative people of all ages rather than simple regurgitators of taught facts. Talented original thinkers, those that can make and mend things, gifted communicators etc. must be identified and given an optimal working environment. Interviewing and entry-assessment processes need to be upgraded rather than relying on examination grades and written references so that special talents can be identified. The role of academic leadership comes to the fore. One major challenge for most universities in the developing world is establishing a collaborative network of industries and service providers. Official functional links with professional bodies are of paramount importance to universities. A wider range of professional bodies must be approached beyond the usual academic professions of law, medicine, architecture etc. Employer organisations, management bodies, certain societies that offer both quality judgements before members are admitted and post-nominals e.g. The Council for Awards of Royal Agricultural Societies in the UK [37], and many of the smaller learned societies should be brought into the university framework for providing guidance on curricula to ensure relevance, standards, and employment advice. To the professional bodies can be added large companies and specialist organisations that offer apprenticeships, certified competencies in sophisticated instrumentation and complex systems and modern management training. Universities must demonstrate the validity of their education and training that extend into continuing professional development (CD) courses.

All universities have no other option than to be involved in the conception, modification, and implementation of transformative technologies. Artificial intelligence and robotics are revolutionising manufacturing and a raft of service industries, as well as undermining traditional forms of employment (e.g. law, routine office work, catering etc.) hitherto considered to be secure. They are also drivers of new types of R&D. This is the new work environment, termed Industry 4.0 (see **Sect. 6. The Roles and Implications of Transformative Technologies**), into which university graduates and postgraduates will be released. Will their education at university benefit them?

More elite, well-resourced institutions will be formed, concentrating state-of-the-art intellectual inputs and associated advanced technologies and instrumentation to a few sites. These resources need to be accessed by demonstrably talented collaborating academics and industry partners, preferably with contractual agreements.

More use will be made by universities to carry out some experimental development work prior to interacting with the private sector. This means a wider range of skill sets will be needed, unless there is already an effective collaborative arrangement with appropriate partners in the private sector respected by both parties.

Charities and certain private-sector firms will conduct more basic and applied research in addition to their development activities as well as offer certified training courses. This will pose competition challenges for universities.

Although universities are often derided for establishing inflexible "silos" of disciplines resistant to change, many areas of STEMM subjects are so specialised that they demand career-long dedication. In this case, the working environment needs to involve other disciplines to stimulate novel thinking and entirely new lines of R&D.

Science and business parks, nascent-business-incubator facilities and university-linked public- and private-sector research institutes and government agencies will become the norm, demonstrating the beneficial effects of synthesising critical masses of expertise and facilities [38].

The concept of "future-proofing" taught courses will require further elaboration, as will breaking the stranglehold of age stratification of salaries and promotion, and ensuring enforced retirement of outdated and unproductive academics. Such academics can always be given honorary non-remuneration positions if thought necessary to retain good relationships. Teaching/lecturing staff must be at the forefront of the relevant technologies and have the essential charisma and energy to transmit their knowledge to students.

Career progression of those involved in R&D will need to be reshaped. A portion will only have a brief time in R&D as their level of originality and skill base becomes outmoded whereas others will deserve proper recognition for their contributions and adaptability to change. Training courses will be needed for those involved in changing careers, these will add to overhead costings of grants and contracts. R&D leaders and their institutions will have to take more responsibility for team members.

Although increasingly challenged by certain academics, military/defence-funded R&D has provided exceptional benefits for the civilian sector. In contrast, issues of cyber security, espionage, ability to cripple energy-generating systems and utilities, germ warfare, robot warfare etc. test the morality of the entire academic R&D system unless these projects are designed expressly for defensive purposes.

The entire educational, employment, and pension framework requires reconfiguration to adapt to the realities of short-term employment problems and the need for continuous skill and knowledge updating. As a consequence, we forecast that the age profile of university students will increase substantially as students of all ages will be involved in lifelong learning, and new government policies will be needed to facilitate employees moving to new areas.

Fresh widespread understanding is needed to accept and manage risk and uncertainty based on scientifically proven facts rather than be subject to activist claims based on prejudice, ignorance, and emotion. Education standards in schools and universities need to be raised and made more relevant to the needs of the modern economy and changing societal perceptions. Politicians must have common sense and balanced judgments and recognise the pivotal role of R&D in facilitating society to adapt to change.

All academic R&D ought to be subject to strict quality-assurance and relevance independent assessments [8]. All R&D practitioners should be seen to operate morally, responsibly, and professionally.

More attention will be given to addressing the mitigation of climate-change effects and also to repairing the atmosphere, atmospheric pollution, and health of the population [10]. R&D are needed to provide new improved products, processes, and concepts that offer resilience to major shocks both to society and to the wealth-creating sectors of the economy.

The publishing industry will continue to be reshaped at a time when there is an ever-increasing number of online offerings. Dominant publishing houses will sustain their dominance with the main university ranking systems using their ability to attract high-profile papers and reviews. Most of the current online publications will have a relatively short existence. The long-standing problem of finding willing expert reviewers will persist while most of this time-consuming work is pro bono and a distraction from normal work. Our preference is for reviewers to be remunerated and identified at least to the author(s). Many papers are merely incomplete studies and represent interim updates; they do no deserve to be formally published. Also, the practice of always including the name of senior academics on papers when their contributions have been zero or negligible should end and more use should be made of the acknowledgements section. Likewise, honesty and integrity should be used in identifying inventors when applying for intellectual-property protection rather than simply adding senior staff out of misguided "respect".

All the university ranking systems need to be upgraded as a matter of urgency so as to avoid misconceptions over (a) who actually published the cited work and where it was carried out; (b) the true location of eminent persons said to be based in the university; (c) the veracity of the data provided to the ranking organisations; and (d) much better information on the societal value of the outputs from universities More emphasis will be placed on societally influential IP compared with pro bono publico work for general distribution.

Greater value will be placed on long-term data sets (e.g. weather, ecological changes, gene flow etc.), collections (historical, in-situ and ex-situ gene banks and germplasm collections of living organisms, and asset audits and registers. Some leading museums and galleries must upgrade their research capabilities so as to contribute to the overall R&D effort, as well as place all their material online.

15 Conclusions

Arab governments cannot afford to ignore or neglect R&D if they wish to participate in and enjoy the benefits and respect of the global knowledge economy. Much of the Arab world, however, cannot afford to finance wide-ranging R&D programmes. It has the options of collaboration, funding the most promising lines identified by national and regional Technology-Foresight programmes in collaboration with industry, and attempting to spread small amounts of money to a wide range of applicants. All three possible routes have their advantages and disadvantages.

The quality of the interactions between the university sector and government must be improved for mutual benefit. The universities must prove they are worthy custodians of taxpayer's monies and, if in the private sector, must demonstrate quality, relevance, and value for money. Governments, however, must not be too intrusive and interfering; they should rely more on independent international quality-assurance and relevance bodies. In our previous chapters [7–10], we made a series of recommendations on governance of universities and governments and how to enhance the quality of interaction. In addition, there is a desperate need to build a culture of innovation and entrepreneurship not only in universities but throughout Arab society. Likewise, the ability to synthesise partnerships must lie at the heart of universities and governments.

Leading universities of the future will need to have symbiotic relationships with local and national governments, professional bodies, civil-society groups, industry, commerce, international agencies, and charities supporting R&D. Entirely new institutions of higher education and R&D will be formed; with full access to the open internet (contrasting with the internet being controlled by autocratic governments there is no monopoly of knowledge just as it is now impossible for any one country to gain supremacy peacefully over all other countries. Ambitious up-and-coming institutions will require a focus on their unique selling propositions refraining from dissipate their resources and must build up resilience to economic and social downturns. All universities should be prepared for changes on a scale unprecedented during the last 100 years.

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Reflections on Research

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Abstract Research has molded the way in which we live and our understanding of the universe around us. It has made previously unimaginable contributions for good and ill, and does so at an increasingly electric pace. It is carried out by public institutions, largely for general good, and by business and industry to improve profit. It is also carried out for more sinister political and military purposes. Each overlaps; marvelous discoveries, contributing positively to humanity, such as the internet have cascaded from 'defense' research, and terrible use has been put to research carried out with peaceful intent, such as nuclear fusion. Public research is generally carried out in institutions or universities and may have an objective outcome or follow random inspiration. It is increasingly competitive, routinely measured and often rewarded according to impact.

Keywords Research · Universities · Institutes · Blue sky · Applied · Productivity · Policy · Competition

1 Research

The evolution of the human condition has been dramatically changed, miraculously improved and formidably challenged as a result of discovery and research. Discoveries as profound as the cultivation of wheat, the use of the wheel and the forging of iron no doubt involved observation and trial however philosophy, logic, mathematics and astronomy were not developed until classical antiquity and subsequently through trial, challenge and debate have helped form the basis of modern research. The more deliberate, focused and methodological approach to discovery has evolved in the last 400 years since Francis Bacon laid the foundations of modern

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scientific method which has been refined and supported by the Royal Society which Bacon is credited with establishing. Research now extends across every discipline and is broadly considered to be an inherently good thing, expanding knowledge, deepening understanding and coloring our picture of the universe. The joy and pleasure brought by knowledge would be reward enough for the labors of research, although the benefits accrued stretch to almost every aspect of life in much more tangible ways.

Research contributes to innovation and thus to productivity, it impacts health and welfare, influences policy and politics, underpins education, and teaches critical thinking. It deepens our knowledge of history, enriches philosophy and our understanding, and appreciation of culture. Research has identified and quantified environmental change paradoxically brought about by the products of research itself and it is likely that our best responses to these changes will be catalyzed by research. Research has historically been quickened and darkened by conflict and while the benefits of nuclear power among other inventions have been great, so has their destructive potential.

As the benefits of research have become universally accepted, society has debated how best to do it and what kind of research makes the greatest contribution to humanity. Should research be carried out in universities, which also support learning or is it more effectively done in institutes specifically established for the purpose? Then again, is research best left to the industries, businesses or other agencies who are the ultimate beneficiaries? Should research be directed to a preconceived purpose or should it bubble from the ideas and inspiration of the individual? Should society support basic research, often referred to as 'blue sky' or fundamental research, which is aimed at a deeper understanding of things, and leave applied activity, which might make research more useful, to the businesses which might benefit? How has the measurement and, by extension, competition in research affected its efficiency, quality and impact?

2 The Impact of Research on Economic Productivity

It may seem self-evident that research which discovers something new or which has an obvious application, or that creates a new way of doing something which is more efficient or effective, should enhance our economic productivity and there is an inherent truth in that. Nevertheless, it is worthwhile considering whether this applies at scale. Are countries which devote a larger proportion of their wealth to supporting research more productive as a consequence? Demonstrating cause and effect is complicated by the likely reality that more wealthy or productive countries have more disposable wealth to spend on research. There is good data to suggest a strong positive relationship between research spend and productivity. High income economies spend substantially more on research than do low income economies [1], furthermore there is a relationship between global spend on research and development (R&D) and Gross Domestic Product (GDP) with dips in R&D spend following economic slowdown (e.g. in 2002 and 2009) [2], supporting but not resolving the chicken and egg relationship between R&D and GDP. There is a more direct relationship between innovation and GDP and it is clear that innovation is not just dependent upon research spend or research output. In order for research to be useful at a national level there must be a range of other supporting pillars such as the essential human capital (an educated and skilled populace), the required infrastructure (transport, construction, communication etc.) and effective markets and sophisticated businesses able to embrace and exploit the R&D. These are all factored into the innovation index produced by Cornell University, INSEAD and the World Intellectual Property Organization (WIPO) [1].

The quality and effectiveness of a country's institutions, and particularly its universities, substantially impact on its innovation. Universities not only deliver much of the higher-level human capital essential to innovation but also provide substantive research output on which innovation is dependent. Perhaps not surprisingly, given the maturity and sophistication of its infrastructure and institutions, Switzerland has led the rankings in the world innovation index for the last 5 years. With the exception of China, all the top performing innovation economies are high-income countries with strong economies. Nevertheless, the index suggests that countries such as Rwanda, which has made sustained investment in innovation (if from a more modest base) have also made substantial improvements in prosperity. When comparing the global innovation index scores with GDP per capita in purchasing power parity, many Arab countries perform poorly. While many of the Arab states have high GDP, presumably associated with the exploitation of natural resources, Qatar, the United Arab Emirates, Kuwait, Saudi Arabia, Bahrain, Algeria and Oman all fall well below expected innovation performance. This characteristic is reflected in other non-Arab oil rich states such as Brunei. In the long-term these countries are likely to see reductions in income as the world more energetically embraces green technology and reduces its requirement for oil and, in the longer-term, as the reserves of oil diminish. It would be wise for these countries to make the investments necessary to support innovation and in particular the research capability which underpins innovation. Jordan, Egypt and Lebanon perform at about the level of expectation given their GDP. The impact of conflict is apparent in the Yemen, which is not only one of the poorest countries in the world by GDP, despite considerable oil reserves, but even acknowledging its relative poverty, the Yemen substantially underperforms in innovation. Of the Arab countries the United Arab Emirates, Morocco, Lebanon and Egypt improved their position in the Global Innovation Index during 2019, with most of the others showing modest declines, and Qatar and Oman more substantial declines [1].

3 The Impact of Research on Health and Welfare

Research has undoubtedly made extraordinary improvements to the general health and welfare of mankind. It has not only done so in a direct way through medical and allied medical research but also in a myriad of other ways. Improved food production and nutrition has had an overall positive impact, reducing hunger across the globe, and although it could be incriminated in the obesity and diabetic epidemics these are primarily brought about by choice and behavior rather than necessity. Research has quantified the risks associated with everything from air pollution to car speeding and provided methods for their mitigation, from dust-masks to seat-belts, all of which contribute to our health and welfare. Furthermore, the improvements in health and welfare have significant positive knock-ons in terms of human capital to economic and social enhancement. Direct medical research has, of course, had the most profound impact on health and welfare, doubling life expectancy [3] and greatly improving our quality of life [4]. Great discoveries which have massively reduced deaths from infection include the use of hand disinfection with chlorinated lime by Ignaz Semmelweis in 1847, which substantially reduced the death of women in child birth (and is preventing death from coronavirus infections today), the evolution of epidemiology in 1854 when John Snow arrested the spread of cholera in Soho in London, the elucidation and refinement of vaccination against smallpox by Edward Jenner in 1796, and the discovery of penicillin by Alexander Fleming in 1928, all of which embraced principles of research albeit some serendipitous and observational. Beyond infection, the discovery of insulin by Frederick Banting in 1921, X-Ray imaging by Wilhelm Roentgen who in 1901 received the first ever Nobel Prize for his work, and anti-cancer chemotherapy credited to Paul Ehrlich the great immunologist, have all been the result of medical research. Progress in medicine during the last century and the early part of this has been staggering and with the description of the human genome now being integrated with a vast array of other biological data using artificial intelligence is certain to provide another step change in biological and medical progress. It is surprising then that with global spending on health care growing faster than GDP [5], drug approvals [6] and research productivity [7] appear to be slowing. The reasons for slower growth, particularly in pharmaceutical products are probably related to competition and regulation. Competition with the many products already marketed means that unless a product is a block-buster, or an entirely new entity for a condition for which no other product exists, it is unlikely to satisfy the required return on investment demanded in the pharmaceutical sector. This has probably also condemned many possible antibiotic products to the archives since they cannot compete on spectrum, potency or utility (delivery convenience). Furthermore, the regulatory burden required to demonstrate safety, quality and efficacy are now so onerous that few chemical entities can adequately comply. It is also true that the specter of a plethora of designer drugs informed by genomic information did not materialize in the immediate post-sequencing era. This may of course change now that artificial intelligence can be used to more effectively utilize the relevant data.

Outbreaks and the spread of Avian Influenza, SARS and the more recent coronavirus pandemic (COVID-19) each demonstrate the threat and risks associated with a more populated, urbanized and mobile world populace. Research has helped identify, quantify and ultimately control the first two of these diseases and will do so for the third. It was artificial intelligence which first identified a cluster of unusual pneumonias in Wuhan and which thereby triggered the measures to control the disease in that city. Interestingly, the epidemiological research carried out following emergence and trans-national spread of COVID-19 resulted in different governments taking different approaches to its containment and control. This is likely to have been influenced by differing national circumstance and national approach to imposed restrictions to movement and other liberties together with the capacity and sophistication of health services.

4 The Impact of Research on Policy

Empirically there can be little argument that policies (national or local; public or private) should be based on evidence, fact and truth, and that these might be best provided through research. Yet policies are rarely set on evidence alone, indeed they are often counterfactual to the available evidence. This may be because the evidence is simply too complex to provide easily discernible policies or because decisions are influenced by emotion, self-interest or the dominant political agenda. The complexity and uncertainty of cost-benefit analysis in big infrastructure projects such as railway construction (a high-speed line up the West coast of Britain) or a new runway at Heathrow airport, make decisions extremely difficult. The research which underpins such analysis is always based on substantial variables and uncertainties which are often ignored or not understood by those making the decisions. Examples where emotion has trumped evidence include the moratorium on genetically modified crops (GM) and some growth promoting hormonal implants for animals in the EU. That these moratoria have continued in the EU long after practice has confirmed evidence-based principles on safety in countries where they are used is testament to the power of emotion and our capacity for irrationality [8, 9].

Self-interest and indeed national interest have undoubtedly inhibited policies which could effectively slow and ultimately limit anthropogenic climate change. Car parking charges levied by institutions are limited by the self-interest of those wishing to use their cars for convenience when public transport is available and often cheaper. At a national level the continued use of hydrocarbons for the majority of transportation and industrial energy production is permissible only because the cost of conversion to renewables is so great and to convert quickly would make our export products uncompetitive. There is now ample evidence that climate change is happening, that it is people that are causing it and that generally it is going to be bad for the planet. Of course, politics invariably influences policy even when the politicians claim that they want to make policies based on evidence. Policies around social housing, welfare benefits and healthcare can vary massively between political parties despite the evidence on housing shortages, social deprivation and ill-health being available to all. In the UK researchers (paraphrased by one of our Government ministers as experts) have come under attack by politicians and the press. This has no doubt been fueled by the uncertainty underpinning many research results but is also likely because the research evidence produced does not support the political agenda being advocated.

Policy makers should be aware that making policies (or not) in an evidence vacuum could be catastrophic. The COVID-19 pandemic is a case in point – although to public and politicians it may appear that the evidence is uncertain and at times conflicting – nevertheless the scientific and research response has been electric in pace and enormous in scale. That different policies have been adopted by different countries is a feature of stage of the pandemic, infrastructure (health services) and national mindset. As the epidemiology of the epidemic has become clearer, and our understanding of the immunology has informed the use of treatments such as dexamethasone and the development of vaccines, so policies have adapted, lockdowns have been imposed, masks introduced, hand sanitizers utilized and vaccines targeted at the most vulnerable. What is certain is that without research the number of deaths and the economic impact of this disease would be many times worse.

Very few politicians have any real experience of research, and particularly scientific research. In the UK in 2019 only one MP had a science PhD and it is easy to see why politicians might wrestle with issues of uncertainty and might appear disparaging to 'experts'. If more logical policy making is desired then it is important that more people with research experience stand for political office or that politicians appoint those with relevant expertise as their advisors. Researchers must also learn to present complex evidence with substantial uncertainties in lay-language and with comprehensible logic. It is remarkable how often academics, whose vocation is to educate, bamboozle their audience when presenting evidence through the media.

5 The Impact on Education and Critical Thinking

Research and education have been inextricably entwined since the Prussian philosopher and political functionary Wilhelm von Humboldt proposed that knowledge should be based on empiricism and not on dogma. He believed in the self-determination of the individual as a world citizen and that academics should have independence from governmental constraints, the idea that is now embraced within academic freedom. His particular genius was reflected in his creation of the University of Berlin in 1890 (now Humboldt University of Berlin) where he introduced a unity of teaching and research free from external authority [10]. This differed from the French Grandes Écoles where the curricula were robustly controlled and where conformity of ideas were encouraged if not imposed. Emergent Universities such as Johns Hopkins University in the United States were early and enthusiastic adopters of the Humboldtian model, and it has been suggested that this catalyzed the extraordinary innovative machinery of the United States and thus its dominant economic position in the world.

The benefits of research to education may seem clear but are not all as tangible as might be imagined. Research does of course provide much of the evidence and truth on which education is based and it is this truth which is taught in our universities, colleges and schools. Conventional wisdom has embraced this approach, since Humboldt suggested that in universities there is a compelling rationale for research and education to be integrated and where the dissemination of research results required the written media then an integrated system certainly benefitted from immediacy. Nevertheless studies determining the educational outcomes or attainment of students suggest that education may be just as effectively delivered by pure educationalists who do no direct research themselves [11, 12] and the speed of information dissemination available today makes access effectively instant. There is a persuasive train of thought which suggests that the experience of discovery by a researcher will confer advantage upon them in enlivening the taught environment with anecdote and lived experience. While this is true, it still depends upon the researcher having the skill to effectively engage and inspire the student. Encouraging students to undertake research projects as an integral part of their degree program is likely to have desirable effects. Understanding the discipline of research process is of itself a useful life lesson, however it is the critical thinking and imaginative approach which lay the foundations for problem solving in any situation which might be the most valuable contribution which research can make in education. The facility to think critically and solve problems is a transferable skill which will not only make the recipient an effective independent researcher themselves but will also be highly valued in a workplace where job evolution and change is now almost universally pervasive. There may be some sound arguments for dissociating research from education in terms of empiric efficiency, however the arguments for its integration are more compelling. Indeed the “customer”, if that is what students are, certainly appears to value the integrated approach and if entry tariff is the currency of purchase, those universities with the most distinguished research profile are also those able to demand the highest entry tariffs.

6 The Impact of Research on Happiness and Fulfilment

The outcomes of research have made life much easier in very many ways. The combustion engine has relieved much back-breaking work in industry and agriculture and made transportation much quicker and easier. Electricity has made lighting our homes and cooking our food infinitely more convenient and computers have made calculations possible which previously were unimaginable. Yet has this made us any happier? Probably it has, but as each new invention becomes the new norm our associated happiness rebalances and indeed there is no obvious long-term trend in reducing depression and anxiety, rather the opposite.

Yet, research into history, culture and philosophy has the facility to fulfil our lives and bring joy and satisfaction through greater appreciation of the workings and beauty of our universe and our understanding of life itself. As history stretches out behind us historical researchers find imaginative ways to discover and interpret everything from architecture in historical civilizations to the changing social and personal interactions of all strata of society over time. The enjoyment and understanding that history gives us is reflected in the number of books and monographs produced on its every aspect and our insatiable appetite to read them. Furthermore, historians have achieved almost cult status on our televisions and social media reflecting the impact of historical research as it colors our past and informs and guides our future. The enlightenment and appreciation brought by our understanding of art, music, dance and theatre are enhanced by research and scholarship and undoubtedly add to the collective fulfilment and happiness of society, indeed they are pillars of what we call civilization. Philosophy creates the environment and state of mind in which research can take place. It is critical thinking and reasoning which underpin the research method. Research in the subject of philosophy seeks to answer fundamental questions about existence, values and reason and about knowledge. Classical Greek philosophers such as Pythagoras and Aristotle are credited with the systematic presentation of philosophical methods. It is philosophy which seeks to answer questions on morality and justice which contribute to civilization and a contented existence. Of course, for some, the deeper questions of humanity, life and the universe can also lead to mind wrenching anxiety.

7 The Impact of Research on the Environment

Many of the ways in which man consumes or uses hydrocarbons and produces carbon dioxide have been the result of research. From coal and oil-fired power stations to steam engines, the combustion engine and the jet engine, all have contributed to the production of greenhouse gases. In agriculture, research into more efficient and effective production of animal protein, milk and eggs has resulted in intensification, massification and homogenization of production systems utilizing feedstuffs produced by cultivation to replace forage grazing. This has had a dual impact on deforestation and on the inefficient ‘middleman’ energy absorbing and greenhouse gas emitting livestock. It takes many kilograms of cereal and many liters of water to produce each kilogram of meat, milk or eggs. Furthermore, each molecule of methane produced by ruminating animals has a greater greenhouse impact than the equivalent molecules of carbon dioxide [13]. Research has contributed to environmental damage in many other ways, from the discovery of plastic and the discard of rubber tyres to the use of polychlorinated biphenyls and other organochlorines as insecticides and antiparasitics. Yet it is also research which has identified the hazards which these man-made products and by-products impart, and which has quantified the risks associated. It was research on ozone depletion and on the impact of greenhouse gas production which led to predictions of weather perturbation and global warming. If unchecked, research suggests that these will result in potentially catastrophic impact on polar ice, ocean levels and salinity and land base agriculture and the living environment. There will be further knock-on effects on biodiversity and animal and human disease patterns.

We now look to research to address, and hopefully resolve, anthropomorphic climate change. The development of cleaner methods of energy production and storage will be vital to continued economic growth with reduced pollution. Wind, water and nuclear energy are already being exploited more effectively and while integrated grid systems maximize *demand: production* harmony, new and more effective battery and other storage systems are being developed to increase the utility of electricity. There is no doubt that it will be battery efficiency and longevity together with size and weight optimization which will make electric car and bus travel greener. Biodegradable plastics will help restore littered sites and will reduce the burden of plastics on our oceans and their inhabitants. Animal husbandry systems are being developed which optimize productivity and minimize environmental impact. Research to assess new herbicides, pesticides and animal drugs offer confidence that they confer minimal negative impact on the environment. Indeed, it is probably the stringency of the tests on such products which has resulted in a reduction in the number of products making it to market. Research may well have produced many products and processes which have contributed to environmental pollution, nevertheless it is research which has identified and quantified the harm caused by these products and processes and it will be research which will allow us to continue to benefit from the contributions that mechanization, packaging and agrochemicals bring to the economy and our standard of living but without the negative impact on the environment.

8 The Impact of Research on Communication

It is unlikely that research as we know it played a major part in the evolution of language or the development of writing, although it has greatly enhanced our ability to understand and translate the spoken and written languages of other cultures either contemporary or historical. The invention of the printing press and moveable type by Gutenberg in the fifteenth century, probably by trial and error and by iteration from previously used woodblock printers, could be ascribed as research of sorts. Its impact was profound, effectively democratizing literacy and making knowledge available to everyone who could read. The mass dissemination of knowledge had a direct impact on the emergence and refinement of research methods themselves. The impact of the printing press was perhaps more profound than any other invention until (or possibly including) the telegraph which allowed almost instant communication across continents. Arguably since the invention of the printing press all other subsequent communication aids (telegraph, typewriter, telephone, radio, television and internet) have simply increased speed rather than quantum of information which could be communicated, although the television and internet have added substantial visual complexity to what can be transmitted, and the internet adds the facility for dialogue, one-to-one and one-to-many overcoming a deficiency of radio and television which provide receive-only communication. The internet has also embraced search engines which allow the interrogation of most of the total of human knowledge at the press of a button – and it has added complexity and uncertainty by making access to misinformation and nonsense as efficient as access to truth and evidence. The internet has added the facility to communicate even when we are unaware it is happening – thus the appearance of unsolicited information and adverts targeted at our desires or demands deduced from the patterns and communities within which we engage. We can laud or blame the telephone, radio, television and internet on research, but we cannot deny the impact of their invention. It is also undeniable that faster communication has quickened the pace of research, discovery and invention. This is particularly true since much research is incremental, and advances are made on the back of those which have gone before. Combining the power of communication with the power of computing is heralding a new era whereby vast amounts of data can be gathered, communicated and analyzed at lightning speed and indeed where intelligence, the ability to think and progress independently can be done by machines.

9 The Overall Impact of Research

The impact that research has had on productivity, health, education, policy, culture, environment and communication undoubtedly demonstrates its power, mostly, but certainly not exclusively, for good. It is certain that without the benefits of research the world could not sustain the 7.8bn people who currently inhabit the planet, nor could it hope to nourish and sustain the 10.9bn likely to inhabit earth at the end of the century at which time the population is predicted to plateau. Furthermore, without research we have absolutely no hope of reaching a steady and sustainable population without cataclysmic detrimental impact on climate and other natural resources.

10 The Research Process

Research is therefore a good thing and the evidence (of outputs and largely of outcomes) suggests that we have got better at it. There are, nevertheless, perennial debates about the efficiency and value of research. Is research better done in a learning environment as proposed by Humboldt or should we support institutes established for the purpose and where researchers are unencumbered by the requirements to teach and mentor undergraduate students? Should researchers be left to follow their own imagination, initiative and ideas like Einstein, or can more be achieved if research has a direction and an objective target like putting a man on the moon? Is basic research to understand underpinning mechanisms and principles of life more important than applied research to produce something useful like a vaccine? Finally, has competition improved the efficiency and productivity of research outputs or has it driven a culture of immediacy at the expense of depth and quality?

10.1 Institutions

The first question, comparing universities and institutes is not easy to answer because in most countries the public (or indeed private) investments in universities and institutes are very different and there is little good analysis of the research outcomes or outputs relative to the dollar investments made. Universities have the advantage that generally they are able to cross subsidize from teaching activity into research. In the UK for example they tend to be able to conduct high-quality research on about 80% of the Full Economic Cost (FEC) of the research. When comparing universities and research institutes it therefore appears on superficial examination that universities are more efficient. In both universities and institutes a substantive proportion of research income is likely to be through competitive grant acquisition, universities are however able to flex their workforce between teaching and research, thus in fallow years teaching academics can still make a useful contribution, whereas in a research institute this flexibility does not exist. The higher the proportion of an institute's turnover which is dependent upon competitive, short-term funding, then the more vulnerable the institute is to financial exigencies. Furthermore, the nature of much research is long-term, programs cannot be turned on and off with ease, and it is likely that when funding troughs arise programs have to be shut down loosing corporate memory, expertise and often consigning expensive equipment to the scrapheap.

A further impediment to change and progress which blighted the UK's research institutes was the civil service terms and conditions of employment which led to a sclerosis and pedantry unsuited to fast moving research activity. In the UK, many research institutes have been merged into universities or shut altogether as a result of these failings. Only those which could demand substantial core funding as part of an essential national resource such as disease control or major shared infrastructure (such as telescopes) have survived, and some have become multinational (such as the Large Hadron Collider). Germany can boast a more successful model for its research institutes. The Max Planck Society supports 83 institutes undertaking basic research in natural, biological and social sciences and in the humanities. Germany has also got an excellent complement of applied research institutes supported by the Fraunhofer Society. The Max Planck and Fraunhofer Institutes each receive funding in the region of 2 billion euros annually. Over and above these facilities Germany has Leibniz and Helmholtz funding for humanities, economics, mathematics, energy, environment, health, aeronautics and space. The success or otherwise of institutes dedicated to the purpose probably depends on culture and scale but also on resources. The complexion of research institutes in the UK was colored by the fact that they undertook 'directed' research. This produced notable success, for instance in the production of animal vaccines to prevent bacterial and viral disease. It did, though, create vulnerability to the current political whims or policy perspectives of their paymasters. In agricultural research the post-war necessity for productivity was met with massive research driven increases in production, however when incentive payments to farmers began to produce ‘milk lakes’ and ‘butter mountains’ research proposals with productivity outcomes, and the institutes established to deliver such outcomes, rapidly lost favor.

10.2 Applied or Basic?

The debate between ‘applied’ and ‘basic’ research in the UK has been fueled by the introduction of an impact metric within the Research Excellence Framework (REF) by which research quality and quantity is assessed. It would, of course, be a tragedy if fundamentally interesting discoveries about our universe which are important of themselves, but show no particular practical usefulness, were not encouraged. Nevertheless, it is also reasonable that the taxpayer who funds the majority of research within our institutes and universities get some useful return on their investment. It is also true that many discoveries appear to have no useful purpose at the time of their discovery but form the basis for substantial contribution to human endeavor at some future date. High quality research whether applied or basic is highly beneficial and debating between the two as if one were better than another is unhelpful.

10.3 Competition

It is instructive to consider whether competition has enhanced research performance. There has probably always been competition in research, between individuals because we are by nature competitive, between institutions to gain reputational advantage and between nations to achieve dominance in a particular sphere such as the exploration of space. More specifically, many governments have intermediary funding councils which create competitions of various sorts which subsequently select the best submissions for funding. The advantage of an intermediary with appropriate research expertise to distribute funding helps prevent political doctrine supplanting research excellence in decision making. This has been enshrined in what is termed the Haldane Principle after Richard Haldane who chaired a committee in the UK in 1918 which recommended ‘arm’s length’ processes between Government departments and those competing for funding [14]. A more comprehensive competition was introduced in the UK in 1986 to determine how much core research funding should be allocated to individual universities or Higher Education Institutions. This exercise has been carried out at approximately 5–7 year intervals since that time and although the name has changed from the Research Assessment

Exercise (RAE) to the Research Excellence Framework (REF), and although some of the metrics have changed (e.g. the introduction of an impact metric), it has remained fundamentally the same since that time.

The assessment process in the UK has been criticized for a number of obvious reasons. It is extremely expensive and rather bureaucratic, involving peer review of outputs, environment and impact. It has been suggested that a purely metric based process would deliver much the same outcome at a fraction of the cost. It has also been proposed that the inclusion of an impact metric disadvantages some subject areas such as the humanities where it is suggested that demonstrating and measuring impact is more difficult (although substantial effort has gone to ensure that impact is not only associated with economic contribution). There are also concerns about the effect that assessments have on the development and progression of academic researchers within their institutions. Early career researchers scramble to produce a sufficient number of outputs to justify their inclusion in the process (and thus enhance their promotion prospects). Indeed, some institutions subtly if not overtly use 'REFability' as a selection criterion for appointment. Researchers may prioritize quantity over quality to the detriment of progress and innovation. Some progress has been made in recent iterations to flex the number of output submissions made by individuals to overcome these concerns, nevertheless there is undoubtedly pressure on younger ambitious research workers to deliver. Proponents of the assessment process can point to the general increases in high-quality research produced at successive assessments and at the position of the UK in terms of overall research outputs (by quality and quantity) where it is generally ranked in the top three nations internationally over the last 3 years despite allocating less funding as a proportion of GDP than most of its major competitors. Despite these apparent attributes, widespread adoption of similar competitive processes have not been adopted in other countries. It may be that as journal rankings and publication impact measures become more sophisticated that other countries will adopt data analytics which could make the process easier and more objective.

11 Conclusion

Research has evolved from observational trial and error into a sophisticated systematic and strategic process, often at multinational scale. It is electric in pace, universal in breadth and of unimaginable depth. Our institutions for the delivery of publicly funded research have evolved according to national policies, culture, wealth and infrastructure. Our researchers have likewise evolved within their organizational culture to embrace, to various degrees, competition, direction and exploitation.

Undoubtedly the products of research have the power to destroy our planet. Nevertheless without research we could not sustain the current global population, never mind look forward to a future where the earth might sustain an even larger population in harmony with our environment and balancing the consumption and production, or access to, required natural resources. Used wisely, research will be our salvation.

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The Future of Science in the Twenty-First Century: Towards a New Paradigm

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Abstract The twenty-first century has brought about an enormous transformation in how research is being done: Instead of lone researchers, we have teams, and increasingly multi-disciplinary teams that are increasingly based in various countries as our communication tools become ever more powerful. Instead of small experiments or small surveys on-campus, we have Big Data, and Big Data Analytics. High-powered computers and the use of imaging as well as artificial intelligence (AI) and Virtual Reality, create a totally new type of atmosphere in which to search for better understanding of nature and society. With almost everything online, almost instantaneous publishing and the movement towards Open Science, the relationship of each scientist to the global scientific effort will be different than it was in the past. Also given the remarkable possibilities that new revolutions in both biology and information and communication technology (ICT, including AI) are making ethical judgements essential. It will be a major transformation, that will be creating a new paradigm for research.

Keywords Scientific research · ICT revolution · Big data · Artificial intelligence · Values of science · Educational reform

1 Introduction

Our age is very much the age of science. There are more scientists working today than all the scientists who practiced throughout the previous history of humanity combined. We live in the era of science, information and knowledge. Actually, we live in the era of enormous data, and:

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- Data when organized becomes information.
- Information when explained becomes knowledge.
- But we need more than knowledge: we need wisdom.

Thus, to cope with the complex realities of our times, from interaction between people in complex societies filled with diversity, to interacting with the environment in a meaningful and sustainable way, we need knowledge, and knowledge generated by science, but we also need to transcend knowledge to make wise decisions.

So, to all those dealing with the application of knowledge, we must add to the knowledge of the natural sciences the insights of the social sciences and the wisdom of the humanities [1]. We cannot allow the continued dichotomies between the world of science and the world of the humanities, the so-called "two cultures", that has been debated for the last half century to continue [2]. We must also think of the ethics of the uses to which the technology can be put. Not everything that is technically feasible is necessarily ethically desirable.

At present, the transformations in our world are accelerating at a remarkable pace, as Science and Technology and Innovation drive the fast-paced evolution of the world we live in. That is the starting point of our journey to respond to three very broad questions:

- What is changing in the world?
- What is changing in science?
- What should also change in education?

Dealing with these three questions covers the bulk of this chapter.

2 What Is Changing in the World?

2.1 Our Changing World

In discussing what is changing in the world, I will not address the remarkable political transformations that led to the collapse of the Soviet Union, and a brief period of triumphalism in the West [3], which advanced the western model of democracy and capitalism as the inevitable choice for all the people of the world [4]. The complexities of the changing world order are a topic for another day. Here we want to focus on the transformations that affect how we do research, how we work and how we study. And in that sense, there is an amazing transformation in the world we live in.

Those born at the millennium will have difficulty recognizing the world of half a century before. Even in the USA, there were only three TV channels (to which we could add the National Public Channel), and everybody read newspapers in large unwieldy paper formats with greasy ink, while movies were shown in large theaters, and messages (letters or cards) were sent by hand-delivered mail. Travel overseas was arduous, expensive and limited. Education and schooling were largely structured for an employment market that valued discipline and a capacity to persevere at doing fairly boring and repetitive tasks, whether at a factory or at the office (more on that later).

Indeed, throughout the twentieth century, the mechanism of linking science to technology to market has been significantly improved. Research & Development (R&D) has become a joint task – or at least mutually supportive roles –of the public and private sectors in most countries with the best universities playing an important role.

The twenty-first century has brought a profound transformation to our world. Largely thanks to the internet, we can see accelerations in all aspects of globalization, travel, trade, financial integration across nations, and social connectivity, which has helped nurture an even tighter new set of links in what is institutionally referred to as Science, Technology and Innovation; a tight linkage that brings ever newer products to the market. Rocked by at least one huge recession (2008–2009), the Euro-crisis (mostly Greece and Southern Europe) and several wars, the world economy has nevertheless grown and the world has pursued a common vision of development: first the Millennium Development Goals (MDGs) to cover the period from 2000 to 2015 and then the Sustainable Development Goals (SDGs) for the period 2015–2030. The success of the first set of goals was largely helped by the enormous transformation of China, which not only grew at a blistering pace, but also lifted hundreds of millions of its citizens out of poverty.

Today, the world is truly interconnected by the most transformative of all inventions: The Internet. Globalization has advanced with trade, international banking and, above all, with enormously increased travel (until the pandemic of 2020) and global social connectivity. Thanks to the internet, national – and even global – society is being transformed, in at least five enormously important ways.

2.2 *Five Profound Transformations*

The internet, the most transformative technology of all time, has contributed to five profound changes in our world that is largely taking shape as we speak.

2.2.1 A New Paradigm for Knowledge

The way we acquire knowledge, how we store and retrieve it and how we interact with it and add to it are all changing. I analyzed this over a decade ago in what I called "The Seven Pillars of the Knowledge Revolution" [5]. These seven pillars are (i) the move from print to digital, which makes the edifice of knowledge built by individual books or essays much more fluid with websites being accessed globally instantly and updated continuously, and linked by hypertext links to other essays and websites, or images and videos. The image we imagine is no longer that of a great structure built by individual bricks (or books), rather it is of a flowing river with many tributaries contributing to its flow. (ii) Picture and image, including video, is as important as text. (iii) Humans can no longer function without machines. They need the mediation of machines to find, retrieve and use the information with which they interact. (iv) Our reality is complex and chaotic, meaning that complex systems have non-linear feedback loops that result in systems and subsystems that are extremely difficult to predict. Many of our models, based on the simple mathematics and analogies drawn from physics, are proving inadequate. (v) Computing science, with its concepts and techniques, will become a central part of the new knowledge paradigm. It will no longer be just for doing calculations. The notions of computing and data science will become part of the very fabric of science and scientific practice. (vi) Transformation and convergence will become more common. Transformation in the sense that new discoveries will change the nature of a field of study, like DNA on biology, where genetics, and all the "omics" replaced the old-fashioned focus on descriptive taxonomies. And convergence like when we had biology and chemistry and now, we have biochemistry. Today we are witnessing a convergence between bio-info-nano technologies which will certainly presage more fertile changes in all these fields. (vii) The old disciplinary silos in education, research and teaching will no longer be adequate. We will need to cross disciplines to understand and deal with all our multi-dimensional and complex problems from the environment to poverty to gender. Already much of the most interesting work is being done in between the disciplines, where they intersect or where the gaps are. All this requires that our education systems train people to have interactional expertise to improve their efficiency working across multiple disciplines as well as within the new inter-disciplinary areas. Just as we say that diversity is enriching, so is the sharing of knowledge across disciplines. And as was mentioned at the start of this essay, the knowledge produced by the natural sciences will need the insights of the social sciences and the wisdom of the humanities as it gets transformed into technologies and these technologies are deployed in society.

2.2.2 Big Data and the Internet Explosion

The information and communications technology (ICT) revolution is continuing to expand the scope of the information available beyond anything that could have been imagined a few short years ago.

According to *Forbes* (Jan 2020) [6] the International Data Corporation (IDC), one of the leading global providers of market intelligence, predicted that the amount of the newly created data in 2025 would reach 175 zettabytes (175 trillion gigabytes) of new data that will be created around the world. That figure is likely to be exceeded, as predicted by earlier forecasts. Today, statistics indicate the following:

- 1.7 megabytes of data is created every second by every person during 2020.
- 90% of the world's existing data has been created in the last 2 years alone.
- 463 exabytes of data (almost half a zettabyte) will be generated each day by humans as of 2025.

So, let's ask, how big is a zettabyte? Well, if all the text in all the catalogued books in the Library of Congress was digitized, one zettabyte would be equal to more than 70 million times more!

Storage of this enormous data is being handled by the rapidly evolving "cloud" technology with many new things on the drawing boards (e.g. storage in DNA), not to mention the transformative power of Quantum Computing, should it become widely available in the next decade(s).

This internet explosion is changing everything. Analysis based on data is rapidly shifting to "Big Data Analytics" confirming the trends discussed in the new knowledge paradigm from working with and through machines, to the growing centrality of computer science.

Economies are being up-ended. The large tech companies now dwarf the giants of yesteryear (oil companies and car manufacturers). Their market capitalizations put their value at much more than the entire economic size of a number of countries.

But the key transformation is that data strategy has become a central concern for leaders and senior managers [7]. It is no longer an issue that is just for technicians and geeks. Today, not only is a data strategy central to the institutions of the twenty-first century, it also deserves institutional attention on the same level as a company's marketing, customer, product, and talent strategies. In fact, it undergirds many of these other facets of the institutional strategy [8].

2.2.3 Social Connectivity and the Personal Hand-Held Device

A predominant feature of the society that is being created before our eyes is the rapidly growing importance of the mobile phone. Today, there are more lines than human beings. A special variety of mobile telephony, the smart phone, represents the marriage of the internet with private telephony, with truly far-reaching consequences. It has allowed unparalleled connectivity and allowed the emergence of social networks, accompanied by a gradual shift from desktop and laptop to hand-held devices, including tablets such as iPads. But the instrument of choice is the smart phone. That personal hand-held device has empowered a whole generation of young people to deal with data and information and communications very differently than their parents, and its power will get multiplied many times over by the introduction of the new generations of technology: 5G, 6G and beyond.

The marriage of the smart phone and the internet is the defining transformative technology, for good or ill. It brings instant news and unlimited information to the fingertips of youth, just as it allows the spread of lies and conspiracy theories on the newly far-reaching social media.

2.2.4 Artificial Intelligence (AI), Robotics and Brain-Machine Interface

The new era of artificial intelligence (AI) is here. Machines can handle our production processes with much greater speed and accuracy, and in fact, robots now handle most assembly line operations in traditional manufacturing. Robots are already landing airplanes, and they will soon be driving cars without human intervention. This AI revolution will be very far reaching. The McKinsey Institute estimated that its impact will be 3000 times greater than the industrial revolution [9].

In addition, the interactions of humans with machines are rapidly expanding. Already we see the biological and the ICT revolutions combining their skills, and creating new domains such as the rapidly expanding field of Brain-Machine Interaction or Brain-Computer Interface [10]. These new developments will have far-reaching consequences for how we live, work and do research, beyond the obvious medical applications that would help paralyzed patients. Activities such as direct reading of brainwaves are actually being tested, and promises of even more far-reaching transformations are probable in the not-too-distant future.

2.2.5 The Internet of Things (IoT)

Machines are talking to other machines without human intervention in what has become known as the "Internet of Things" (IoT). But they don't just exchange information, they act upon information without further human intervention. Examples are plentiful and benign. For instance: Security sensors in buildings to prevent fires or other problems, or when a car caries a tag on its windshield and a tollgate reads it without having to stop the car and query the driver. Many everyday uses of this capacity are undoubtedly benign and widely accepted. But the technology is evolving rapidly and will open immense new fields of conceptualization and application, especially when the interaction of the machines gets linked with the latent power of AI.

These five aspects of our rapidly changing world underline the enormous range and magnitude of the transformation we are going through. These changes have also influenced the manner in which contemporary science is being done. In fact, we can argue that scientific research in this twenty-first century is going towards a new dominant paradigm.

3 What Is Changing in Science

3.1 The Changing Practice of Science

The twenty-first century has brought about an enormous transformation in how research is being done: Instead of lone researchers, we have teams, and more and more multi-disciplinary teams that are increasingly based in various countries as our communication tools become ever more powerful. Instead of small experiments or small surveys on-campus, we have Big Data, and Big Data Analytics. High-powered computers and use of imaging, and increasingly the use of AI and virtual reality, create a totally new type of atmosphere in which to search for better understanding of nature and society. With almost everything online, almost instantaneous publishing and the movement towards Open Science, the relationship of each scientist to the global scientific effort will be different than it was in the past. Also, given the remarkable possibilities that new revolutions in both biology and ICT (including AI) are creating, the exercise of ethical judgements will be essential. It will be a major transformation, creating a new paradigm for research.

3.2 The Increasing Centrality of Data Science

Today, and even more tomorrow, data science has moved from the periphery to the mainstream of how we organize society and how we manage the scientific pursuit of knowledge. Advanced research institutes will be bringing together cross-disciplinary teams to advance innovation in the very design of data sets and their integrity, from blockchain, data transparency, and closely associated topics. But large corporations and government agencies will also need to handle Big Data analytics [11], and for that purpose, they will also be building their own specialist teams. But to do so effectively, this will require the capacity to hire and manage a team of skilled individuals to build and implement applications and systems based on Big Data Analytics and AI. That too, requires special attributes for the supervisors and managers of the evolving institutions [12].

These specialist teams will continue to expand and refine the study and implementation of everything from the physical aspects of sensing, generating, collecting, storing, transporting, and processing large data sets, to the harvesting and use of data generated by people and data about people to understand human behavior, whether for marketing or for social science research.

But if individuals will also benefit by the improvement in the quality of the services they will get, they – and society as a whole – have to be aware of the risks that these data developments pose to privacy and security. An example is the development of much better health data systems that will improve the delivery of health services to individuals and improve the overall efficiency of the health care system through data-driven methods. But it will also raise questions about who would have access to such data, and how they could use it.

On the macro-scale, we can certainly turn the idea of "Smart Cities" from a slogan into reality, as we develop, monitor, and improve infrastructure, the power supply, buildings, transportation routes, and everyday activities in our dense urban environments.

But whatever the risks, whatever the fears, large-scale computing systems for data-driven science are here to stay, and the trend will accelerate towards the design, analysis, and application of massive-scale computing systems for processing data. Much of these services will be accessible from relatively small, even hand-held devices, as we see in the ability of any smartphone to use "apps" to access everything from Wikipedia to google maps.

3.3 Open Science

Similarly, the future of science is now passing a new milestone into a new domain: The domain of "Open Science".

Eminent institutions such as the US National Academy of Sciences have adopted and advanced the "Open Science" paradigm, that not only aims to ensure the free availability and usability of scholarly publications, but also the data that undergird the scholarly research, or result from it. Indeed, Open Science goes further as it makes accessible the code or algorithms or other methodologies that were used to generate those data, and the National Academy of Sciences has already published an important Report on Open Science, titled "Open by Design" that was released in 2018 [13].

Marcia McNutt, President of the National Academy of Sciences, placed the Open Science movement within the "vast arc of human history," declaring it the fifth and latest notable milestone in the "purposeful sharing of information" [14].

She pointed out that the previous four milestones were:

- The development of language by early humans,
- The development of written language,
- The creation of libraries, and
- The creation of the research journal to disseminate the results of scientific research.

The pressure towards Open Science resulting from the increasing speed of our times, the greater ease of communication, and the sheer volume of important and relevant material being produced is impossible to stop. In this past year of 2020, where a pandemic of a disease (COVID-19) spread by a corona virus (SARS-COV-2) and the huge impact it has had, and continues to have on the world, has resulted in an unbelievable acceleration of scientific research and publications [15]. *Nature* has published a major review of this phenomenon [16], and we witnessed a huge expansion of the number of COVID-19 related publications, faster peer review, and almost all journals dropping the fire walls to allow open (free) access to the new publications. Also, there is a large number of postings of preprints pending publications on digital platforms such as ARXIV. Indeed, the numbers cited in the Nature review are stunning:

> Submissions to publisher Elsevier's journals alone were up by around 270,000—or 58%—between February and May when compared with the same period in 2019, one analysis found. The increase was even higher for health and medicine titles, at a whopping 92% [16].

The volume of scientific research today is truly amazing. Despite its dominance in the media, only about 4% of the world's research output was devoted to the coronavirus in 2020, while 2020 also saw a sharp increase in articles on all subjects being submitted to scientific journals [16].

We are already moving – bit by bit – towards open science as part of the new paradigm of science in the twenty-first century. Obstacles remain, and the economics of publishing will need a new model, but the trend towards increased openness is there, and for its opening issue (January first) for 2021, *Science* devoted a special feature to the emergence of open access for all [17].

But the Open Science movement is far more than just open access to the articles, it is also access to the data and the algorithms that make the data on which the article was built, or which was produced by the research, available for all. In fact, today, "Open Science" is widely understood to include: Open data, open sources, open methodology, open peer review, open access, and open educational resources [18].

And for a definition of what kind of formats the data should be available in, there are some simple acronyms that are now widely known and accepted, such as FAIR (which stands for Findable, Accessible, Interoperable, and Reusable); or STREAM (which stands for Sovereignty, Trusted, Reusability, Exchangeability, Actionable, and Measurability).

At present, however, making good use of data across disciplinary fields and across different countries cannot currently be achieved because of varying and incompatible standards that have been used across the different disciplines to codify data. Today, even where the data is easily available, the integration of diverse data can generally only be achieved within, and between, closely allied fields.

A number of international efforts have been initiated to assist important regional efforts, such as the African Open Science Platform (AOSP) which is supported by the Republic of South Africa and the African Union as well as the International Science Council (ISC). The National Research Foundation (NRF) of South Africa will host the AOSP Project Office for the next 3–5 years. The mission of AOSP is to put African scientists at the cutting edge of contemporary, data-intensive science as a fundamental resource for modern society [19].

There are also other efforts to bring data to market as public goods, which not only requires resolving issues of ownership of data with tech giant companies, but also to construct a global data market infrastructure, including exchanges, connectors, catalogs, brokers, and above all a trusted framework [20].

3.4 Ethics

As Bronowski observed more than half a century ago [21], although the results of scientific research are value-neutral, there are fundamental values that must be adhered to for undertaking scientific research. The enterprise of science requires the adoption of certain values: Truth, honor, teamwork, constructive subversiveness, engagement with the other, freedom, imagination, and a method for the arbitration of disputes [22]. These values are established by teacher example and student practice [23]. The values of science are adhered to by its practitioners with a rigor that shames other professions.

Truth Any scientist who manufactures his/her data is ostracized forever from the scientific community. In science, truth will always come out, and the practicing community of scientists ensures that all its members rigidly adhere to the standards it has set.

Honor To give each his or her due, is another tenet for the practice of science. The second most heinous crime in science is plagiarism. And a whole array of tools, from footnotes to references are deployed to ensure that none steals the work of others. Perhaps giving credit to predecessors was most elegantly expressed by Newton's statement which reads: "if I have seen farther than most, it is because I have stood on the shoulders of giants".

Teamwork has become essential in most fields of science. The image of the lone scientist who challenges the established order with unique and brilliant insights, exemplified by Newton and Einstein, exists only in a few small domains of contemporary science, if at all. Increasingly it is teams of researchers in labs who make the breakthroughs, especially in experimental science. We must teach our young scientists of the future the importance of teamwork, and the essence of that is to ensure that all the members of the team receive the recognition that they deserve.

In addition, science advances by overthrowing the existing paradigm, or at least significantly expanding or modifying it. Thus, there is a certain **constructive subversiveness** built into the scientific enterprise, as a new generation of scientists makes its own contribution. And so it must be. Without that, there would be no scientific advancement. But our respect and admiration for Newton is not diminished by the contributions of Einstein. We can, and do, admire both. This constant renewal and advancement of our scientific understanding is a feature of the scientific enterprise. Its corollary is that scientists must engage with all opinions, coming frequently from very young persons, no matter how strange or weird it appears at first, subject only to the **arbitration of evidence and logic** to confirm the claims.

This final point is essential. For in science, there is a process and a method, based on rationality and empirical evidence that rules. It is the way to arbitrate disputes, and it is what makes science great. Thus, the then relatively unknown Einstein's view of the bending of light by celestial objects affecting the space-time continuum was only accepted when it was empirically verified by Sir Arthur Eddington with his 1919 observations of the positions of stars during a total eclipse of the sun [24]. Conversely, the claims of cold fusion made by the well-established professors Pons and Fleischmann were rejected [25] when the claims could not be replicated in other labs. Therefore, in science, the ultimate authority is not a person, but a process of reasoning and a method of empirical observation.

These are societal values worth defending, not just for the practice of science, but also because they help promote a tolerant and open society. But they are not sufficient. There are additional dimensions to the scientific enterprise that include the ethical manner in which we deal with the subjects of research. Medical research must have the informed consent of the subject being studied, and animals subjected to experiments must be treated humanely.

Beyond these values there are other ideals that societies need such as altruism, solidarity, courage, equity, justice, and freedom for all. Respect for human rights, appreciation of art and concern for nature are all valuable aspects of a contemporary society.

But given the enormous power of the new technologies that the new scientific discoveries make possible, there is a special responsibility on all those who manufacture them, such as applied scientists and engineers, agronomists and/or medical practitioners, to think about the ethics of deploying these technologies.

Thus, the US Academies of Sciences and Medicine also created an international panel: The Committee on Human Gene Editing: Scientific, Medical, and Ethical Considerations; which held hearings in the USA and Europe and reviewed them and produced an important report released by the National Academies in 2017 [26]. The report provided guidelines for the use of the new technologies on humans. Seven global principles were retained and defined by the Committee, to organize the governance of the Human Genome Editing, these include: Promoting well-being, Transparency, Due care, Responsible science, Respect for persons, Fairness, and Transnational cooperation. It also recommended that we should not – at least for the time being, given our limited knowledge – edit human genomes in heritable (germline) situations. Yet, in 2018 Prof. He Jiankui, at the genome summit in Hong Kong, presented two baby girls whose genomes had been edited [27]. The international condemnation resulted in the Chinese government removing him and condemning him for “Medical Malpractice”.

But some may say that today we are rapidly advancing towards the use of AI in the pursuit of science and in the elaboration of the technologies that will be in widespread use in the future. One recent example of the use of AI in basic science, is the reported success in solving the Schrodinger equation, an important issue in Quantum Chemistry, using AI [28]. But as we move more and more into the domains of developing technologies and deploying such technologies, will the ethics we demand of the scientists also be applied to the AI?

Thoughtful people have been reflecting on that already. A recent review [29] of the global landscape of evolving AI Guidelines seemed to indicate a convergence on several general principles. These have been summarized in a number of essays [29] for the general public:

- Transparency: The public needs to understand what the AI is doing and why;
- Non-maleficence: The AI should “do no harm”
- Justice: AI should not be just to add luxury to the rich, but also enable services to the entire society including the poor;
- Responsibility; and
- Privacy.

“Ethical AI”, as it is sometimes referred to, wishes that privacy should be seen both as a value to uphold and as a right to be protected [30]. How this will develop is still very uncertain as the field grows very rapidly.

4 What Should Change in Teaching?

Because the education system is intended to equip our youth to be better prepared to function within the new paradigm of scientific research, as well as to live better and function more effectively in this rapidly changing society, it is clear that truly transformative change is needed in our education systems. The education systems in most countries were developed largely in the twentieth century to prepare students for employment in the economy of the twentieth century, which largely needed disciplined workers who could take instruction from an authority figure and do repetitive (largely boring) tasks, whether in the factory or the office. In many countries, the education system has perpetuated the cultural divide between the humanities and the sciences, and introduced a major emphasis on examinations rather than on identifying and nurturing talent. Moreover, science was introduced largely as a series of rules and formulae, and its history (if taught) was about remembering names and dates rather than the exciting journey of discovery that it is.

It is clear that I want to recommend a broad-based education system that values the skills that the twenty-first century needs, not a perpetuation of the past practices, especially those that have prevailed in many parts of the Arab and Muslim worlds. However, education reform is a topic that requires a separate essay. Consequently, here, I will simply address some of the highlights of the reforms that are needed in content, method, participants, venues and links to society, remembering that educational reforms will generally succeed only if there is national and community support for the implementation of these reforms. Many voices are now raised reminding decision-makers, especially in the developing countries, of the importance of involving all stakeholders in the initiation and implementation of reform programs [31].

But because this is about the Arab world, let me start with a look at the legacy of our forebears… let's listen to some voices from the past, to be better inspired to face the future.

4.1 Voices from the Past

As we celebrate the values of science and the modern scientific method, and ask for the reformulation of our education systems [32] to better equip our youth to fit in the rapidly evolving contemporary society, and to interact with science in a new way, it behooves us to also remind ourselves – and our students – that, contrary to general perception, it was the Arabs and Muslims, who defined the modern scientific method, and who created the climate of openness and tolerance that allowed science to flourish during the middle ages [33]. Names like El Khawarezmi, El Razi, Ibn Al-Nafis, Ibn Al-Haytham, Ibn Sina, Ibn Rushd, are forever engraved in the honor roll of humanity's benefactors through their efforts in advancing knowledge and rejecting superstition. Listen to their powerful, modern voices as they speak to us through the centuries.

Listen to Ibn El Nafis – on the importance of listening to the contrarian view:

> When hearing something unusual, do not preemptively reject it, for that would be folly. Indeed, horrible things may be true, and familiar and praised things may prove to be lies. Truth is truth unto itself, not because [many] people say it is.
>
> — Ibn Al-Nafis, (1213–1288 A.D.) Sharh' Ma'na Al Qanun.

Listen to Ibn Al-Haytham, known in the west as Alhazen, who revolutionized optics and made major contributions in several fields of inquiry. Listen to him speak of and how he prefers the experimental method to the authority of the ancients, which should always be approached with caution:

> He who searches for truth is not he who reviews the works of the ancients…[it is] he who follows argument and evidence, not the statement by an individual, who is inevitably affected by context and imperfection. It is the duty of he who reads science books, if he wants to learn truths, that he should set himself up as an opponent to all he looks at.. [accepting only what is supported by evidence and argument].
>
> — Ibn Al Haytham, (965–c.1040) Al Shukuk Fi Batlaymous.

Even more impressive, is this description of how the scientific method should operate, through observation, measurement, experiment and conclusion:

> We start by observing reality … we try to select solid (unchanging) observations that are not affected by how we perceive (measure) them. We then proceed by increasing our research and measurement, subjecting premises to criticism, and being cautious in drawing conclusions… In all we do, our purpose should be balanced not arbitrary, the search for truth, not support of opinions.
>
> — Ibn Al-Haytham, (965–c.1040) Kitab Al-Manadhir.

Centuries before Bacon and Descartes, before the emergence of modern science in the west, our forefathers were calling for the experimental method, relying on the power of observation and the application of rationality and logic. They promoted openness to the contrarian view, balanced by a healthy skepticism. They advocated prudence in running ahead of the available facts, and finally to beware of our innate prejudices and weaknesses that may bias our work without our noticing it. This is a truly amazing description of the modern scientific method, which was way ahead of its time!

These are stellar lights in the history of science and in the advance of knowledge. They are our forbearers and we should be their proud disciples. We need to recapture that great tradition; our tradition, our history, our legacy.

This is the tradition that Muslims and Arabs should be proud of. Our forefathers took the torch and carried it for centuries, and if today the torch has passed to the west, we should be proud that we have done our share and more in earlier times, and should strive to take our place, by dint of hard work and innovation, alongside our western colleagues at the forefront of the global scientific endeavor.

Worthy of note is that tolerance in society is general, and it is not just related to scientific work. Contemporary to Ibn Al-Haytham in Egypt, Abul Alaa' Al-Ma'ari (973–1057) lived in Syria. Al-Ma'ari, a giant of Arabic literature, wrote poetry attacking religion, God and the prophets, and he was not punished for it, even though it generated a certain amount of opprobrium attached to his name. His work was not only published and known in his own time, it has arrived to us, now in the twenty-first century without loss. Even more, he was appreciated for his talent as a poet and a linguist even by those who totally rejected his heretical writings.

The challenge for many Arab countries today is to ensure that it can create an overall climate that is open and tolerant, for that is how democracy will flourish and science will advance [34]. Democracy requires pluralism, which is based on difference of opinion, and democracy is about protecting the rights of those who hold minority opinions from the tyranny of the majority. That is why the belief in the values of science, which is so essential for proper scientific research and for the development of new ideas, is also essential for the development of a proper democratic system.

4.2 Reinventing Education

In the preceding sections of this chapter, we have identified the many facets of what the content of education in the twenty-first century should be. It should bridge the gaps between the natural sciences and the humanities and the social sciences. It should promote a capacity for openness and working with multi-disciplinary teams, and it should also have an exposure to the history of science that alerts many of our students to the enormous legacy of our distinguished forebears.

For those who are concerned about the "employability" of graduates, it is important to note that the economies of the world are changing rapidly. The future is one where repetitive tasks will increasingly be performed by robots [35], and workers will be valued primarily for their creativity and their capacity to learn and adapt to new technologies and their interpersonal skills in a vastly expanded services sector.

So, to cope with societal and the scientific transformations underway, the education systems must change profoundly in many ways [36]. Here are a few of the changes that I would suggest.

4.2.1 Content

While the education and training system must provide the capacity for depth and specialization, it will also have to provide the breadth of a framework of ethics and humanities as well as exposure to social sciences for the future scientists of tomorrow.

The seminal work of Howard Gardner in the 1983 on "multiple intelligences" [37] has been revised at the end of the twentieth century as Gardner redefined his approach to multiple intelligences for the twenty-first century, and in the process has helped us to identify the aspects of the Mind we seek to nurture. These characteristics include five aspects: the ability to synthesize, as well as to be disciplined, respectful, creative, and ethical [38].

We hope that our students will be endowed with creativity and imagination, while they exhibit persistence and discipline, and decide matters on the basis of ethics and critical thinking. Also, it is their ability to participate in teams, and their capacity for working with others, that will display openness and appreciation of diversity. The content that the curricula and syllabi of the new systems provide must be designed to promote these values as they impart the kind of skills that will increase the self-confidence of the young [39, 40].

4.2.2 Method

In terms of method, we will rely much less on classroom instruction and much more on group projects, guided (distance) learning [41], and self-learning.

4.2.3 The Participants in the Education Process

Participants in the education process will still involve parents, teachers, students, peer groups and the community; but the last two will include virtual as well as physical peers and communities.

4.2.4 The Venues

The schools and universities will not be replaced by on-line technologies. Education is not just about imparting skills, it is also about socialization. Children need to be with other children of their age because they learn to interact and socialize with peers, and it is only schools that can provide the requisite setting for such socialization, which is an essential feature of emotional development and the formation of effective citizens.

Furthermore, as has been made abundantly clear during the 2020 COVID-19 pandemic lockdowns, parents will not be able to effectively resume work if the children are not in school. But it is not just a matter of convenience for the parents, it is essential to remember that education is not just about the imparting of skills, but also about socialization, which requires that children and teenagers learn with their peers.

4.2.5 Libraries

Libraries in the digital era will help by organizing coherent domains of knowledge and sharing in the global explosion of information. They will not be just repositories of books and magazines, but will become essential portals through which learners – and the general public – will be helped to explore the vast and growing resources that will be at their fingertips.

4.2.6 Links to Society

Distance learning (guided learning) will become a major feature of the new education system. Continuous learning will be more than a slogan; it will be an economic necessity. Enterprises will seek to continuously upgrade the skills of their workers. People will also be able to go to an endless open access cornucopia of offerings for self-improvement as well as hobbies.

4.2.7 The Five Transitions Mediated by the Education System

The education system is the locus of the transition of adolescents into adults, and the incubator of effective citizens. It is the custodian of the great generational transition. There are five essential transitions that occur between the ages of 15–24 in most societies and they make these years particularly important. And since the High School and the University help mediate all these transitions, it is essential that the education system focuses on and improves the fashion in which it plays that role in the lives of our youth. These five transitions are: (i) Continuing to learn (or dropping out of the education system); (ii) acquiring good health habits (avoiding smoking, drugs and unsafe sex); (iii) entering the labor force; (iv) forming families in independent households; and (v) becoming a citizen, i.e. learning about political issues and civic responsibility [42].

In addition to these five major transitions, it now appears that contrary to general belief, personality traits like conscientiousness, creativity, resilience, and empathy, are not largely fixed by early childhood. Researchers have discovered that almost all of these qualities continue to evolve through early adulthood. This suggests that educators may be able to do much more than was previously thought to help students to develop these qualities. This would be a major asset for them to flourish in later life.

Taking in all these aspects raises important questions about designing curricula and organizing faculty-student relations in the undergraduate years. Derek Bok, Former President of Harvard, has just written a book that treats these issues [43].

5 Conclusions

There is no doubt that things are changing very rapidly, in society at large, in the economy, in the practice of science and in the deployment of technology, and we hope that the education system will also be changed apace. In the most advanced countries where the Research Universities play a central role in the development of new ideas and technologies, the educational changes are being studied, developed and pursued. Top scientists and decision-makers are aware of the importance of that locus of scientific research and education, and of its link with the public and private institutions that develop and deploy the ensuing technologies [44].

Peter Diamandis, one of the leading futurologists of our time, and founder, inter alia, of the Singularity University, has spoken and written about "Exponential Technologies", where the growth and rapidity of their impact is growing exponentially, and hence the changes they wreak on society and the economy are deep, lasting and transformative [45–47]. Serious discussion of these issues must be undertaken, in an open and transparent fashion in every society. In Japan, the annual meeting of the Science and Technology in Society Forum in Kyoto every October for the last 17 years, brings together the leaders of science, government, and industry as well as youthful leaders for structured discussions of "the lights and shadows" of science and technology and society [48].

These changes that were discussed in this chapter, were given their original impetus by the scientific and technological revolutions in the information and communication technologies and the new (post-DNA) biology, that begat many new disciplines from functional and structural genomics to the new cell biology to so many new applications from medicine to agriculture, as well as from engineering to computing and communications. The novel aspects that compounded all that were spelled out at the outset of this discussion are: AI, Big Data, connectivity, human-machine interaction, the internet of things, as well as the new knowledge paradigm. The paradigm of "Open Science" was discussed, as was the acceleration of the scientific enterprise in the face of the pandemic of 2020.

But we should welcome all this. For science has been the basis for every beneficial aspect that has given humans longer, freer, healthier lives than they have ever had before. And today as we face the challenge of a pandemic, a profound economic disruption, and as the scientific enterprise is rapidly evolving its paradigm for research, we must take heart and remember that science can heal the sick, feed the hungry, protect the environment, give the dignity of employment and create a space for self-expression. Let us make sure that the next generation is fully equipped to promote the positives, avoid the negatives, and go beyond information and knowledge towards wisdom as they take us on the course of sustainable development.

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The Opportunities and Challenges Facing Arab Universities as Part of the International Community of Higher Education that Supports Economic Development

Malcolm Parry

Abstract The breadth of benefits that universities contribute to society combine in varying degrees through their social, geographic, and economic impacts. In the context of their role in research, development and innovation their benefits are largely documented by their contribution as economic engines, that includes their capacity to attract global talent, build international connections, and help to resolve societal challenges and inform public policy through independent assessment of these challenges and through effective research.

The degree to which universities contribute to each of these dimensions of activity is in turn influenced by national policies that support research, the capacity of universities to undertake research, and the willingness and capability of business to absorb new ideas and take them to market.

This chapter explores some of the intricacies of these dimensions facing Arab universities in the context of driving research and its extension into innovation, while reflecting on the challenges and opportunities faced by the sector in terms of the delivery of this important role.

Keywords Higher education · Research universities · Arab world · Research and development · Innovation · Triple Helix model · Strategy

1 Scholarship and Premium Knowledge

The history of universities as seats of learning dates back to antiquity and reflects the profound human interest in discovery and gaining access to premium knowledge through scholarship. Out of this long tradition the current concept of the modern university found its direction in the early nineteenth century in Germany, when

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Humboldt University was established and based its education on the unity of teaching and *research as a way of creating and disseminating prime knowledge*.

This scholastic regime was further detailed in the 1990s when Ernest Boyer categorized a relationship between four domains of scholarship. This interconnection brought together ‘discovery’ that pushed out the boundaries of the known, ‘integration’ of the new known with other fields of knowledge to create new intellectual patterns, benefits of their ‘application’, and transmission through ‘teaching’ to solve social and economic problems [1].

Today at a social level, universities attract local, national, and global talent to a region: they establish national and international connections and relationships that help build a national knowledge base and on which discovery (research) thrives. There is a widely held view that they build stronger and more tolerant societies both directly through public outreach and indirectly through the student experience they offer.

Their influence on geography is predominantly through the physical and social spaces they provide as part of the built environment that creates ‘place’, which not only has a cultural, social and economic impact on their surrounding area, but is commonly revered by society.

Although universities do not have a primary responsibility for economic development, it is their economic and social impact that has gained most prominence over the last 50 years [2]. This impact includes the financial returns to graduates and postgraduates as they secure employment or develop as entrepreneurs who create and grow companies that increase the economic value of science, which includes social science, technology and engineering [3]. This is particularly the case when these businesses are involved in reforming or revolutionizing the pattern of production by exploiting an innovation or an untried technology to produce a new commodity, produce an old product in a new way, create a new outlet for products, or reorganize an emerging industry [4].

This spectrum of benefits has been reinforced with a recent analysis which shows that an increase in the presence of universities in a region is positively associated with faster subsequent growth. To some degree, this growth is influenced by the supply of innovation derived from the combination of research outputs and human capital rather than simply increased demand [5].

Not all universities operate under funding regimes or economic and social environments in which it is easy to deliver these benefits or change their regime of scholarship. To varying degrees, they are influenced by levels of funding that include the preference of some governments to focus their research interests in national research institutes rather than universities. They are also influenced by ownership, whether private or public, and in economic terms there is a very significant influence from the nature and dynamics of the business environment in which they operate. They are also influenced by social factors such as population dynamics and the age profile of their catchment area, whether regional, national or international, and by national culture that includes the legacy of history.

Despite these and many other differences, what has emerged is a global economy that is becoming increasingly based on the production and use of knowledge. This has led to a growing demand for access to premium knowledge by individuals, business and governments in order to deliver the commercial and social imperative of translating this knowledge into economic activity.

Looking forward, the view of many governments and organizations such as the League of European Research Universities [6], UNESCO [7] and the Arab Academy of Sciences [8], and commentators on Arab universities [9], is that no region or nation can remain a simple 'user' of new knowledge but must also become a 'creator' of new knowledge.

This wider vision has also been set out in the United Nations (UN) Addis Abba Action Agenda of 2015 in which the notion was extended to include the wider implications of research by stating "the creation, development and diffusion of new innovations and technologies and associated know-how, including the transfer of technology on mutually agreed terms, are powerful drivers of economic growth and sustainable development" [10].

Meeting this challenge will not be simple because it will require an increased level of mutual understanding and coordination of the respective activities and roles of universities, business and governments.

2 Meeting the Challenge of Linking Universities, Business and Government

It is important that universities continue to evolve in order that the current model on which so many are founded does not outlive its usefulness. This will require all universities to continue to develop teaching and research activities that ensure their graduates have the knowledge, skills and capacity for critical thinking in order to add value to society; they need to attract the interest of business by producing research and educational outputs that match the demands of a modern economy; and they need to secure the funding to enable them to undertake these functions with integrity.

All businesses, regardless of size, need to adapt to ensure they build and retain a competitive advantage for their products and services. They need to improve their operational efficiency to make productivity gains and decrease their levels of environmental impact and stay ahead of competitors or create new markets. Some of these changes can come from skilled leadership but as the complexity and reliance on innovation increases, strategies that are being adopted to drive this include: recruiting graduates that bring with them new knowledge; creating in-house research and development (R&D) departments; forming research, consultancy and collaborative links with universities and government research institutes; and where necessary establishing open innovation strategies that include mergers and acquisitions that enable them to acquire technology from other businesses, as well as working with their supply chains and customers.

Governments also need to put in place policies and funding to support not only the national research base but also those that support the integration and application of research outputs that result in beneficial social and economic activity.

These policies and funding streams need to focus on supporting universities and research institutes, as well as implementing tax policies that encourage businesses to invest in R&D. An example of this kind of strategy is that China in its 14th five year plan has increased its tax deductions to 100% for R&D expenses for manufacturing firms and the country is planning to increase the proportion of its GDP it spends on R&D [11]. In addition, there need to be good standards of probity that encourage competition based on innovation-led novelty for customers not on monopolistic tendencies.

Despite acknowledging the importance of these three stakeholders the remaining challenge is what combination of planned policies that encourage individual choices are most likely to deliver the desired economic development and how can these policies and choices be linked to drive innovation. One suggestion [12] has grown out of an idea based on a triangle [13] that links science, government, and industry, and has now become the subject of an explanation described as the Triple Helix model [14].

This is based on the proposition that there is an increased chance of driving innovation-led economic and social development if: (a) there are effective knowledge transfer structures in universities that are supported by academics with access to appropriate levels of funding for research out of which to transfer ideas; (b) a commercial sector is willing and capable of absorbing the research findings and converting them into fulfilling a need in their market and selling this above cost; (c) a government is prepared to commit to fund discovery (research) at a level that is beyond the risk profile that can be tolerated by the majority of the private sector and has a long term national benefit.

A critique and debate about the Triple Helix explanation recognize that to implement this relationship there are a number of enablers and barriers that exist to differing degrees in different countries and cultures. These include, among other factors, relationship issues in different cultures between government, universities and business; challenges related to the perception of the status of universities and their capabilities; and the prevailing government policy environment for their university and business sectors [12].

Achieving the kind of relationship between these three components of the model into an economic theory still remains the subject of debate [15]. Questions that are central to this include the degree of control each of the three organizational groups has over their own activities, the extent of their capacity to undertake research, the relationship they currently have in place with each other, the extent of government policies that foster and support these links, the degree of funding required to drive collaboration, and how to ensure that all parties in the relationship accede and respond to the common value of working to drive economic and social development [16]. In the context of regulations, at best these regulations need to be either neutral or positive in relation to elements that include funding national research particularly for universities, business regulation that encourages investment in R&D such as tax benefits, intellectual property (IP) legislation, and factors such as those defined by the World Bank Doing Business for measuring business regulations [17]. However, despite these questions this model has value in visualizing a framework for discussion between stakeholders in order to try to create an agenda that can lead to integrating policy for trying to maximize innovation [18].

3 Research Universities

The OECD summarized the key characteristics of leading research universities as: (a) producing pure and applied research; (b) delivering research-led teaching; (c) offering of a breadth of academic disciplines; (d) operating a high proportion of postgraduate research programs; (e) working to secure a high level of external income; and (f) developing an international perspective. To add granularity to these characteristics, the League of European Universities [6] proposed that universities can engage in research at three levels of endeavor. In this nomenclature those involved in 'basic-research' have structures that focus on funding streams through which to engage in creating new knowledge. This enables offering an education to those individuals that have a high-level capability and ability to exercise the necessary 'disinterested' view and show the creativity necessary to define new knowledge that becomes, at some point, the ultimate source of innovation in the economy, society and culture. Universities that are 'research-intensive' tend to attract teachers who have leading-edge knowledge, mainly acquired through research, but it can be through practice and provide a combination of basic and research-based education. Those in the third category are 'research-universities'. These offer student courses in a breath of disciplines but maintain their standards of teaching by creating opportunities for teaching staff to undertake research to enable the provision of a research-based education [19].

To implement these institutional strategies requires selection in the recruitment of undergraduates, postgraduates and staff, and the capacity to fund the research base. The competitive nature of universities as they seek to recruit the most able staff and students follows their historic practice of elitism. Despite the increasing capacity of universities this competition remains, and international ranking of universities reflects this inclination.

There is little doubt that these research-based universities remain as central institutions of the twenty-first century by providing access to global science, producing basic and applied research, and educating key leaders for academe and society. However, they are expensive to develop and support, and the pressure of massification has placed priorities elsewhere in the university system. For developing countries, research universities are especially rare and yet they are important as key ingredients for economic and social progress [20]. However, there is a view that [8] among the number of Arab universities there needs to be a process of supporting selectivity and to focus development on creating a few 'basic-research' universities in the Arab region to match the rising standards of performance that is now being documented through university ranking programs. More importantly, this selectivity will provide indigenous education for the best and most able science undergraduates who have the potential for a career in 'basic research'.

History shows that in the 1950s the traditional funding model of basic-research, research-intensive, and research-universities was one of being sponsored by governments or other benefactors. They were selective in their intake and the number of places was limited either by regulation or restrictions on funding from the public purse. Once recruited, most students left with a degree while a few secured a place to undertake postgraduate studies, which in the case of studying for a PhD was considered to be necessary training for a career in research. There was also an expectation that academic staff would extend scholarship through research on which they based teaching premium knowledge in a relatively narrow range of disciplines. In many research universities the choice of topic for academic research was often a personal matter and less related to the needs of commerce, business, industry, or government policy than is expected today.

Historically many lower income countries outsourced their demand for places at university by sending students overseas with destinations for study in the United States and across Europe as examples. In more recent times, the response to this growing demand for a university place has been to stimulate a national supply; however with reducing levels of national funding for universities, their only source of revenue has been to increase the number of fee-paying students with the result of adding to the teaching load of academics. A consequence of this is that faculty staff have reduced access to research funding and have less time for research which in turn has a deleterious impact on their regional economic value. This regional influence of universities is further undermined in those Arab countries where national research institutes receive the greatest proportion of public research funding because they very often work towards national research priorities, while universities tend to have broader links to regional economies.

4 Investment in Global Research: An Increasingly Competitive Environment

In an international context, figures for 2013 reported 7.8 million full-time researchers worldwide, representing a growth of 21% since 2007. This growth was spread unevenly across countries with China reporting the highest growth and an increasing proportion of researchers at 19.1%. Arab states in Africa and Asia together accounted for another 1.9% [21].

In parallel with the increasing number of personnel involved in the research there have been heightened levels of global investment in R&D. Since 2000, international expenditure on R&D has more than tripled from USD 676 billion to USD 2.0 trillion in 2018 [22], and in 2013 [23] the overall investment by the world's top 2500 companies in their R&D activities totaled USD 645 m.

OECD [24] data reported that businesses undertake the largest share of R&D in most economies and more than 60% of the R&D expenditure in OECD countries. This has remained stable in most of these countries across the 10-year period 2005 to 2015. However, this expenditure has increased in the US, China and Turkey but has fallen in some other states. The majority of R&D is also reported to be typically concentrated in a relatively small proportion of the business population, especially large firms.

In contrast, in a number of smaller OECD countries, small and medium sized enterprises account for a larger share of this expenditure; however, the report indicates that in OECD countries, government is a minor performer in actually undertaking research, but is a major funder of R&D in universities through grants and in the business sector through tax rebates against investment in R&D activities [25, 26]. One aspect of the terms and conditions now being demanded in competitive public funding for university research is it must prove its 'impact' in underpinning innovation [27]. These broad-brush statistics are important in showing the upward trend in R&D expenditure. However, with increasing financial constraints on most government funding for universities as they grow their role in teaching, their role in research is commonly being squeezed.

At a university level, in order to overcome this challenge many universities are building soft and hard infrastructure to exploit the products of their research. This model first emerged in the US through a largely bottom-up driven process that came out of the Bahy-Dole Act 1980, which enabled universities to exploit their intellectual property [28]. Since then the concern to increase the impact of universities on the development of communities (business and society) has been progressively adopted in other countries and the pace at which many universities are restructuring their technology transfer activities to grasp this opportunity, is gaining momentum. In contrast to the increasing level of expenditure R&D there has also been an alternative strategy to drive economic growth. Some nations have taken non-R&D intensive paths to economic growth, for example by serving as low labor-cost locations for the manufacturing and service needs of other nations, by licensing or acquiring the intellectual property needed for production activities, and by extracting and refining natural resources (e.g. oil, gas and minerals) [22]. However, in many of these countries, the increasing ambition of new cohorts of graduates to participate in their economies with higher levels of personal reward has created a rising tide of social pressure to build increasing levels of engagement with the knowledge economy, as evidenced by many countries now publishing innovation strategies that are directed to reduce dependence on these natural resources.

Looking ahead it is apparent that research-based universities will gain in importance as central institutions of economies in the twenty-first century by providing access to global science, producing basic and applied research, and educating key leaders for academe and society. However, they are expensive to develop and support, and the pressures of massification has placed priorities elsewhere in the university system. For developing countries, research universities are especially rare, and yet they are important as key ingredients for economic and social progress [20], particularly so because the distribution of the world's research resources remains very skewed. Almost all of the world's researchers are located in Europe, North America, and Eastern Asia. Sub-Saharan Africa is home to just one hundredth of the world's researchers, even though one seventh of the Earth's population lives there. In addition, nearly all the research resources in the world go to solving the problems of economically rich countries. For example, very few resources are used to combat infectious diseases that affect people living in poverty, or to refine crops grown mainly in low-income countries. All countries need to conduct their own research so that they can find solutions to problems and develop into sustainable societies, where both people and the environment can thrive. Research also plays an important role in democracy because it contributes to critical thinking: it provides the knowledge necessary for people to make wise decisions and question the actions of those in power [29].

5 Arab Universities

The expansion in the number and capacity of Arab universities is part of the increase in the global level of provision of the sector that started in the 1950s in the United States. In 2020, 20,000 [30] institutions labelled themselves as universities worldwide. Of these, 1400 are ranked annually in terms of their performance [31]. This growth reflects an international increase in demand for access to premium knowledge [32], a predicted 265 million university students will attend a university by 2025 [33], and the proportion of graduates in the 25–44 age group of the population in some countries will be close to 50% [34].

In the context of the universities across the Arab region, there have been a number of reports, reviews and critiques based on the pragmatic exploration of their teaching, research and development, and innovation activities [8, 9, 35, 36, 37]. Several observations reflect positive research-related activity and the potential for the extension of this, while others reflect on the very significant challenges facing Arab universities in their work to maintain the research-teaching unity and extending this into 'integration' and 'application' to drive economic and related social development.

Measurement of this relationship is difficult in Arab Universities because of the lack of published national data on their R&D activities and the level of investment they receive from government [35]. This dearth of data has resulted in a degree of underestimation of the commitment to this activity within universities. This is particularly the case where the bulk of expenditure on this research has been funded by government rather than by business.

UNESCO have also reported that Arab States are launching initiatives to better interconnect university curricula to the needs of the economy; in 2013 it was reported that 1% of global R&D expenditure is in Arab States [38]; Arab countries are closer to gender parity by those involved in research compared with other countries, e.g. in Europe [39]; and there is increasing intensity of the publication of research findings [38].

There is also a growing regional policy focus on knowledge as an engine of economic expansion with organizations such as the Arab Association of Universities taking a stance that Arab higher education would benefit from reforms to keep abreast of global changes and advancement in order to serve socio-economic development goals. Responses to this include the publication in 2007 of Saudi Arabia's National Science, Technology and Innovation Plan that heralded a more diversified technology and innovation-driven, knowledge-based economy by 2030 [40]. This included a series of investments to drive this, which included funding for SMEs, soft and hard infrastructure such as incubators, and business education on IP. There are also larger projects such as the King Abdulaziz City for Science and Technology (KACST). The UAE published a National Innovation Strategy in 2014 [41] that incorporated an involvement of its universities by promoting research and innovation across the sector, and knowledge sharing across universities, research institutes and innovation incubators. This project also provides educational material about innovation for both the compulsory and post-compulsory education sectors with associated investment in laboratories to promote invention. Two specific programs noted include an investment in the Semiconductor Research Centre (KSRC) at Khalifa University that is now reporting a wide range of Centers of Excellence in a range of advanced technologies [42], and Abu Dhabi University hosting an incubator that not only focusses on a number of specific technologies and industries but also offers an option that is industry agnostic [43]. There is also a move for many universities across the region to set up Technology Transfer Offices (TTOs) to support the exploitation of IP [44, 45].

Other countries in Arab region that have published industrial and innovation strategies include:

- An industrial acceleration program in Morocco to create clusters in which universities are reported to be active partners [46].
- In October 2020, the Tripoli-based Libyan Ministry of Economics and Industry announced that its Innovation Committee was planning to develop indicators to monitor innovation in the country [47].
- A study of the impact of innovation policies in Algeria recommended a number of strategies to finance innovation and increase the engagement of the private sector in driving innovation while also encouraging education and training to support innovation [48].
- In 2018, Tunisia passed a new 'Start-Up Act' to clear the path for innovation with the intention of driving economic growth [49].
- In 2016, Sudan launched its 'Innovation System Landscape in Sudan' that clearly stated an important role for its universities in delivery of its broad-based objectives [50].
- A report on Innovation in Iraq [51] makes no mentions of universities, however, a separate report [52] has noted a recommendation in 2012 that there is a significant need for help supporting the research infrastructure in the country's universities.

- In addition to these national plans, there are a number of university-based initiatives such as the Centre for Research and Innovation (CRInn) [53], which plans to strengthen the American University Beirut Tech Transfer Office in its commitment to expand its capacity to drive innovation from its research base.

Notwithstanding these positive features of research in Arab universities, the commentaries [8, 35, 36, 37] also identified a number of historic external influences on individual academics and on the university sector as a whole that they recorded as making it difficult for universities to gain traction and have the impact on economic and social development from their research base that they would like to achieve.

Funding for public universities is commonly paid as grant; however, the findings of a UNESCO report show that the major proportion (80% to 90%) of these funds are being allocated to teacher and staff salaries and there is little left for investments in the learning environments or infrastructure development, in further education, in research or student services [54]. In addition, there are added challenges of few published national research strategies [55] and where these do exist, the majority of funds are directed to research institutes. This leaves universities to work on their own, meaning that research in universities is at a relatively low level and research training is not high on the agenda. Much of their potential, therefore, is being overlooked and the private economic sector has taken relatively minor interest in higher education and in research in particular. This may also reflect the fact that often the main movers of the economy in many Arab countries have been large international companies which have little interest in developing the local economies and tend to recruit their main – and well educated – manpower from other international sources.

The commoditization of a university education to match increasing demand over the last 50 years in nearly all countries has, in part, been funded through public subscription, but it has also attracted significant private investment with some countries licensing overseas operators to establish a branch campus. In Arab countries this massification has seen the number of universities increase to over 700, with more than 250 of these being funded by the private sector. This leaves the majority financed by the public sector [54] but the share of private sector provision is increasing. This has enabled student enrolment to exceed 10 million and the number of faculty members has reached 350,000 [56], but little in the way of interaction or collaboration on innovation between the two sectors is apparent. If this is a challenge, then it is an aspect of the university sector that can be addressed.

This expansion of capacity in private universities has increased access for young people to a university education. However, maintaining the unity of research and teaching has presented difficulties because the economics of funding both science-based research and teaching has limited the growth of research activities. It has also been necessary to attract and develop academic staff that can teach the premium knowledge required for a university education. The acquisition of this leading-edge knowledge comes through practice and research, but the scarcity of government funding for research has increased the challenge for academics to maintain their connection between research and its distillation into premium knowledge. This has meant that many Arab universities, particularly those in the wealthier Arab countries, are drawing in academic staff from other less wealthy parts of the region. Despite the movement of academic staff between countries having value in building academic connections, there are a number of negative repercussions for universities in countries where income levels are less competitive for staff, and the consequence is that they migrate to higher income jobs abroad. In addition to this, where research funding is at a low ebb there is a risk of breaking the link between research and teaching. This question also raises the challenge of whether there is any value in universities with reported low levels of investment in research recruiting staff that have undergone the research training of studying for a postgraduate research degree which then continues to undermine the research-teaching unity. In addition, the scale of demand for undergraduate studies has influenced the curricula on offer with a greater inclination towards 'comprehensive studies' through mixed options rather than focus to on STEM subjects that are more costly to run [9]. The reduction in university research has also had an impact on the capacity to create cohorts of 'home-grown' postgraduate researchers, help them move on as early career researchers and continue to build the necessary indigenous capacity to develop research expertise in order to address regional and national challenges. These additional factors need to be addressed to try to rebalance the research activities in universities.

The formalization of assessment of universities through international ranking mechanisms relies on the productivity of their academic staff [31]. This research-led activity has a significant influence on shaping and dictating an individual academic's career and status among peers as they become recognized as disinterested experts through their publication and citation record, improve their value as teachers, and raise their status through professional accolade [19]. This personal record also has important ramifications at an institutional level. The international ranking of individual universities is partly measured though publication and citation rates which helps these institutions gain prominence and status. In turn, this influences the recruitment of their graduates in the employment market [57] and has an impact on attracting research funding from business and government.

A number of questions have been raised about the method of weighting in world ranking systems in the context of them favoring certain institutions. These include restricting the weighting of publication and citation rates to those in the English language and to some specific disciplines because these outstrip others, helping to elevate universities that focus on engineering, health, and other non-social science subjects. Other social and economic factors that make it difficult for universities in some regions to gain visibility in international rankings include:

- A lack of any substantial state and private sector funding for university research.
- The time that academics can allocate to research is limited because of the demands on their time for teaching.
- Difficulty in securing internal funding for research equipment.
- The infrastructure to support bids for research funding is not well established.
- At a personal level, salaries are low which means some academics take private tutoring roles to supplement their income.

There has also been a loss of talent through the Arab diaspora which is evidenced by a disproportionately high number of patents in the US in which Arab authors are citied compared to the number of Arabs in the US population [56].

Recognition of the challenges faced by Arab universities in securing a ranking that is commensurate with their performance has prompted the publication in 2021 of a Regional Ranking for the Arab regions by the THE World University Ranking [58]. This is planned to evolve over time to ensure that it continually reflects the changing higher education landscape in the region and supports strategic goals across different university missions. This regional ranking is planned to continue to assess research output but sets a regional standard of 500 publications over a five-year period compared with 1000 publications in the global table. Both universities and institutions that do not teach are eligible for inclusion and it will use metrics that are specific to the missions of universities across the Arab world. This includes reflecting the important work being undertaken on sustainability based on the United Nations' Sustainable Development Goals. This will also incorporate the results of an academic reputation survey based on views of published scholars on the universities across the region [59]. Participation in this new regional ranking is expected to help to increase the level of influence on the way universities are managed by their local governing bodies with respect to their research activities [60]. It is anticipated that it will help to develop student-facing services, influence the development of knowledge transfer programs, and with these changes help universities build symbolic capital. The recognition of the importance of universities in these reports will help Arab universities to show much societal leadership, which is needed in order to secure their positions in the region and to engage with regional challenges when governments are funding major national investments [8].

A further challenge for Arab universities is that many of their graduates find it difficult to find meaningful employment. The need to address this imbalance of demand for meaningful work and the creation of relevant employment is now pressing universities across many countries but it is particularly challenging in the Arab states where youth unemployment is reported to be already be one of the highest in the world. Employers in the region have observed that university graduates lack the skills needed to work in the global marketplace [61]. Many are not well-trained in science, mathematics, engineering and other technical subjects that are believed to have the most impact on employability. In addition, these observations suggest that insufficient numbers of graduates have the necessary 'soft skills', including creativity and teamwork, to make an impact when employed by business, partly because their training has overemphasized memorization and rote learning.

However, on the positive side it is not uncommon in many countries and universities to find a growing interest by entrepreneurial graduates in creating their own businesses because they understand the level of productivity that can be achieved in business with new technologies. An example is the creation of a full student enterprise program in Gadjah Mada University in the Indonesian city of Yogyakarta [62]. This university has a selective intake, has built a research base and now offers opportunities for staff to create businesses on its science park as well as offering student enterprise as an option in its curriculum. This is also common across the spectrum of Chinese, Korean, and other Asian universities as well as across the EU, UK and USA. This opportunity is also now being developed in some Arab universities. These innovation-focused entrepreneurial graduates, who understand the level of productivity that can be achieved in business with new technologies, are a key national resource, with the adoption of a number of program that include a strong commitment to supporting student enterprise programs [8].

The conclusion of the World Bank is that future economic growth and performance will be influenced by knowledge and that the successful transition to this 'Knowledge Economy' will require long-term investments in education, developing innovation capability, modernizing the information infrastructure, and having an economic environment that is conducive to market transactions. This will require the efficient mobilization and allocation of resources to stimulate creativity and incentives for the efficient creation, dissemination and use of existing knowledge. It is also necessary to have an appropriately educated and skilled workforce that can continuously upgrade and adapt its skills to efficiently create and use knowledge. This involves developing an effective innovation system of firms, research centers, universities, consultants and other organizations that can keep up with the knowledge revolution, tap into the growing stock of global knowledge and assimilate and adapt it to local needs. This system needs a modern and adequate 'information' infrastructure that can facilitate the effective communication, dissemination and processing of information and knowledge [63].

Commerce is a necessarily competitive activity. Discovery focused research, on the other hand, is concerned with creating a collective view in a disinterested manner. Although these two perspectives are mutually exclusive there is a view today that if countries want to compete at the highest level, they have to treat university-business collaboration as a competitive advantage.

The increasing demands placed on universities for their strategies to support economic development through a research role is in many countries an embryonic process. It is also true that even in many developed countries the ambitions are still under development because the scale of variables in the process – not least of which is that innovation entrepreneurship is a relatively high-risk activity and requires a planned environment – matches the needs of personal choices, which in turn requires collaboration. The importance of fostering this collaboration has long been a challenge for governments. In the UK alone there have been more than 15 reports on the relationship between business and universities since the late 1990s and the matter continues to be a topic of debate. In 2014 the UK government reorganized this and created the National Centre for University Business Collaboration [64] to work on creating and reporting the output of this collaboration. Many other countries are also putting in place programs to raise the performance of their universities with some focus on moving towards becoming more entrepreneurial. Examples include the 'Excellence Initiative' across Germany's universities [65]; the application of the Research Excellence Framework in UK universities [66]; the structural reorganization of higher education in France where research-focused academics have to align themselves with research poles [67]; the Chinese government's 'Project 985', 'Project 211' and subsequent plans such as C9 [68]; and the Russian 5–100 program

[69]. In the UK, the government merged the Research Councils and its Innovation Agency to create UK Research and Innovation (UKRI), and with that required all applications for research funding to demonstrate impact if they are to be eligible to apply for an award. The UK government also is trialing University Enterprise Zones that are focused on coordinating business and university links [8].

An additional dimension to this strategy is the need for universities to fund the deficit they face through lack of funding for research or non-full cost basis from government-funded research. Some universities are developing entrepreneurial strategies of pushing research outputs up the value chain and taking these to markets as IP that can be licensed or through forming a company. In addition, many universities are now building enterprise into their undergraduate curriculum and providing training at postgraduate research level. The aim is to increase awareness of the need for research output to deliver 'impact' and, where possible, income from IP by creating incubation systems to support commercialization and generate value in the marketplace.

The OECD also published advice for universities looking to drive cultural change in order to increase their impact in driving economic development by evolving into a more effective entrepreneurial based institution [70]. This advice includes: developing leadership and governance that creates a role model for students; building organizational capacity and incentives to enable and encourage entrepreneurship; adding entrepreneurship to the curriculum; creating pathways for entrepreneurs, particularly for the formation and growth of 'Micro' companies (fewer than 10 employees) that can scale to create a raft of Small and Medium Sized Enterprises (SMEs i.e., >10 employees and <250 Employees); and building business and other external relationships for knowledge exchange [71, 72].

Many governments and business organizations respectively recognize the value of these Micro companies and SMEs in driving economic performance and innovation [73, 74]. In the EU, SMEs represent 99% of all businesses, employ around 100 million people, account for more than half of Europe's GDP and play a key role in adding value in every sector of the economy. The value flows from these SMEs is reported in creating innovative solutions to challenges like climate change, resource efficiency and social cohesion, helping to spread this innovation throughout Europe's regions and are regarded as important in the transition of Europe to a sustainable and digital economy. SMEs are seen as important in competitiveness and prosperity; within industrial ecosystems, they provide economic and technological sovereignty and help with resilience to external shocks [75].

Notwithstanding the cultural aspects of creating change to this business landscape many universities are creating internal structures that are focused on building links with their regional corporate and SME business sectors to contribute to adding new skills and capabilities where needed. They are looking for opportunities for innovation, helping companies to adopt new business models and new ways of thinking, and investing in digital transformation.

In the context of the business community in the Arab region, this has a very broad base that spans from large industrial conglomerates to start-ups that are now beginning to populate business incubators across the region, in terms of the sectors represented, and the management structures and ownership. In addition, the attitude of governments to business varies. For example, at the large industrial scale it is not uncommon for governments to buy in expertise from outside the region [9]. An example of where this can be seen is in the cross section of businesses in the Dharan Techno Valley which has historically predominantly attracted large international corporations to set up R&D centers [76]. This site is now offering wider access through an Innovation Center, an Entrepreneur Institute, Prototyping Centre, and Industrial Liaison Office in order to create indigenous capacity.

Setting apart the large industrial complexes that operate in managing natural resources in the Arab region, a review-based study of the structure of the business environment in the Arab Middle East over an 18-year period to 2018 concluded that there are prevalent culture traits of patriarchy and collectivism resulting in family businesses dominating the business landscape. These companies represent over 90% of all companies that employ 80% of the workforce and contributing to 60% of the GDP [77, 78]. The report also noted the top challenges for creating growth in this important stratum of the economy including establishing the right skills base, a need for innovation and some modification to the national financial business regulations in order to support entrepreneurship, and sourcing employees from the pool of graduates that are seeking employment [77].

Taking a broader view, the regulatory environment for business across the Arab region [17] shows with some exceptions that this creates significant barriers to progress. One of these regulations that is around bankruptcy may be a factor in stalling entrepreneurship and investor interest in supporting entrepreneurial businesses [8]. In addition the high levels of government regulation of business in some countries makes for a difficult operating environment: there are varying degrees of corruption and sectarian influences, and fragmentation of family businesses because of inheritance laws and traditions that do not separate corporate and family property. In the context of universities, historically there have been few student 'enterprise' programs, all of which adds to the challenge because of the poor understanding of business, commerce and exploitation of IP.

To develop the structures and the processes that support the relationship between research outputs and economic development is not a simple matter. These complexities are grounded in a raft of variables, including the benefits and constraints imposed by culture and social norms. There are wide variations in the attitude of those involved in research, which includes the timescales for delivery: universities commonly operate much more slowly than industry for a number of reasons, such as the extent of academic researchers' workload and the depth to which they like to take discovery process compared with a business that, unless the research is strategic, normally look to gain results more quickly. There is broad variation in the way governments prioritize their funding for research and the research systems. This includes whether they have research strategies that have long-time horizons, or the priorities are focused on shorter term gains through incremental innovation. The presence and performance of the mechanism for linking research outputs to users – the final step – is the interest and capacity of the market to pay the economic cost for outputs and, through that capacity, to share the risks of undertaking research.

6 The Response by Universities to these Challenges

The continuing influence on universities from the demands of business, expectations of government, and the demands of students has resulted in a number of changes to the way universities structure their activities. These include changes to the contents of the curriculum that is offered to undergraduates and how this is delivered, how postgraduate researchers are trained and postgraduate research programs are conducted, the responses they make to opportunities for securing research funding, and the way Technology (Knowledge) Transfer (Exchange) programs are now developing in response to government and business in terms of seeking research funding and outputs.

Many universities are now exploring and implementing student enterprise strategies in order to increase their relevance to students, business and government in terms of both undergraduate and postgraduate education, including postgraduate research, to make the outcome more relevant to the prevailing economic environment. The intention behind these programs is to help students to develop transferable skills such as idea generation, public speaking and business communication. Typical business courses, taking examples from the University of Surrey, include a Bachelor's course in Business Management with modules for students in other disciplines that include, for example, Entrepreneurship in the Digital Domain, Social Entrepreneurship, Entrepreneurship and Innovation, and Engineering Enterprise Projects. Others include a Masters course in Entrepreneurship and Innovation Management, and MBA modules in Problem Solving and Innovation Thinking.

For those students that are interested in creating a company, there is a series of programs that include skill sessions and opportunities to undertake a placement in businesses, followed by the opportunity for team building at a three-day boot camp. This provides a 'primer' for market evaluation exercises, and from that individual ideas are exposed to an acceleration program that leads to an opportunity to pitch for a small initial fund. Those that demonstrate commercial value are then offered the opportunity to pitch for sufficient investment to establish a company, begin to build a network to showcase their idea and gain access to business networks and wider networking (Fig. 1).

There are also programs that are focused on doctoral college students which are typically offered as a residential course branded as a 'Research to Innovator program' and include meetings with industry. These provide an opportunity to **explore the value of entrepreneurial thinking as a means of advancing ideas and research into impacts – whether scientific, economic, social, cultural or environmental – with the view to assessing value.**

In the UK, a more advanced program has been developed by the government's innovation agency Innovate UK. This is branded as 'Innovation to Commercialization of University Research' or ICURe [79]. The program enables teams of academic researchers who wish to explore the commercial potential of their research to use this structure in their decision making. Initially developed as a pilot that demonstrated the methodology of the project and process, participation has proved to be

Fig. 1 Student enterprise program

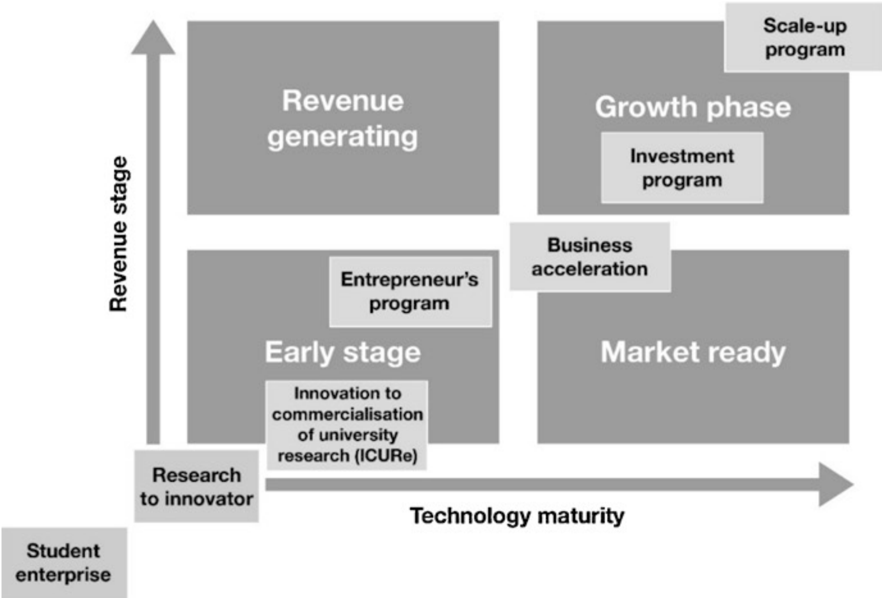

Fig. 2 Revenue and Technology Maturity programs for university spin-outs

successful on a number of fronts with high levels of additionality. This and the further programs noted in Fig. 2 take technology through additional levels of commercial tests that help to define its technology maturity and market potential. This series of opportunities has resulted in increased and deeper links between participating academics and industry that in many cases help to accelerate the commercialization and the technology development process. These additional programs include Business Acceleration, an Investment program and then, if successful, how to scale a business.

Many universities have improved the structures and management of their postgraduate research activities through the formation of Doctoral Colleges. The purpose of these is to enhance the experience of doctoral and postdoctoral researchers. Typical services offered include:

- Closer links between faculties/academic schools to enhance inter-disciplinary networks that can aid innovation.
- Training in the globally practiced 'three-minute thesis' in which doctoral researchers develop a research presentation in just *three minutes* with one slide, and an alumni network and post-doctoral network to encourage network approach to research output development activities.
- A link for post-doctoral candidates with external networks for employment opportunities.
- Locations on a campus that are dedicated to postgraduate research students.
- A structure that gives oversight of a university's postgraduate research activities and performance.

The impact of this not only has value for individual researchers but also has a number of wider benefits. These include business and other collaborators being better able to assess the consistency and quality of a university's research outputs. They develop local, regional and international networks for collaboration by contributing to regional entrepreneurial discovery, which links research to regional businesses' strengths that in turn help to influence regional economic development.

However, to achieve this and enable it to be funded there is a view that there will need to be differentiation in the academic system where some universities create international links that drive global research themes and others will focus their research on more local problems that require solutions that are deliverable in the context of local capacity.

The formation of science and technology parks (STPs) across Europe in the early 1980s was a first practical step in delivering the relationship and creating the linkages between research-teaching-integration-application. This happened at a time when the idea of the 'knowledge economy' was only just coming into focus and its economic and commercial imperative was still not fully understood, other than by a few leaders in the USA, UK and European universities.

These leaders also realized that, for universities to retain their historic role of research based teaching, they would need to create an environment around their campus that has the capacity to take knowledge beyond the discovery stage to the marketplace. Closing the innovation gap has become a necessary role of universities and innovation has become as important a mission as teaching and research.

Today the concept of the STP has been adopted by nearly all countries as part of creating an environment in which entrepreneurs can deliver economic value to science. The level of sophistication of these projects has seen them develop programs that range from student enterprise, provision of incubators and accelerators, space to scale a business, and even act on a national focus for attracting large companies to the country. In addition to providing the infrastructure for these innovation cultivators most universities have also established networks that link into commercial markets using mentors and coaches, investment agencies comprising external investors such as Business Angel Clubs, and created links with Venture Capital organizations, if not creating their own.

To align these processes requires effective governance structures within universities that understand the degree of sophistication necessary to create effective links to support the commercialization of science, while understanding the risks involved.

The process of connecting university research with business has been growing as a mainstream activity in the university sector over the last 50 years in Europe, but since 2000 the pressure to increase these links has increased as governments across all countries seek to driving productivity in terms of social and economic impact out of their public investment in research.

However, observations reported on the formal relationship between higher education and business in the Arab world in particular, is that these links have been slower to develop than in countries like China, Korea, and other south Asian countries [80].

The commentaries about the links between research activities in Arab universities and business has not developed as quickly because there are many instances where national governments have been bypassing universities when placing research contracts and using either research institutes or bringing in overseas resource to undertake the work [9]. There has also been underreporting of the relationships between business and universities.

The increasing demand on universities has resulted in the restructuring of technology transfer offices to provide a number of services. The evolution of these has created structures that encompass:

- Creating a Doctoral College structure to support post graduate research students.
- A team responsible for Innovation Strategy, which involves a small group responsible for linking with the regional business community and national/international companies, where appropriate. This team looks outward into the business community, and into the local and regional government to seek out opportunities for research projects.
- A team concerned with Research Strategy that looks inwards toward the academic community to assess where there are academic activities (Doctoral College and Academic led research) that can respond to government call for research bids or work with government departments to develop research themes that have a regional or local focus.
- Research and Innovation Services that provide a support function for academic staff writing research bids and assisting with the legal contracts for these projects and managing delivery.
- A student enterprise team that co-ordinates and delivers to students (undergraduate and post-graduates) enterprise related education and training (Fig. 2).

Some of the commentaries have also noted that there has been under reporting by governments of the research investment in universities.

To ensure there is national capability, governments need to work closely with business within the bounds of probity to monitor their interests and respond with high-risk ‘challenge funding’ for their research capability, which needs to include universities not just research institutes in order to be effective.

The relationship between universities and business needs to be clearly documented and managed: documented business-funded R&D efforts are generally more product-oriented and time sensitive, while academic research focuses more on fundamental research work to solve long-term challenges which takes time to produce results. This also overcomes the observation that companies often pursue the collaborations with universities in an ad-hoc piecemeal manner, based on individual initiatives rather than systematic corporate strategy, leading to duplication of effort, lost opportunities and disputes over intellectual property [81].

It is also important to recognize that the nature of the problems which companies want to address vary widely. These span an extensive array that, for example, include business strategy, management, product performance, markets, customer choice, and compliance with regulations. In addition, the nature of the questions raised varies across business sectors, within companies of different sizes and capitalization, and the maturity of the markets they address. This means that there are opportunities for research, consultancy, and collaboration across a broad range of disciplines. In response to this many business schools are looking to engage business by offering Continuous Business/Professional Development courses.

However, to develop the structures and the processes that support the relationship between research outputs and economic development is not a simple matter. These complexities are grounded in a raft of variables. These include: variations in the attitude of those involved in research, through the priorities of those that fund research and the systems they adopt for the allocation and distribution of funding for research, whether they have any explicit innovation policies to support moving research outputs into the market; the presence and performance of the mechanism for linking research outputs to users; and the final step of the interest and capacity of the market to pay the economic cost for outputs and through that capacity to share the risks of undertaking research. Tucked away under these national arrangements, there is also the question of how university funding and governance is managed.

7 Conclusions

The growing importance of the economic- based relationship between universities and business has resulted in increased interest in the underlying structures that increase the utility of research by linking research-based discovery with the solutions. If universities are to raise and maintain their status, they need to continue to build on the unity of research and teaching. This ideal has been stretched further through the growing obligation being imposed on them to work hard to ensure the premium knowledge they develop and teach becomes integrated and applied, to ensure community development through economic and social gains.

There is growing international recognition that to ensure this happens, the links between universities, government and businesses are cemented. The greatest influence on building this relation is the government, through the strategies, policies, and investments decision they make in relation to funding research. These can be directed at business to encourage links with universities or directed at universities to encourage business to seek out the premium knowledge created through research.

This view has been echoed by the Association of Arab Universities, which is promoting the idea that governments must prepare national strategic plans for science, technology and research in order to encourage all sectors within their states to work together towards common objectives and key performance indicators, including universities and higher education institutions.

The Association is also clear there is a need to establish a Pan-Arab scientific program for R&D, capacity building and exchange of students and staff amongst universities and institutions of higher education, as a necessary step towards enhancing and consolidating cooperation between Arab countries [56].

A further strand of knowledge transfer that leads to community development is the curricula offered to undergraduates and structures to support post-graduate research, particularly where this has local, regional, and national relevance. Encouraging opportunities for research in university also helps retain talent in the country.

The observations on research in Arab commentaries reported in the chapter reflect on the challenges of achieving this when academic time to commit to research is short and funding is hard to secure. A consequence of this is that Arab universities are finding it difficult to create the capacity to increase their international ranking; however, moves by the THE ranking to create an exclusive ranking metric for these universities will help to encourage closer focus on this part of the research-teaching unity.

The structures that have been developed to try to build and sustain gain value from university research are now penetrating university systems in all countries, because there is growing demand from students and business for this to happen.

These include:

- Research and innovation strategies.
- Developing and professionalizing the management of the research career path in universities through the creation of a doctoral college within a university. The purpose of these colleges is to help with recruitment and management of doctoral students and early career researchers.
- Improving measurement of the impact of university research through managing the research funding application and the assessment of the likely impact of research outcomes. This aims to encourage increased business and government involvement in university research, and in particular, in creating solutions to local challenges.
- Developing the concept of an entrepreneurial university to increase spin-off activities which involves adjusting commercialization strategies. This can include creating effective processes for student related research protocols, publishing advice for staff and student that include an 'Inventors Guide', and creating the necessary incubator or accelerator program to try to influence the success of company development.

- Increasing the level of collaboration between business and universities that can be aided with university publications; for example a guide on 'Advice for Collaborators', to help businesses navigate and connect with university research bases.
- At a national level many governments have responded to the increasing interest in the benefits of university research by creating research and innovation strategies in order to try to direct outcomes into positive economic outputs.
- A recognition that entrepreneurship has increased in importance in giving economic value to science and has influenced a number of government policies to link science with markets by funding translational research in the health sciences, and to support innovation in other sectors.
- The increasing influence of knowledge in driving economic development has influenced some countries to respond to this trend. These generally include two broad strands of activities. One is to increase access to HE to provide education, and where appropriate training, to create the flow of skills and talent that respond to the demands of an economy. To complement this, the other avenue has been to create policies that integrate higher education and research systems into macroeconomic policies to stimulate technology renewal by creating socio-technical systems [82]. These systems comprise clusters of elements that include technology, appropriate regulation, develop user practices and create markets, have cultural meaning, and the right infrastructure, maintenance networks and supply networks, which are now commonly defined as innovation systems [83].

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Ups and Downs of Science and Technology Indicators in Arab Countries

Adnan Badran and Serene Badran

Abstract Investing in research and higher education is a priority for building a knowledge-based economy dependent on human capital. Knowledge is gained from basic research to stimulate innovation, introduce new technologies in industry and agriculture, and develop new goods and services to overcome unemployment and poverty. Problem-oriented research by universities and research centers would lead to the creation of startups that are closely related to the development of wealth, as well as increased domestic production and income per capita.

Indicators show that the United Arab Emirates (UAE) leads the Arab countries in the Global Competitiveness Index. In addition, indicators show that investment in research is mostly made by governments in the Arab region compared to member countries of the Organization for Economic Cooperation and Development (OECD), where investment in scientific research is made mostly by the private sector. The United States continues to lead the world in science and scientific research funding by investing 2.8% of GDP ($465 billion a year) in the fields of scientific research and technological development, noting that 50% of Nobel laureates in science and medicine are American scientists.

UAE leads the Arab world (with 1.3% of GDP) followed by Jordan, Egypt, and Tunisia. The UAE ranks first in the number of researchers as FTEs (full-time equivalents) per million people followed by Tunisia, Morocco, Egypt, Jordan, Kuwait, and Oman.

As for the number of scientific papers reviewed by counterparts, China leads the world, followed by Unites States, India, Germany and Japan, while in the Arab world Egypt ranks first, followed by Saudi Arabia, and Tunisia. Turkey tops the density of indexed publications (Scopus in the Middle East) followed by Iran, Egypt, Saudi Arabia, Tunisia, Morocco, United Arab Emirates and Jordan.

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As an indicator of technology in terms of percentage of total exports, UAE leads the export of high technology, followed by Tunisia, Morocco, Lebanon, Egypt and Jordan. In patents, China, the United States, and Japan lead the world in filed patents while, Saudi Arabia leads the Arab World in filed patents followed by Egypt, Sudan, Morocco, Tunisia, UAE and Jordan. As for patent applications for every $100 billion of GDP, South Korea leads the world, followed by China, Japan, and Germany as pioneers of global science.

Keywords Science · Technology · Innovation indicators · Research investments · Publications · Hi-tech exports · Patents · Science in Arab region

1 Introduction

The Arab region is facing a widespread collapse, and the Arab hope now is to preserve what the Arab countries achieved with the United Nations Millennium Development Goals (MDGs) at the end of 2015. And it is doubtful that Arab countries can achieve the United Nations Sustainable Development Goals (SDGs) by 2030. Unfortunately, Arab societies are disintegrated due to internal wars and religious and ethnic strife, with some Arab countries classified internationally as failed states for being unable to achieve security, stability and prosperity for their people.

The question is, how to get out of this mess. The answer is to go to the basics of renaissance and enlightenment that is proper "education", and start international reforms to get out of the darkness to enlightenment, starting from early childhood, through primary, secondary, and higher education.

2 GDP per Capita of Arab Countries as Compared to the World

A comparison of the per capita GDP of Arab countries with other countries in the world (2019) clearly shows that Luxembourg leads the world with $114,705 income per capita, followed by Switzerland ($81,994) and Ireland ($78,661), Norway ($75,420), Iceland ($66,945), the United States ($65,298), Singapore ($65,233), Qatar ($62,088), Germany ($46,445), the UAE ($43,103), Japan ($40,247), Kuwait ($32,000), Bahrain ($23,504), Saudi Arabia ($23,140), Jordan ($4406), Egypt ($3019), and finally, Yemen ($774), as shown in Fig. 1 [1].

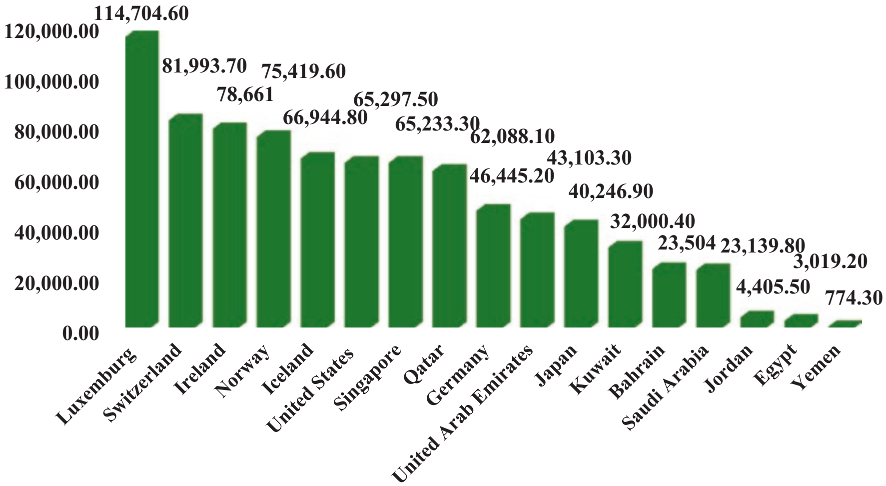

Fig. 1 Comparing the per capita gross domestic product (GDP) of Arab countries with other countries in the world. (Source: World Bank (2019))

3 Global Competitiveness of Arab Countries as Compared to the World

The natural ranking of global competitiveness (2019) clearly shows that Singapore leads the world index with 84.8, followed by the United States (83.7), the Netherlands (82.4), Switzerland (82.3), Germany (81.8), the United Kingdom and Sweden (both at 81.2), Finland (80.2), Canada (79.6), the UAE (75), Qatar (72.9), Saudi Arabia (70), Bahrain (65.4), Kuwait (65.1), Oman (63.6), Jordan (60.9), Morocco (60), Tunisia (56.4), Algeria (56.3), Lebanon (56.3), Egypt (56.5), and Yemen (35.5), as shown in Fig. 2 [2]. There is no doubt that the quality of education plays a major factor in the growth of research, technology and innovation leading to competitiveness.

Looking at the Arab region in Fig. 2, the UAE tops the list of Arab countries with an index of 75.0, followed by Qatar (72.9) and Saudi Arabia (70.0).

4 Who is Who Conducting Scientific Research

Universities are the leaders of research and development all over the world, contributing to 56% of global scientific research. Table 1 shows that basic research and applied research are mostly carried out by academia in universities (accounting for 29% and 25%, respectively) and scientific research centers (accounting for 9% and 8%, respectively). In fact, basic research has been neglected by the private sector which looks for rapid return of research for marketing purposes (Table 1) [3].

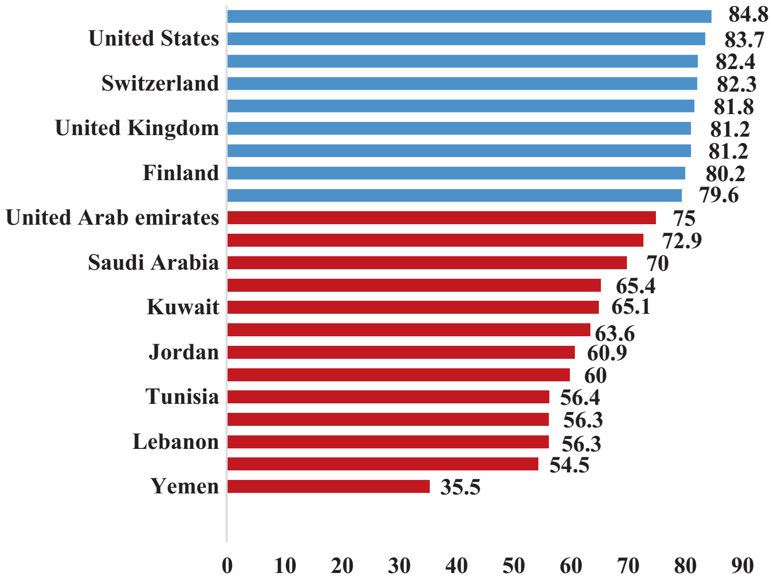

Fig. 2 Global Competitiveness Index 2019 in the ranking of countries of the world. (Source: The Global Competitiveness Report 2019 (World Economic Forum))

Table 1 Who is who of conducting scientific research internationally, 2014

	Basic research	Applied research	Development	Consulting & other	Total
Academia/University	29%	25%	1%	1%	56%
Research Institute	9%	8%	1%	1%	19%
Government	1%	3%	0%	0%	4%
Domestic Corp.	0%	2%	2%	2%	6%
Multinational Corp.	1%	7%	3%	1%	12%
Other Organizations	1%	2%	0%	0%	3%
Total	41%	47%	7%	5%	100%

Source: R&D Magazine

Government research on the world stage contributes to 4% of all scientific research, of which only 1% consists of basic research and 3% is applied research.

In general, companies direct their funding toward applied research and development as a short-term goal, and are not concerned with long-term basic research. This task is left to academia in universities, as well as research centers and institutes.

But when we look at the expenditure on research and development (R&D) in the Arab region, we find that research is mostly done through funding from the government sector (70%), as compared to countries of the Organization for Economic Cooperation and Development (OECD), where the private sector undertakes 70% of R&D (Fig. 3). Therefore, the outputs of R&D in developed countries are directed

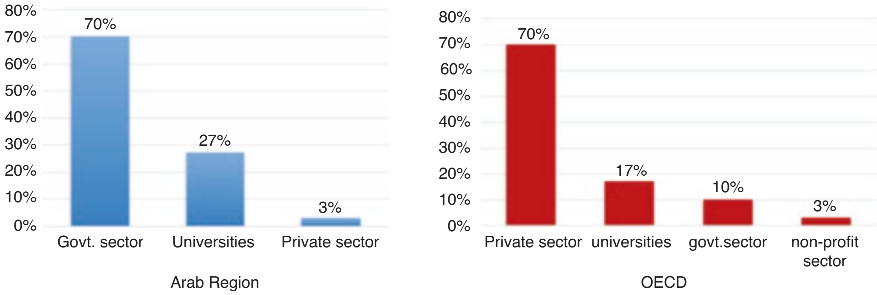

Fig. 3 Distribution of investment in scientific research between the government as a public sector and companies as a private sector in the Arab region compared to the industrialized countries. (Source: Badran 2018 [4])

towards industrialization and marketing, especially with regard to patents, while Arab countries lack not only the participation of the private sector in R&D, but also the lack of marketing incentives of government research outputs. Government funding for R&D is subject to reductions and instability as a result of emergency deficits in the government treasury [4].

5 Global Expenditure on Research and Development

Major industries and companies worldwide are setting up their own R&D laboratories to conduct research on their own. They hire scientists to do target-oriented R&D in order to acquire new materials or to create marketing technology, especially in the fields of internet, computing, software technology, electronics, pharmaceuticals, and automotive industries.

Global spending on R&D by industry is shifting towards a knowledge economy such as computing, software, internet, artificial intelligence healthcare and education, where quality education for building human capital is vital for driving sustainable research and innovation.

Total investment in R&D expenditure has maintained a great momentum worldwide as shown in Table 2. And the United States forms the pinnacle of competitive research intensity, as 2.8% of its GDP is spent on scientific research annually. It ranked first worldwide in 2018 for investment in scientific research, followed by China, and Japan (2018) [5].

Table 2 Indicators of spending on research and development, 2018

Share of total global R&D spending	
United States	25.25%
China	21.68%
Japan	8.52%
Germany	5.32%
South Korea	4.03%
India	3.80%
Russia	2.80%
Middle East	2.51%
Africa	0.92%

Source: R&D Magazine

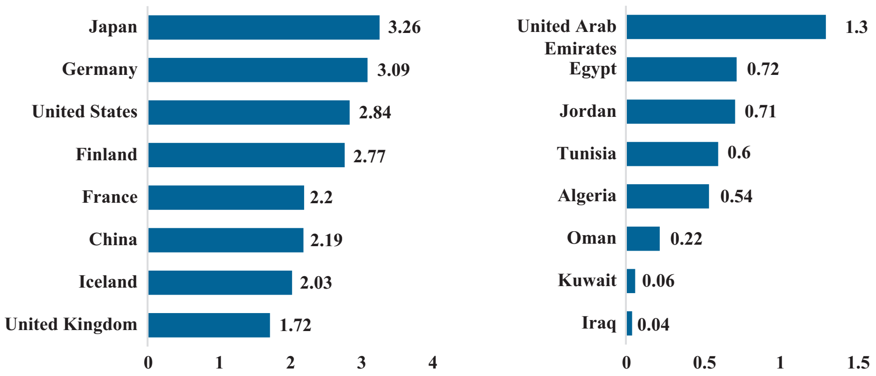

Fig. 4 R&D expenditures in Arab countries as compared to other countries in the world (as a percentage of GDP). (Source: World Bank 2017–2018)

6 Expenditure on Research and Development in the Arab Countries as Compared to the World

Indicators show that the Arab world has failed to devote 1% of their GDP spending on R&D as recommended at the United Nations Conference held in Vienna in 1979. The UAE ranks first with a 1.3% of its GDP dedicated to R&D as shown in Fig. 4, followed by Jordan (0.72) Egypt (0.72), Tunisia (0.6), Algeria (0.53), Oman (0.22), Kuwait (0.06), and Iraq (0.04).

While looking at other countries, Japan ranks first in the world in spending on R&D dedicating 3.26% of its GDP in 2018, followed by Germany (3.09), the United States (2.84), Finland (2.77), France (2.2), China (2.19), Iceland (2.03), and the United Kingdom (1.72) (Fig. 4).

Spending on R&D is crucial to maintain market leadership and ensure national security. Countries that increase their investments in scientific research are developing a better and healthier world for humanity. Of course, it is stimulated by free trade and competition on the global market. However, any short-term imposition of a national tax or customs by politicians is a short-term view that will lead to a humanitarian catastrophe and disrupt the lives of people on this planet. Therefore, in order to improve the quality of life on our planet, protectionism must be reduced in order to drive progress and scientific research with the aim to have more diversified goods and new technologies that allow people to lead a better life in a sustainable environment [6].

7 Researchers of Research and Development per Million People in Arab Countries as Compared to the World

Professional researchers participate in creating knowledge, new technologies and innovations, which would lead to new products and processes.

Figure 5 shows that Finland leads in the number of researchers with 6861 FTEs (full-time equivalents) per million people in 2018, followed by Iceland (6131), Japan (5331), Germany (5212), the United Kingdom (4603), the United States (4412), China (1307), and South Africa (518).

When we analyze the number of researchers as FTEs per million people in the Arab countries, we find that the UAE is leading with 2379 researchers in 2018, followed by Tunisia (1772), Morocco (1074), Egypt (687), Jordan (596), Kuwait (514), Oman (281) and Iraq (111) [7].

8 Published Scientific and Technical Journal Articles

Another indicator of science and technology is the number of research papers published in peer-reviewed journals, particularly in the fields of physics, biology, chemistry, mathematics, medicine, engineering and technology, and earth and space sciences. Scientific articles are good indicators of research outcome.

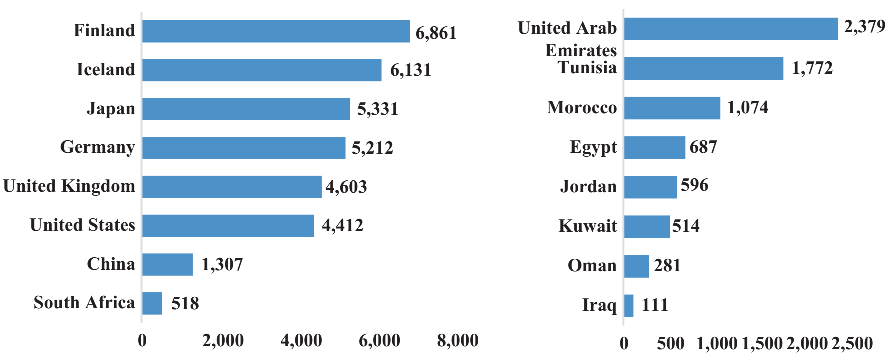

Fig. 5 Number of researchers as FTEs per million people in Arab countries compared to the world, 2016–2018. (Source: World Bank)

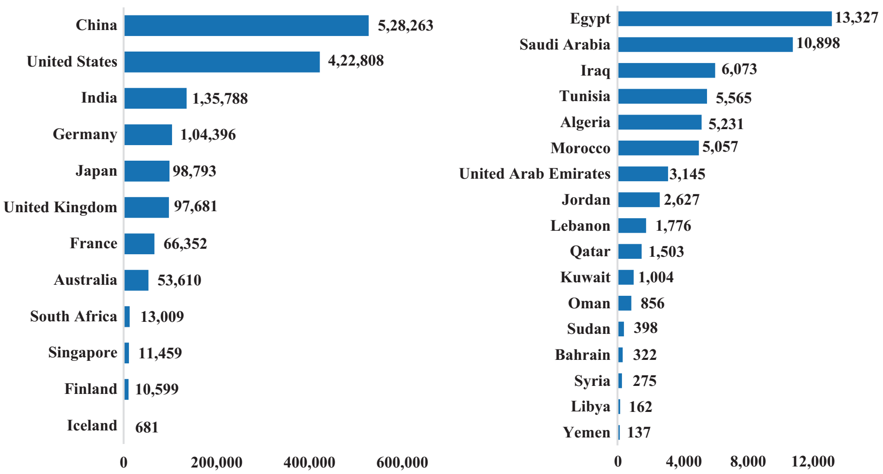

Fig. 6 The absolute number of published research papers of Arab countries as compared to the world, 2018. (Source: Knoema.com)

In absolute numbers, China leads the world in the number of published articles with 528,263 peer-reviewed scientific papers published in 2018, followed by the United Sates (422,808), India (135,788), Germany (104,396), Japan (98,793), United Kingdom (97,681), France (66,352), Australia (53,610), Southern Africa (13,009), Singapore (11,459), Finland (10,599), and Iceland (681), as shown in Fig. 6 [8].

In the Arab world, Egypt leads in the number of published articles with 10,807 articles in 2018, followed by Saudi Arabia (9231), Tunisia (5265), Algeria (4447), Morocco (4062), the UAE (2180), Jordan (1651), Lebanon (1397), Qatar (1310), Iraq (1227), Oman (795), Kuwait (738), Libya (438), Sudan (368), Syria (273), Bahrain (210), and Yemen (111) (Fig. 6) [8].

9 Density of Indexed Publications and Quotations of the Arab World

Indexed publications accumulated for the years 1996–2016 was led by Egypt with 152,954 articles, followed by Saudi Arabia (127,612), Tunisia (64,445), Algeria (48,608), Morocco (44,578), the UAE (34,927), Jordan (30,556), Lebanon (30,927), Kuwait (19,366), Qatar (16,313), Iraq (14,098), Oman (13,733), and others as shown in Fig. 7 [9].

Regarding the h-index Tunisia is ranked first among Arab countries with 210.06, followed by the UAE (78.28), Egypt (74.65), Saudi Arabia (66.94), Morocco (56.37) and others as shown in Fig. 8 [10].

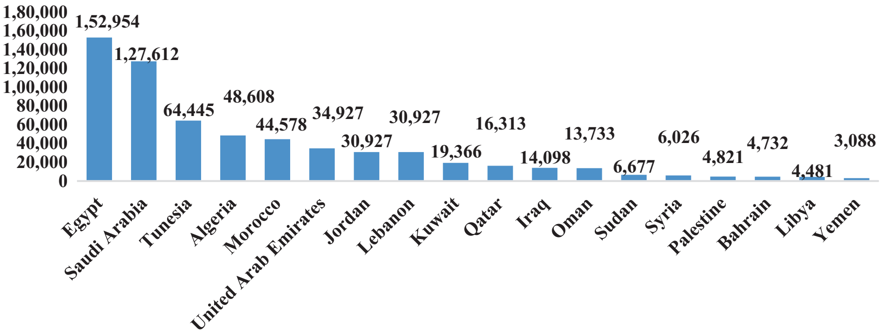

Fig. 7 The accumulated research density of Arab countries during the years 1996–2016. (Source: SJR Scimago Journal & Country Ranking)

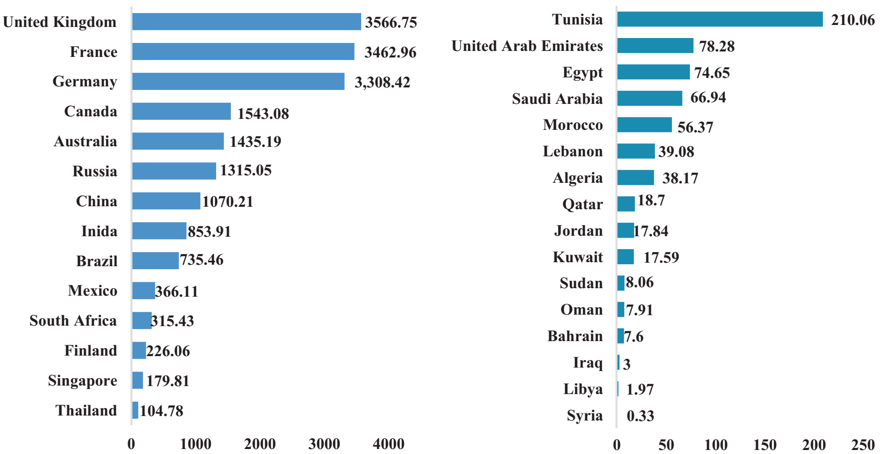

Fig. 8 H-index for Arab countries as compared to the world. (Source: IDEAS)

Worldwide, the United Kingdom is leading with an h-index of 35,66.75, followed by the United States (10,677.72), France (3462.96), Germany (3308.42), Canada (1543.08), Australia (1435.19), Russia (1315.05) and others as shown in Fig. 8 [10].

10 Who Leads What in World Productivity

- The United States ranks first in agriculture and food production, commercial and military space, nano-advanced materials, healthcare and life sciences, information and communications, tools and electronics. And it ranks second in energy technology, environment and sustainability, and third in automobiles.

- Germany ranks first in automobiles, power generation and efficiency, and environmental sustainability. And it ranks second in advanced nanomaterials, and ranks third in airspace, health care and life sciences, tools and electronics and ranks fourth in information and communications.
- Japan ranks second in automobiles, information and communications, tools and electronics, while it ranks third in nano-advanced materials, environment and sustainability, fourth in healthcare and life sciences, energy technology, and fifth in commercial space.
- China ranks second in agriculture and food production, third in military aviation, energy technology, information and communications, fourth in commercial aviation, automobiles, nano-advanced materials, electronics, and fifth in health care and life sciences.
- The United Kingdom ranks second in healthcare and life sciences, military aviation, nano-advanced materials, environment and sustainability, tools and electronics [11].

11 High-Tech Exports in Arab Countries as Compared to Other Countries in the World

The UAE leads the Arab world in high-technology exports ratio, accounting for 137.58% of its manufactured exports, followed by Tunisia (6.89), Morocco (4.9), Lebanon (2.35), Egypt (2.34), Jordan (1.37) and others, as shown in Fig. 9 [12].

Worldwide, Singapore shows the highest high-technology exports percentage which account for 52.13% of its manufactured exports, followed by Iceland (38.08%), France (26.99), the United Kingdom (23.47), Australia (21.52), the Unites States (18.97), Japan (17.02), and others as shown in Fig. 9 [12].

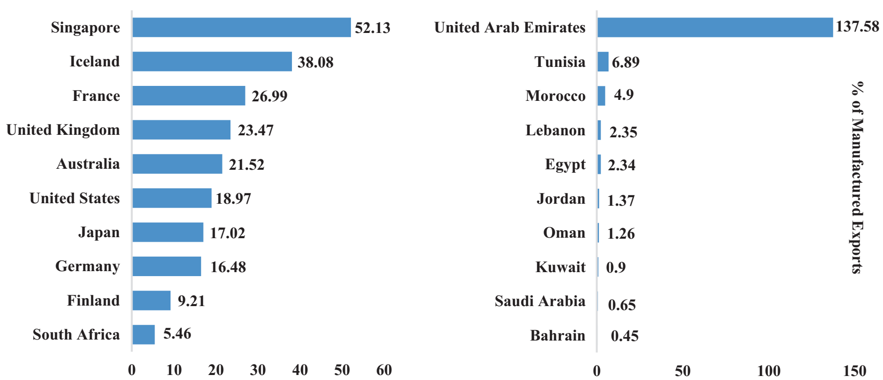

Fig. 9 The ratio of high technology in total exports of Arab countries as compared to the world, 2018–2019. (Source: TheGlobalEconomy.com)

12 Patents in Arab Countries as Compared to the World

Patents are considered good indicators of technology transfer and innovation. It is granted through worldwide patent applications by a national patent office giving executive rights to the owner of the invention for a limited time, generally 20 years.

The Arab world is weak in its invention and patent registration. This is an indication of the poor application of knowledge and research findings contributing to innovation and technology transfer. In fact, there is a gap or divorce between academia and industry in the Arab region, where both do not communicate with each other.

Figure 10 shows patents submitted by **residents** in Arab countries as compared to the world (2018–2019) [13]. Saudi Arabia ranks first with 1188 filed patents in 2019, followed by Egypt (1027), Sudan (238), Morocco (199), Tunisia (180), UAE (58), Jordan (21), Bahrain (4), and Kuwait (1).

Comparing the Arab world with other countries in the world, Fig. 10 shows that China tops the number of applications of **filed residents** in the world with 1,243,568 patents, followed by United States (285,113), Japan (245,372), Korea (171,603), Germany (46,632), Russia (23,337), India (19,454), France (14,103), the United Kingdom (12,061), Brazil (5464), Canada (4238), and others as shown in the same fig [14].

As for **non-resident applications** submitted in Arab countries, Fig. 11 shows that Morocco comes first with 2531 patents, followed by Saudi Arabia (2463), the UAE (1846), Egypt (1156), Bahrain (322), Jordan (290) and others. The United States tops the world with 336,340 patents, followed by China (157,093), Japan (62,597), Korea (47,372), India (34,173), Canada (32,250), Australia (27,121), Germany (20,802), Brazil (19,932), Mexico (14,636), Singapore (12,409), and Russia (12,174), and others [14].

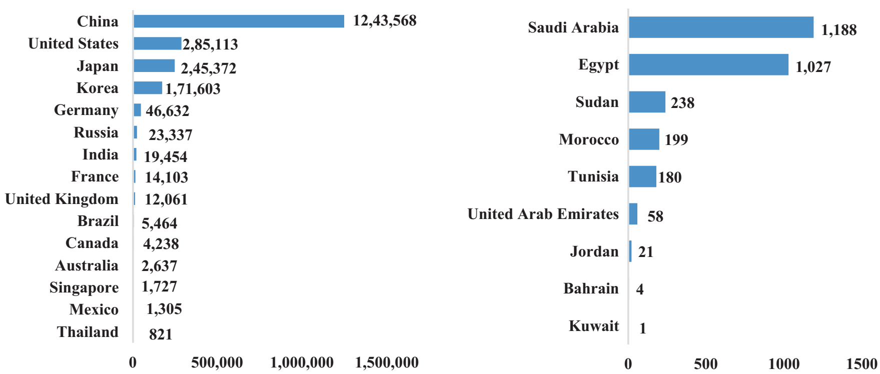

Fig. 10 Patents of residents in Arab countries as compared to the world, 2018–2019. (Source: World Bank)

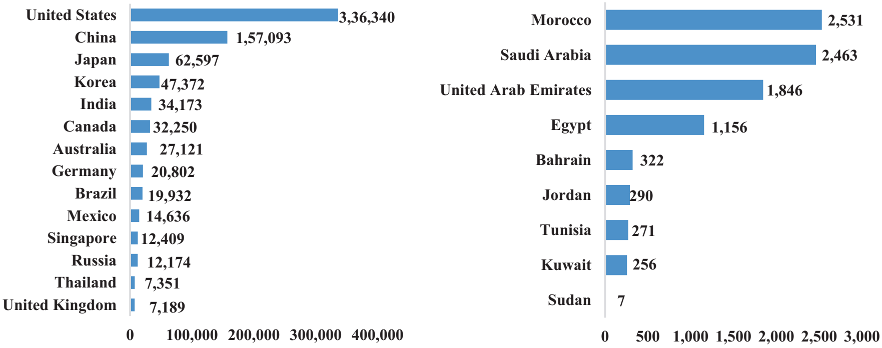

Fig. 11 Patents for non-residents in Arab countries compared to the world, 2018–2019. (Source: World Bank)

13 The Widening Gap of Wealth Between Rich and Poor

At the Davos Economic Forum (2020), Oxfam stressed that "the gap between the rich and the poor cannot be resolved without deliberate policies to combat inequality". Governments should ensure that companies and the rich pay their fair share of taxes. Traditionally, Oxfam stressed that "egregious inequalities are at the heart of social divisions and conflicts around the world. They are not inevitable (but) as a result of policies that reduce the participation of the richest in solidarity efforts through tax, had weakened public service financing." The report indicates that:

- 2153 people own wealth more than 4.6 billion people.
- The wealth of the 1% richest in the world represents more than twice the total wealth owned by the 6.9 billion least wealthy, or 92% of the world's population.
- 42% of women in the world cannot get paid work compared to only 6% of men.

Oxfam considers that between the work of household cleaning, cooking, collecting firewood and fetching water in the southern countries "the monetary value of unpaid care work performed by women from the age of 15 years represents no less than $10,800 billion annually, which is three times greater than the value of the digital sector globally".

In France, seven billionaires have more money than the poorest, who make up 30% of the population, while the wealthiest 10% among the French own half of the country's wealth [15].

14 Conclusion

There is a growing gap in R&D, inventions and innovations between the Arab world and the developed world, and there is growing gap between rich and poor in most countries of the world. Arab countries need to increase their investments in R&D in the field of science to reach a goal of 1% of their GDP by 2023. They need to build knowledge and transfer technology in order to develop self-reliance, create wealth, increase per capita income, and overcome poverty and unemployment, especially among the youth.

The Arab world needs to develop the inquisitive minds of men and women through quality education and develop critical thinking, problem solving, logic, as well as empowering graduates to become creative thinkers and leaders in the field of research. Arab scientists need to communicate with the industry to gain their trust and provide technological solutions in a competitive market. They also need to bridge with other scientists abroad and learn how to coexist with other cultures and other civilizations.

Capital investments in R&D alone cannot perform the task without a stimulating environment that unleashes the minds of men and women to leap forward to new horizons of technologies and innovations. To unleash the minds, Arab countries must provide a creative environment of freedom of expression and thought, justice and equal opportunities for all, good governance, and full participation of all segments of society to maximize the potential of everyone.

Governments cannot do everything, and the private sector should take its share of the initiative in carrying out this task, with governments becoming regulators by issuing appropriate legislations, that promote the private sector to grow and employ the masses of unemployed, and therefore contribute in overcoming poverty.

Arab countries have failed to use the income generated from their vast natural resources, especially oil, to build the human capital through quality education and investments in R&D for self-reliance by building technological goods and services. Instead, they have become large consumers of others' technologies. They also failed to produce the entrepreneurs needed for innovation and for transforming Arab societies into a productive knowledge economy for a better future.

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Measuring Knowledge Production in Arabic Using Arcif: Statistical Indicators and Impact Factor

Najeeb Al-Shorbaji

Abstract This chapter aims to present the Arab Citation and Impact Factor (Arcif) as a method to measure the impact of peer-reviewed research journals in the scientific literature published in the Arab world, emphasizing on the criteria used by Arcif for the selection of journals and analysis methods. The history and development of the impact factor at the global level including the different measurement tools that have emerged will be discussed in addition to the use of these measures and their role in ranking universities.

The chapter includes statistical and trend analysis of the impact factor based on Arcif reports published since 2018. The tendency to publish in social sciences and the humanities such as education, economics, business administration, management, library science and media will be discussed. Plans to improve research conduct and the quality of science publishing in order to create maximum impact on social and economic development, and to improve citations and university ranking will be also addressed.

Keywords Arcif · Bobiolomertic analysis · Arab countries · Arabic Scientific Journals · Journlas Selection Criteria · Citation analysis · Impact Factor

1 Introduction

The quantitative analysis of publications and citations have attracted the attention of many practitioners as well as policy and decision-makers in charge of research, publishing, and library services. The interest in counting and manipulating statistics has always been a way to prove or disprove a position. The simple counting of publications, citation analysis, ranking of authors, and academic institutions are all part of scientometrics. This analysis has taken different forms, names and complexities,

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to measure the trends and rank the producers of knowledge such as universities and research centers based on the ranking of the journals they publish in. It is also used to measure the ranking of researchers, based on the number of times they were cited and the ranking of countries, based on the size of knowledge production in that particular area. A number of global actors have been compiling full-text journal articles, conference proceedings, books and book chapters. In fact, statistical bibliography or bibliometrics has been used to predict the future of publishing and the status of researchers based on their publications and citations. The move towards the digital age and knowledge societies means more materials are being produced and made available on the internet. This may become a game changer in the way that bibliometrics is managed by both knowledge producers and users. The amount of knowledge that is being posted on the internet and exchanged between scientists is becoming a phenomenon that requires attention by those who care about scientific communication.

The Arab Citation and Impact Factor (Arcif), a product of the eMarefa database, is the first comprehensive system that aims to statistically measure the knowledge output in the form of citation analysis and ranking of journals, authors and institutions in the Arab world.

The purpose of this chapter is to review the development and current status of citation analysis and to present a full analysis of the work of eMarefa, as a regional full-text database and Arcif, as a method to measure the impact of peer-reviewed research journals published in the Arab world.

2 Statistical Bibliography or Bibliometric Studies

The term "bibliometrics" was first used by Alain Pritchard [1] in 1969 to denote a new scientific field as an alternative to the term "statistical bibliography", to study the process of scientific communication using quantitative methods (statistics), aiming to measure and analyze various aspects of the published documents. Interest in this field then escalated to become the approved measurement tool for studying all branches of human knowledge for the purpose of ranking scientific knowledge and managing policies. Thus, statistical bibliography or bibliometric studies are essentially a quantitative (numerical) assessment of the patterns of science communication, both at the macro and micro levels using mathematical and statistical methods. This type of statistical studies can be applied to any field or scientific discipline to study the literature published around it, whether in an analogue or electronic format. It should be emphasized that bibliometric studies are a branch of library and information science [2]. Citation analysis, being the most common bibliometric method, is a tool used by a number of stakeholders including:

- Librarians: They use citation analysis for information management and analysis of knowledge resources. One should not forget the fact that citation analysis was

originally performed to help in identifying the most relevant journals in chemistry, which helped librarians draw a list of the most used journals in the field;
- Acquisition librarians and budget officials: They use citation reports to identify budgetary resources;
- Publishers of academic research journals: They may find the most attractive journals for sponsorship, publishing and dissemination, as well as identify those that need individual or bulk subscription;
- Authors, researchers and scientists as producers and consumers of knowledge: They attempt to publish in journals with high impact factors and most likely read and cite articles from such journals;
- Researchers, scholars and those interested in the ranking of academic institutions: University ranking is based on a number of criteria, one of these is the journals that they publish in and their impact factor;
- Researchers who have an interest in scientometrics, bibliometrics, citation analysis, and the ranking of authors, journals, countries, subjects, etc.

The debate on the value of a journal (qualitative) and its impact (quantitative) has been going on for a long time. Citation analysis provides a numeric value based on the fact the more times the article is cited by other articles, the more important is that article. One could argue against this assumption on the basis of what the citing author does with the cited article or how this article has influenced the citing work. Citing an article is done for the purpose of criticizing it, referring to it to emphasize being part of a community or for just making a point that the article has been read and used. Christenson and Sigelman [3] resolved that citation data "permit scholars to evaluate the importance of journals based not on opinion but on the frequency of citations" and that the "frequency of citation implies scholarly acceptance, or at least acknowledgment of importance through utilization of others' work". They also added that "journals have prestige, but their prestige is only derived from the usefulness of the articles they publish". However, Kostoff [4] warned against using citation analysis in research evaluation as further investigation into specific areas should be warranted, and that is should always be accompanied by expert analysis/or peer review.

Despite the importance attached to citation analysis, one has to acknowledge that the real value of research lies in its translation into policy and action, as well as in the change it makes in the public opinion towards an issue. The bigger the gap between knowledge (research) and action, the more difficult it becomes to bridge that gap.

3 Citation Analysis and Impact Factor

A number of agencies have been globally providing services to the scientific community by providing measures of citations i.e. citation counting. In all cases these agencies depend on databases of published material (journal articles, conference papers, books and book chapters) to make their analysis. The focus of this chapter will be on two of them, Web of Science (WoS) [5] and Scopus [6], as they are considered the more prominent in the field taking note that electronic presence and impact of authors, institutions, etc. is being measured. Altmetrics (alternative metrics) includes a range of nontraditional metrics that can be used to assess the impact that researchers have on research and its products in their areas of work. Since these are all based on digital presence, they may include the number of article downloads, and citation of the research in online news or social media sources. Much criticism has been made on this method, including its heavy reliance on social media. Webometrics (Web Impact Factor) is a form of altmetrics, which is a quantitative tool used for the analysis, evaluation and ranking of website content based on structure, number of pages, as well as top-level domains and subdomains and their interrelations. Other systems such as Google Scholar [7] which is becoming a serious competitor to the two major databases, WoS [5] and Scopus [6], ResearchGate [8] and Microsoft Academic [9] will not be discussed in the scope of this chapter. Martín-Martín et al. [10] provided a comparison of six data sources for citation services aiming at answering the question of "How much overlap is there between these services?". The Impact Factor (IF) is an indicator of the performance of a journal that is calculated based on the total number of citations in a given year divided by all papers published in the past 2 years divided by the total number of articles published in the past 2 years. The choice of 2 years was not based on any specific reason except convenience. It is possible to calculate the IF on a 5-year basis, which consequently extends the impact of the journal over a longer period. Eugene Garfield [11] was the first to invent the concept of citation analysis, which led eventually to the creation of the journal impact factor. In his article of 1955 entitled "Citation indexes to science: a new dimension in documentation through association of ideas" [12], he proposed the design "of a bibliographic system for science literature that can eliminate the uncritical citation of fraudulent, incomplete, or obsolete data". And in 1960, Garfield founded the Institute of Scientific Information (ISI) and the journal impact factor (IF), which then produced the Science Citation Index (SCI) with the main purpose to help selecting key journals in a specific discipline [13]. Since 1975, the SCI yearly report was published as the Journal Citation Report (JCR), which is a database that gives the Journal Impact Factor (JIF) in addition to the total citations, total articles, and immediacy index [14]. In 1994, ISI was sold to Thompson Reuters, a Canadian media company, which continued to compile and publish the SCI until 2016 when Onex and Baring [15] acquired the Intellectual Property and Science Business component from Thomson Reuters. This new company was renamed Clarivate Analytics and continued to issue the same products in addition to new ones, all based on the WoS database, which is a multidisciplinary set of integrated databases that currently includes 1.9 billion cited references, 1171 million records and over 34,000 journals covering different scientific disciplines with a clear focus on science and technology [5].

The other global citation analysis company is Scopus [6], which was established in 2004 and is owned by Elsevier (1880). It has been considered by many to be the primary competitor to the WoS database [5] for citation analysis and journal ranking statistics. Scopus has over 75 million records with over 24,000 journals in addition to a book collection based on agreements with about 5000 publishers. Titles in Scopus cover four broad areas including health sciences, physical sciences, life sciences and social sciences. It gives four types of quality measures for each title in its databases: h-Index, CiteScore, SJR (SCImago Journal Rank) and SNIP (Source Normalized Impact per Paper). The most famous product from Scopus is its CiteScore, which was established in 2016 as a competitor to Clarivate Analytics IF, available free of charge and which provides a view of a journal's impact based on a 3-year citation calculation [16]. The quality of journals indexed in the database has been questioned as Scopus hosts papers from more than 300 potentially 'predatory' journals that have questionable publishing practices [17]. Together, these titles contributed to more than 160,000 articles over a 3-year period – almost 3% of the studies indexed in Scopus during this period. Their presence on Scopus and other popular research databases raised concerns that poor-quality studies could mislead scientists and pollute the scientific literature [17].

The use of a single system to measure the impact factor is extremely risky and provides a distorted view of the truth. The University of Waterloo's white paper [18] provides a comprehensive review on the topic. Each of the systems used has its disadvantages and is used to please particular individuals, institutions or geography which makes it impossible to rely on any single method to measure the quality and quantity of publications and citations. Among the problems encountered are:

- The focus on English language. It has been wrongly claimed that it is the language of science. Multilingual publishing and use of national languages have presented challenges to this status quo;
- The focus on North America and Europe. The world is much larger and more diversified that limiting science production and its documentation to these two geographies. Latin America, China, Africa, the Middle East and many other countries in Asia are coming on strong with their national databases and bibliometric systems;
- The selection criteria for the inclusion of a journal in what is called "international databases" represent a barrier to most journals that do not fit the criteria set by these systems. These may include the subject matter, peer-review process, novelty of the topic, copyright and intellectual property challenges, and reputation of authors;
- The differences in the format of the publications listed and measured by a database makes them incomparable, to a certain extent. Systems may focus on one or more of the following formats: paper-based and electronic publications, journal articles, conference proceedings, books, book chapters, patents, etc.
- The use of the IF, as a measure of the quality of journals, has long been criticized. In fact, there is an overwhelming consensus that it is not considered a perfect tool to measure the quality of an article or even the abilities of researchers and professors; however there is nothing better than this particular measure and that is the reason such an index should be considered today as a good technical resource for scientific assessment [19–22]. Despite all these criticisms, the influence of the IF on decisions by different entities is still there and the legacy of Garfield contin-

ues until today as the father of citation analysis despite the multiplicity of citation analysis databases, methods and tools.

4 H-Index

It is worth including in this part of the chapter the h-index, which is focused on authors as producers of knowledge rather than on journals. One can argue that a journal may get a high IF as a result of publishing an article that has received a high number of citations. Hirsch [23] introduced an important measure related to the impact of authors based on the scientist's most cited papers and the number of citations that they have received in other researchers' publications. Hirsch defined this index as "the number of papers with citation number ≥h, as a useful index to characterize the scientific output of a researcher". An author with an index of h will have published h papers, each of which has been cited at least h times. He proposed this index as a single number, the "h-index," a particularly simple and useful way to characterize the scientific output of a researcher replacing the many numbers that are used to measure the importance, significance, and the broad impact of a scientist's cumulative research production compared to other researchers. It combines the number of publications (quantity) a scientist has with the citation frequency (quantity) to give one number (quantity) called the h-factor or index. The h-index is influenced, of course, by the number of years during which the scientist has been publishing and his academic age. The h-index has since then been used by universities as a method to rank scientists for different purposes and as a measure of the impact of a scientist compared to others. Hirsch warned about self-citation in his calculation of the h-index. He said that "ideally one would like to eliminate the self-citations. Although self-citations can obviously increase a scientist's h, their effect on h is much smaller than on the total citation count".

5 The Role of Impact Factor in University Ranking

Times Higher Education (THE) ranks universities against the United Nations Sustainable Development Goals (SDGs), based on the research they produce in relevant topics, in addition to stewardship, outreach and teaching [24, 25]. The ranking of universities is based on five main areas: 30% teaching, 30% research, 30% citation, 7.5% international outlook and 2.5% industry income [26]. What is more relevant to this discussion is the percentages allocated to citations as referred to as research influence by THE. The ultimate test of the quality of research is its impact and the importance of that research is measured by the number of times the work of an academician at that university is cited by another scholar. The greater the number of citations of a university's work, the more likely that one will engage with scholars who are leading and expanding the discussions in the field. THE considers that research impact reflects on "how much an institution contributes to the worldwide project for collective and collaborative understanding of the world. This contribution is both a measure of the quality of the university and a source of pride for both academics and students" [26].

Another university ranking agency is QS World University Rankings which uses six simple metrics that are believed to capture university performance, including 40% for academic reputation, 10% for employer reputation, 10% for faculty/student ratio, 20% for citations per faculty, 5% for international faculty ratio, and 5% for international student ratio [27]. Of particular relevance here is the 20% allocated for citations per faculty as it takes into account the total number of citations of all papers produced by an institution across a 5-year period against the number of faculty members at that institution.

A third agency involved in the ranking of universities is Round University Ranking (RUR) Ranking Agency founded in 2013 and based in Moscow, Russia [28]. The agency publishes world university rankings for the benefit of students, the academic community, university management and policy makers. RUR measures the performance of 1100 leading world universities from 82 countries using 20 unique indicators and four key areas of university activities including teaching, research, international diversity, and financial sustainability. Three types of data are made available and analyzed: statistical, bibliometric and reputation data. Research ranking indicators are based on bibliometric data extracted from the WoS Core Collection, which is the "premier resource on the platform and the world's most trusted citation index for scientific and scholarly research. It is a curated collection of over 21,000 peer-reviewed, high-quality scholarly journals published worldwide (including Open Access journals) in over 250 science, social sciences, and humanities disciplines. Conference proceedings and book data are also available." [29]. In these indicators, research represents 40% of the weight, divided equally between the following five categories: citations per academic and research staff, normalized citation impact, papers per academic and research staff, doctoral degrees per admitted PhD, and research reputation.

Looking at the above university ranking methodologies it is very clear that bibliometric indicators represent a major element in the ranking of universities. After all universities were created to teach (disseminate knowledge), research (create knowledge) and provide community support (translate knowledge). The quality of a university is based on its ability to create knowledge that influences others and can be measured by the bibliometric tools available.

Generally speaking, one can notice the low contribution of bibliometrics (publishing, citation counting and IF) in the ranking of Arab universities at the international level. This could be due to publishing in Arabic, focus on social sciences, and the weak electronic publishing of journals [30].

From an Arab university perspective, Khazendar [31] believes that controlling the ranking of universities has dictated research priorities and policies of scientific research at these universities to fit the requirements of the Western ranking criteria. This has been clear, for example, through the requirement by the ranking agencies to publish only in English so that articles are listed in international databases such as Scopus and WoS.

6 Science Publishing in the Arab World

The Global Directory of Publishers [32] is an information marketplace related to the publishing industry, with 16 Arab countries in its database that have 90 publishing houses together. The Directory divides publishing according to format (books, eBooks, daily newspapers and internet publishing) or by subject matter (children's books; no details given), or by language (Arabic usually) or location of the publisher (city). It is surprising to have this very limited number of publishers listed despite the fact that the numbers are much higher in reality. Moreover, many Arab countries are not even listed in the Directory such as Iraq and Libya. More shocking is the total absence of publishers of scientific journals especially by universities, research centers and other science publishers in the Directory. A number of studies have carried out bibliometrics analysis of the contributions of Arab researchers in international databases such as WoS and Scopus. The results showed the total reliance on USA and European indexed journals and abstracting services to provide a bibliometric analysis of the science and technology knowledge production in the Arab world in addition to the extensive use of English for publishing. In fact publishing in English in international indexed journals was seen to have a role in raising the rank of the university [30]. In addition, the small-sized journals published in developing countries, including the Arab world, have different problems and challenges from the mainstream journals, mainly related to authorship, conflict of interest, ethical issues, and redundancy in publications. More fundamental problems include lack of infrastructure for running a journal, insufficient funding, lack of expertise in desktop publishing, editors having little knowledge of their craft, difficulties in dissemination of publications, low visibility, and problems with attracting high-quality research articles [33].

A Lancet article (2003) found that Arabs produce less than 1% of the biomedical citations in the world, despite the available wealth and human resources [34]. The region has been unstable over the past 10 years due to civil wars, economic deprivation and occupation. For example, research output in the field of integrative and complementary medicine (ICM) during the period 1980–2013 was low in most Arab countries as demonstrated in a bibliometric analysis of scientific publications from the Arab world in leading journals of ICM indexed in WoS. It is interesting to note that none of the 22 international peer-reviewed ICM journals indexed in WoS is from an Arab country [35]. This clearly demonstrates the fact that Arab researchers, at least in ICM, publish in foreign journals in English. Furthermore, the findings of a study on six Arab online library and information science journals showed that none of these journals is indexed in WoS or Scopus and only one was listed in the Directory of Open Access Journals (DOAJ) [36, 37]. This study called for creating an Arabic citation index. Another study [38], which used the Social Science Citation

Index (SSCI) list of WoS on communication and media studies showed that the contribution of the Middle East between 1975–2012 was less than 1% and that between 2013–2017 it accounted for 1% of the total world contribution. This weakness could be due to various reasons: indexing is limited to the English language, North American focus of WoS, selection criteria by WoS, and the topic of communication and media itself which is not strongly covered by Middle Eastern researchers.

The Index Medicus for the Eastern Mediterranean Region (IMEMR) [39] is a project that indexes regional health and biomedical journals, compiled and produced by the World Health Organization Regional Office for the Eastern Mediterranean (EMRO) covering 20 Arab countries (Algeria, Comoros and Mauritania are in the WHO African Region and Afghanistan, Iran and Pakistan are non-Arab countries in the Region). The IMEMR was first published in 1987 in English translating records from their original language (Arabic, Persian and French) into English. It covers all public health topics, all medical subspecialties, environmental health, dentistry, pharmaceutical, nursing, health management and administration, and veterinary sciences. In addition to indexing and abstracting the journals published in the region, it aims to provide health care professionals and researchers from the region with access to health and biomedical information as well as to increase the visibility of their work at national, regional and international levels. Statistics from the Index showed that since 1983, it has 226,488 records generated from 691 journals published by 20 countries of the Eastern Mediterranean Region, of which 308 (44.6%) journals from 17 Arab Countries that have generated 128,375 records in the database [40]. English is the dominant language of publishing in health sciences making up 43.65% of the records of the IMEMR, while French constituted 27.1%, Persian 3.35% and Arabic only 0.16%. And when looking at the records from the Arab world, those in English and French represent 38.28% and 33.45%, respectively while records in Arabic represent only 0.28%.

There is a clear belief that scientific and medical research are of paramount importance for progress and development in developing countries. The need to develop policies, allocate funds, train researchers and focus on local issues was clearly expressed in the same study by Habibzadeh [33] in which he says "Scientists, physicians, and health policy-makers in developing countries are faced with situations far different from those encountered by practitioners in industrialized countries". He adds "It is thus essential for developing countries to conduct research on their own problems and to be able to make use of global knowledge in a local context". Salager-Meyer [41] proposed to create private editorial bodies at regional scales to start up new regional high-quality refereed journals that would be based in developing countries, publish in local languages, provide local perspectives, transcend national borders, be peer-reviewed, be multilingual, be exchanged at no cost, adhere to open access principles, and be included in non-English science communication databases. Such journals could be published by the Association of Arab Universities [42].

Publishing research in open access predatory journals is not a solution as it could lower the quality of scientific research in the Arab world. Arab researchers tend to publish in these journals due to lack of awareness of the risks involved, easy and fast acceptance and are driven by the desire to publish research to accelerate their promotion at the university. Arab authors who publish in predatory journals were mainly from Egypt and Saudi Arabia. Researchers from Sudan, Jordon, Algeria, Palestine, Bahrain, and Oman also publish in these journals [43].

7 e-Marefa

There are over 700 universities in the Arab world of which 280 are members of the Association of Arab Universities [44] from 22 countries. The vast majority of universities in the Arab world conduct research and publish in academic peer-reviewed journals as demonstrated by the distribution of publishing institutions in the e-Marefa database. The e-Marefa database provides a comprehensive view of science publishing in the Arab world limiting its coverage to journals published in Arabic in the region [45]. The vision of e-Marefa, is to promote the relationship between the use of the national language with scientific research production and socioeconomic development, as supported by findings of the World Intellectual Property Organization (WIPO) on patents and which clearly show countries that use their national languages produce and register patents in these languages such as China, Japan, Germany, Korea and Russia [46]. Khazendar [31] concluded that there is a strong link between mainly using mother tongue in scientific research to produce knowledge and socioeconomic development, innovation, knowledge creation and technology.

e-Marefa has been driven by:

- An increased reliance of the society on knowledge and the tremendous increase in the demand for information in various fields;
- The acute shortage of Arabic digital content;
- The remarkably weak interest in building Arabic electronic databases whether by institutions in the Arab World or international institutions specialized in the design of databases.

The following facts are from the e-Marefa database [47]:

- The database includes 5100 journal titles which have been evaluated for possible inclusion in Arcif based on the criteria set for the purpose (will be discussed later);
- The database contains the full metadata for over 2.2 million entries;
- Journals have been published by 640 public and private universities, learned societies, science federations, private research centers, commercial publishing houses, and government ministries;
- A number of these journals have seized publishing or stopped releasing new issues. This resulted in removing them from Arcif;

e-Marefa is an integrated database that includes the full text of Arabic knowledge products and publications such as journals, journal articles, theses, dissertations, books, eBooks, book reviews, research paper abstracts, conference proceedings and statistical and scientific research reports. The e-Marefa database has the following characteristics:

- Diversity and comprehensiveness: e-Marefa is multi-disciplinary, covering 59 subjects and sub-subjects including Finance, Economics and Business (Business and Business Administration, Economics, Commerce, Marketing, Finance and Banking, Accounting, General Administration, Islamic Banking and Islamic Economic policy), Engineering sciences and Information Technology (Materials and Metals Science, Communications Engineering, Electrical Engineering, Civil Engineering, Mechanical Engineering, Highway Engineering, Architecture and Information Technology), Humanities as an Interdisciplinary field (Islamic Studies, Comparative Literature, Religion, History and Geography, Psychology, Arts, Languages, Literature, Philosophy, Arabic Language, Library and Information science), Literature (Comparative Literature, Arabic Language and Sciences, Languages), Social sciences as an Interdisciplinary field (Information and Communication, Political Science, Sociology, Military sciences, Law, Education), Medical sciences, Pharmacology and Health Sciences (Psychiatry, Epidemiology, Diet and Nutrition, Nursing, Public Health, Dentistry, Human Medicine, Pharmacology, Exercise) and Natural sciences as an Interdisciplinary field (Veterinary Medicine, Biology, Mathematics, Earth, Water, Environment, Zoology, Astronomy, Physics, Chemistry, Botany, Agriculture, Science, Marine Science). Each discipline is in a database of its own allowing for users to search in that particular database while virtually integrated with the other databases allowing cross-searching. The focus of the database content (research published in Arab journals) is more on social sciences and humanities as the top five cited disciplines are Education, Psychology, Economics, Business Administration and Political Sciences;
- Utilization of standards for bibliographic description and representation in the database: The MARC 21 Format for bibliographic data is used to ensure interoperability with computer systems in the Arab world and globally;
- Compliance with copyright and intellectual property rules: Agreements have been signed with over 300 organizations in 19 Arab countries to incorporate their knowledge products and published materials in the database. Respect of these rules allowed for trust building and fruitful collaboration between the publishing authorities and the research community;
- Reasonable subscription prices: Based on the understanding of the economic situation of academic and research institutions in the Arab world, e-Marefa provides flexible pricing structures that consider the needs of all subscribers and offer special discounts for associations or group subscriptions;
- Up-to-date content: e-Marefa aims to keep the database up-to-date with the of the knowledge products enlisted above;
- Immediate results of relevance: e-Marefa provides relevant search results to meet the thematic requirements of researchers in various disciplines in an immediate

and rapid manner. New content added to the system, is made readily available for searching;

- Ease of use: e-Marefa has developed a user-friendly interface that provides an easy and highly flexible interactive method of communication and interaction between the user and the system;
- An integrated content within a single window: e-Marefa allows its users the ability to navigate in numerous sources of information that provide large, diverse and comprehensive content in a way that guarantees saving time and effort during the search and retrieval processes;
- Overall quality: e-Marefa is subject to a series of scientific steps and a variety of quality assurance processes that aim to control and guarantee the quality of the content presented to users;
- Social media presence: e-Marefa is accessible via social media platforms aiming to accelerate the access rate to its content [48].

8 Arcif: Arab Citation and Impact Factor

Arcif was established by e-Marefa to fill a gap that exists in the Arab indexing and abstracting services. Arcif is managed as an independent private sector initiative and is one of the products of the e-Marefa database, which uses the actual bibliographic references in the database and the citations in each one of them [49].

8.1 Rationale and Basic Facts

e-Marefa established in 2013 the Arabic database and a citation analysis system, Arcif, that serves the Arabic speaking and international research community by providing citations analysis for peer reviewed academic journals in the Arab world based on the full text of publications available in its bibliographic database and the citations for each publication [36, 49]. Arcif provides reliable, integrated, and multidisciplinary data, linking the output and volume of citations to articles published in Arabic.

Arcif provides research and knowledge on research trends for different disciplines and subdisciplines. It also delivers high-quality scientific data and information from Arab research institutions that can be shared, analyzed and used in research or policy decisions. Arcif's commitment to ease of use allows for the possibility to rank journals and scientific articles by total citations, authorship, affiliation, discipline and a number of other search queries. In other words, Arcif's mission is to highlight and encourage the discovery of relationships between researchers, to stimulate research, to bring researchers and their findings closer, to identify research patterns and emerging trends, and to realize the Arab world's academicians' excellence. The specific aims of Arcif are:

- To offer an Arabic systematic and standard-based approach to evaluate and measure the impact of Arabic science journals objectively and qualitatively;
- To build an Arabic science-based tool that is reliable and trustworthy to measure research and science publishing, and to evaluate Arabic science journals which will help in establishing their impact and influence in their field of specialization;
- To make available data and indicators to measure science production in the Arab world. Documentation of this literature as a heritage and cultural investment will help to regain recognition that reflects the actual size and importance of that literature and to strengthen its presence in the global knowledge production;
- To overcome the challenge of using a foreign language by some Arab researchers to conduct and publish research in international English high impact journals;
- To establish itself as an accredited indicator among other international ranking systems which can be used by Arab universities to ensure equity and improve their ranking globally.

8.2 Characteristics

Arcif has committed itself to comply with the following characteristics:

- Transparency: The scientific nature of Arcif allows for a completely unambiguous process, in which access to all bibliographic data, citation sources (references), selection criteria and actual results is granted;
- Independence: The results of Arcif are not subject to any political, gender, or religious motives, but rather only scientific and professional standards are applied;
- Neutrality and objectivity: Arcif relies solely on scientific criteria for inclusion and processing. It does not ally itself with any competing side (politics, geography, institution, religion);
- Dynamic report generation: Arcif annual reports provide users with a detailed view of the ranking of disciplines, universities, research bodies, countries and authors in the Arab world, based on the number of citations;
- Comprehensiveness: The coverage of Arcif in terms of subjects and countries of origin ensures that no country is left behind. The expansion of the database as more institutions come forward to provide content is an assurance of its sustainability;
- Reliability and competency: Data in Arcif are provided by their original sources and copyright holders which guarantees trust and accountability regarding every single record provided;

8.3 Selection Criteria of Journals

Arcif uses a set of 31 criteria [50] that conform to basic international standards, with certain adjustments to meet the conditions, characteristics and culture of the Arab world. The selection criteria are divided into four categories: journal publishing standards, editorial content, Arab regional and/or international diversity, and citation analysis.

8.3.1 Journal Publishing Standards

(a) *Standards for international agreements and customs editing*

These are designed to take into consideration the journal's adherence to the basic elements of the international convention for editing articles, with the aim to improve the discoverability of source articles. The basic elements to be observed are:

- Titles of the entire journal
- Full article titles and their description
- Bibliographic data of all references cited
- Abstracts (by authors)
- Basic information on each author

(b) *Basic technical and scientific standards*

- Being Academic or peer reviewed
- Publishing regularly
- Having an editorial body, with a respected reputation
- Having an advisory body, with a respected reputation (a flexible standard)
- Having an International Standard Serial Number ISSN (paper or e-version)
- Practicing publishing rules and ethics
- Following Standard publishing format (paper, electronic, or both)
- Releasing issues in the Arab world in Arabic or Arabic with English or French
- Being issued by an institution or body and not an individual

(c) *Date of issue*

- The journals should be issued for at least 3 years and still publish in full text until the date of the Arcif's report

8.3.2 Editorial Content

For journals to be selected by Arcif, the editorial content will be reviewed and studied according to the following considerations:

(a) *Specialization*

- Journals with a single or dual specialization are compared with similar journals
- Inter-disciplinary specializations are compared with similar journals

(b) *Preliminary evaluation of content*

- Recognized academic values are based on research and documentation
- Issues and topics are dealt with seriously and carefully
- The journal publishes only scientific research and not promotional and marketing materials.

8.3.3 Arab Regional and/or International Diversity

(a) *Journals should target research topics relevant to the Arab community*

- Arabic should be the primary language of publication, with the possibility of a multilingual publication (with Arabic as one of the languages)
- The criteria used to evaluate the journal is the language (Arabic), place of publication (Arab world). To include or to exclude the journal is the prerogative of the selection committee providing that the issues that are discussed are of value at national level.

(b) *Diversity among contributors to the journal should be seen at many levels, including:*

- Authors
- Editorial Board
- Advisory Body
- Beneficiaries (Arab scientific or research community)

8.3.4 Citation Analysis

The analysis of citations/reference citations plays an important role in determining the impact of journals in the scientific and research ecosystem. The main elements covered by this analysis are as follows:

(a) *Policies in citation analysis*

In order to determine the proportion of the journal's influence in its scientific environment, citations of the journal in question are reviewed by analyzing references of articles and studies of scientific journals published in Arabic alone or in Arabic and English/French, and all found citations are then indexed. This includes citations from journals that do not meet the Arcif selection criteria in order to be able to determine the true influence of the journal in its field. Thus, reference citations are analyzed based on two levels:

- The level of citation of each other by journal articles approved by Arcif.
- The level of the citation of articles in Arab journals that have not met the Arcif selection criteria

(b) *Analysis of self-citation rates*

Self-citation rates are taken into consideration, where the accreditation of journals is reviewed if they reach an exaggerated level of self-citation.

(c) *Analyzing citations and the range of disciplines*

When analyzing citations within the range of disciplines, the following aspects are considered:

- The use of quantitative citation data to measure impact is feasible only in the context of journals with an extended scientific field or specialization, i.e. here well-established, and deeply-rooted ones such as physics, mathematics.
- Narrow disciplines do not generate a large number of articles.
- Technological and applied disciplines are limited in Arabic and therefore do not generate a large number of articles and citations.
- Although many articles are published in the humanities and social sciences, the publishing cycle takes a relatively long time, compared to the fields of technology, medical and natural sciences. In light of these considerations, there is no rapid accumulation of citations and this may take several years to accurately measure impact.

(d) *Time range for citation analysis*

- The analysis of the Arcif coefficient in each annual report includes at least the last 3 years of citations for the journal
- More recent citations are prioritized

(e) *Changes in the adoption of the journal*

Journals that have been rejected in the past may be re-evaluated and can be reviewed based on: changes in editorial content and publishers, as well as in the application of some basic publishing standards that were missing.

In contrast, journals that were included in the Arcif report may be rejected or excluded as a result of loss or malfunction in their application of Arcif's standards

(f) *Issues related to the analysis of citations for articles published in Arabic*

In light of the long time needed in undertaking new research and scientific publication, especially in the humanities and social sciences, there is a need to give enough time to cite journal articles after publication (2 years on average). For the results of Arcif to be truly accurate, citations will be analyzed every year and their Arcif coefficient will be adjusted accordingly.

Arcif published its first annual report in 2018 which included data from 2016 and 2017. Since December 2020, the analysis trend takes into account annual reports from the last 3 years, showing the progress over these years and highlights from the most recent year.

8.4 Sustainability of Arcif

Statistics from the last three Arcif annual reports (2018, 2019, 2020) have shown noticeable progress in the number of journals and consequently number of articles that have met the criteria for eligibility described above.

Table 1 shows the progress registered in a number of core areas of coverage by Arcif's reports for the years 2018, 2019 and 2020. These include the number of journals that were examined, the number of references (citations) in these journals, the number of articles that were analyzed, the number of unique authors (author whose name is mentioned in the index only once regardless of the number of cited articles he/she has in the database), number of authors who were repeated (the name of this author is equal to the number of times his/her name was mentioned in the database), the number of cited authors by other researchers, the number of journals that were included in Arcif, and the number of institutions that publish journals. The number of countries covered was not included due to the very minor increase observed in the three reports.

Also, Figs. 1, 2, 3, 4, 5, 6, 7 and 8 show a steady increase in the different indicators associated with an increase in all areas that influence citations counting and percentages.

Figure 9 shows the absence of pure and applied sciences from the top five subjects covered by peer-reviewed journals published in Arab countries. Arab journals publish mainly articles in the social sciences and humanities related to the Arab world. In fact, authors tend to discuss social, cultural and economic issues in these journals. This clearly sets the direction of subject coverage by Arcif as it focuses on social sciences and humanities. This is also not surprising knowing that authors use Arabic to communicate knowledge of these topics and that these authors represent the majority of researchers in the Arab region who do not publish in foreign journals. As mentioned earlier, subjects in e-Marefa and Arcif are divided into 59 categories and subcategories. Each of these subjects have records of citing and cited work in the database, but are not part of the top five disciplines mentioned in Fig. 9.

Figure 10 shows the top five countries with the highest number of cited authors out 19 countries examined. A number of factors contribute to this state of affairs

Table 1 Progress registered in a number of core areas of coverage in Arcif

Area of coverage	2018	2019	2020	2018 to 2020% increase
Journal titles examined	3000	4300	5100	59%
Number of journals in Arcif	362	499	681	53%
Number of references	5000.000	5,700,000	8,600,000	58%
Number of articles	180,000	218,000	306,000	59%
Number of unique authors	77,000	103,000	152,000	51%
Number of repeated authors	122,000	187,000	273,000	45%
Number of cited authors	7000	13,000	17,400	40%
Number of countries covered	18	18	19	1%
Number of institutions	330	422	647	51%

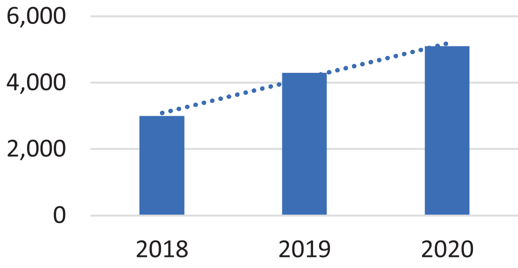


Fig. 1 Journal titles examined

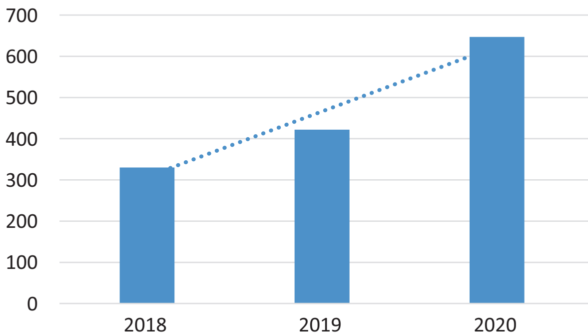


Fig. 2 Number of journals in Arcif

mainly the number of journals from each of these countries, effective internet presence and ability to reach out by authors and journals editors. Having reliable internet presence in addition to having the journals published on the internet would increase the potential for communication between authors/researchers and increase the visibility of the journal.

Figure 11 shows the five top institutions that have contributed to citations from the Arab world. Three facts need to be highlighted here:

- The top five institutions are universities (Balqa University was not present in 2019). This is confirmed by the high percentage of universities as they conduct research and publish science journals;
- Three top universities are from Jordan. This could be due to the fact that it is easier to get journals from Jordan, since e-Marefa is based in Amman, Jordan which makes movement of staff to get copies of the journals form publishers easier and much less costly. This has not precluded other institutions from other Arab countries from being on the list;
- The sharp increase in the number of institutions form Iraq is due to the fact that these institutions have developed digital repositories and publish their journals electronically which increased the chances to be read, used and cited.

Figure 12 shows the top five countries based on number of institutions producing journals and citations. This shows the diversity of countries as five of them are the top contributing in terms of number of institutions. This is also a demonstration that the number of journals cited is linked to the number of institutions but the link is not

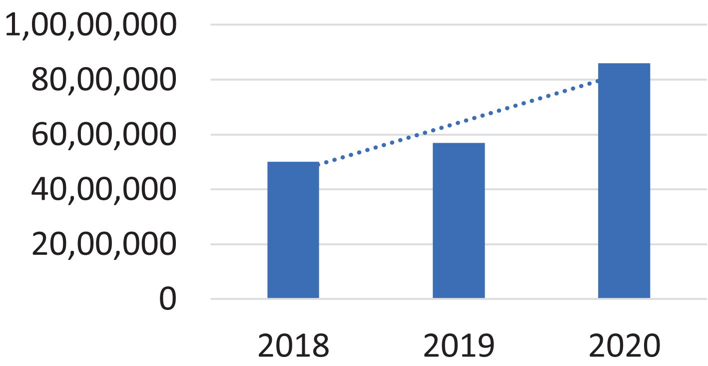
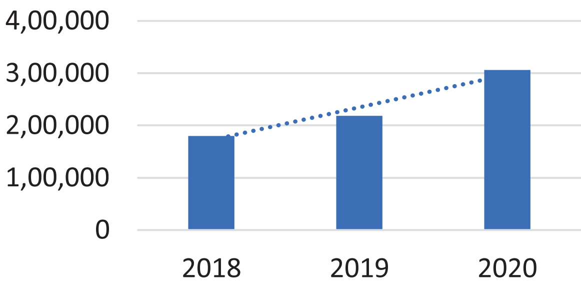


Fig. 3 Number of references in Arcif

Fig. 4 Number of articles in Arcif



causal, i.e. the high number of institutions in a country does not necessarily mean a high number of cited journals.

9 Arcif Report 2020

Core data that were used to generate Arcif report of 2020 are:

- 681 Arabic peer reviewed journals that met the selection criteria;
- 306,000 articles;
- 647 institutions;
- 17,400 authors;
- 19 Arab States;
- 59 academic disciplines

Calculations in this section are based on these numbers and include the following:

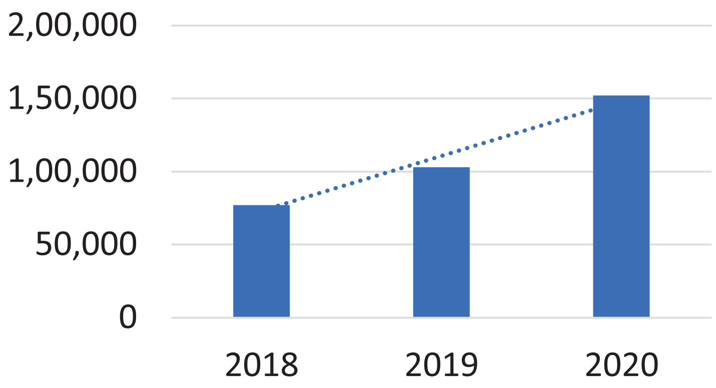


Fig. 5 Number of unique authors in Arcif

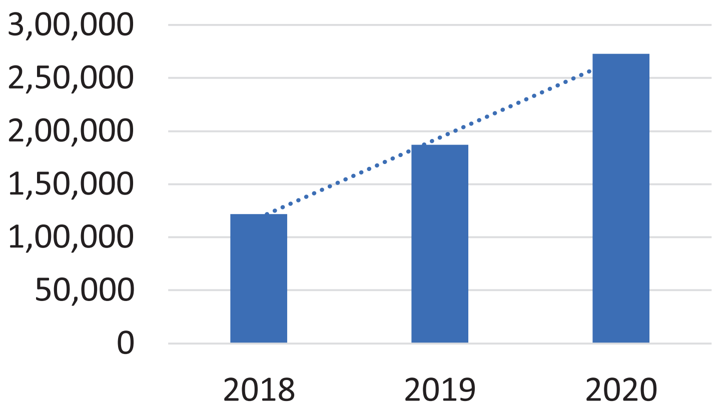


Fig. 6 Number of authors repeated in Arcif

9.1 Countries Represented

Figure 13 shows the distribution of journals from 18 Arab countries. Algeria is on the top with the highest number of journals followed by Iraq, Egypt, Saudi Arabia, Jordan, Palestine, Syria, Lebanon, Sudan, UAE, Kuwait, Libya, Qatar, Yemen, Bahrain, Tunisia, Morocco, Oman and Mauritania. Having few journals from a country does not mean that the country does not publish research in journals there. It could be that researchers publish in English, or that publishers of journals didn't sign agreements to have their journals listed in e-Marefa and ranked by Arcif, or that simply they are not interested or not aware.

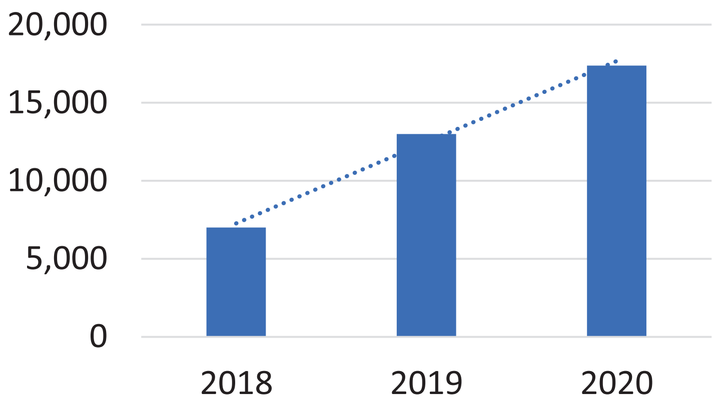
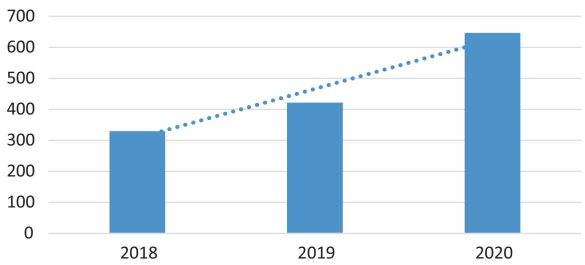


Fig. 7 Number of cited authors in Arcif

Fig. 8 Number of institutions in Arcif



9.2 *Citation Ranking*

Among the 681 journals the top ten cited journals are:

1. Jordanian Journal of Business Administration, of the University of Jordan, Jordan
2. Algerian Journal of Economic Development, of Kasdi Merbah University of Ouargla, Algeria
3. Jordanian Journal of Educational Sciences, of Yarmouk University, Jordan
4. Arab Journal for Media and Communication, by the Saudi Society for Media and Communication, Saudi Arabia
5. Arab Journal for Quality Assurance in Higher Education, of the University of Science and Technology, Yemen
6. Algerian Journal of Globalization and Economic Policies, of the University of Algeria, Algeria
7. Politics and Law Journal, of Kasdi Merbah University of Ouargla, Algeria
8. Journal of North African Economics, of the University of Haseeba Bin BuAli Al Chalaf, Algeria
9. Journal of Educational and Psychological Sciences, of the Islamic University, Palestine

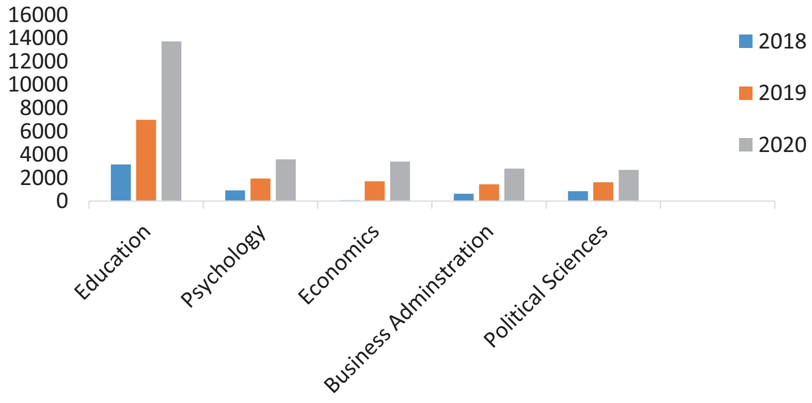


Fig. 9 Top five subjects over the last 3 years

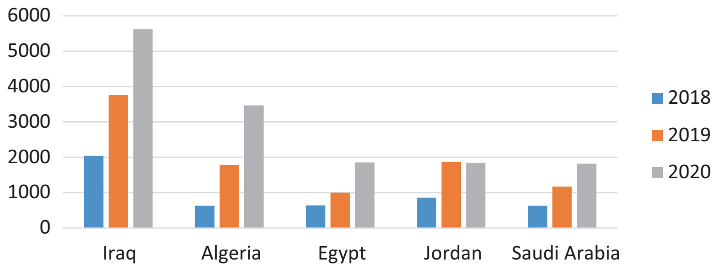


Fig. 10 Top five countries with cited authors

10. Journal of Research in the Fields of Specific Education, of the Association of Arab Educators, Egypt.

The point that was made earlier about the number of journals versus the number of citations, can be further demonstrated; Algeria for instance contributed 255 journals with four journals only among the top ten cited journals. And Iraq has 120 journals, but none makes the top ten list of cited journals. Other countries have contributed different numbers of journals and ranked among the top ten such as Jordan (with two journals), and Egypt, Palestine, Saudi Arabia, and Yemen (with one journal each).

The report also provides ranking for 165 cited multidisciplinary journals. These journals reflect the nature of publishing by many small and starting universities. They tend to cover multiple disciplines due to the small size of the research community at that university or research center in addition to economic factors limiting their expansion. Among these, one would find journals of law and economics, education and psychology, and languages and history. The top ten journals include:

1. Al-Aqsa Journal: Humanities Series, Palestine
2. The Journal of Research and Human studies, Algeria

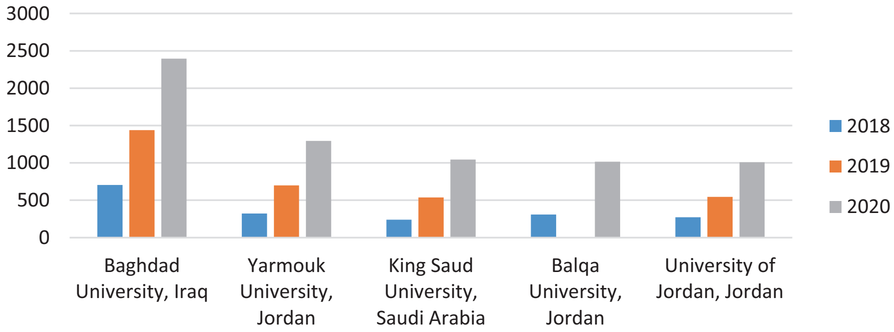


Fig. 11 Top institutions based on the number of citations

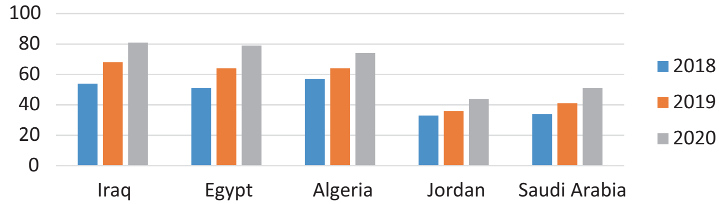


Fig. 12 Top five countries per number of institutions

3. Journal of the North for Humanities, Saudi Arabia
4. Arab Future, Lebanon
5. Milev Journal of Research and Studies, Algeria
6. Arab Journal for Security Studies, Saudi Arabia
7. Academy Journal for Social and Human Studies, Algeria
8. Zarqa Journal for Research and Studies in Humanities, Jordan
9. Horizons Intellectuals, Algeria
10. Journal El-Bahith in Human and Social Sciences, Algeria

Five of the top ten cited journals are from Algeria. One common factor is that the vast majority of these journals cover studies and research in the humanities. In fact, the complete list (of 165 journals) includes journals that were very difficult to place under one discipline.

The report provides a complete listing of the disciplines covered in Arcif according to the number of citations and number of articles. The top five are: education, psychology, economics, business administration, and political sciences (Table 2).

The report provides a list with the number of citations for each author from a total number of 17,400 contributing authors. The top author was in economics, finance and business administration, and the following three authors were in educational sciences, followed by a mix of language research and economics. The majority of the most cited authors are in educational sciences.

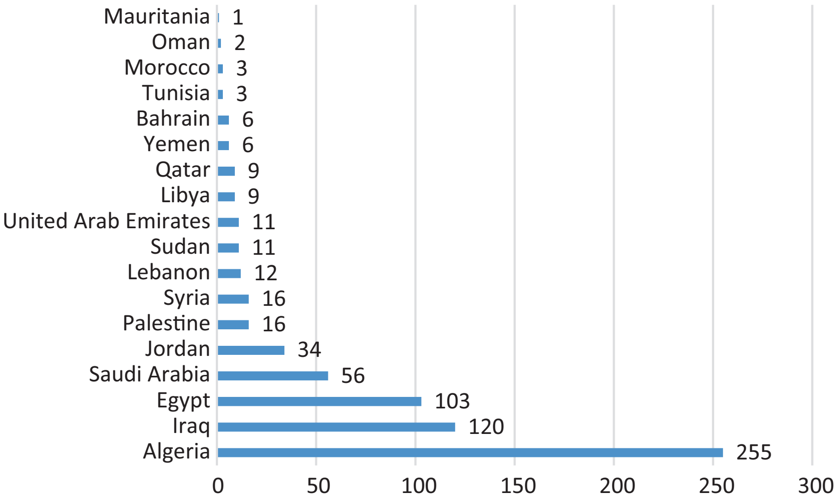


Fig. 13 Distribution of journals from Arab countries

Table 2 Top five disciplines covered in Arcif

Rank	Discipline	# of citations	# of articles
1	Education	13,721	12,200
2	Psychology	3591	3509
3	Economics	3405	4986
4	Business administration	2790	2747
5	Political sciences	2687	3701

The report provides a list of 28 journals meeting the selection criteria in the area of engineering and information technology out of the 681 journals in Arcif (0.04%). Articles from only three of these journals were cited, with all of them from Iraq. The same applies to journals in the fields of natural sciences and biology, with 29 journals (0.42%) listed by Arcif and articles from only four of these journals were cited. The top journal was from Iraq, followed by a journal form Lebanon, then Iraq (again), and Saudi Arabia. These results show the tendency for these disciplines to publish in English and outside the country. More shocking is that Arab authors do not tend to cite others who publish in Arabic journals specialized in engineering and information technology as well as natural sciences and biology.

The report provides an index of 185 journals (or 27%) that have met the immediacy index, which is described as “the average number of times an article is cited in the year it is published”. It indicates how quickly articles in a journal are cited and provides a useful perspective for comparing journals specializing in cutting-edge research such as political issues and surveys, computer science innovations, and emerging diseases (COVID-19 pandemic for example). The top ten journals included in the Arcif immediacy index came from Algeria, Oman, Saudi Arabia, Palestine, Qatar and Jordan. Journals from Palestine and Saudi Arabia were repeated three times each in the ranking, which means that researchers from Saudi Arabia and Palestine possibly have better access to or tend to use journal articles published in the same year, which allows them to cite these journals in the same year as they were published.

The report also ranks the cited articles. The top five articles were cited 56, 50, 49, 43 and 40 times in 2020. It has to be emphasized that the IF is a tool for the ranking of journals, which means that if an article was cited 20 times for example, and another article from the same journal was never cited, the author of the article with zero citation would still benefit from the IF of that journal.

The h-index is not part of ranking of journals, although it might affect it as it is associated with authors. The report provides the h-index of the authors who were cited. It is worth noting that the h-index for the vast majority of researchers in the Arab world is important as it is used as an indicator of knowledge production and citation. The top ten h-index values were 7 (one author in the field of economics, finance and business administration), 5 (eight authors of educational sciences) and 1 (one author of educational sciences).

10 Conclusion

Based on the analysis of the data provided by the Arcif reports, one can conclude the following:

- The majority of the authors do not interact with other Arab authors. Joint authorship is not strongly presented in the published research. This might be due to the fact that the majority of articles are on "social sciences" where collaboration is less apparent than in other disciplines such as medicine. More important is that authors do not seem to cite other Arab authors, which results in weak scientific research networking.
- The vast majority of scientific journals published in the Arab world do not meet international standards to be considered for the impact factor analysis. This is demonstrated by the fact that only 681 journals out of a total of 5100 journals met the selection in the last report;
- The majority of Arab researchers specializing in pure and applied sciences do not publish their work in Arabic and prefer to publish in English and abroad. Social sciences and humanities are overwhelmingly represented in the database;
- Scientific communication among Arab researchers increases when the journal is available online. The trend to use electronic journals more often has accelerated because of lockdowns due to the COVID-19 pandemic;
- Publishing policies, ranking of universities, awareness of risks, language barriers, lack of skills and lack of awareness influence the decision by Arab researchers as to where they publish their research. Changing policies, training and awareness are among the top required steps to improve this situation.

For Arcif to achieve its aims and objectives, the following is suggested:

- The e-Marefa database should be expanded to cover all the Arabic journals published in all Arab countries;
- e-Marefa should continue to support publishing research in Arabic especially in the areas of pure and applied sciences, by reaching out and encouraging editors and researchers;
- e-Marefa should develop a curriculum for a diploma course for science journal editors and researchers in collaboration with one of the private universities in Jordan. Private universities tend to collaborate with commercial companies. Such universities are more flexible in their approach and more responsive to needs of the society;
- The e-Marefa team should undertake a more in-depth subject analysis of every article indexed in the database. This will guarantee that no article in any discipline is missed for retrieval and ranking purposes;
- e-Marefa should develop a marketing campaign using the different methods available to ensure that the target audience in the Arab world is familiar with the value and importance of Arcif. The primary target audience should include researchers, university decision makers, librarians and publishers;
- e-Marefa should aim at forging alliances with other national, regional and global actors in the fields of indexing, journal ranking, university ranking and citation analysis. e-Marefa's experience will be very useful and its capacity may be enhanced through collaboration;
- e-Marefa should open Arcif for academic researchers interested in science information in general and citation analysis in particular allowing them to assess, investigate and make recommendations for future development and enhancement of the system;
- e-Marefa should put more focus of metadata analysis of the bibliographic citations available. Big data has become the new currency and the wealth that should be utilized for better understanding and improving knowledge production in the Arab world.

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Bolstering Economic Growth in the Arab Region Through Commercialization of Research Outcomes

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Abstract Despite the prevailing socio-political and diverse economic situation Arab countries have sustained over three long decades, the Arab region is currently experiencing pronounced economic growth largely attributed to the huge reservoirs of natural resources disbursed across the region. In contrast, many countries around the world, that would exhibit close resemblances to the economic dynamics of the Arab region, have had immense developments, crossing economic boundaries, and attaining competitive edges industrially and economically at the world stage. In the context of the current COVID-19 pandemic, for instance, Arab countries are left with little option but to delve into their own higher education research and development strategies to slowly unpack and replicate viable forms of technology into their local economies. In this chapter, we address current barriers, challenges and difficulties that have impacted severely the current adverse situations while exploring solutions and potential opportunities that are direly needed to transform the rather primitive, less competitive and outdated industrial paradigms into industrial pursuits that would leverage core industries to catalyze real economic growth. In so doing, we address industrial venues harnessing ongoing endeavors around the

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academic sector in ways that would veer academic outcomes in a direction that would invigorate serious world-class industrial formations. Along the way, we shall be addressing notions like innovation and entrepreneurship, intellectual property (IP) management, and start-up evolutions leading ultimately to spinoffs and thereon to small and medium enterprises (SMEs); the primary levers for job creation and real economic growth under any productively functional economy. Meanwhile, we explore the various contributions, if any, which have taken place in the Arab region as a result of ongoing endeavors of researchers to bolster economic growth and incentivize viable paths towards contriving real industrial models. This is considering a multitude of research pursuits around Arab universities and within indigenous research centers, a great many of which were receiving funding through local funding agencies or via international sponsors to carry the research wheel forward. Based on that, we draw conclusions, offer recommendations, and suggest policies that are commensurate with the United Nations 2030 Strategic Development Goals, which have become the benchmarks against which various world economies would fare. We also assess the impact of research endeavors, which have taken place in the Arab region, and whether they have, in fact, contributed to the evolution of livable industrial pursuits for the Arab world.

Keywords Research and development · IP commercialization · Technology transfer · Higher education · Arab world · Economic growth · Innovation · Entrepreneurship · University-industry partnerships

1 Introduction

Research and development (R&D) in higher education offers methods of investigation where new scientific knowledge is determined due to a series of linear and sequential stages that consist of basic research, and applied research followed by experimental development. An R&D model necessitates the assumption of science as a monopoly over knowledge which leads to technology and economic development. This model binds innovation to technology and then technology to the prevalent R&D process. R&D in higher education brings along innovative ideas, novel work products, new customer-driven services, and channels associated processes into active business entities that might eventually culminate into small and medium size enterprises (SMEs). This promotes comprehensive development and the type of rapid transformation necessary for nations that are facing the threats of globalization. It plays a prominent role in raising society to higher levels of economic livelihoods by contributing to a culture of problem-solving regimes and opening the doors to highly unlikely opportunities such as energizing a whole culture of productivity, creating new jobs and invigorating economic growth. The set of innovative activities could come from R&D centers as well as academic institutions, where R&D constitutes the bedrock upon which such institutions rest and thrive.

In general, the culture of R&D is shaped by a wide range of interconnecting factors, each exerting their own influences and raising their own challenges [1]. Developed economies across the world have long relied upon carefully designed, well rounded, and fully utilized academic systems of higher education towards achieving sustainable development objectives, national security and economic growth. Progress in science, technology and information (STI) all begin at the tertiary level, with its supporting foundations, offering the scholarly spaces needed for generating the fundamental knowledge utilized to address the challenges facing society while solving ensuing problems coming along the way.

Over the last three decades, the Arab world has progressively witnessed downward declines in the performance of R&D resulting in perpetual delays in its endeavors towards achieving sustainable development. This situation continued to witness incessant declines in quality outcomes with little commitment, if any, towards upholding research pursuits coupled with proper interactions with the communities involved. Furthermore, it is noticeable that R&D in the Arab world is not tackling immediate community concerns nor serving the needs of the national efforts in leveraging knowledge creation towards industrialization.

Knowledge dissemination has always been a key component of a university's mission. The dissemination of knowledge in the forms of high quality academic publications, abstracts, conference proceedings, and invited presentations is a definite measure of success, both for the university in question and the individual faculty members involved. University research comprises a common denominator for knowledge creation and technology transfer under any successful economic regime. Furthermore, university research generates new science, technology and renders process improvements which readily become available to firms through contracts, consulting and publications contributed to the body of the literature, all in good service to the community. Generation of knowledge and its dissemination constitute the core business of academics [2]. Private firms use these outputs to improve the productivity of their capital and to create new products, processes and services, which result in job creation, exports and, most importantly, profits [3]. Positive impact on the economy and society including social, health, and environmental needs is the outcome of scientific knowledge dissemination from research disclosures to commercialization [2].

At the root of these research disclosures and commercialization of technologies is intellectual property (IP), and the protection and management of IP for research outputs which are deemed as significant incentivizing drivers for innovation and its various associated activities. One of the key implications is building institutional IP management capabilities together with the four underlying constituencies that need to act in accord to make innovation work efficaciously: government policy makers, senior management, directors, scientists and technology transfer officers. It often takes an institution time to build an IP portfolio, establish contacts and develop skills in technology transfer. IP policy at institutions of higher education typically addresses ownership, conflicts of interest and commitment, confidential information, broad IP licensing and IP generated revenues that alleviate burdens of commercialization of transferable technology. This will further enable technology transfer managers and scientists alike to understand the complex array of options that should be considered before publishing research results or filing for patent certifications.

Meanwhile, higher education institutions in the Arab world lack the ability to address directly the shortcomings of an outdated policy framework. A clear IP policy for the university could set out the roadmap for commercial application of intellectual property within higher education institutions and facilitate negotiations of commercial IP arrangements, including royalty, and licensing agreements [2]. Such a policy transformation for merging basic research and applied technology is common practice across advanced world economies, and, under a more defined context, within academic institutions. The mechanism of converting research outcomes into commercial applications and subsequent knowledge for educational purposes represents a linear model for higher education institutions all across western societies. The focus is on profit-generating research pursuits such as in new discoveries, patenting, patent disclosures, licensing and assignment of patent rights [2].

Historically, results of basic research did not have commercial value and were often driven by the researcher's interest in a scientific or research issue. The main motivation was to expand human knowledge and acquire new knowledge, as opposed to contriving an invention. For instance, the biotechnology revolution in the 1980s started with basic life sciences research that, only at some later stages, began to have immediate commercial applications and value [4]. In particular, the landmark case of Chakrabarty (a US citizen and biochemist), who developed a biological process capable of modifying the genetic composition of living organisms with an inherent ability to break down components of oil pollution in oceans and rivers, presents a living example [5]. Applied research, on the other hand, is designed to solve practical problems of the modern world, rather than to acquire knowledge for knowledge's own sake. The result of applied research could be a research-rooted invention (novel use of new knowledge) or design-based invention (novel use of prior knowledge) with some commercial application and, as a result, possible patentable work products. The demand-side pull for patents may yet lead universities to favor research pathways that generate patentable outcomes. The result may be to fundamentally skew university-provided infrastructure toward applied, readily commercialized, and profitable research all at the expense of basic research that generates greater long-term spillovers [6].

2 Challenges at Institutions of Higher Education in the Arab Region

Research results often times indicate promises that, up until the point when they materialize, would still have not resulted in actual work products. Researchers are primarily interested in basic scientific research for the sake of making discoveries, rendering publications, and in some rare cases patenting outcomes. The passion and the skills are preoccupied with the research end of the R&D lifecycle, falling short on the product development side in the process due to an imminent lack of experience under such realms. In the few cases where interest in a product development venue may exist, these researchers are commonly comfortable with patenting their discoveries, and letting their host institutions license them to private companies to be integrated into product development activities. This model is particularly a workable model within advanced economies, but not when dealing with technologies designed for poorly performing economies. Particularly, technology development companies are rarely found to operate under such economic regimes in countries of the developing world. So, who should do the development work? Training and capacity building projects, as a way forward, are readily required to familiarize additional staff members at the institutions involved with life sciences R&D processes, for instance, and of the importance of gearing up their endeavors into relevant international R&D projects to increase their understanding, sense of ownership, and commitment to moving technologies from the laboratory to the field towards eventual commercialization.

Unfortunately, one would find that academic institutions in the developing world are quite often unprepared to handle effectively the process of turning technology leads into viable and approved seed products. Typically, they lack both the human and infrastructural capabilities. They tend to be severely decoupled from the notion that higher education is commonly a primary driver for economic growth and competitiveness in an increasingly knowledge-driven global economy; thereby a contributor to employment of highly skilled workforce, while, at the same time, disseminating knowledge created towards societal wellbeing [7]. As such, the primary mission of higher education would serve to contribute to the betterment of the underlying socio-economic dynamics through knowledge creation by ways of research and innovation and the dissemination and use of knowledge contrived as such. Hence, the most common and foremost mission of higher education is to actively engage in teaching and research and, as such, contribute to national and regional socio-economic development [7]. Research, development and innovation provide essential inputs to the innovation ecosystem which consists of R&D, innovation in production together with social innovation. The knowledge index for the Arab world in the sectors of research, development and innovation is shown in Fig. 1. This key index illuminates the strategic role of knowledge and the importance of developing objectives and scientific tools to evaluate research, development and innovation in the Arab world. Major challenges that currently challenge the Arab world include, but not limited to, lack of ability to improve the efficacy of higher education in leading a transformation that would leverage knowledge and technology into socio-economic benefits. More specifically, do we have the capacity within our higher education systems to determine research and innovation policy and create legal opportunities and strong incentives for commercializing research and innovation such as licensing, patents and start-ups? The fact of the matter is that higher education in the Arab world lacks the incentives and capacity to research commercialization or to effectively compete for international research venues or research funding [7].

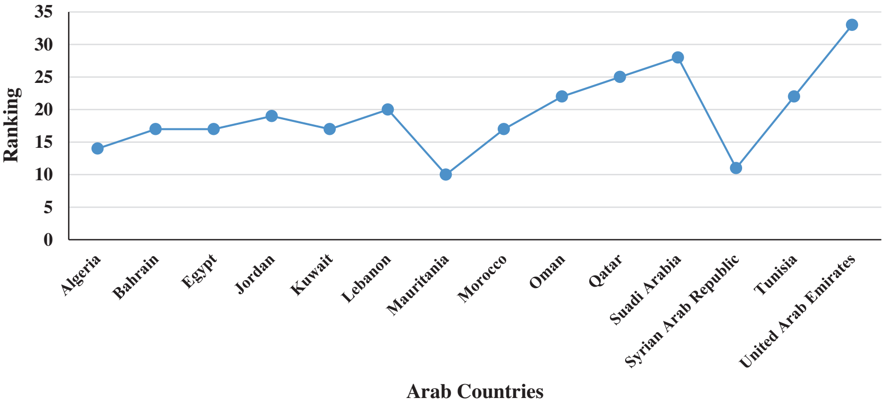

Fig. 1 Research, development and innovation index in the Arab world in 2019. Data is visualized from Knowledge 4All.org (All values are normalized to a scale from 0 (worst) to 100 (best))

One can readily surmise that linking up to and networking with other research organizations and private industries in ways that would foster research excellence and improve the ability of higher education to disseminate much of the knowledge created is readily in order. Innovation has always been in focus, whereas technology transfer and commercialization have never received the level of popularity as there has been appetite for it to date [8]. It must be acknowledged that not all Arab universities are encountering similar levels of crises due to economic and political concerns. In general, Arab universities, particularly in the Gulf region, and a few others in Jordan, Egypt and Lebanon enjoy some financially sound propositions with politically mildly stable environments. Within this context for Arab countries, the current situation of Arab universities has been characterized by inadequate resources to fund R&D, inadequate and ill-equipped research facilities, lack of a comprehensively established science and innovation policy, non-existence of IP policy or lack of a clear IP policy to guide researchers and scholars, lack of incentives for disclosure and commercialization and to excel and move right to the top job through research, lack of private sector investment in R&D, and lack of sufficient engagement to contribute towards the needs of the global economy, all serve as common denominator in describing the status quo of R&D all around the Arab world. This is further complicated by the inadequate leverage of information technology in research [9], limited academic freedom [10], and a difficulty in progressing and advancing scientific research in the proper directions [11].

There are concerns, therefore, about the general enabling environments where institutions of higher education operate and are often governed by several of key influences such as political, socio-economic, health-related and environmental factors. The general environment recognizes the multidimensional nature of knowledge generating systems in all contexts and applications relating to economic and social structures. It also enables a more scientific and evidence-based linkage between development and a multidimensional concept of knowledge while

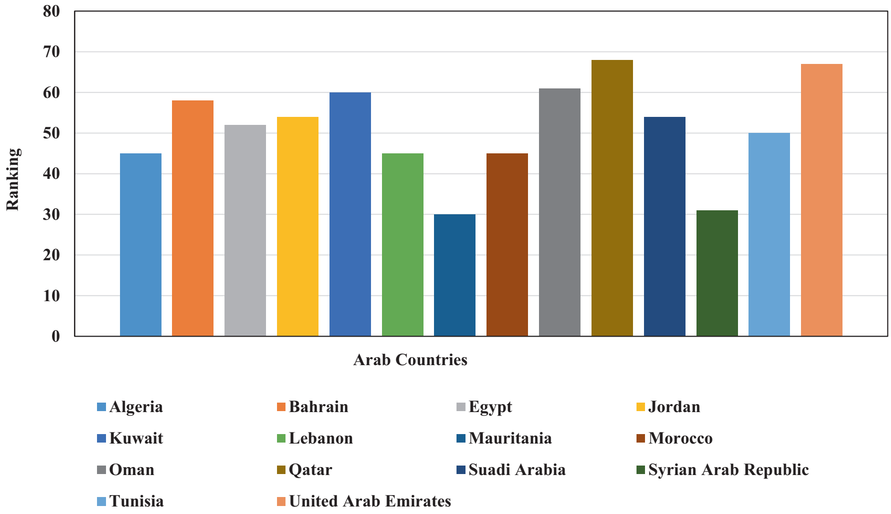

Fig. 2 General enabling environment of the Arab world in the Global Knowledge Index 2019. Data visualized from Knowledge 4All.org (All values are normalized to a scale from 0 (worst) to 100 (best))

maintaining the notion of human development, as shown in Fig. 2, as pertains to the ranking of the Arab world in the global knowledge index 2019. Moreover, the general enabling environment facilitates the flow of knowledge across the higher education system and bolsters innovation quality and diffusion to support the building up of scientific excellence and transformation into a realm of an innovation ecosystem.

3 The Role of Technology Transfer Offices and Public-Private Partnerships (PPPs)

Within higher education institutions, day-to-day activities of monitoring relevant policy, legislation and opportunities for R&D often involves technology transfer offices, also dubbed industrial liaison offices. It is these offices that would monitor existing or potential public-private partnerships (PPPs) in R&D. PPP is the formation of collaboration between the public and private sectors to acquire and develop the technology to fulfill innovation roll out requirements [12].

The process of transferring the results of scientific research into practical applications that would facilitate widespread social and economic benefits is known as technology transfer [13]. This term has often coincided with emphasis on the transfer of technology, within the higher education ecosystem and the inclination for linear, often top-down diffusion of technologies from one context into another (e.g. technologies sent from a developed country to a lesser developed one) [14]. As mentioned above, the term technology transfer is used primarily due to the prominence of issues related to IP management. Technology transfer holds implications for multi-stakeholder pathways and the often legally-protected arrangements underlying scientific R&D that often involve private and public sector organizations.

The practical aspects of technology transfer often require public and private organizations to play different roles: (1) public organizations often fund research for education and training purposes and commit themselves to science education and related infrastructures which also warrant a supply of well-trained scientists to the private sector; (2) both private and public organizations will instigate IP protection within R&D agreements and contract research and seek timely judicial remedies if IP protection is violated; and (3) unlike public organizations, the private sector will assume the risk from market forces to take research from the laboratory or the field and commercialize the technology; subsequently, it is the private sector that will seek out and increase private sector investment in technology [13]. These are the three primary areas warranting attention within the realm of technology transfer, with no one role, in itself, being sufficient or strong enough to create and transfer the technologies or products targeted by research and innovation at higher education institutions. This means that PPPs often involve these roles put together along with the appropriate government policies, as is argued, to promote applied research and commercialization activities that properly guide market and private sector investment efforts [13].

To mobilize PPPs, many countries (for example, USA, Canada, Australia, Japan and Britain) have technology transfer and commercialization programs within universities and research institutes that inspired other countries to simulate and mimic them to their advantage [15]. Nowadays, in the Arab world, technology transfer offices exist in most academic research institutions to ensure that adequate incentives are provided by universities to encourage participation and invention disclosures by researchers as well as effective contractual negotiations with potential industry partners. The role of technology transfer offices is to capture ideas, evaluate them, protect IP rights in the appropriate manner (which involves consulting with law firms and certified patent agents), and then move forward on commercialization through licensing arrangements [15]. The process of research commercialization is creative and complex. An office of technology transfer at a given university is a business model, the main role and objectives of which are typically to engage in technology transfer practices, identify market opportunities, evaluate inventions and proceed with patents, waive rights, assign rights to inventors, and, finally, establish and maintain contacts with industry and other R&D institutions. Furthermore, the obligation of technology transfer is to: generate licensing revenues and research funding, disseminate new knowledge to the benefit of society, and provide avenues for faculty members to interact with businesses, in order to ultimately stimulate economic development [16].

Managing new knowledge may also involve capacity building that involves educating faculty and scientists, staff and students on the necessity of managing their intellectual assets. This may involve such things as how to make an invention disclosure, or file a patent application before a scientific publication, or the decision-making related to allowing industrial partners to request delays in publication in order to claim a patent. Table 1 below demonstrates Arab countries patent profiles including filling international applications for patents in the last 5 years via the Patent Cooperation Treaty (PCT) that is administered by the World Intellectual Property Organization (WIPO) [17]. As far as PPPs in the US are concerned, patenting the results of scientific inventions and then licensing the inventions to the private sector was enhanced through the Bayh-Dole Act of 1980 [18, 19]. The logic underlying this Act was to enhance quality of living and boost productivity in the economy by creating incentives that will also stimulate the education of new generations with science-savvy minds as well as creating new knowledge via increased innovation capacity. Furthermore, inventions could be moved from laboratories into the market by galvanizing new products for commercialization [18]. The Bayh-Dole Act of 1980 in the US created a uniform licensing system for all federal agencies, reduced the steps needed to grant licenses, and provided incentives for industry to invest risk capital in product commercialization from federal patents [20]. This was seen as stimulus for commercializing federally funded research that coincided with the start of the biotechnology revolution in the 1980s and 1990s such as those in the San Francisco Bay area, the Greater Boston area, and Research Triangle Park in North Carolina in the US, Oxford and Cambridge in the UK, and similar venues in Japan. The Act also allowed private industries to license and develop products from publicly funded university research with full legal protection from adverse competition. As a result, a proficiency in technology transfer and professional staff that

Table 1 International applications by Arab countries in the last 5 years for patents via the World Intellectual Property Organization.

Arab countries	Population (million 2018)	Gross domestic product (billion US $) 2018	2015	2016	2017	2018	2019
Algeria	42.23	586.39	8	13	12	16	9
Bahrain	1.57	65.87	5	6	1	1	2
Egypt	98.42	1084.01	58	44	36	44	44
Iraq	38.43	598.20	2	1	2	—	2
Jordan	9.96	82.73	1	1	6	12	19
Kuwait	4.14	271.06	3	3	4	6	5
Lebanon	6.85	79.50	7	6	5	6	3
UAE	9.63	641.58	77	81	98	100	108
Tunisia	11.57	128.33	8	6	9	7	11
Syria	16.91	—	1	2	1	1	3
Sudan	41.80	176.84	6	—	11	6	3
Saudi Arabia	33.70	1651.15	274	294	378	663	552
Qatar	2.78	313.03	19	14	26	15	25
Oman	4.83	177.87	3	8	3	14	10
Morocco	36.03	279.33	34	35	47	49	34

The data relating to population and GDP are from the UN Statistics Division and the World Bank. Data for PCT applications are extracted from WIPO statistics database deals with patents and licensing was developed throughout major US research universities [20]. Financial rewards in the form of royalties and fees from patents and licenses were readily the outcome of their activities.

It is noted, however, that supplemental revenue streams to universities were not the express intent of the Bayh-Dole Act of 1980. Rather, the intention was to enable creativity and innovation that would potentially generate and transfer technologies solely for economic development [20]. Technology transfer offices were an emerging model for life science industries which sprang up around universities. The route of technology transfer in developed economies starts with a company that funds a university to do a specific research towards the creation of new products. If the invention has commercial potential, then the institution enters into licensing deals for successful products and, in the process, collects royalties, and in lieu of licensing to existing companies, the institution may opt to help inventors to contrive spin-off companies of their own.

Public and private academic institutions in the Arab world are well aware that comprehension and full use of IP rights for research is lagging drastically behind other developed nations. There is a recognized need for designing specific incentives and approaches for collaboration that could open new opportunities for innovation and socio-economic development. Certainly, ever since the dawning of the Bayh-Dole Act (1980) in the US, PPP as a model for R&D has grown in importance rather significantly. Such partnerships aim to contribute to planning, investment in resources, shared risks and benefits, and activities that achieve mutual objectives and common goals between the public and private sectors [19]. There are, however, issues at stake with regards to IP rights and technology transfer, however, that are crucial for academic research institutions operating within PPPs.

In contrast, very few scientific researchers operating within the realm of public academic institutions do, at instances, come forth filing for patents. The prevalent practices are that while many scientific researchers may assign some economic value to their inventions, they, in fact, are not in a position to attract and engage the private sector in negotiations for investment. Hence, this readily becomes the role of university technology transfer offices, and it is often a demanding role on often limited human resources [16]. In summary, PPPs are increasingly important at a time when capacity development is direly needed, while discovering new knowledge should be the primary focus of universities by adding value to product development and increasing research sponsorship, thereby driving university research programs, particularly life sciences, biotechnology, energy, environment and health, and moving them forward. Albeit being limited in extent, paradigms for the advancement of theory and practices in technology transfer have, in fact, been sought by just a few universities in the Arab world [21]. There is, therefore, need to develop research capabilities which readily involve all the necessary knowledge and skills for negotiating and collaborating with the private industry and understanding issues of IP rights in the management of research and innovation processes.

4 The Roadmap for Research and Innovation-Driven Commercialization

Recent years have witnessed an overall downturn in the quality of research and innovation throughout the Arab World. There has been little done towards any corrective measure to drive the Arab economies towards more industry-oriented economies. There had been many ongoing efforts, though, on the part of individual scientists/researchers from the academia, to bring about some form of coupling between the academia and the private sector in anticipation of generating some feasible industrial model that would fulfill the ambitions of those concerned people in the Arab world. This is the traditional model where academia, industry and laboratory continue to produce their traditional output and contribute independently to economic development, and, hence, societal prosperity as shown in Fig. 3.

To have a knowledge-based economy that would move any industrial model to fruition, collaboration and coordination on many fronts must exist: (1) it takes a willing society as a primary driving force for any conception of a productive economy; (2) it takes a well-connected and highly harmonious academic system, at the one system level, but, also, at the inter-institutional level. This requires a good feedback system that would sense the direction of the market, and how closely a given academic model follows it. It, also, requires government sponsorship of a well-oriented research system that would ultimately fulfill the needs of the underpinning economy; (3) it takes a supporting private sector that can foster the needs of researchers who can, in turn, service the dire needs of that sector; and (4) it takes a full-fledged, well-designed review process of the academic system and its suitability for the prevailing job market needs. Through experiences, world-class institutes of science, technology and information nowadays view R&D as a potential source

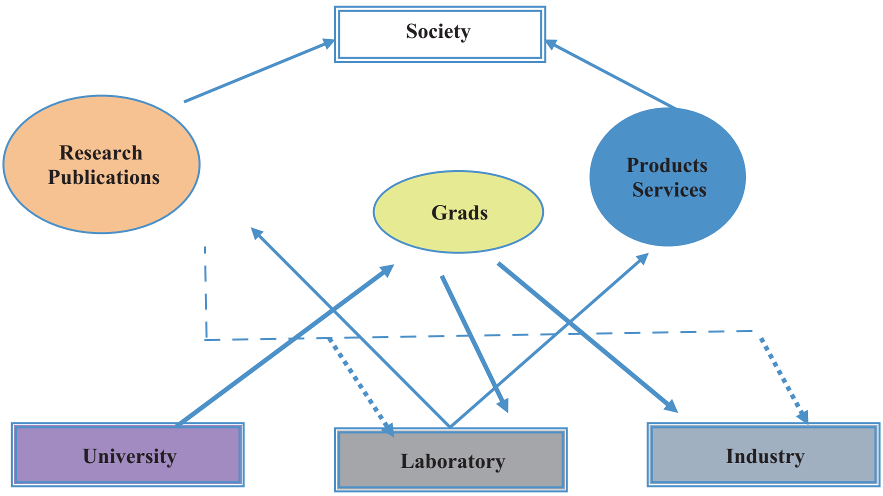

Fig. 3 Traditional model: independent contributions to society

of innovation, rather than the ultimate source of innovation. Therefore, the new outlook for innovation focuses on the confluence of innovation and entrepreneurship. In the advanced economic world, university, industry and government have a history, direction and evolution where academia contributed in the commercialization of research findings and R&D services as shown in Fig. 4. Under this model, through which potential partners collaborate to create research spin-offs or new ventures, or technology transfer companies for consultancy and R&D contracting, or spin-off or start-ups to transfer and commercialize inventions and technologies. In the field of R&D collaboration, universities, funding agencies and other collaborative partners often exchange intellectual property in order to join their research efforts and combine their knowledge. Licensing agreements or commercial licensing are also very relevant in this collaboration, for instance, a company may seek to acquire a technology useful to its work by entering R&D projects whose outcome can address the company's technological needs. Today, business technology parks, incubators, accelerators, start-up programs, entrepreneurial training programs, and social networks were established and clustered around major academic institutions, and all have assisted the process of translating new science findings into product opportunities.

In many Middle Eastern and North African (MENA) countries that share some common heritage, at various stages of the economic development lifecycle, there has been some rapid growth and development of science and technology park models as shown in Table 2, including business incubators and accelerators, which mimic paradigms of science and technology parks as those in the developed world. These parks were established to bolster startup technology-based projects and stimulate economic diversification away from the realm of declining industries. Business support incubators and accelerators offer an important spur to entrepreneurship and their programs are proliferating across the world. They are increasingly developing customized models of support with local or sector-specific case studies, mentors,

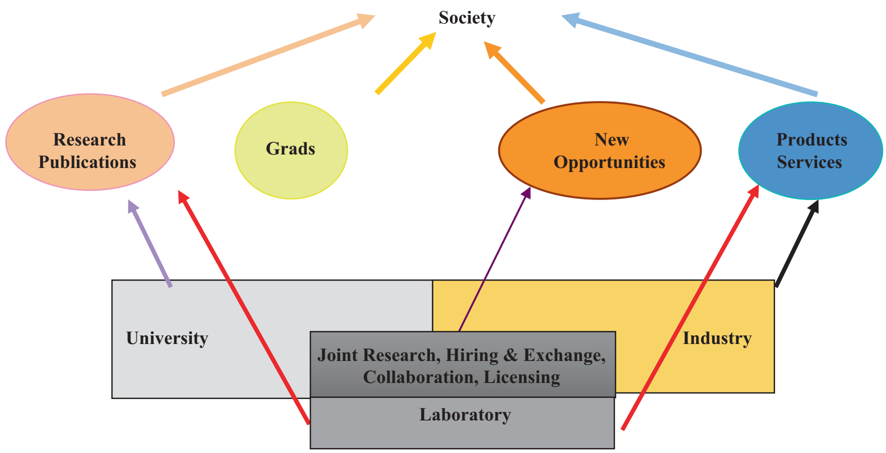

Fig. 4 New model: university-industry – laboratory partnership

Table 2 Science and technology parks in the Arab world

Bahrain Technology Park
Qatar Science and Technology Park
Technopole of Sidi Abdallah (Algeria)
Mubarak City for Scientific Research & Technology (Egypt)
Kuwait Technology Park
Syria Science and Technology Park
Dubai Techno park
iPark (Jordan)
King Abdul-Aziz City for Science and Technology (Saudi Arabia)
Berytech Technological Pole (Lebanon)
Casablanca Techno Park (Morocco)
Knowledge Oasis Muscat (Oman)
Elgazala Techno Park (Tunisia)

and instructors. They are also seen as a viable means to create new jobs, as well as an alternative to traditional employment-based livelihood approaches. However, the contribution and achievements of these parks, incubators and accelerators have often been disappointing in terms of patents granted, various small and medium enterprises that got supported, startup formations observed, and the licensing of emerging technologies. These disappointing results emphasize the need and importance for a general enabling environment for effective research, development and innovation systems.

The path ahead is probably to be more focused on applied scientific research and its commercial and industrial applications which help to drive the knowledge-based and data-driven economy in the Arab world. As the Arab world looks for its prospects, it needs to think of academic institutions as a powerful stimulant and an essential ingredient for the national economic development. Indeed, collaborative partnerships between academia and industry are needed to induce industrial innovation and tackle together many common multidisciplinary research activities. Nonetheless, what seems to stand in the way of such collaborative partnerships is a lack of a strong and committed R&D strategy with proper funding and infrastructure development, a lack of capabilities and incentives for engagement and participation, inefficient science and innovation policy, and improper training and leadership approaches. Where possible, the current COVID 19 pandemic needs to be reckoned as an opportunity to bolster research and innovation in the Arab world. This would require the different types of actors and all segments of an enabling environment where individuals and organizations come together and take the time to understand what research and innovation are needed and why research and innovation need to be leveraged a certain way. This readily becomes an integral part of the building of a research portfolio and/or development of a targeted product [16]. However, the prevailing and surrounding political and economic systems such as corruption, political instability and human rights violation in many Arab countries has had a negative impact on the prosperity and development of academic institutions in the Arab world, which end up impacting the quality of research and development [22].

5 The Role of Governments to Bolster Technology Transfer Efforts to Invigorate Innovation-Driven Commercialization

It is often times misleading to researchers to fathom the real essence of what technology transfer entails and/or what it is all about! Academic institutions have themselves fallen short on such notion notwithstanding the fact that technology transfer offices have solidly materialized at many of these institutions. Technology transfer, to reflect its physical reality, without a number of steps implemented on the parts of governments involved, cannot render the levels of service anticipated as a result of their sheer existence. Such steps usually involve, but are not limited to, the following:

(i) Proper legislation would need to be put in place to cater for the protection of various forms of IP, in general, patents, copyrights, trademarks, proprietary information that are reliable and meaningfully enforceable.
(ii) Proper measures would need to be instated such that the jurisdiction system would facilitate litigation of legal cases of foreign investors and speed up court verdicts.
(iii) Proper measures would need to be instated by governments to protect and safeguard foreign investments in the face of corruption, dishonest competition and any adverse consequences that could severely jeopardize the best interest of foreign investments and the underlying business models that are in play.
(iv) Proper legislation would need to come to fruition when it comes to offering medium- and long-term incentives to foreign investors including tax exemptions and export tax waivers.
(v) Proper labor legislation would need to be put in place to help foreign investors recruit both local and international labor forces, complemented with further legislations to grant essential imported labor forces the benefits of naturalization in terms of ultimate citizenship rights for the investors themselves as well as the essential foreign workforce.
(vi) Properly serviced infrastructure would need to be availed to foreign investors, including general infrastructures, transportation infrastructures, upscale and attractive accommodation facilities, upscale schooling, and world-class (K – 12) services together with globally accredited/recognized college education.
(vii) Proper higher education infrastructure would need to be availed at full scale particularly one that would fit the imminent needs of R&D requirements by foreign investors.

5.1 How Can Governments Lure in Foreign Investors to Operate Locally and Roll Out Globally Competitive Work Products

What matters the most to foreign investors as they set out to make significant investments in any country in question would usually involve a *strategic industrial estate* be already set in place. A strategic industrial estate is one that can cater for the needs of foreign investors in terms of integrated infrastructure facilities, accommodating telecommunications infrastructure together with upscale transportation infrastructures catering for freight capabilities via air transport, railway systems, freeway systems, access to nearby shipping ports, together with all the associated industrial infrastructures that would stand in support of the imminent needs of the foreign businesses involved and the associated workforces exercising stewardships over these businesses.

Availing such strategic industrial estates to foreign businesses would usually need to be leveraged to help the local sectors including the higher education sector and the local industries identify the proper mechanisms, channels and venues that would allow for technology transfer to take place readily locally. This can inherently take place by means of several approaches. In one approach, the governments involved would need to readily allow for local industrialists to operate in geographic locations not far apart from viably established strategic industrial estates. Furthermore, a government in question would need to shore up efforts to facilitate the existence of higher education institutions fostering graduate degree programs that stand in support of solving industrial problems relatively close by, geographically. Finally, governments would readily need to harness the research capabilities of research and science parks; ones that can be directly associated with a strategic industrial estate and/or ones that are already operating in conjunction with various academic institutions.

Nonetheless, but first and foremost, any projected strategic industrial estate in any of the countries involved must readily cater for some forms of core industries to exist for other peripheral and service industries to succeed. Figure 5 [23] illustrates, while summarizing, a successfully established schema that would bolster the various elements addressed in this chapter. This encompasses several players including the industrial sector, which inherently must cater for some core industries, together with a variety of other supporting industries. The model also addresses the need for some IP model to exist, which would operate across any successful academic-industrial partnerships. Other elements in the model point to the need for Foreign Direct Investment to take place, together with a much needed framework for innovation-fostering legislation all across the spectrum and amongst the various players.

Strategic core industries could entail such industries as automotive, locomotive and railways manufacturing; building of electric power generators including powertrains and various gears that would support renewable energy production; earth moving equipment, including bulldozers, cranes, mining equipment, jumbo

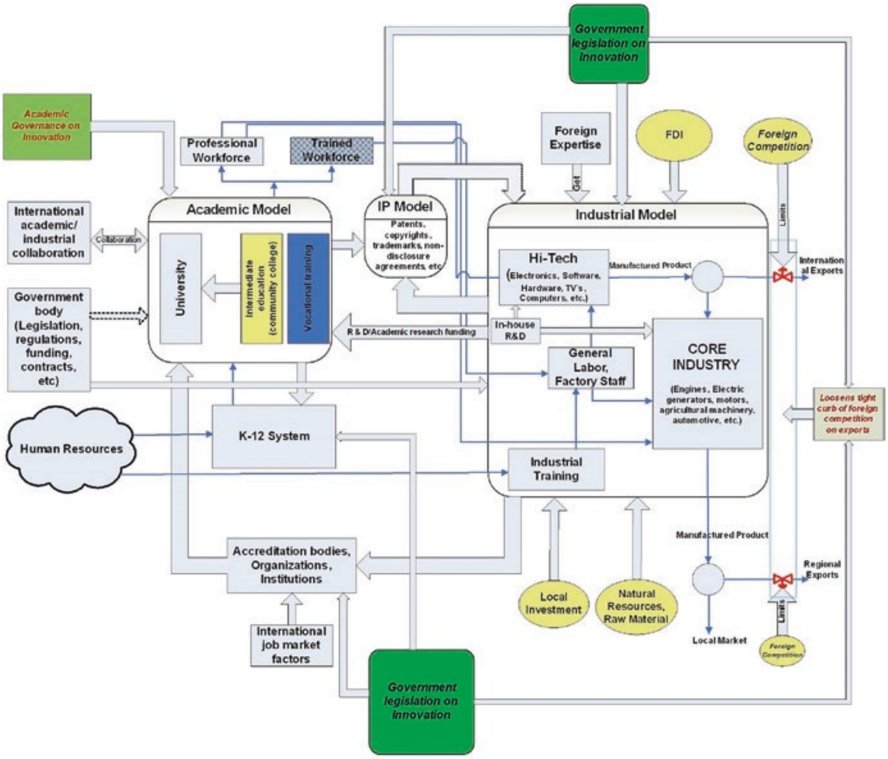

Fig. 5 System of interoperability complemented with innovation-enabling academic governance and supporting government legislations on innovation

construction trucks; and essential ball bearing industries, amongst others. These could also entail smart agricultural machineries including irrigation systems, tractors, and harvesting machines. Now, around many of these core industries, it would become imminent that other servicing and support industries, including electronics manufacturing, software solutions, networking gear (both for computer networks and smartphone applications), and intelligent systems, most of which would harness artificial intelligence (AI) and machine learning paradigms, all would need to flourish all around for the sake of creating a balanced industrial-economic ecosystem.

The existence of international core industries coming in to any given country, in the form of major investments, would at some point require the presence of other local industries that can be readily tallied for outsourcing tasks and other supporting jobs towards fulfilling the needs of existing foreign industries. It is precisely here, in fact, where real technology transfer can come about in various forms, at varying scales and at various levels. This is how the local work force would get to educate itself about the need for proper packaging, shipping and delivery paradigms to exist in order for the local industries to compete globally. This is precisely where many of the local industries will come to learn how best they can bring forth products to the local, regional and international markets thereby successfully bringing about globally competitive work products. This is also where many local industries would be able to leverage the expertise they earn via industry-industry collaborations and be able to understand market relevance when it comes to rendering new products and services to the markets. Most importantly, this is how new local industries are born and can ultimately survive the thrust of the prevailing global competition. This is where a given country would be able to tell whether it had been successful enough at transferring good technology from world-class industries and bringing them home to the benefit of the immediate communities involved.

5.2 How Has Technology Transfer Worked to Bolster the Progress of Other Economies and What Cultural DNA is more Inviting to Foreign Direct Investment

Observers of some other world economies would readily recognize that the countries involved have developed by leaps and bounds, catering for one or more, if not both, of the fundamentals outlined in the introduction of this chapter. Countries such as China, Ireland, Taiwan, Hong Kong, South Korea, Japan, Australia, Singapore, Malaysia, a number of countries in Europe and Africa, together with Turkey and Israel have adopted high-quality principles, embraced hard-core science, upheld research integrity, and fostered well-rounded education paradigms in their social ecosystems, and put in place practical frameworks for R&D.

International technology and life sciences firms like IBM, Microsoft, Intel, Motorola, Lucent, Huawei, Apple, Samsung, Google, CISCO, Seagate, Toyota, Ford, Tesla, Volkswagen, Tata, Hyundai, Mercedes, Caterpillar, Schaeffler AG, NSK Ltd., Pfizer, AstraZeneca, Bayer, Syngenta, Monsanto**,** BASF, and Corteva AgriScience, to mention just a few, have often found great inviting atmospheres in many of the countries just cited to roll out production facilities of their own. Amongst the primary driving factors that commonly entice many of these firms to embark on international ventures in these countries include well-functioning IP protection laws, competitive tax laws, high-end infrastructural facilities, competitive advantages towards export but, one and foremost, highly functional higher education systems bolstered with world-class research labs and centers, together with highly skilled workforces. What is more, in terms of the advantages tallied by these multinational companies, would include a leverage of the cultural DNA entrenched into the indigenous R&D processes when executed in the various world countries (outside the home country), added to that would be an associated reduction in labor costs accruing upon manufactured work products when produced off-shore. Moreover, these companies would readily reap the benefits of an added proximity to the consumer markets around the world cutting short the added expenses of shipping and handling and likely harnessing the tax advantages, thereby being at a competitive advantage economically.

In the Arab world, on the other hand, people often times tend to resort to types of discourse directly related to fictitious conspiracy theories that people tend to find solace and comfort in so as to blame shortcomings of their own on forces that wish the indigenous cultures great harm and stand in the paths of their progress. Here, people tend to deliberately forget that nations that had fallen short on any progress had often been highly emotional in their narratives and had often ignored rendering any serious attention towards furthering their educational and industrial wellbeing.

An examiner of the state of affairs of many Arab nations would readily realize the tragedy these countries have imparted upon themselves, particularly so during the ongoing COVID-19 crisis. While many developed nations around the world have exhibited perseverance and reflected genuine effort towards contriving vaccines and remedies, in service of humanity, to the COVID-19 disease, one would readily discover that none of the Arab countries have demonstrated any effort in the direction of working towards realizing any successful therapeutic outcomes in the service of their own constituents. This particular situation comes as a direct reflection of the prevailing clumsy R&D environments together with some severely dysfunctional educational and societal ecosystems, altogether.

The Arab world certainly is in dire need for a real revolution when it comes to its educational, both (K – 12) and tertiary education, ecosystem. The prevailing ethos of the Arab world at present is one that neither is inviting, as things stand, nor encouraging for outside investors to consider any of the Arab countries as some of their favorable destinations for serious major investments. When such situation continues unabated it is only regrettable to expect that countries of the Arab world will only go from one failed state right into another.

6 Reshaping the Way of Future Research and Innovation

6.1 How Arab Universities Can Maximize the Notion of Knowledge-Based Value

The mission of higher education is to disseminate knowledge broadly with the goal of capturing proprietary knowledge to gain competitive advantage. More specifically, for higher education institutions in the Arab world to prosper academically there is need to align universities' contributions with what is happening in their respective local economies, together with the national agendas involved [24]. In Western societies, universities are central to the foundation of a new knowledge-based and data-driven economy. Universities need to lead, but they also need to be held accountable, researchers need to take on responsibility for success and integrating research into teaching courses and policy rather than being only interested in themselves and receiving funds. Within a university eco-system, a researcher is driven by the desire to discover new knowledge and is motivated by pressure for peer recognition. For private industries, the commercialization of new technology and the financial gains through proprietary technology, on the other hand, is what matters the most. To bridge the gap between academic institutions and the industries involved, governments need to establish and implement legislations and a uniform innovation and science policy to encourage such partnerships for innovation. Higher education has always played a large role in the economy as a producer of human capital and as a center for R&D. Adding a third explicit expectation that higher education supports regional and local economic growth has clearly had its toll, but it remains to be seen whether all higher education institutions should embrace this engagement mission [25].

In the Arab world, the question for policy and decision making and for university administrators is how the key role of universities in economic growth and competitiveness can be taken to a higher level in ways that would leverage funding opportunities that potentially would go into them. In advanced economies, legislative and judicial changes play out significantly not only in legitimizing the place of a university as a knowledge producer, but in incentivizing it to develop, protect and exploit IP [26]. The substantial financial gains by Western universities from extraordinary scientific breakthroughs have been powerful motivators for many universities to increase their engagement in technology transfer [26]. Certainly, an innovation-leveraging economy readily translates new knowledge and insights into high value (value-added) products and services [25]. So, how good Arab universities are at maximizing the notion of knowledge-based value? How should they be governed and in the particular interest of whom should that be? Universities, indeed, should focus on giving students the ability to acquire any form of knowledge and move beyond an emphasis on vocational training to a broader, more classical education in order to develop the knowledge workers of the future [27]. The Arab world should promote programs and investments in advanced research and innovation in the key areas of biotechnologies, life sciences, energy, and in the environment and health sciences. University administrators, with the properly supporting governance, should provide their governments with long term strategic advice on research and innovation, systematically evaluate opportunities, make recommendations and implement strategies to support the development of technology, and foster the needs of an industry sector whereby the Arab world can be globally competitive. This should be done with the total collaboration and support from the governments involved, by introducing new programs with further partnerships developed to enhance technology and business development environments for research, innovation and technology commercialization.

Higher education systems in the Arab world are facing a multitude of challenges, that, amongst others, include the associated pressures to expand and also, simultaneously, having to address the issue of equity, while also ensuring high quality and market relevance. Currently, the demand for investments in higher education is only increasing, because of the strong population growth, and large cohorts of young people who are looking for good education and for rewarding career opportunities around society. Furthermore, in addition to the extra funding needed, several structural changes are required in national higher education policies and also at the level of higher education institutions themselves. The mismatch between the entire education system and the labor market requires a number of new measures particularly that in several countries there is a large, highly educated, but still mostly underused segment of society representing the female gender.

6.2 Strategic Principles in Technology Commercialization

There are many strategic considerations on organizing IP planning and management as well as technology commercialization including licensing and venturing. Higher education institutions should be evolutionarily restructured in accordance with changes in strategy, goals, and external environments. In general, there are many organizational alternatives to be considered including outsourcing and collaboration. Table 3 lists the recommended strategic principles in technology commercialization.

For those at the initiation stage, the following recommendations are suggested:

- Centralize oversight of commercialization processes and add venture start-up for its own technology commercialization – will leverage resource and database in IP management, information technology support, and knowledge management for commercialization activities.
- Assign new business development responsibility to each R&D unit to spearhead commercial efforts – will scan and identify innovative and marketable technologies within each R&D unit.
- Create a commercialization supervisory board of senior executives as a forum for decision making and oversight – will act as senior advisors and decision makers; responsible for approving portfolio strategy, previewing and overseeing approval processes for all venture activities and major licensing deals, allocating seed funding, hiring Chief Executive Officers and Director Generals for new ventures, and resolving conflicts among stakeholders.

Table 3 Recommended strategic principles in technology commercialization

Typical situation	Recommendations
Require cultural change	Build consensus internally and externally for proactive and strategic technology commercialization
Need new skills and experience	Go slow initially
Align with R&D planning needed	Build skills and processes first
Have limited capital availability	Spin-off technology ventures are preferred over licensing to maximize value creation
Comply with the government and organization regulation and supervision	Create some early success stories
Require legal and policy changes to support various technology commercialization activities and profit sharing	New performance measurement and profit sharing models are needed

- Review (and modify, as needed) patent/IP policy, profit sharing models, R&D project management systems to expedite technology commercialization activities.

7 Conclusion

R&D efforts all around the Arab world were neither of the level required for supporting any genuine local industries (core industries), nor were they of the quality that would incite citations of published research endeavors. As such, many universities within the realm of the developing world, particularly those in the Arab region, now, lack the level of visibility that would allow them to compete globally. Hence, it is well noted that without industry-grade research, fostered pervasively in Arab countries, that would lead to a real professional development of the faculty body involved, any teaching effort, conducted in ways of developing the learning abilities of the students involved, is ultimately bound to go off-track altogether. In fact, being in a rapidly changing world driven by core technological developments, galvanizing real economic growth would readily necessitate the production of high quality relevant research in ways that would invigorate innovative marketable outcomes.

In this chapter, we have addressed the issue of R&D at higher education institutions in the Arab world from various perspectives, taking into account collaborative efforts that must avail themselves to the industrial and academic sectors. The imminent roles of national governments, bolstered by the necessary R&D efforts within the industrial sector itself, and the assistance of outside parties, amongst many others, are readily in order. We have also addressed a potential business model that is expected to set forth some suitably practical niches for developing countries to conceptualize their own industrial infrastructure and would inherently lead the underlying economies towards real sustainable development. Furthermore, we underlined the notion of a transformative approach that would inherently connect universities to society and, thus, serve as a driver towards a productive society in developing human capital, and, therefore, making a positive contribution to the socioeconomic and cultural wellbeing of the Arab countries.

There is a need to shift our thinking and look at things in totally new ways. We, therefore, strongly recommend for the Arab world to kick off genuine endeavors that would help move this part of the world rather more aggressively up the industrial ladder. This would inherently rely on developing core industries of its own, leveraging the much-needed infrastructure and the requisite types of investment and tax legislation needed, in ways that would also enable leading global industries to take part in strategic-type foreign direct investment (FDI) in the Arab region in ways that would eventually galvanize global export markets.

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Research Possibilities in Computational Modeling as a Low Cost Alternative to Traditional Experimental Research

Sohail Murad

Abstract As resources for conducting traditional laboratory based research become more expensive and elusive, a low cost alternative of conducting computer based "experimental research" is presented. In this paper, as an example, the use of computational molecular modeling to address an important problem on separating drug enantiomers is described. Enantiomers are molecules that are images of each other but have distinctly different chiral centers and consequently therapeutic behavior. This can result in one enantiomer being therapeutically beneficial, while the other can be at best benign, but sometimes toxic. An example of this is thalidomide that was used beneficially in the 1970s for morning sickness in pregnant women but the second enantiomer caused birth defects. Separating enantiomers is therefore becoming important, but their separation experimentally is very challenging and requires many "trial and error" studies for a successful strategy. Computational molecular modeling can be used for screening studies and has the potential for cutting such experiments and the final cost by up to 80%. Such research is relatively low cost but can still be very impactful.

Keywords Computational molecular modeling · Water desalination · Gas an liquid separations · Drug enantiomers · Drug delivery

1 Introduction

The overall objective of this paper is to present an approach to conducting high profile research. Such a strategy is very suitable for developing countries in the Arab Middle East, that often lack resources for experimental research. Often such sophisticated equipment is generally only widely available in developed countries.

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Many researchers in Arab Countries obtain their advanced degrees in developed countries and invariably conduct their thesis research in state of the art and rather expensive research facilities. Once they return to their home countries, such equipment is generally not available and this often leads to considerable frustration amongst the returning researchers. The most common causes of such frustration include:

- Lack of experimental equipment for conducting state of the art research
- High cost of equipment
- Bureaucratic hurdles for importing such equipment
- Lack of maintenance services for equipment
- Lack of spare parts for minor breakdowns
- Lack of supplies needed for using equipment

In this paper we report an area of research, which while being high impact and high profile requires only a small fraction of resources needed to conduct state of the art research in other fields. The main ingredients of such a research program can be described as:

- Theoretical research
- Computational research
- Computational molecular modeling
- Minimal resources needed for such research
- Use of shared central computing services
- Use of services available at a university or national service
- Use of local computing facilities – work stations
- Dedicated equipment generally inexpensive (~USD 10,000)

2 Examples of Research Possible Using Such Resources

2.1 Desalination of Brackish Water

Most of the countries in the Arab Middle East are facing acute water shortages. In reality there is generally no shortage of water in the region, rather it is a question of both managing water and treating the available water to make it suitable for both human use and agriculture use in some cases. Computational molecular modeling is an ideal tool for such studies. This method can be used to test new membranes for water treatment technologies such as zeolites, as well as to understand the separation mechanism in these membranes, that leads to the high separation factors and fluxes that are key to making these separation processes economically viable. The systems for conducting such studies can be readily setup in these computational studies and they can serve both as a very effective screening tool to test new membranes for possible applications and understand the molecular mechanism in such membranes to design more efficient membranes. A simple setup for such a study using zeolite membranes is shown in Fig. 1 [1, 2].

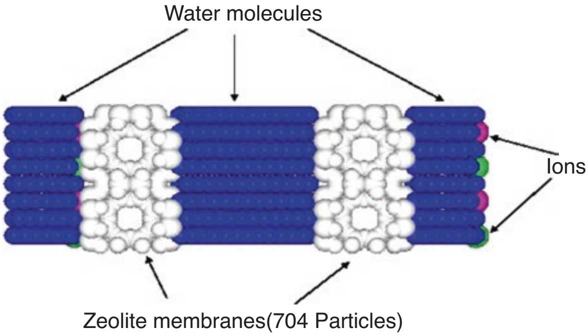


Fig. 1 A simple molecular setup for conducting studies for desalination of brackish water

2.2 Separation of Gases

Many countries in the Arab Middle East have highly developed petroleum industries. A key process in these industries involves separation of petroleum-derived gases. For example to convert natural gas into petro-chemicals, catalysts are often used, which are very sensitive to impurities (gases such as sulfides and even carbon dioxide). Thus developing efficient methods for gas separations are key to the success of these industries. Computational molecular modeling can play an important role in developing more efficient separation processes for separating such gases. We give below some setups that have been successfully used for such separations (Fig. 2) [3, 4].

2.3 Separation of Drug Enantiomers

Many drugs when manufactured contain enantiomers (stereoisomers that are mirror images but have identical chemical composition). In many such drugs only one enantiomer is therapeutically active, and the other at best can be benign, but in some cases can be toxic. An example of a toxic enantiomer is a drug marketed during the 1970s (thalidomide) for preventing morning sickness amongst pregnant women. In thalidomide the undesirable enantiomer was found to cause birth defects amongst the children born when this drug was taken during pregnancy [5]. There is therefore an important need to develop separation technologies for such enantiomers. An example of such a pair of enantiomer is shown in Fig. 3.

Typically, such separations are carried out by HPLC (high pressure liquid chromatography), which is rather expensive. And picking the correct chiral stationery phases and the solvent and modifiers is often a trial and error procedure, which makes developing technologies for new drugs rather cost intensive. In fact the separation of enantiomers is a major impediment for developing new orphan drugs. Computational molecular modeling can make significant contributions to developing such technologies with benefits such as cost saving screening technology

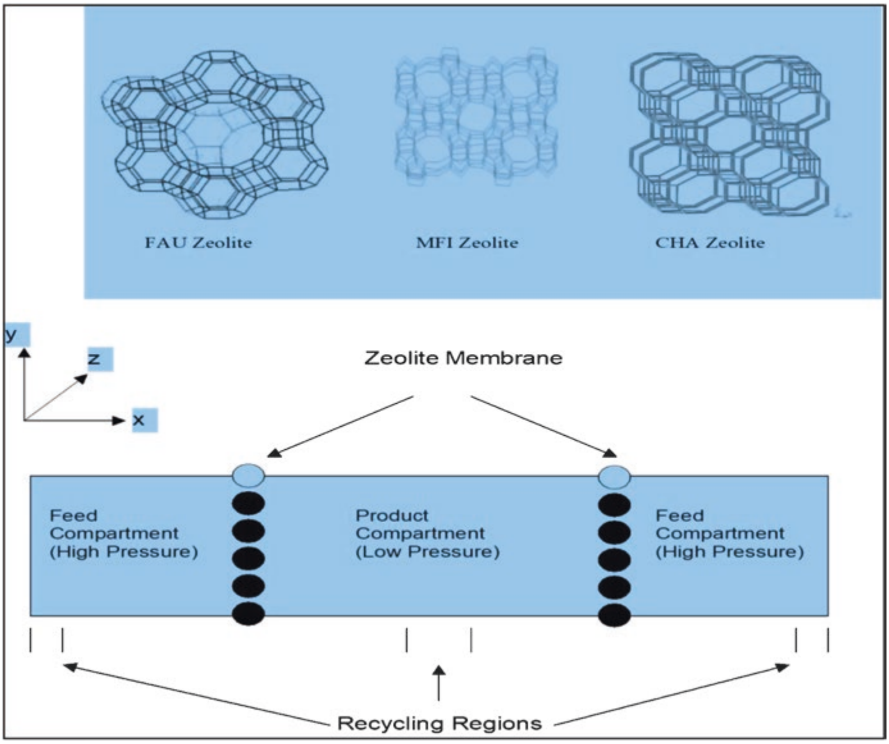
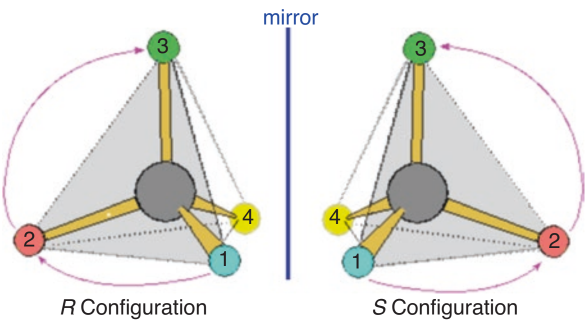


Fig. 2 A setup to study separation of gases using zeolite membranes

Fig. 3 An example of enantiomers in a typical chiral drug



(50–70% expected savings) based on molecular modeling for separating molecules that are identical except for geometric differences, that are present in the development of pure orphan drugs [6, 7].

2.4 Developing New Generation of Batteries

Most Arab countries have immense potential for solar energy. However, solar energy is an intermittent source of energy, so efficient power storage technologies are an important ingredient of developing commercially viable renewable energy. Once again computational molecular modeling can play an important role in developing such new technologies. One example of this is the development of redox flow batteries. Such batteries are not being widely used because the ion exchange membranes being used are not stable in the long run, and do not prevent ion leakage which leads to battery discharge. An example of a typical redox flow battery is shown in Fig. 4.

Computational molecular modeling can be used to screen new ion exchange membranes rapidly and efficiently. For example one recent computational study showed that a range of zeolites performed significantly better than the Nafion membranes currently being used in these batteries [8, 9].

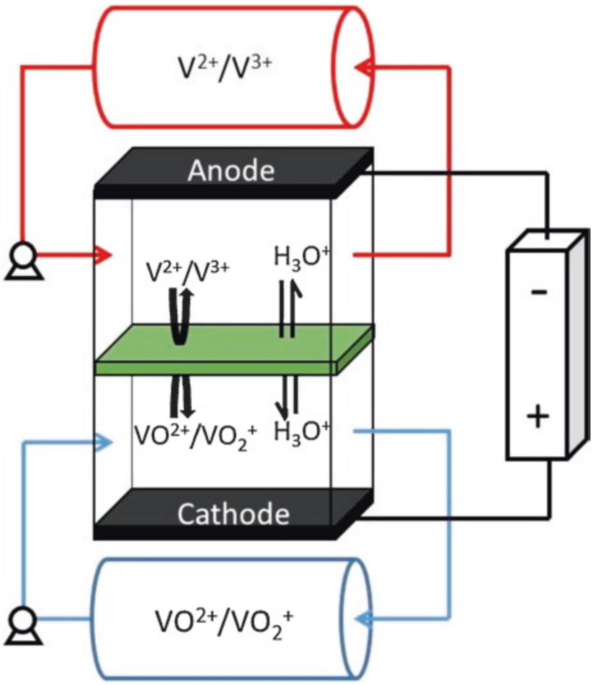


Fig. 4 A typical redox (reduction-oxidation) flow battery. The ion exchange membrane key to the successful design of such batteries is shown in green

2.5 Improve Heat Dissipation in Semi-Conductors

There is a continuous need to develop semi-conductors that are smaller in size. However these devices are rather power intensive and thus efficient methods have to be developed to dissipate the heat generated in these devices. In fact thermal buildup is the main impediment to further miniaturization. Once again computational molecular modeling can play an important role in the design of such devices, since the interfacial thermal resistance is a key roadblock for improving heat dissipation. Molecular modeling techniques are ideally suited to study such interfacial resistance and make them more efficient. A possible setup for such a study using molecular modeling is shown Fig. 5.

Such studies can play a pivotal role in [10, 11]:

- Understanding the heat transfer rate at the solid-liquid and liquid-liquid interfaces
- Understanding the interface resistance and the role of surface characteristics
- Comparing simulation results with experiments when possible
- Determining if thermal rectification is possible in liquids by manipulating surface interactions and nature of liquids
- Determining if interfacial resistance is anisotropic

2.6 Using Nanoparticles as a Vehicle for Drug Delivery

Computational molecular modeling can be used to address several important issues related to targeted drug delivery using nanoparticles. These include [12, 13]:

- Understanding the impact of drug delivery vehicle (i.e., nanoparticles) interactions with biological cells
- Increased understanding of what types of nanoparticles are viable candidates for drug delivery applications
- Microscopic behavior of molecules can be calculated by molecular simulations

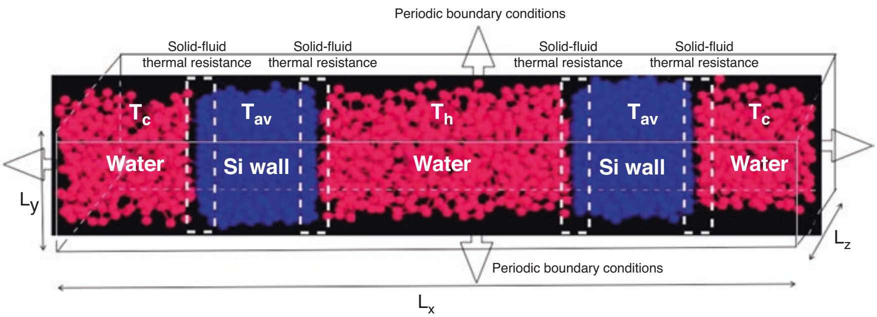


Fig. 5 A schematic of the system setup to study interfacial thermal resistance

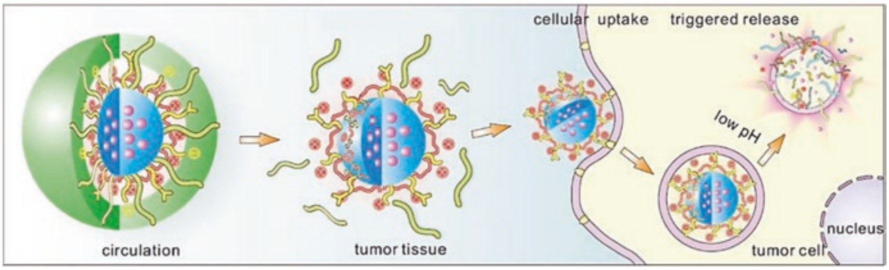


Fig. 6 Issues critical to targeted drug delivery using nanoparticles

- Approximating the interactions in the system using simplified models (fast calculations)
- Asking "What if?" and gain insight into situations that are difficult to study experimentally. A schematic of the range of systems that can be investigated is shown in Fig. 6.

3 Conclusion

In conclusion, computational molecular modeling is a low cost alternative to more financially demanding experimental research, but has the potential of having a significant impact on a wide range of both scientific and societal problems. In summary:

- It is possible to do high impact research using relatively inexpensive computing facilities
- Most software needed for such research is available free of cost (examples: LAMMPS, NAMDA etc.)
- Commercial softwares also available at low cost to academic institutions (examples: Amber, Gaussian, VASP, etc.)
- There is the possibility of examining a wide range of scientific problems using the same software and facilities

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Contemporary Challenges Confronting Scientific Research in Humanities within Higher Education Institutions in the Arab World

Diala A. Hamaidi, Yousef M. Arouri, and Helene Kordahji

Abstract Scientific research plays a vital role in a nation's development and progress. Yet, research conducted within the Arab region still confronts many difficulties. This chapter reviews aspects related to the reality of these obstacles in the field of humanities based on the analysis of research papers conducted by faculty members from higher education institutions in the Arab World. It discusses specifically the financial, administrative, and personal obstacles of scientific research in the humanities faculties. It also provides constructive recommendations on how to tackle these challenges. Such reforms will allow universities to create a sustainable research climate where its faculty are encouraged and supported to conduct projects that address the needs of nation and make an impact, while working within a collaborative team setting.

Keywords Scientific research · Humanities colleges · Challenges of scientific research · Universities of Arab region · Opportunities of enhancement · Scientific research climate

1 Introduction

When measuring the development of societies, scientific research is considered an important indicator. It is crucial in any field of knowledge as it ensures the sustainable progression of nations and the well-being of their people [1].

Scientific research can be interpreted in many ways. It is an organized attempt directed at solving human problems in different aspects of life [2]. It is also an

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intellectual effort that seeks to solve existing and future problems while uncovering new knowledge [3].

It can be perceived as a way to discover, examine, and develop knowledge that is generated through scientific methods of investigation and integrated in a manner that contributes to the development of global civilization [4]. However, such efforts require specialized and well-trained researchers who are highly skilled and have specific attributes [5]. For research to make an impact, it is contingent on the quality of researchers and their ability to create original work [6].

Universities are contributors to scientific research. Many higher education institutions are renowned for their contributions in the field of research, development and innovation [7]. Within the Arab world, some universities are lagging in research especially in the field of humanities as they have not yet embraced research as an important pillar for their development.

This chapter will examine in-depth the challenges related to scientific research in the field of humanities in the Arab region. It will shed the light on the hindrances that are delaying the progression of this research and will examine aspects of development that can enhance the quality of scientific research in humanities in the Arab world. This chapter is based on the review of related previous research conducted between 2000 and 2020.

2 The Importance of Scientific Research in Humanities

Scientific research plays a prominent role in solving and finding solutions to problems efficiently and objectively. The contemporary scientific revolution would not have been possible without the sound scientific methods that were developed and implemented.

Unfortunately, natural research seems to be the recipient of more attention when compared to research conducted in the fields of social sciences and humanities [8]. The importance of humanities research is that it focuses on context. What this means is that researchers often pursue to describe and understand the phenomenon at hand following quantitative and qualitative approaches [9].

Research in humanities does not aim to find the correct answer to a question. It uncovers the issues and details that surround the question. It provides information and data necessary for decision-making and paves the way of change in societies. It also advances knowledge and provides solutions and alternatives that deepen the understanding of the different dimensions of social studies.

3 Challenges Confronting Research in Humanities

Despite the many resources in the Arab world, scientific research is still not thriving as it should be. There is an array of challenges that confront the progression of research in the humanities. Unless serious steps are taken to tackle them, creating a research environment that makes an impact cannot be achieved or sustained.

On a national scale, scientific research is closely impacted by the political, economic, social, cultural, and educational circumstances of the society. It is also affected by the society's perspective and understanding of scientific research and its importance and need [7].

Even though many Arab nations have formulated national research policies, they have not been properly or clearly implemented due to lack of funding, not enough emphasis on rolling out such initiatives, human capital challenges, and weak collaborations with research institutions and the industry [3].

On an institutional level, universities in the Arab world need to reform their structures to ensure that research is a critical pillar within their strategic planning. Also, the role of universities should not be limited to knowledge creation but sharing and exchanging knowledge are equally important.

In addition, faculty members are encountering many difficulties during their research such as under-developed infrastructure and teaching loads, which in turn affect research. It is important to highlight that the number of full-time Arab researchers is considerably lower when compared to the numbers in developed countries. This has a negative impact on the productivity of research in this part of the world [2].

The below sections summarize the major challenges and issues that hinder the improvement of research in the field of humanities in universities in the Arab world. It sheds the light on the concerns highlighted by faculty members at humanitarian colleges across the Arab landscape.

3.1 Publishing of the Scientific Research

Scientific publishing, its importance, and role in developing human knowledge have been highlighted in the previous literature [10, 11]. The importance of published research is that it showcases recent statistics, contributes in knowledge exchange and aids in decision-making processes and in the formulation of policy work.

Some studies have demonstrated that there are many realistic difficulties related to publishing in the Arab world. Some of these obstacles are related to the process of publishing scientific research in peer-reviewed journals and others to the process of writing it.

With regards to publishing, one example is demonstrated at the University of Babylon in Iraq [11]. The findings of this study concluded that there are seven peer-reviewed journals at this university. Since the journals were self-funded, the production and publication processes were relatively weak. In addition, there was a low appetite for non-Iraqi researchers to publish in these journals as they contributed to 14% of publications as opposed to 86% by Iraqi researchers. Foreign scholars, on the other hand, have not yet published in these journals. Hence, such publications had a minimal impact on research and development.

One important factor in the issues related to publishing is the linguistic difficulties. Within the humanities colleges of education, many faculty members have voiced their concerns that most of the publications seem to be in English and other foreign languages. This affects the access of researchers to specialized knowledge as they are unable to utilize it for their Arabic publications [12]. These researchers struggle to find information that is up to date including scientific references and published research papers necessary for their projects [13]. Because of the lack of adequate references, many researchers face difficulties in publishing their papers in prestigious scientific journals [14].

It is uncommon for an Arabic paper to be translated into other languages [11]. This is a hindrance as it affects the ability of these papers to reach a wider platform and to be used by non-Arab researchers. Many Arab researchers choose to write their research papers in English in order to reach an international audience.

In addition, publications do not seem to receive enough attention and publicity from universities. There is also an absence of proper distribution networks for university journals. Such factors have led many faculty members to become reluctant to publish within the university's journals and seek external outlets for publications [15].

Further challenges related to publishing in the field of humanities are attributed to delayed approval processes of research proposals [1]. There is an evident delay in publishing the accepted research by educational journals. Another important point is providing researchers with the arbitrators' comments within an accepted timeframe. Also, the professional quality of the arbitrators chosen by the editorial board to review the research before it is approved for publication can be contested [16]. Bureaucratic administrative obstacles that are tied with proper follow-up of the publishing and arbitration processes were among the difficulties experienced by faculty members [13].

When discussing publications within the Arab world, it is important to note that the laws of publications in some countries impose restrictions on circulation and publications, which is not in alignment with the current era of globalization, technology and communication [15].

With regards to the process of writing scientific research papers, some of the highlights of the literature review reflected that many students in graduate studies do not rely on themselves in writing original research. There are private offices that provide writing services related to research papers [11]. Some students also lack academic writing skills and an understanding of how referencing works [7]. Such attempts affect the quality of written research in institutions of higher education which, as a consequence, have an impact on the publishing process [11].

3.2 Financial Support

Inadequate financial funding and support for research has contributed to lower levels of productivity and publishing in the Arab world. One can argue that what is spent on scientific research in the Arab world does not even compare to expenditures on research and development in developed countries [12].

The review of the previous studies indicated a clear consensus on the financial barriers faced by humanities scholars in higher education institutions within the Arab region [10, 13, 17–19].

Not receiving enough financial support was a clear challenge articulated by many scientific researchers [18]. Financial budgets allocated for scientific research seemed to be insufficient [13]. In addition, some researchers have also stated that they do not receive fees for publishing in journals by their institutions [10]. Many higher education institutions were found not to offer incentive plans to motivate faculty to conduct research [14, 16, 18]. The lack of investment in platforms that provide modern academic references and highly classified journals in libraries were also concerns voiced by researchers [20].

Increased travel costs and high participation fees for regional and international conferences are also financial barriers faced by Arab researchers [21]. The availability of limited resources is affecting the adequacy of funding provided for research. For instance, higher education institutions receive minimum funding from community institutions to support research [22]. This is partially attributed to the negative perception on research within the Arab community [22].

Many view universities as pathways to obtain a degree and find a job; hence, the importance of research and its contributions is overlooked or misunderstood [6, 23]. In conclusion, the weakness of funding research and development in humanities has resulted in many graduate programs developing a curriculum which heavily relies on theoretical studies due to the unavailability of experimental research requirements [1].

3.3 Attributes of Scientific Researchers

Many researchers in the Arab region face an array of personal obstacles that affect their scientific research attributes.

Studies have shown that plenty of experienced researchers endure the same hurdles as fresh researchers [14, 19]. Without a doubt, the financial aspects play a major role, and this has been discussed in the previous section.

A considerable personal obstacle is the lack of technical training researchers receive; the importance of this training is that it enhances their skills and abilities to conduct all types of research in accordance with the needs of society [24].

Many researchers are more inclined to perform quantitative research as opposed to qualitative since some editorial boards in Arab scientific journals prefer quantitative methods. As such, this has had a direct impact on undergraduate and graduate studies in humanities where qualitative methods are not well studied [25].

When discussing the challenges of researchers in the Arab world, one cannot but shed the light on the issue of brain drain and the migration of research competencies [2, 12]. Many prominent researchers have been leaving the Arab world in pursue of better futures in the west. As a result, several Arab higher education institutions struggle with retaining qualified researchers due to the phenomena of brain drain [10]. Universities must endeavor to retain qualified scholars and researchers through well-implemented incentive plans. These researchers are critical for improving the universities' ranks through their publications and citations.

Within the colleges of humanities, some researchers require proper training on how to access and properly utilize modern databases necessary for research. Although there are thousands of databases within the Arab region, many researchers are not well versed in using them. Acquiring such a skill is a necessity as it affects the quality of the research work produced [26].

Another important note to highlight is the spirit of teamwork required in research. One of the twenty-first century skills is the ability to work cooperatively with other colleagues [27]. Some may argue that the culture of teamwork within research is lacking at the university level in the Arab world [1]. One reason is the inability to appoint scientific research committee members from within the higher education organization [14] who are able to consider and welcome input from other colleagues and build on it [28].

3.4 Scientific Research Climate

Building a conducive and well-sustained environment is important in higher education institutions. It directly affects the quality of research output and the faculty's performance.

There seems to be an absence of clearly defined research policies within universities [2]. These policies create clear pathways for researchers to conduct their work in an orderly manner. Their absence or lack of implementation directly impacts the ability of researchers to engage in meaningful projects.

In general, the research climate within the Arab region does not have the advantage of strong ties and relations with the industry and development sector [8]. There is also a weakness in linking scientific research with the needs of the nation and industry; hence, often, the research is not addressing priority needs. It is critical that Arab nations develop clear research strategies with key priorities based on the needs of their societies. As an illustration, if postgraduate students' research is directed to serve the problems facing society, then the results could be directly applied and implemented [1]. This also highlights the importance of applying the results of the research on the ground [29]. Research is meant to make an impact.

There is a pressing need to establish a new climate that boosts the image of research in humanities. Spreading the culture of scientific research in all components of academic work is therefore critical [15].

3.5 Work and Organizational Commitments

On the work front, administrative commitments of faculty reduce the time that can be devoted to research [14]. Many researchers face difficult working conditions. Faculty suffer from increased teaching and administrative loads which hinders their ability to conduct research [16].

Many researchers in the field of humanities have voiced their concerns that research is considered part of their work duties and as a result they are not properly compensated for all their work [14].

On the organizational front, most Arab universities suffer from bureaucracy, administrative and organizational problems [13, 30]. They require fundamental reforms in terms of their governance structures and strategic planning to ensure that faculty are given the space to conduct research. This means investing more in their infrastructure, building sustainable research centers, acquiring adequate funds, and reforming their teaching vs research loads are all necessities.

4 Suggestions and Aspects of Development

Within the colleges of humanities at higher education institutions in the Arab world, the success of scientific research is dependent on the continuous and cumulative efforts of all those in the sector. Individuals cannot achieve tangible research progress without the adequate conditions that will allow them to prosper and grow.

An important step in the right direction is the provision of sufficient funding and financial support through allocating appropriate budgets for scientific research with incentive plans that encourage researchers to undertake projects [31]. To improve the quality of research writing and publishing processes, scientific research deanships and publishing bodies in universities must ensure additional issues are accepted to reduce the accumulation of approved research. This will reduce the delay in publishing time and ensure that research results are not lost [16].

To overcome publishing hardships, a suggestion has been put forward to establish an administration for scientific publishing in universities to facilitate the publication process for researchers in local and international peer-reviewed journals.

Some researchers presented a development vision that focuses on activating aspects related to improving the quality of scientific research which includes providing undergraduate and graduate students with a study plan that includes courses concerned with scientific research skills. These courses should also focus on academic writing skills that enhance the attributes of the researcher. In addition, faculty members are encouraged to properly mentor their students in different research methods. There is also a need to publish distinguished research conducted by students and faculty in scientific periodicals issued by the university [32].

On a strategic level, universities must develop clear visions for their research in alignment with the nation's priority plans. Faculty members and researchers must be encouraged to prepare applied research plans that stem from the needs of society [2]. Specialized committees should be formed within universities that study research priorities and guide the application and implementation of research within the institution. Universities must also develop comprehensive plans to collaborate with local and international institutions and the industry to ensure knowledge is properly exchanged.

On the human resource front, clear incentive plans should be mapped for faculty to conduct research [33]. In addition, universities must properly address the balance between teaching and research so that faculty can allocate appropriate efforts in each area. Faculty should also be supported financially to attend local and international conferences to discuss their research and network with fellow researchers.

It is equally important to devise professional development plans for researchers in the humanities particularly in the areas of qualitative research. There is a pressing need to focus on the importance of conducting high-quality qualitative research to highlight the scientific role of such studies in the fields of social sciences [25].

Other training topics could cover the usage of digital resources and libraries when it comes to sourcing references. Professional development could also incorporate sharpening the productivity skills through better organization of time and method of work, documentation of information and results, and improving the scientific methods of thinking, analysis, communication, and dialogue with others [27].

To improve the internal climate for research within higher education institutions, better work conditions [34], teamwork and cooperation should be encouraged. This is also very important for multi-disciplinary research.

Without a doubt, the importance of scientific research in the field of humanities within the Arab region is a necessity. However, this type of research requires support from a national, financial, human capital, and institutional level. The notion behind the importance of such research and its potential should be clearly understood. To thrive and succeed, researchers need a sustainable climate that supports their work and encourages their progress. National strategies should be aligned with institutional policies to ensure research is not wasted and is beneficial.

Enhancing collaborations and building international networks is crucial for researchers to sharpen their skills, conduct multi-disciplinary research, and most importantly, exchange knowledge. Researchers should work in a research climate that inspires and develops their capabilities. There should also be clear performance indicators for them to ensure the quality of research is not compromised.

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Innovation and Scientific Research at Jordanian Universities: The University of Petra as a Case Study

Marwan El-Muwalla

Abstract The shift towards knowledge-based economies that depends on innovation, scientific research and a well-trained workforce has led to many changes in the higher education landscape worldwide. In Jordan, the value of research for achieving long-term national, regional and international academic and economic competitiveness has received growing recognition over the past few years. This paper departs from the premise that innovation and research conducted at the institutions of higher education play a crucial role in the development of effective academic systems and in competing in the knowledge economies of the twenty-first century. To this effect, this paper investigates how the University of Petra has promoted scientific research and innovation to secure its academic development and sustainability in a globalized world in which research and innovation have become vital contributors to the advancement of the economy and the society as a whole.

Keywords Innovation · Scientific research · Knowledge-based economy · University of Petra

1 Introduction

Although research has been defined in a number of ways by different organizations and entities working in the field of higher education, there does not seem to be a single, all- encompassing definition adopted by all the parties engaged in the higher education system. Nonetheless, there is a common denominator that is shared by all the definitions, namely knowledge. Indeed, there is unanimous agreement among researchers that research aims at increasing knowledge, and hence enhancing peoples' understanding of a particular topic or issue.

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The Organization for Economic Cooperation and Development (OECD) defines research as "Any creative systematic activity undertaken in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this knowledge to devise new applications" [1]. This definition entails that research plays a significant role in developing a multi-faceted human knowledge upon which economic, social and technological progress depends. According to Tripp et al. [2], in today's knowledge-based economy "research is the glue that ties society and the economy together, and underpins almost all productive human activity".

Innovation involves the creation and implementation of a new product or service with the aim of improving the economy. In fact, it is considered one of the key factors underlying the changes that take place in the way of thinking and productivity witnessed by a society. Innovation is not a new activity pursued by individuals and institutions; rather, it has been pursued throughout history as exemplified in the agricultural, industrial and information revolutions that introduced innovations that have changed the quality and value of peoples' lives [3]. It is therefore not surprising that Rosenberg et al. [4] consider that research and innovation constitute the real wealth of Nations. This explains why research and the ensuing innovation have been an important component of the work carried out by universities since their establishment. It is believed that higher education institutions can only fulfill their goals, if education, research and innovation are considered complementary forces that deserve to be given equal attention.

This paper investigates how the University of Petra (UOP) has promoted scientific research and innovation to secure its academic development and sustainability in a competitive educational milieu that invests extensively in research and innovation as a driving force behind national progress.

2 Innovation and Scientific Research at Arab Universities

Although the institutions of higher education in the Arab region have come a long way during the past 25 years or so, these institutions still face a number of common challenges that need to be addressed to improve the kind of education they offer. One of these challenges is associated with the quality and paucity of innovation and scientific research.

In the past few years, researchers have invested in studying the reasons underlying the weak status of research at Arab institutions of higher education because this problem has hampered these institutions' advancement as well as their ability to compete with universities in developed countries [5]. The research conducted in this field has revealed that the Arab countries have reacted in very similar ways regarding their approach to research and innovation, and hence the intersection of factors that have acted as stumbling blocks towards the improvement and advancement of scientific research carried out at these institutions.

Research conducted on the different Arab universities dispersed all over the Arab world indicates that research and innovation is lagging behind in these institutions. Anderson [6] considers that the deterioration of research at Arab universities can be attributed to limited academic freedom, open enrolment policies, and underinvestment in public institutions. Hafiz and Farah [quoted in 5] both attribute the status quo to the lack of strategic planning as well as the disinterest in research by the private sector. According to Almansour [5], Naifah is in agreement with Hafiz and Farah, for he contends that strategic planning is missing at Arab universities and that the research conducted is detached from the market realities. He also notes that the frustrations experienced by the members of staff with regards to the research funding and research incentives that they are granted have played a key role in the decline in the quality and quantity of research; needless to say, these frustrations have forced members of staff to produce research that is adequate merely for promotion purposes. Albargouty and Abosamrah [7] reiterate the impact of low expenditure on the research output noted at Arab universities. They indicate that Arab universities have to allocate more funding towards research and innovative practices if they want to improve their rankings and academic reputation in order to be able to compete with renowned international institutions of higher education in the long-run. The Secretary General of the Association of Arab Universities also discusses a number of challenges that have a negative effect on research in the Arab region; two of the most pressing challenges that he mentions are the low rates of expenditure and the lack of a clear strategic planning [quoted in 5]. These challenges "warn of the poor level of scientific and applied research in the Arab region compared to Western countries". Interviews administered by Almansour [5] with university rectors and experts in the Arab world have underscored the need to develop a research infrastructure that "values faculty, offers recognition, and supports research through grant funding, training and publication assistance". The components of this infrastructure are expected to secure the improvement of research carried out at Arab universities and to guarantee a better innovative environment at these institutions.

As far as expenditure on research is concerned, statistics by the UNESCO reveal that research activities at Arab universities is quite humble in comparison with universities in other parts of the world. The 2004 figures indicate that expenditure on research related matters in the Arab region did not exceed USD 1.7 billion which represents 0.3% of the Gross Domestic Product (GDP) of these countries. Also, the 2010 UNESCO figures show that the Arab region is classified among the lowest regions concerning the funding allocated to research and innovation. Abu-Orabi [8] considers that Arab expenditure on scientific research is limited when compared with the scientific research expenditure in industrialized developed countries. While the expenditure amounted to about 0.2–0.6% of the national income GDP in the Arab countries in 2014, this amount was around 2–4% in industrialized countries.

Studies have also considered the quality of research presented by faculty members affiliated to Arab universities. The results reveal that publication in quality journals continues to be an issue that needs to be addressed by these institutions. Statistics provided by Khraif et al. [9] for the year 2015 indicate that publications from Arab universities in Top Quartile-Q1 journals was 34%, while the number of publications for Seoul National University and the National University of Singapore were 49% and 62%, respectively. The researchers note that the average citations per paper for the aforementioned research remains low, whereas papers grouped under the zero-cited papers index represent a large proportion of those published in the year 2012. These findings show clearly that the caliber of research carried out by Arab universities fails to meet international standards; an issue that needs to be resolved if institutions of higher education in the Arab region want to improve their research reputation.

In addition to the studies conducted on the quality of research provided by Arab universities, studies have been undertaken to investigate the quantity of this research. According to Khraif et al. [9], the total number of papers published by staff working at Arab institutions of higher education in the year 2015 amounted to 35,486, whereas the number of papers published by Korean universities for the same year was 56,204. This is a noted difference if the population of the two regions is taken into consideration. In another study conducted by Al-Khatib [10], the data indicate that by the year 2018 the total number of papers published by researchers affiliated to universities in the Arab world amounted to 410,549. Although an increase is noted in comparison with the 2015 figures, Kent [11] is of the viewpoint that the "combined output of Arab states remains minimal compared to powerhouses in the West."

Studies conducted on research in the Arab world reveal that Arab universities have to increase their expenditure on research, develop their research infrastructure, give incentives to quality research and collaborate with the private sector to be able to develop and improve the kind of research that is presented by these institutions.

3 Innovation and Scientific Research at Jordanian Universities

In Jordan, the higher-education sector has witnessed significant changes since the establishment of the first institution of higher education, namely the University of Jordan. The transformations experienced since 1962 that included the introduction of new specializations, the adoption of new teaching methodologies, the establishment of private universities, and the advent of internationalization have all played a role in changing these universities' teaching missions, research interests, economic and social development, and entrepreneurship strategies [12]. One of the challenges that these institutions have encountered is associated with the promotion of scientific research and innovation.

The importance of scientific research and innovation on the socio-economic development of Jordan has tempted the government to give these two scientific fields the attention they deserve. As a result, activities grouped under research and innovation have been "institutionalized under a national umbrella that would set science and technology policy, strategies, plans and programs" [13]. To fulfill this goal, the Higher Council for Science and Technology and the Scientific Research and Support Fund were established to provide guidelines that would contribute to the development and advancement of the country's science, technology, research and innovation activities. Also, the Law of Higher Education and Scientific Research and the Law of Jordanian Universities were amended in 2018 to secure quality education at Jordanian institutions of higher education [14].

Therefore, the project entitled "Defining the Scientific Research Priorities in Jordan for the Years 2011–2020" was initiated to achieve three aims: (1) to identify the national priorities related to scientific research in the different fields of science, technology, research and innovation; (2) to direct researchers towards the scientific tracks that are expected to contribute to the nations' development; and (3) to provide funding to research projects of a national dimension. In fact, determining the scientific priorities of a number of sectors has given "scientific research the feature of comprehensiveness" and "has realized balance among the different sectors" [15].

The research and innovation status at Jordanian universities for the years 2012–2015 are clearly noted in the research results reached by Khraif et al. [9]. The study shows that the faculty at all the Jordanian universities published 1310 papers in 2015 which is a humble number if compared with the 12,980 papers published at Saudi universities; out of the 13,10 papers, only 57 papers appeared in the top 3 journals. The number of papers in high-impact journals published by faculty at the Jordan University of Science and Technology and the University of Jordan amounted to 5.5% and 2.7%, respectively. The results also reveal that the *h*-index for Jordanian universities for the year 2012 was 26%; a weak percentage in comparison with the *h*-index achieved by other Arab universities. This status quo witnessed an improvement in the academic year 2017–2018 when the papers published at the Jordan University of Science and Technology reached 689 papers with an average of 0.73 papers per staff member [16]. However, much needs to be done regarding the quantity and quality of research produced by members of staff at Jordanian universities if these institutions want to compete with their regional and international counterparts.

However, the combined efforts of the government organizations and those of the institutions of higher education have played a positive role in the remapping of the research activities conducted in the country. It is noted that more funding has been allotted to research and innovation, faculty have been given incentives for publishing research in high-impact journals, and innovative centers were established and rewards were granted to excellence in research. In an interview with the president of the University of Jordan in 2016, the president stated that the university has undertaken a number of measures to advance the university's ranking, including "systemization of scientific research and instituting measures to encourage the faculty to increase publication in high-impact journals" [5]. Such measures, according to the president, have paid off and led to advances in the university's world ranking. Indeed, the faculty affiliated to the university published more that 17,000 research papers by January 2020 and have registered more than 110 patents [5].

Although the abovementioned developments helped in improving the research and innovation environment in the country, there seems to be unanimous agreement amongst specialists and researchers that this activity in Jordan is still very weak [17]. According to Bawab [18], although the Scientific Research and Support

Fund spent a total of USD 58.8 million on scientific research between the years 2008–2018, this figure remains very low. Bawab added that the percentage of the GDP invested in other countries is way higher than in Jordan. Also, Ibanez Prieto [17] quotes Abu Orabi who warned of the poor level of scientific and applied research in Jordan. He attributed the status quo to the lack of funding and the immigration of researchers.

It is my contention that scientific research and innovation have gone a long way in Jordan in the last 20 years. Nevertheless, much needs to be done in this area if universities in this part of the world are to compete with their renowned regional and international counterparts.

4 Innovation and Scientific Research at the University of Petra

Since its establishment in 1991, UOP has given research and innovation due attention. The Deanship of Scientific Research and Graduate Studies is responsible for supporting and promoting these two aspects by setting future plans in accordance with the vision and mission of the university. The Deanship's organizational structure (Fig. 1) indicates the type of work it performs and the areas of interest emphasized, namely scientific research, business and technology, technology transfer, and graduate study programs.

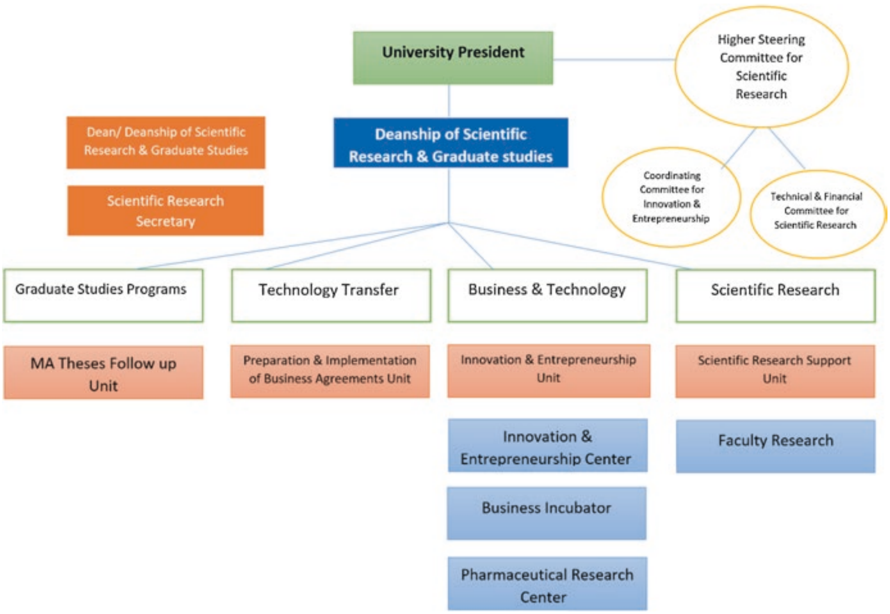

Fig. 1 Organizational structure of the Deanship of Scientific Research and Graduate Studies at UoP

4.1 Scientific Research

The value of scientific research has always been acknowledged at UOP. In fact, the belief that research plays a pivotal role in improving knowledge and facilitating learning has made the university adopt a clear systematic strategic plan toward the advancement of research. This plan is continuously amended and improved, and the positive impact accrued has been noted over the years.

During the years 1991–1999, the research activities at the university were modest in terms of quantity and quality. This was the case because the funding and incentives allotted to research projects were limited; publication in high-impact journals was not emphasized; and the university's main focus, as a newly established institution, was on teaching and building a reputation in that domain.

However, these conditions witnessed a turning point as of the year 2000 when a number of steps were taken to improve the status quo. To this effect, the university introduced a strategic plan for scientific research and innovation that takes into account four major significant aspects: (1) providing adequate funding; (2) encouraging publication in prestigious, high-impact journals; (3) liaising between the research conducted at the university and the national scientific research priorities; and (4) emphasizing applied research.

As far as funding is concerned, the university was committed to spending 3% of its budget on scientific research, with around 55% of this budget allocated to research grouped under the rubric of national interests and priorities. This sum was later increased to 5%, with 3% spent on research related issues and 2% on scholarships for postgraduate studies. The 3% spent on research went to fund: (1) research projects; (2) publishing incentives; (3) participation in conferences; (4) summer research grants; and (5) patents.

This rise in expenditure is clearly noted in the sum of money spent to support publication as well as incentives given to publish in accredited scientific journals. A comparison of the figures for the years 2014, 2016, 2018 and 2020 reveals two points regarding the amount of funding provided towards research. First, there was a quantum leap from the 2014 figures allotted to research and the 2016 figures. In 2014, only USD 5355 was spent on scientific research, while USD 50,120 was spent for the same purpose in 2016. This noted increase may be attributed to the implementation of the regulation on scientific research, patents and participation in conferences of the year 2016, which clearly delineated between the funding allocated for publication and that allotted to incentives to publish in top journals. In 2014, a differentiation was not made between the two types of support; consequently, only USD 5369 was spent to support publication. In 2016, however, the funding assigned by the university was distributed to support publication and incentives for publication, whereby USD 32,760 were spent on the former and USD 17,360 were spent on the latter; this encouraged faculty affiliated to the different faculties to produce research of a diversified nature.

The above figures also reveal a substantial increase in the total amount of funding spent on research between the years 2014 and 2020. In 2014, USD 5355 were allotted to research publications; this figure jumped to USD 66,255 in 2020. The USD 60,900 increase in 6 years is a clear indication that UOP has realized the correlation between funding and the increase in research output.

This development was the outcome of the amendments made to regulation for scientific research, patent and participation in conferences of the year 2017 which provided more systematic guidelines for research funding. These regulations differentiated between the two categories: funding for support for publication and the incentives for publication categories. The former form of funding provides researchers with the financial sources needed to conduct their research, while the latter form of funding is given to members of staff after publishing their research in quality journals. These incentives set the amount of money spent on research on the basis of the impact factor of the journals and the SCImago Journal Rank (Scopus). Moreover, incentives were allotted to journals published in Arabic and which are not covered in international databases, such as Scopus and ISI; these criteria encouraged faculty and staff to produce research projects that cover a wide spectrum of topics as well as high-quality research papers publishable in prestigious journals (Figs. 2, 3 and 4).

In addition to the funding allotted to the publication fees and the scientific publication incentives, UOP has provided generous financial support to the research projects that cover a wide array of topics, many of which abide by the national scientific research priorities. While, UOP allocated USD 182,615 to funding research

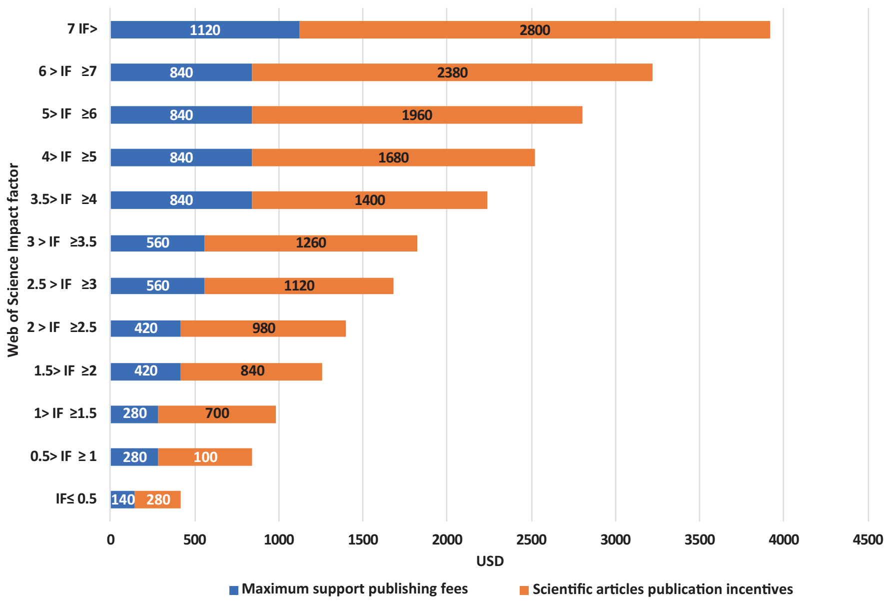

Fig. 2 Funding allotted to support for publication and incentives for publication based on the Impact Factor

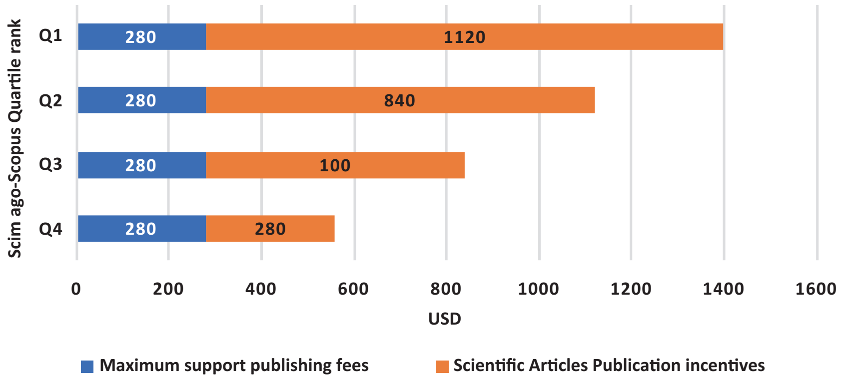

Fig. 3 Publication Support and Publication Incentive Criteria for Research Papers based on the SCImago Journal Rank (Scopus)

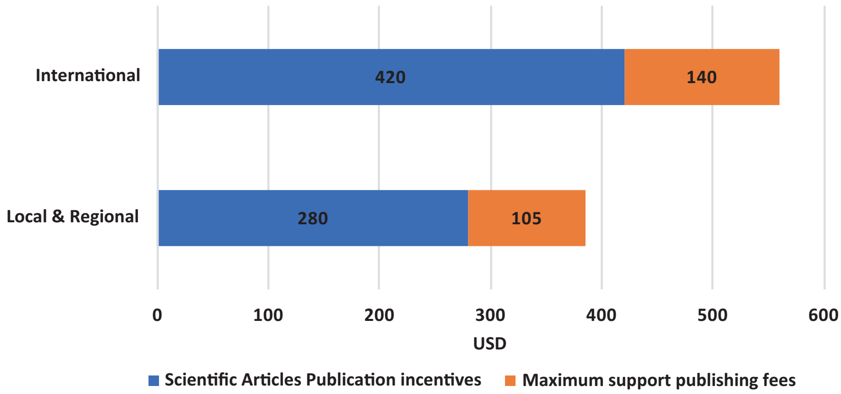

Fig. 4 Support and incentives for journals published in Arabic (No IF in Web of Science-Clarivate Analytics)

projects in 2012, this figure rose to USD 740,628 in 2020 which is a threefold increase in less than 10 years (Table 1).

When research proposals are submitted, the Deanship of Scientific Research and Graduate Studies takes into consideration the national scientific research priorities set for Jordan in the selection process. UOP adopts the vision of the Higher Council of Science and Technology which stipulates that the research sectors grouped under the national priorities can be addressed by researchers "in order to contribute to solving numerous problems suffered by different sectors in the national economy, thus contributing to push forward the wheel of economic, social and cultural development in the Kingdom" [15]. Indeed, out of the 79 research projects submitted for the year 2021, 60 proposals address national priorities (Table 2), which indicates that research related issues at UOP are geared towards the public benefit and are directed towards national needs.

Table 1 Distribution of Funding for the years 2014, 2016, 2018 and 2020

Year	Support for Publication (USD)	Incentives for Publication (USD)	Total
2014	5,355	–	**5,355**
2016	32,760	17,360	**50,120**
2018	52,150	15,400	**67,550**
2020	42,875	23,380	**66,255**

Table 2 Research Proposals & National Scientific Priorities 2021

National Scientific Priorities	Number of Research Proposals
Innovation & Entrepreneurship	1
Information & Communication Technology	9
Basic Sciences	6
Humanities, Social Sciences & Economics	12
Agriculture & Veterinary Sciences	2
Medical & Pharmaceutical Sciences	24
Engineering, Nano & Bio Technology	3
Water & Environment Sciences	3
Not within the remit of the National Scientific Priorities	19
Total	**79**

The aforementioned forms of support have impacted research at UOP in terms of quantity, quality and scope. With regards to quantity, the financial support provided has encouraged faculty and staff to indulge more in research, for a steady increase in the number of papers published was noted between the years 2000 and 2020. In 2000, 7 papers were published; in 2010, the number rose to 128; and in 2020 the number stands at 652. This means that from 2000 to 2010, the publication of research increased at a rate of 12 articles per year, whereas from 2010 to 2020 this number reached 52 articles per year which is a noticeable increase in performance (Fig. 5). Although this increase may seem humble, it is considered a marked development if compared with the research activities carried out at other national and regional institutions of higher education [9].

This increase in quantity was coupled with a rise in publication in high-impact journals, which in turn resulted in a significant jump in the number of citations for the papers published. Whereas the citation figures were 287 for the year 2000, these figures amounted to 4458 in 2020. Thus, the citations per published paper ratio rose from 41% in 2000 to 68% in 2020 (Fig. 6).

The number of citations has resulted in an increase in the *h*-index with 33 in 2020, as opposed to 28 in 2019. Figure 7 indicates that out of all the documents considered for the *h*-index, 33 have been cited at least 33 times. This rise in the *h*-index shows that there was a steady increase in the number of papers published in 1 year; a clear indication that the efforts exerted towards research have yielded positive results. However, it is the university's contention that more needs to be done in spite of the improvements noted in the number of citations and the *h*-index in order

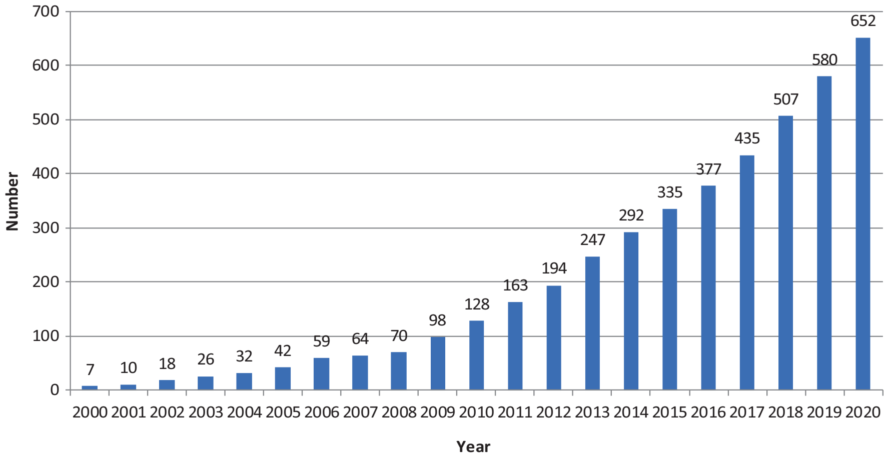

Fig. 5 Accumulative annual research papers published in Journals

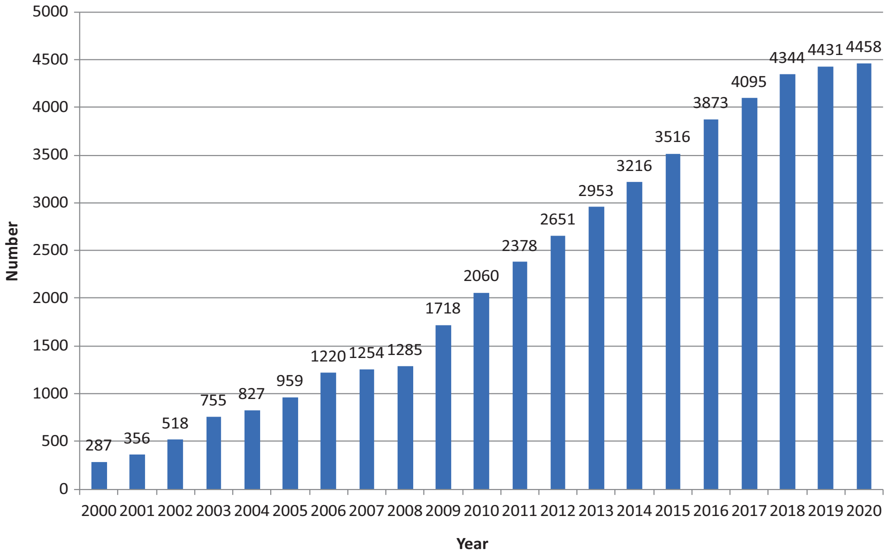

Fig. 6 Accumulative number of citations

to compete with regional and international universities and secure better world rankings. To fulfill this goal, the Deanship of Scientific Research and Graduate Studies is reconsidering the support and incentives allotted to research as well as amending the promotion regulations.

The number of research projects funded also underwent a significant increase during the years 2010–2012. Figure 8 reveals that there has been an exponential

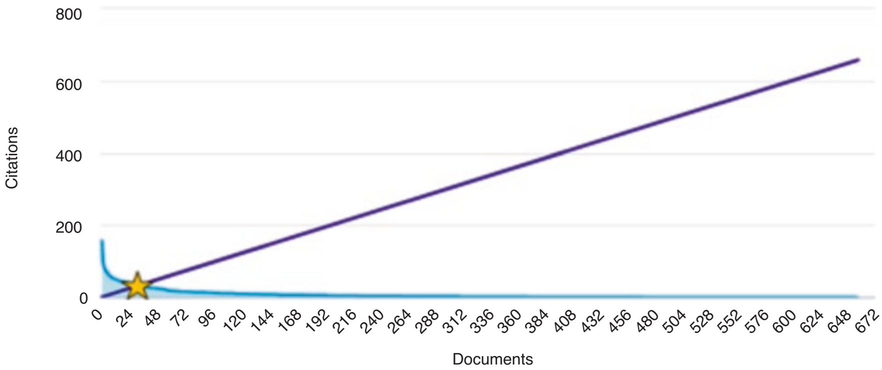

Fig. 7 Number of citations for the 33 documents considered for the *h-index* in 2020

Fig. 8 Cumulative number of funded research projects for the years 2012–2020

increase in the funded research projects at UOP from 2012 to 2020. Whereas the university funded 13 projects in 2012, this cumulative number rose to 295 in 2020. This surge underscores the importance of funding in encouraging faculty and staff to submit projects that might lead to long-term rewarding effects on the national level.

To ensure accountability and effectiveness, the Deanship of Scientific Research and Graduate Studies implements a rigorous assessment process of the submitted project proposals. The proposals are subjected to a two step procedure. First, the project is assessed internally; then, the successful projects are assessed by external reviewers. Once unanimous agreement is reached concerning the project's academic, economic and social impact, the researcher receives the allocated funding for the project. This evaluation process is considered a key element in setting the university's research priorities, and hence policy making regarding scientific research.

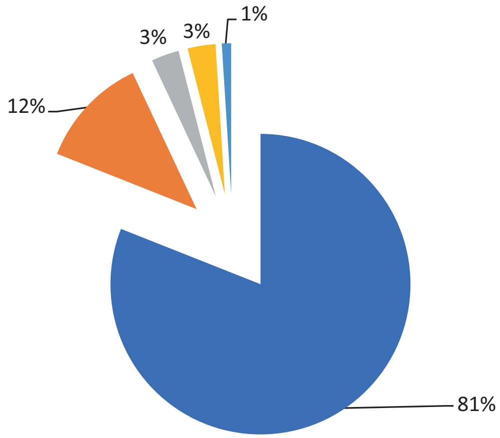

Fig. 9 Forms of Research for 2020

As for the prevalent types of publications, the research published came in different forms: books, articles, conference papers, reviews and book chapters. Figure 9 indicates that articles represent the primary channel for the dissemination of research, followed in order of importance, by conference papers, reviews, book chapters and books; a result that is in accordance with the findings on university research in other parts of the world [19].

The developments noted in the quantity and quality related to the research performance at UOP indicate that the culture of "publish or perish" has steadily gained momentum among the faculty and staff working at the university. The systematic regulations, the generous funding, and the research milieu have all played an instrumental role in improving the research performance at UOP.

A further step taken to encourage research at UOP was the amendment of the Summer Scientific Research Grant in 2016. This grant allows researchers from UOP to spend the summer period at a host institution working on collaborative research. If the host institution does not provide financial support, UOP regulations stipulate that it pays the researcher an economy-round trip ticket and a monthly living expenses allowance for a 3-month period [20]. The cumulative number of researchers who received the grant in 2019 was ten, but due to the COVID-19 pandemic this grant was cancelled for the summer of 2020 (Fig. 10).

To join the fourth age of research, which is characterized by international collaboration between "elite international research groups" to secure the increase in quantity and quality of published research [21], UOP has expanded its scientific collaboration with international institutions of higher education. According to Adams [21], the "citation impact is typically greater when research groups collaborate, and the benefit strengthens when co-authorship is international". To this effect, faculty members are currently involved in research with the University College of London (UCL), Bradford University, the Royal Academy of Engineering, Universität Tübingen, Abertay University, Imperial College London, University of East Anglia,

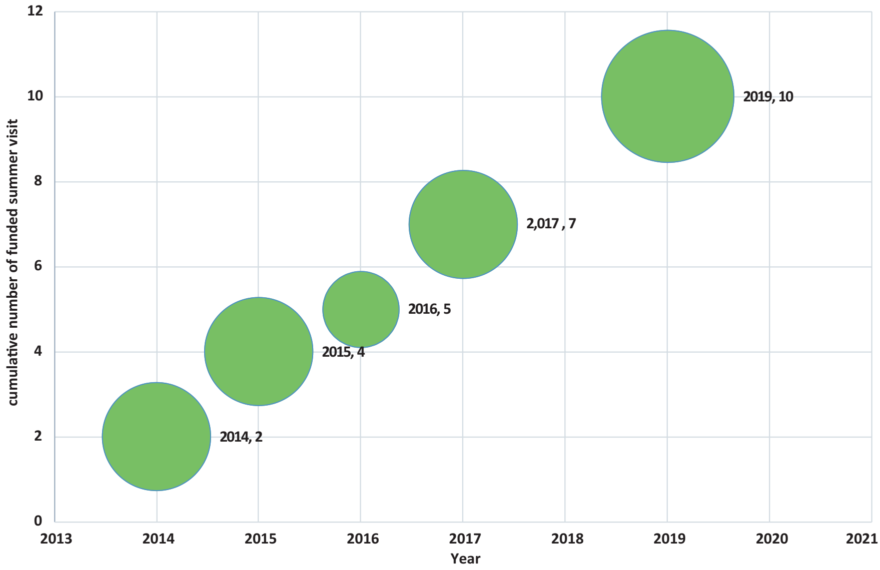

Fig. 10 Cumulative Number of Funded Summer Research Grants

and Norwich Medical School, among others. Researchers at UOP have also received national and international grants and awards to conduct applied research that covers a wide spectrum of topics. For instance, researchers from the faculties of engineering and pharmacy have received a USD 105,000 award from the Newton Khalidi Fund in collaboration with the Royal Academy of Engineering and Bradford University in the UK to work on the project entitled "A New Heavy Metal Treatment Process Using a Bio-adsorbent Based on Modified Olive Leaves Biomass". These awards and grants indicate that research at UOP has won international acclaim. Table 3 shows the quantity of collaborative research work conducted by faculty at UOP with their national, regional and international academic and industrial counterparts. This is a clear indication that UOP tries to create links between academia, applied research and the market realities.

Needless to say, the scope of research has also been positively affected as a result of the generous funding provided by the university. Faculty at UOP started giving applied research the attention it deserves, and new links with businesses and the industry were established. For example, a joint research project with a local chocolate factory has led to the production of a sugar-free chocolate that is enriched with vitamins and minerals. This end-product, which is considered the first of its kind in the Middle East, has succeeded in fulfilling the following: (1) achieving the requirements of applied scientific research; (2) creating links with the industry; and (3) meeting the needs of the community.

Also, faculty and staff affiliated to the different departments have become more involved in scientific research, producing research that is diversified in nature. The pie chart below reveals the percentage of participation in research conducted in

Table 3 Collaborative Research between UOP and National, regional and International Institutions

Institution	Documents
The University of Jordan	118
Hashemite University	41
Applied Science Private University	28
Al-Zaytoonah University of Jordan	28
Al-Balqa Applied University	27
Jordan University of Science and Technology	25
Jordanian Pharmaceutical Manufacturing Co. PLC.	25
Universität Tübingen	21
Al-Ahliyya Amman University	20
Taif University	17
Al Al-Bayt University	15
King Saud bin Abdulaziz University for Health Sciences	14
American University of Madaba	14
American University of Beirut	13
Jordan Center for Pharmaceutical Research, Amman	13
Abertay University	11
Imperial College London	10
The World Islamic Sciences and Education University	10
University of East Anglia, Norwich Medical School	10
Philadelphia University Jordan	9
Universität Duisburg-Essen	8
Yarmouk University	8
University of Baghdad	8
Oxford Brookes University	7
University of Sharjah	7

2020 by the faculty and staff associated with the different specializations at the university (Fig. 11). It is clear that members of staff working in pharmaceuticals, and its related disciplines, have been the most active in research, representing 13.6% of the research conducted at UOP. Indeed, this represents a shift away from the domination of research presented by the social sciences during the years 2004–2010. This discrepancy may be attributed to the fact that the number of faculty employed at the Faculty of Arts and Sciences was much higher in comparison with the number of faculty employed at the Faculty of Pharmaceuticals and Medical Sciences. For example, during the academic year 2004–2005, the faculty affiliated to the Faculty of Arts and Sciences represented 35.5% of all the faculty employed at UOP, while this figure was 15.5% for the Faculty of Pharmaceuticals and Medical Sciences.

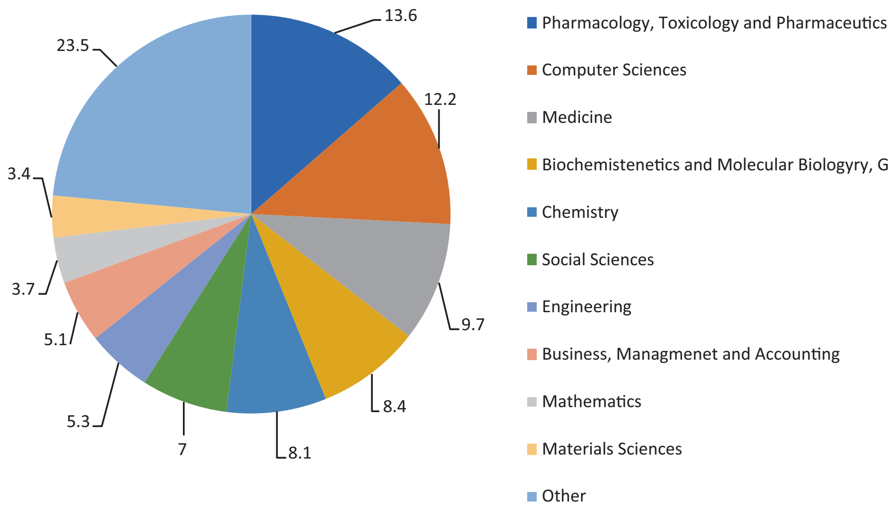

Fig. 11 Research Publication according to field of specialization (percentage)

4.2 Innovation

Innovation at UOP follows the national innovation strategy which aims at creating a Jordanian innovation-based economy and disseminating the culture of innovation, research and development and the development of specialized human resources as the framework for the innovation and technology transfer activities conducted at the university.

Accordingly, a number of steps were taken to implement the framework adopted and to secure its success. The first step was the establishment of centers that aim at encouraging and motivating innovation and technology transfer projects that are in alignment with the national priorities. These include the Petra University Pharmaceutical Center and the Innovation and Entrepreneurship Center that aim at developing the research and innovation capabilities of the faculty and students for long-term sustainable growth.

The second step is related to funding patents and the registration of patent ownership rights. Lately, awareness concerning the need for conducting scholarly activity that translates basic research into commercially viable processes and technology has become of utmost importance to universities seeking sustainable prestige and recognition [22]. This approach has gradually changed the academic culture at universities because it reinstated the need to partner with the industry in order to transfer the new knowledge emerging from university research to the society at large; a gap that still exists between academia and the industry in many parts of the world.

To keep up with these new developments and to encourage innovation and the commercialization of the technological advances achieved by faculty and students, the university's higher administration has allocated USD 35,000 towards these two activities since 2017. This has resulted in 2020 in the registration of six patents by the university at the Department of Intellectual Property affiliated to the Ministry of Industry and Trade in Jordan, making UOP the first private university in the country to have registered this number of patents. In addition to these patents, two others have been filed with national and international patent registration entities and another patent is in the drafting process (Tables 4 and 5). Indeed, the innovative activities carried out at the university will help in enhancing the university's reputation, sustaining its scholarship level, maintaining student success and, in the long-run, securing public benefit and national economic development.

The third step concerns the promotion of innovation and technology transfer by holding conferences that tackle such issues. Indeed, UOP held an Innovation and Technology Transfer Conference in 2019 to highlight the importance of innovation and to market its innovative practices by creating links with the industry and businesses. Also, a ceremony was held to honor the researchers who have contributed to

Table 4 Patents Registered in 2020

Title	Inventor	Status
Portable neck treatment devices	• Abdal-Kareem M. Albanna • Majed Naser Albanna • Ghassan F. Issa • Sanad Mohammad Omar Barjawi • Ghiath Mhd Kheir Eriksousi • Tamara Aljubooru	Published
Substituted quinolone compounds, their use in the treatment of cancer, and a method for preparation	• Ahmad Moh'd Kamel Al-sheikh • Tawfiq Abdul Raheem Mohamed Arafat • Luay Fawzi Moh'd Abuqatouseh • Eyad Mazin Omar Mallah	Published
A composition for treating anemia	• Nidal Adel Mohammad Al Qinna	Published
A composition for accelerating would healing	• Mayyas Mohammad Ahmad Al-Remawi • Faisal Tawfiq Al Akayleh • Nidal Adel Mohammad Al Qinna	Published
Orally-dispersible solid pharmaceutical formulation	• Mayyas Mohammad Ahmad Al-Remawi • Faisal Tawfiq Al Akayleh	Published
Pharmaceutical composition for use as analgesic, anti-inflammatory, or antipyretic agent, and a method of preparation thereof	• Mayyas Mohammad Ahmad Al-Remawi • Faisal Tawfiq Al Akayleh	Published

Table 5 Patents in the Process of Registration

Title	Inventor	Status
"Surfactant-free" safe foaming liquid composition for personal care	• Mayyas Mohammad Ahmad Al-Remawi	Filed at the United States Patent and Trademark Office
Alginate sodium gelation in a two-step sequential addition of magnesium followed by calcium ions	• Mayyas Mohammad Ahmad Al-Remawi	Filed at the International patent system (PCT)
Novel room temperature therapeutic deep eutectic systems of fentanyl and fatty acids	• Mayyas Mohammad Ahmad Al-Remawi • Faisal Tawfiq Al Akayleh • Rana Obaidat (Jordan University of Science and Technology)	Drafting process

the advancement of innovation, creativity and research and development at the university. These two activities have underscored the importance the university attributes to innovation and technology transfer.

The achievements noted on the innovative front at UOP reveal the systematic planning adopted by the university's higher administration and the Deanship of Scientific Research and Graduate Studies in this domain. To maintain and improve innovative practices, UOP has to increase the financial support allocated to innovation and to strengthen the links with industry.

5 Conclusion

Much needs to be done with regards to research and innovation at institutions of higher education in the Arab world if they are to compete with their international counterparts. The research published in prestigious, and high-impact journals remains meager if compared with the number of universities in this region and the percentage of faculty employed at these institutions. This has resulted in limited citations and a low *h*-index, which in turn has affected the world ranking of these universities.

Like research, innovation and technology transfer is not faring very well at Arab universities. The educational system at schools does not promote innovation, and interest in innovation and technology transfer is stimulated at an advanced stage in the students' educational life. Even then, the courses that address innovation, creativity and entrepreneurship are limited and do not expose students to explorative and applied research.

Although research and innovation have gone a long way at UOP since 1991, much needs to be done if the university is to compete with other regional and international institutions of higher education, and hence secure long-term sustainability and better world rankings. To achieve such a goal, more funding has to be allocated to research and innovation and practices that encourage quality research have to be implemented to meet the ever-changing needs of today's knowledge-based economy.

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Research Policy in Morocco and the Impact on National Development

Wail Benjelloun

Abstract The research policies in Morocco's private and public sectors illustrate the uneven progress made during the past 65 years or so, ever since its independence in 1956. Initially placed on the backburner as the nation struggled to train cadres capable of managing the challenges of nationhood, research picked up as the new universities strove to become internationally competitive. In fact, in spite of the efforts of the state during the last two decades to restructure, coordinate and mobilize national research initiatives, this domain today remains fragmented, and in need of an appropriate governance policy. Essential human and material resources are still lacking, even as the new Moroccan constitution of 2011 specifically mentions research as a national priority. Like most other countries, Moroccan research today faces three immediate challenges: the health crisis resulting from the pandemic spread of COVID-19, the transition to a green economy, and the fourth digital revolution and its impact on industry. Morocco boasts a number of research facilities, mostly placed within the 12 public universities, in addition to several laboratories in private and public/private partnership institutions. Autonomous national research structures, such as the Moroccan Foundation for Advanced Science, Innovation and Research (MAScIR), also contribute to scientific production. Public universities thus continue to dominate research output, whether as measured in indexed publications or in number of registered patents. In spite of its favorable position when compared to African francophone countries, Moroccan research production remains modest and its socio-economic impact (eg. employment opportunities) remains limited. The strategic research plan for 2025 sets policy measures meant to improve research governance, to integrate research activity and innovation with the needs of the economy, to reinforce technology innovation, especially in the automotive and aeronautical industries, and to further research in energy efficiency and alternative energy sources. In addition, the recent research initiatives launched in response to the COVID-19 pandemic by the National Center for Scientific Research (CNRST)

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and the Ministry of Higher Education have already started producing tangible results in pharmaceutical, biomedical and related industries.

Keywords Research policy · Innovation · Research governance · Priority research areas · COVID-19 · Employability · Economic development

1 Introduction

Scientific research poses a complicated dilemma for all developing countries given that it requires resources that are frequently needed elsewhere, and Morocco is no exception. For decades after independence, research in Morocco was a matter of personal initiative. Young university faculty, returning from their studies in France and from other countries in Europe and North America to work in the only modern higher education center in the country, Mohammed V University (UMV, founded in 1957), were influenced by their mentors abroad and by the tradition of research they had experienced. They continued to publish, albeit at a slower pace, within the conditions of the new reality they found at home, adapting the complexity of their work to the means available. They frequently stayed in contact with their mentors and were able to execute the more complex tests of their experiments in the laboratories of international partners. Nevertheless, through determination and initiative, several laboratories were established in the university's Faculty of Science in areas like nuclear physics, organic chemistry, zoology, physiological adaptations in arid zones, human geography, neuroscience, etc. To this day, the Faculty ranks first in international peer-reviewed publications among the country's research institutions.

Initially, a major push to train scientific bachelor's degree holders in French universities provided a critical mass of doctoral faculty involved in teaching and research, and that were eventually able to expand the university studies (and research) to other parts of the country through establishing public universities, totaling to 12 universities today.

In the humanities and social sciences, research requires less infrastructure, and several analyses by faculty at the UMV Faculties of Law as well as Humanities and Social Sciences provided in-depth analyses of national and international events and frequently challenged socio-economic policies adopted by the government during the post-independence period.

2 Historical Note

In its quest to better understand the social composition and the natural wealth of the three North African countries it occupied (Algeria, 1830–1962; Tunisia, 1881–1956; and Morocco, 1912–1956), the French colonial power established what were to become the first local centers for research, and which would eventually serve as the nuclei of the first modern universities [1]. In Morocco, the Higher Institute for Moroccan Studies was established in Rabat in 1917, dedicated to humanities. Over the years it produced a wealth of high-quality sociological, anthropological and cultural studies highlighting the diversity of the Moroccan society and detailing regional customs and traditions. Founded in 1920, the Cherifian Scientific Institute is the oldest scientific research establishment in Morocco and played a major role in the development of experimental and survey research in meteorology, geology, geophysics, geomorphology, zoology and botany. It housed the first geography laboratories in the country and undertook a massive program to identify all the plant and animal species of Morocco, a particularly biodiverse country, as well as all of its mineral resources.

The first modern university after independence was Mohammed V University in Rabat, which incorporated the Institute of Higher Moroccan Studies and the Cherifian Scientific Institute into the Faculty of Letters and Human Sciences and Faculty of Sciences, respectively.

The period from the independence of Morocco in 1956 to the year 2000 was considered a time of consolidation of the institutions of the State and the completion of its territorial and social integration and economic foundations. And from 2000 till today, it has been one of construction, consolidation of infrastructure and building a consensus around the contours of an open, diverse, forward-looking nation, with an economy capable of competing on an international scale. Such ambitions must necessarily be built on a solid knowledge base and human capacities.

3 The National Research and Innovation System

The national research and innovation system in Morocco is managed through a series of public and autonomous institutions whose role is to execute national policies for scientific research and technological innovation. The legislation, regulations, orientation, planification, programming, funding and evaluation of research activities are under the oversight of the Permanent Inter-ministerial Committee for Scientific Research and Technological Development, presided by the head of the government. Research policies are funneled through and moderated by the Ministry of Higher Education (MoHE), which effectively supervises all public research facilities, except for a few such facilities attached to and funded by other ministries. The Ministry relies on the National Center for Scientific and Technical Research (CNRST), which offers funding opportunities, as well as digital access to information and to advanced laboratory analyses. The CNRST also manages calls for projects and evaluates the execution of funded projects. The relatively recent National Agency for Evaluation and Quality Assurance is also mandated to evaluate research projects but has yet to do so. The Moroccan constitution [2], one of the few in the world which stresses the importance of scientific research for national and regional development, involves a consultative Higher Council for Education, Training and

Scientific Research, with wide representation from different social sectors, which can evaluate current programs and expenditures, undertake missions as assigned by the government and propose initiative changes and new orientations. Also, the Hassan II Academy for Science and Techniques, which is composed of national and international members, contributes to the prioritization of research efforts. Finally, the Research and Development (R&D) Foundation plays an important role in ensuring synergy between research efforts and the needs of the public and private sectors.

The Moroccan system of research and innovation is thus centered around the MoHE, whose 12 public universities produce nearly 85% of the indexed publications in Morocco [3]. Universities, higher institutes and other public agencies undertake research and are encouraged to ensure this research provides added value, through university-enterprise interfaces, incubators for innovative enterprises, competence networks, business incubators, clusters, business innovation facilities, and technopoles.

4 Research Strategies and Orientations

The first national workshop on scientific research was held in 1981, a year which also witnessed the launch of the National Center for Coordination and Planification of Scientific and Technical Research (CNCPRST), the precursor of the current CNRST. Both events underlined the country's intention to reinforce its research capacity. Within the scope of its mission to set policy for, plan, direct, coordinate, evaluate, and reinforce scientific research, the CNCPRST established five strategic laboratories in 1990: the Institute of Biotechnology, the Institute of Applied Chemistry, the Center for Oceanography, the Center for Astronomy and Geophysics, and the Center for Nuclear Studies and Research. The year 1990 also witnessed the creation of the Hassan II Academy for Science and Techniques, the establishment of the national repertory of research laboratories, the incorporation of research output in faculty promotion criteria, the launch of the Support Funding Program for Scientific Research (PARS), and, the launch of the R&D Foundation in an effort to promote research-business partnership.

A major impetus for scientific research occurred in 1998, with the creation of the State Secretariat for Scientific Research, under the umbrella of the MoHE. This was considered as a recognition of the essential role of scientific research in accompanying the country's development efforts and was followed by a series of decisions that focused the responsibilities of the Hassan II Academy and the CNCPRST, which then became the CNRST, charged with public-private coordination and synergy, as well as international cooperation. The Permanent Inter-ministerial Committee was also established, as were funding mechanisms for research in science and engineering and a mechanism for the accreditation of laboratories that have developed special expertise in their sectors (*pôles de compétences*). Finally, the Provision for Research and Development was instituted which offered enterprises the possibility of a 20% reduction in taxes for investments in R&D.

The private business sector presently contributes 30% of Moroccan expenditure on research and development, compared to 22% in 2001. The government encouraged companies to support research in their areas of activity through the National Fund for Scientific Research and Technological Development (established in 2001). Moroccan telecom operators, for instance, dedicate 0.25% of their turnover to finance about 80% of all public research projects in telecommunications [4].

The decade which started in 2000 was characterized by a major reform of universities including the alignment of academic reference norms with those of the Bologna process, an initiative launched in 1998 to promote standardization of degree norms and credit requirements in the European Union. Research laboratories were restructured and a relatively modest university autonomy was introduced [5]. In spite of this effort, the results remained modest and the number of indexed publications by Moroccan researchers was insufficient, as the country's rank in Africa dropped from 3rd in 2005 to 5th in 2009 [3].

Two reports published by the MoHE, one in 2006 [6] and one in 2012 [7], set out the areas that need attention if past challenges and problems were to be avoided. Significantly, they raise issues related to continuity of policy, communication, management and finance, international cooperation, and opportunities for added value. The report on "National Strategy for the Development of Scientific Research, Horizon 2025" [7] presents a detailed and complete dashboard for the governance of research and its orientation, reinforcing four major levers of Morocco's development: connectivity to international standard networks, consolidation of macro-economic equilibria, modernization of public governance, and repositioning of the national economy. All of these levers require the contribution of researchers in both public and private venues, and in science and technology, as well as in humanities and social sciences.

At the same time, the Inter-ministerial Committee issued the official list of national developmental priority areas that should be addressed by the nation's researchers:

- Agriculture in inhospitable environments
- Improving the quality of life
- Identification, conservation and added value of natural resources
- Environment and sustainable development
- Biotechnologies
- Risk management
- Innovation and competitivity of enterprises
- Socio-economic and cultural development
- Offshoring of automobile, electronics, aeronautics

To this end three essential approaches were identified:

- Training and mobilization of researchers and competencies
- Implementation of the National System of Research and Innovation effectively and efficiently

- In-depth overhaul of the educational system, reinforcing science and technology, and the dissemination of a scientific culture, with special attention to foreign languages.

Further, the Higher Council issued a report in 2014 insisting that though it is true that the advancement of research and innovation is intimately linked to available budgets, it is even more dependent on the quality of education and training of potential researchers. Thus research is fundamentally dependent on the educational system. It concluded that education has been repeatedly shown to be an important factor in economic growth and that the Moroccan educational system has been found lacking on several fronts [8].

In response to these challenges, the Higher Council developed the 2015–2030 Strategic Vision in October 2014, which resulted in the Education Framework Law 51-17 [9]. Passed in parliament, this law sets the stage for a society whose needs determine all political, economic and ideological policy and are directly supported by research and innovation. The law commits the State to appropriate funding for research, set to attain 3% of GDP by 2030. Morocco is already one of the leading Arab countries in this aspect. Moreover, the MoHE has launched major remedial programs for education at all levels and instituted measures to better organize research and ensure coordinated synergies between its various actors.

The year 2000 was also the start of a major push in the political, economic and ideological fields reflecting a determination to ensure a rapid economic takeoff. The National Research and Innovation System was therefore called upon to accompany these changes and respond effectively to the country's socio-economic needs. This new dynamic required the identification of Morocco's social needs in the fields of science, technology and culture in order to define the strategic actions necessary to support Morocco Vision 2025.

The MoHE translated the national priority areas into six themes for both basic and applied research:

- Health, environment and quality of life
- Agriculture, fisheries and water
- Natural resources and renewable energies
- Aeronautic and automotive industries, transportation, logistics and advanced technologies
- Education and training,
- Humanities and contemporary challenges facing Moroccan society

It was recognized that for maximum return, investment in research would necessitate a capacity to innovate in order support a competitive economy. The ministry thus worked to create a favorable ecosystem that caters for synergy and interaction between enterprises, research project leaders, universities, and risk capital and technology development centers. The international competitiveness of the Moroccan economy thus depended on the ability to reinforce economic sectors offering exceptional opportunities for growth and to develop supporting innovative technologies.

In 2009, the first national innovation summit was organized by the Ministry of Industry and the MoHE. This resulted in an ambitious Morocco Innovation Initiative, meant to encourage private-public partnerships through the creation of technological infrastructure, value added initiatives and clusters. This meeting also witnessed the launch of a funding mechanism to encourage young innovators and to create support facilities such as the Moroccan Club for Innovation.

The government identified the professions that will be determinant in Morocco's development. These are the automotive industry, aeronautics, electronics, offshoring textile and agroalimentary industries. Additionally, several national commitments were articulated around strategic programs that set specific objectives. The Morocco Energy Plan illustrates the country's determination to reduce its dependence on fossil fuels and to increase the use of renewable energies. The Green Morocco Program, with its extensions the Green Generation and Forests of Morocco, is meant to render agriculture a true lever for socio-economic development while the Azur Program was established to further develop tourism. The transversal Digitalization Program seeks to place Morocco among the top performers in terms of Datacom and IT infrastructure in the MENA and Africa regions as well as to increase human resource competencies in these fields.

In order to accompany these ambitious developmental objectives the MoHE is launching as of 2021 a series of thematic reference institutes to federate competencies in the identified areas, and to promote excellence in research, with the aim to drive the national development objectives. Some of these institutes will be extremely relevant in the future, chiefly in facing pandemics such as the current COVID-19 health crisis. A number of these institutes are planned in the following fields: artificial intelligence, genomics, water energy food security nexus, environment and climate change, oceanography, biotechnology, space science and technology, high energy and astroparticle physics, and green chemistry. All these fields have either a critical mass of established researchers or a promising cohort of young researchers.

5 Innovation

Green technology occupies an important position in Morocco's innovation efforts. The Institute for Research in Solar and New Energy (IRESEN) is currently financing research in the field of renewable energy, carried out by more than 200 engineers and PhD students, and some 47 university researchers. In 2014, the government inaugurated the continent's biggest wind farm at Tarfaya in the southwest of the country. And the world's biggest solar farm is near completion at Ouarzazate, with a capacity of 560 MW. Morocco ranked 7th in the Climate Change Index (the first three ranks were not assigned since no country was considered as having done enough to merit the highest ranks) for its efforts at mitigating climate change through resorting to alternate sources of energy and through behavior change [10].

Another major orientation aims at increasing the share of value-added goods, which currently represent about 20% of exports [11]. In recent years, clothing and leather goods have suffered from international competition but have been replaced by automobiles, aeronautic parts, fertilizers end electrical components. The economy maintained a 4% growth in spite of the unfavorable conditions worldwide, however high unemployment remains a problem. More than 9% of the population is unemployed and about 41% of the labor force lacks any qualification. In support of this orientation, the Research Strategy for 2025 recommended raising the secondary education enrolment rate from 44% to at least 80% and the tertiary education enrolment rate for 19–23 year-olds from 12% to over 50% [7]. Although tuition for all levels of education is free, only primary education is compulsory. Efforts to develop secondary and tertiary education have centered around a more equitable geographic distribution of schools and faculties, with distance being a major limiting factor to pursue education.

5.1 Instruments

Recognized as an important lever for national development, innovation has been encouraged over the past two decades through a series of instruments:

5.1.1 Innovation-Based Entrepreneurship

An important feature of this instrument is the INOV'ACT program. In order to develop R&D activity and support innovation in the national productive sector, R&D Maroc, a national NGO, has developed, in partnership with the MoHE, the INNOV'ACT program. The objectives of the program include encouraging innovation and R&D in market-oriented enterprises, providing assistance in the launch of R&D and innovation services within enterprises, facilitating the hiring of researchers by enterprises for the duration of the project, and bringing the business environment closer to the that of universities and technical centers. Projects have a maximum duration of 2.5 years.

The program provides administrative, technical and financial support to R&D and innovation projects submitted by enterprises (very small, small, medium or business consortia), in partnership with public research laboratories (universities and centers) or industrial technical centers. The program accepts submissions in all fields of economic activity, with special attention to those where Moroccan research can have an international impact. Candidates must demonstrate the innovative character of the project as well as the expected results and the scientific and socio-economic benefits. Projects are also rated on value addition and improved industrial quality and competitiveness.

Administrative and technical assistance includes help with the preparation of the project application, partnership contracts, researcher recruitment, periodic evaluations and final evaluations. Financial support depends on the productive sector, and essentially involves fees or salaries for experts providing technical assistance in the initial phases of the project and during its execution as well as the purchase of small equipment. This assistance can amount to 700,000 MDH (about $US 70,000) for entrepreneurial consortia.

This instrument also includes the Moroccan Incubation and Spin-off Network, which is a joint program between the Ministries of Higher Education and of Industry, managed through CNRST, and established to encourage the creation of innovative enterprises based on research outcomes, through incubation and spin-offs. The funds allocated cover studies to acquire expertise, the business plan, prototypes, documentation and logistics, hosting (office and/or industrial lab space), scientific support, and scholarships for project leaders.

5.1.2 Financial Incentives

Several mechanisms contribute to this instrument. The R&D Fiscal Provision provides for a tax exemption of 20% (which can reach up to 30% under some circumstances) of a company's R&D investment. The Investment Promotion Fund also offers partial financing (10% in rural zones, 5% in urban areas) covering land acquisition, construction and professional training for projects involving technology transfer. The Hassan II Fund for Economic and Social Development provides sectorial financing for land acquisition and construction for projects involving R&D, including design and engineering in textiles and leather, electronic sub-contracting, vehicle parts, precision mechanics, aeronautics sub-contracting, production equipment and environmental protection. The National Fund for Scientific Research and Development offers support for research in telecom and communication technologies. CNRST is also active in supporting this instrument as it coordinates with nearly 20 risk capital enterprises as well as the Moroccan Association for Capital Investment in order to promote and encourage the participation of risk capital in value added activities. Risk capital is still a nascent domain in Morocco and needs further development because of its potential contribution to the economy.

The business enterprise sector contributes 30% of Moroccan expenditure on R&D. The government has encouraged companies to support research in their sector through the National Fund for Scientific Research and Technological Development since 2001. Moroccan telecom operators, for instance, have been persuaded to cede 0.25% of their turnover. Today, they finance about 80% of all public research projects in telecommunications supported through this fund. The government is also encouraging public institutions to contribute. The Moroccan Phosphate Office (Office chérifien des phosphates) is investing in a project to develop a smart city, King Mohammed VI Green City, around Mohammed VI University located between Casablanca and Marrakesh, at a cost of 4.7 billion dirhams (US$ 479 million) [12].

5.1.3 Technology Transfer

The Industrial Emergence Program identified eight sectors in 2006 for targeting investments, in order to face the challenges of globalization: Off-shoring (Casa-technopark, CasaNearshore, Technopolis Rabat, Agropolis Meknes, Agropole Berkane, Fès shore park, Oujda shore park, Tétouan shore and Tétouan park); the automotive industry, which grew from 50,000 cars in 2009 to 400,000 in 2018, and saving 92% of jobs during the COVID-19 crisis, noting that the automotive industry now ranks second in Africa and third in the MENA region; the aeronautics industry, producing parts entirely for export (amounting to $550 million, with 7500 employees and an annual growth of 25%); Agro-alimentary industries; Fisheries; and Textile and clothing (producing 16 million masks a day during the COVID-19 crisis).

5.1.4 Moroccan Association for Research and Development (R&D Morocco)

The Moroccan Association for Research and Development (R&D Morocco) is a public interest association, including public and private enterprises, public agencies, ministry departments in charge of research and innovation.

This association aims to promote innovation and R&D in Moroccan enterprise through:

- Encouraging R&D initiatives in enterprise
- Promoting the adoption, by public decision makers, of an appropriate regulatory and financial framework for R&D initiatives
- Attracting national and international funds for R&D
- Establishing an operational communication channel between national and overseas Moroccan researchers to facilitate R&D cooperation
- Facilitating synergies between entrepreneurial R&D laboratories and those in other research environments

5.1.5 Office for Industrial and Commercial Property (OMPIC) Patent Registry

Patent registry is often used as a measure of innovation. The national agency for patent registry in Morocco is the Office for Industrial and Commercial Property (OMPIC) [13] which maintains, in addition to its registry function, an active training program for companies and universities. In Morocco, universities have traditionally been the major patent registrants. Of the 1287 patents of Moroccan origin registered with OMPIC between 2013 and 2017, 632 originated from universities, and 133 from research centers.

5.2 Regionalization

Morocco's 12 regions are slowly becoming major actors in wealth creation through innovation at the local level, thanks to the Advanced Regionalization Policy, which is included in the 2011 Constitution and whose gradual implementation was first launched in 2015. They are actively developing their competitive advantages and increasing their attractiveness to productive and innovative investment. Some regions, such as Fez-Meknes and Souss-Massa, currently invest in R&D through the financing of research projects and the provision of research scholarships. Involving local intellect (elected Councils and local talent) in identifying the economically attractive possibilities of each region promises to create an effective environment for adapting economic policy serving the local potential, within a national strategy. A 2019 report by the Ministry of Finance on regional profiles also contributed to regional development by establishing a comparative profile of regional economies: incomes, agricultural activity, industries, services, tax base, etc. [14]. Although their autonomy remains limited, regions offer interesting possibilities for investment and economic development through offshore free zones and fiscal incentives which attract national and international enterprises. The added attraction of technoparks, clusters, innovation cities in the universities and modest risk capital opportunities create a healthy business environment. A good example is the Tangier-Tetouan region, which is fast becoming a prime development hub. One of the major regional success stories is the TangerMed port, which in 2020 became the first container port in the Mediterranean with 81 million tons handled, 23% more than the previous year. TangerMed now handles 47% of port tonnage in Morocco, surpassing the port of Casablanca [15].

6 Conclusions

The stated objectives of the government to stimulate research and innovation have led to some important successes. In the field of energy, Morocco has become a continental leader and a global model with an enviable energy mix, and exports to both Spain and Algeria. The COVID-19 pandemic reformatted the ailing textile industry to produce millions of masks, alongside respirators. Digitization has invaded the Moroccan administration and robotics are now present in the aeronautics and automotive production lines. Diversification of the economy and value-added products have rendered the pharmaceutical industry the second most important chemical industry after the phosphate industry. Infrastructure is improving at a steady pace as the country's regions equip to vie for investments. However the research-innovation-development system remains fragile, in need of coordination and continuity of policy [16]. A national dashboard needs to be established that allows for a transparent evaluation of progress for each actor in the equation. Both the private and public sectors need to work together and to live up to their engagements. This dashboard must prominently include the educational system, underpinning for any knowledge-based socio-economic development.

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Research, Development, and Local Impact: A Case Study of the Australian College of Kuwait

Isam Zabalawi, Helene Kordahji, and Khalil Khanafer

Abstract Building sustainable economies requires universities to keep contributing more into Research and Development (R&D). Nowadays, the higher education sector is becoming a key player in innovation, exchanging knowledge, and research and development. R&D in Arab countries lags significantly when compared to different regions in the world. However, with the increasing pressures to meet the demands of knowledge-based economies, governments, within the Arab world, have been pursuing reforms to expand their R&D base by strengthening the higher education sector. This chapter will focus on the reforms that are required for R&D in the higher education sector in the Arab world that will in turn change the ecosystem of universities. The Australian College of Kuwait (ACK or the College) was chosen as a case study to support this narrative. It also presents a summary of the research infrastructure that was integrated into ACK's landscape to establish a sustainable research ecosystem.

Keywords Research · Development · Reform · Australian College of Kuwait · College · Kuwait · New vision

1 Introduction

Research and Development (R&D) has been used as one of the key indicators to distinguish between developed and underdeveloped countries. Within the Arab region, R&D is modest with no significant breakthroughs. As Arab countries seek to diversify their economies, the role of R&D as a driver of economic growth and innovation becomes more critical. There are many challenges that hinder the progress of R&D in the Arab world. Several countries have incorporated R&D into their strategic planning, yet implementation of such initiatives are thwarted by the lack of

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funding, limited number of full-time researchers, and lack of requisite infrastructure. In addition, weak collaborative efforts among governmental institutions, higher education sector, and industry underpin the low level of knowledge exchange.

In recent years, Arab countries have been seeking to transition from resource-based economies to knowledge-based economies. They have been diversifying and expanding their base of human capital skills. An example that demonstrates the adoption of serious steps toward this end is the national strategy adopted by the State of Kuwait, namely, the ‘New Kuwait Vision 2035’ (or the Vision). The plan aims to transform the country into a regional, financial, commercial, and cultural hub, within 17 years. The Vision is organized around seven pillars: global positioning, developed infrastructure, creative human capital, effective public administration, high quality healthcare, sustainable diversified economy, and sustainable environment. Two of the seven pillars identify investment in human capital and economic diversification as crucial elements to reducing the country’s dependence on oil export revenue. The Vision seeks to reform the education system to prepare Kuwaitis to become competitive and productive members of the workforce.

Building sustainable economies requires universities to keep contributing to R&D. Dr. Edward Crawley, a Professor of Engineering at the Massachusetts Institute of Technology, refers to universities as ‘engines of economic development’. Within this context, universities are prerequisites to the advancement of nations.

During the decade of 2010–2020, the number of public and private universities within the Arab region have increased. Reforming the higher education sector is becoming more critical as countries seek to diversify their economy. Universities must prepare graduates to become entrepreneurs, problem-solvers, research-oriented and innovators. This cannot be achieved if the higher education sector does not transform its traditional teaching landscape into a teaching and research model. This is important for ensuring that graduates are able to serve the national needs of the country and that universities are conducting research that will benefit the community.

This chapter will focus predominantly on the reforms that are required for R&D in the higher education sector in the Arab world that will in turn change the ecosystem of universities. The Australian College of Kuwait (ACK or the College) was chosen as a case study to support this narrative. This chapter will also discuss the integrated framework developed by ACK which allowed it to foster an R&D environment that produces world-class research and meets the national priorities of Kuwait.

2 R&D as the Driver of Economic Growth

In 1956, the neoclassic Solow Growth Model identified labor productivity, changes in capital-intensity, and technology as the main drivers of economic growth. Since then, economic growth theories have laid particular emphasis on the relevance of technological advancement to growth [1]. Specifically, in 1986, the economist Paul Romer developed the first economic growth theory with endogenous technological change based on R&D [2]. Romer emphasized that R&D expenditures are likely to lead to economic growth through its constructive impact on innovation and Total Factor Productivity (TFP). The difference between the neoclassic theory and the endogenous growth theory is that the former places emphases on external technical progress as the most important determinant for economic growth while the latter regards investments in R&D that provide new knowledge and lead to technological innovation as the most important contributor to long-term economic growth.

In economic literature, R&D is defined as the choice of firms and individuals to invest in the invention and commercialization of new products and processes. As a result, R&D generates positive spillovers that benefit others [3]. Bozkurt (2015) explains that R&D activities have two main functions: doing and learning. The transmission of knowledge is referred to as the spillover effect since it causes innovation and enables producers to make new products, reduce costs, and improve the quality of products [4]. This spillover is essential to identify efficient science and technology strategies that may lead to higher productivity and competitiveness among firms and industrial sectors.

R&D is also referred to as the creative work undertaken on a systematic basis in order to increase the stock of knowledge and the use of this knowledge to devise new applications [5]. Accordingly, R&D can be classified into three broad types: basic research, applied, and experimental development.

Through basic research, new knowledge is acquired without targeting any specific application while applied research is the use of existing scientific knowledge for practical goals such as advancing technology. Experimental research draws on existing knowledge with the aim of producing new materials, products, or processes [5].

R&D activities are carried out by businesses, industry, higher education sector, individuals, and governments. In general, R&D performed by businesses and the industry produces new products, services, and technologies while R&D performed by government bodies and universities have a direct impact on knowledge creation and development. This chapter will focus on R&D in the higher education sector.

The cumulative nature of R&D leads to increasing returns for society, individuals, and industry. Hall (2006) explains that the stock of knowledge created by R&D makes one more productive in acquiring additional knowledge [3]. In addition, long-term economic growth requires R&D and human capital accumulation as essential pillars. R&D is critical for invention and innovation from which an economy acquires new and better products. Technologies and human capital accumulation are the means by which skills are improved for the benefit of productivity including R&D [6]. Between 1990–2010, the relationship between R&D expenditures and economic growth was studied in member countries of the Organization for Economic Cooperation and Development (OECD) and the results indicated that there was a significant relationship between R&D expenditures and economic growth in the long-term [4].

3 R&D in the Arab World

During the period of 2000–2020, Arab countries have been transitioning from their resource-driven economies toward building knowledge-based economies. A resource-based economy is dependent on natural resources such as oil and gas while knowledge-based economies capitalize on production, distribution, and the use of knowledge and information with emphasis given to information, technology, and learning [7]. There is however growing consensus that the Arab region's economic development and growth is unsustainable [8]. Their dependence on non-renewable sources of income poses great risks to their economic development and resulted in Arab countries being characterized by low standards of economic development [7].

The Arab region is challenged to utilize oil revenues to build and diversify its sources of income to facilitate the transition to knowledge-based economies and sustainable development [7]. Arab countries need to create other sources of income to build their economies. As a result, the paradigm shift toward knowledge-based economies means that more emphasis needs to be placed on R&D as the mainstay of a technology, innovation, and information driven society.

R&D is a critical tool that can pave the way for Arab countries to build their knowledge capital. Creating this enabling environment requires funds, resources, and human capital. An array of challenges currently hinders the development of the required R&D. These can be categorized under two headings: governance and organization.

At a governance level, many governments have recently incorporated R&D within their national strategies; these initiatives, however, are yet to be properly rolled out through policies, grants, and international collaborations. There is also insufficient allocation of human and financial capital to undertake R&D. The lack of human resources is correlated to inefficient educational systems. The skill gap that exists is due to a mismatch between the educational systems' outcomes and the labor market requirements [7]. On the financial front, there seems to be a lack of governmental appetite to properly invest in R&D. As an illustration, leading developed countries usually allocate more than 2% of their GDP to R&D [4]. Within the Arab region, R&D investments remain lower than 0.5% of annual GDP [9], though there are a few exceptions such as the United Arab Emirates (UAE) and Saudi Arabia (ranging from 0.6% to 1%) as illustrated in Fig. 1 [10]. Figure 2 illustrates spending on R&D per capita (in US dollars) between global and Arab Gulf States [10]. R&D spending per capita is substantially higher in other countries compared to Arab Gulf States. It is important to note that even though China is a middle-income economy with low R&D expenditure per capita, it is known for its quality innovation. Figure 3 presents the Global Innovation Index for 2020, with the exception of the UAE (ranked 34), there is a lack of Arab countries presence in the first 50 top innovative countries [11]. A similar observation is noted in the Digital Competitiveness Index 2020, which reflects a weak Arab presence. The UAE and Saudi Arabia were the only Arab countries listed in the top 50.

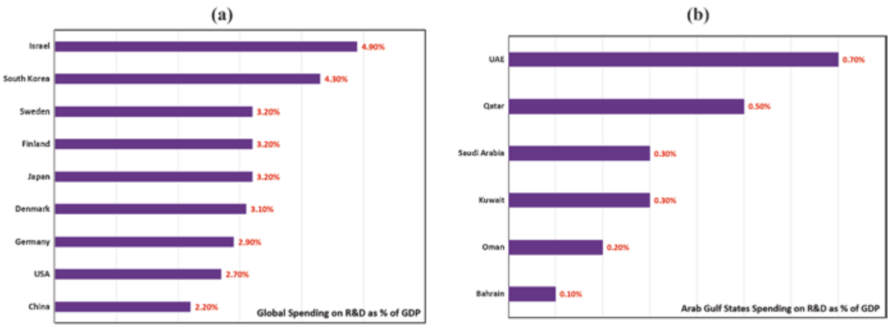

Fig. 1 Comparison R&D expenditures as a percentage of GDP between (**a**) Global and (**b**) Arab Gulf States [10]

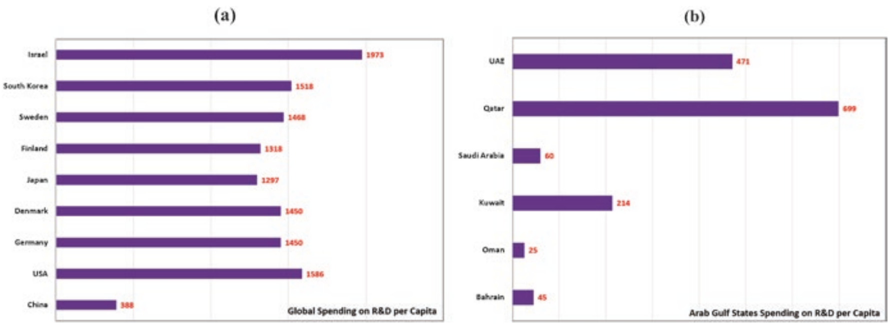

Fig. 2 Comparison of R&D expenditures in USD per capita between (**a**) Global and (**b**) Arab Gulf States [10]

Sub-par investments in R&D is associated with a decline in innovation. Businesses do not seem to engage in innovative processes, products and solutions, thus, leading to slow productivity growth. Moreover, barriers such as workforce mobility and trade impede the formation of more proficient innovative networks [12]. Furthermore, the Arab region is home to many multinational companies from different fields such as oil and gas, and pharmaceuticals that generate billions of dollars in sales. Arab governments should endeavor to implement targeted policies that ensure these companies allocate a percentage of their profits to progressing R&D in the region.

At an organizational level, the lack of an R&D culture in the Arab region is manifested in the industry sector not properly developing an R&D environment. There is ineffective dissemination and exchange of knowledge among the industry, government, universities, and communities. The result is weak links between scientific R&D institutions that offer research services and production companies [5]. Research organizations should transform their structure of rigid hierarchical silos to knowledge-intensive organizations that build comprehensive knowledge-intensive systems aligned with national programs [8].

Country/Economy	Score (0–100)	Rank	Income	Rank	Region	Rank	Median 30.94
Switzerland	66.08	1	HI	1	EUR	1	
Sweden	62.47	2	HI	2	EUR	2	
United States of America	60.56	3	HI	3	NAC	1	
United Kingdom	59.78	4	HI	4	EUR	3	
Netherlands	58.76	5	HI	5	EUR	4	
Denmark	57.53	6	HI	6	EUR	5	
Finland	57.02	7	HI	7	EUR	6	
Singapore	56.61	8	HI	8	SEAO	1	
Germany	56.55	9	HI	9	EUR	7	
Republic of Korea	56.11	10	HI	10	SEAO	2	
Hong Kong, China	54.24	11	HI	11	SEAO	3	
France	53.66	12	HI	12	EUR	8	
Israel	53.55	13	HI	13	NAWA	1	
China	53.28	14	UM	1	SEAO	4	
Ireland	53.05	15	HI	14	EUR	9	
Japan	52.70	16	HI	15	SEAO	5	
Canada	52.26	17	HI	16	NAC	2	
Luxembourg	50.84	18	HI	17	EUR	10	
Austria	50.13	19	HI	18	EUR	11	
Norway	49.29	20	HI	19	EUR	12	
Iceland	49.23	21	HI	20	EUR	13	
Belgium	49.13	22	HI	21	EUR	14	
Australia	48.35	23	HI	22	SEAO	6	
Czech Republic	48.34	24	HI	23	EUR	15	
Estonia	48.28	25	HI	24	EUR	16	
New Zealand	47.01	26	HI	25	SEAO	7	
Malta	46.39	27	HI	26	EUR	17	
Italy	45.74	28	HI	27	EUR	18	
Cyprus	45.67	29	HI	28	NAWA	2	
Spain	45.60	30	HI	29	EUR	19	
Portugal	43.51	31	HI	30	EUR	20	
Slovenia	42.91	32	HI	31	EUR	21	
Malaysia	42.42	33	UM	2	SEAO	8	
United Arab Emirates	41.79	34	HI	32	NAWA	3	

Fig. 3 Global Innovation Index 2020 Rankings [11]

4 Rethinking R&D in the Arab Higher Education Sector

The previous sections highlighted the position of R&D as an important component for driving the economic growth of a country; it also included a brief description of the general challenges of R&D in the Arab region. As universities are prerequisites for the advancements of nations, this section will provide an in-depth insight into the challenges of R&D in the higher education sector within the Arab region.

Over the last decade (2010–2020), the R&D domain has become a fundamental pillar in the higher education sector. According to the National Science Foundation (2017), total expenditures on R&D in universities in the United States of America in 2008 was around 51 billion dollars and increased to 75 billion dollars by 2017 [13]. Furthermore, one of the dimensions of the term 'World-Class University' is used to denote research-oriented institutions. For this reason, the support for research universities, with science, technology, and innovation strengths has become an important priority in OECD countries [14].

The increasing pressures to meet the demands of knowledge-based economies have led governments within the Arab world to pursue reforms to expand their R&D base by strengthening the higher education sector. A number of stumbling blocks have been hindering this progress. Challenges facing R&D in the Arab higher education sector include: insufficient government support, funding, collaborations, university research infrastructure, and human capital.

4.1 Government Support, Funding, and Collaborations

The higher education landscape in the Arab world is diverse. It includes public and private universities and colleges, profit, non-profit, technical colleges, different modes of learning which include traditional, blended, and online, and all levels of offerings are available (diploma, bachelors, master's, PhD) [15].

The majority of higher education institutions in the Arab region are public [16]. Building a healthy sustainable research ecosystem requires strong collaboration among the government, higher education sector, and industry.

From a governmental perspective, there is a lack of clear national priorities that address the R&D gap with proper funding and identified research themes. This has manifested in governments not properly fostering a healthy research ecosystem where R&D is clearly channeled into the higher education sector.

Poor funding has resulted in universities not investing in developing an infrastructure that supports and nourishes an R&D environment. Furthermore, the lack of national research priorities has led many universities to conduct scattered research with no significant national impact. In addition, once research is published, there seems to be no clear guidelines for patent follow-up or commercialization of the products developed. To this end, governments are required to design the right governance framework to channel research efforts and monitor them effectively [17]. As a way of example, the Kuwaiti government established the Kuwait Foundation for the Advancement of Sciences (KFAS) as a non-profit organization to promote a research culture within the local society. It is considered a pioneer model of strategically envisioned governance in the region.

The collaboration network between government and the higher education sector is generally not very strong as they do not work closely enough to effectively exchange knowledge; therefore, research efforts conducted by the higher education sector remains confined within universities without serving the wider public. There is a low level of public disclosure of research output among Arab higher education institutions which in turn limits internal data mining, reporting and quality of measures adopted [15].

Even though governments play a critical role in encouraging collaboration between the higher education sector and industry, such collaboration is not properly capitalized on. Once collaboration is established and managed in areas of research, innovation, and education, it can increase the capacity to exchange knowledge between the industry and the higher education sectors. An example of a successful collaboration between the higher education sector and industry is the 'Faculty for Factory' initiative which was launched by the University of Jordan in 2003 to tap the potential of applied scientific research in improving the productivity and competitiveness of industry. The program has become a national success and an effective tool to link industrial companies to academic institutions [18]. In Kuwait, KFAS offers a similar program by encouraging Kuwaiti companies to improve their operations and strategic objectives through developing a scientific approach to their business operations. It also offers a co-funding program to support R&D in the private sector with the aim of identifying innovative solutions, enhance productivity, and competitiveness.

4.2 University Research Infrastructure and Human Capital

Most universities in the Arab world are mainly teaching institutions [19]. They lack the proper infrastructure to conduct research. Between 2010 and 2018, the number of full-time researchers per million inhabitant in Kuwait was 514, while Oman had 281, and Qatar had 577. Singapore, on the other hand, had around 6803 full-time researchers per million inhabitant, Switzerland had 5450, and Sweden had 7536 [20]. In fact, until recently, research conducted in the Arab region is mostly theoretically-based and is not properly streamlined to make an impact.

Though the global innovation landscape is changing as more researchers and entrepreneurs actively drive innovations, yet it remains concentrated in a few countries and regions. This is reflected in key innovation indicators such as R&D, researchers, and intellectual property [12]. The number of individuals contributing to R&D in countries of the Gulf Cooperation Council (GCC) is modest. It averages around 1000 researcher per million inhabitant, while in the United Kingdom, the number is more than seven times higher [18]. One reason behind that modest number is that Arab universities do not produce enough postgraduate students with PhD degrees that could support continuing research policies [16]. The lack of full-time researchers in universities has resulted in many postgraduate students conducting most of the research. University faculty also have relatively high teaching loads which have negatively impacted their research productivity.

Researchers also face a complex web of barriers on a daily basis that can range from access to grants, lack of research culture, bureaucracy, poor internet connection, lack of access to current academic journals, poor international collaboration, complicated governmental approval processes to initiate research, to visa difficulties that impede travel and conference attendance [21].

The result is that many Arab researchers migrate abroad (Fig. 4). This phenomenon is referred to as brain drain versus brain gain. Brain drain is causing higher education institutions to lose prominent Arab researchers to more advanced countries. Within this context, governments need to significantly increase their investments in the higher education sector in order to retain good researchers. The University of Jordan has developed a successful R&D model which includes initiatives targeting scientific research, intellectual property, programs for marketing scientific and academic production, a research teams program, joint research programs in partnership with international universities and research centers, a unified database for scientific research including an electronic library, a program for

Fig. 4 Brain Drain in Arab World [21]

classification of researchers, and schemes for rewarding excelling researchers and promotion requirements for producing higher input research [22]. Many universities can benefit from adopting a similar model.

The teaching/research nexus in Arab higher education remains a struggle. The focus of academics remains on teaching. Research should become a main component of the job description of faculty and not just a means to receive a promotion. Poor incentives and professional development plans are also factors that hinder the development of research in Arab universities. Furthermore, many university promotion policies are designed without emphasizing the importance of producing research that tackles developmental challenges. This often results in research output that has minimal societal relevance.

Weak research output is also attributed to the mismatch of skills gap that exist between universities and the workplace. The Arab region education systems do not produce what the market needs [7]. An important point to highlight is the underlying assumption that holding a Master's or PhD degree is enough for one to be a qualified researcher. Many researchers however lack essential skills that are required to conduct research such as the use of IT [23]. Little attention is directed toward the importance of Bloom's taxonomy which places particular importance on issues related to R&D such as knowledge and psychomotor essential skills that promote development within a cognitive domain.

To the best of our knowledge, it has been observed that there are few high impact journals in the Arab region. We have also noted the paucity of Arab faculty on international journals' editorial boards. Due to the absence of any available information in the literature on the statistics of the impact of Arab journals and Arab faculty members in editorial boards, the Union of Arab Universities should consider conducting a study to this end.

5 Changing the Current R&D Arab Higher Education Landscape

As stated earlier, an array of challenges hinders the progression of R&D in the higher education sector in the Arab region. However, for the purposes of this chapter, the focus will be on the reforms that need to be adopted by higher education institutions to allow them to create a landscape that fosters R&D. Once they reposition themselves as research institutions, universities will be of more benefit to their local and global communities. It is time that governments, industries, and universities develop the appropriate research ecosystem that nourishes a sustainable research environment.

The Arab world, with its high proportion of technologically savvy youth, may witness real creativity devoted to how high-quality education can be delivered, and world class research conducted [24].

With the right reforms in place, many Arab universities will be able to make an impact with their research. Changing the landscape of the higher education sector to become more R&D focused requires a fundamental shift in the paradigm of the university from teaching to teaching and research.

Universities should create an environment that values faculty members and supports them in their endeavors to produce and publish research. However, in order to do so, the creation of infrastructure, the removal of teaching overloads, and the provision of incentives must all be tackled [23]. This also requires universities to adopt systems for tenure and promotion based on objective criteria to assure that faculty are rewarded according to merit [26]. Equally important is the adoption of clear and transparent policies and procedures that enhance the quality and integrity of research.

The creation of a research infrastructure starts with emphasis on areas of specialization related to local, national and regional needs [25]. Universities should create clear strategies with R&D as a stand-alone pillar with clear metrics to continuously evaluate and monitor its impact. With the proper support from governments, universities will be able to launch initiatives that include research sabbaticals for professors, funding their participation in conferences, and establishing faculty exchange programs [17].

Progress in research also entails revisiting university programs and courses to ensure they generate knowledge utilized to solve the problems that confront society. Course content needs to be modified to include a research component embedded in it. Students should be taught to think as innovators, developers, and researchers. In addition, programs should be evaluated in a systematic and on a regular basis by applying a set of measures that articulate issues related to R&D. Such practice ensures that programs are continuously enhanced to meet the needs of the industry and produce work-ready graduates. Doing that requires a shift in the mode of teaching in Arab universities as they transition to a student centered approach where students are encouraged to become innovative thinkers and mix theory with practical application [23]. Arab universities should play a role in closing the skills gap facing industry by aligning their learning outcomes to the needs of the market.

6 Case Study: The Australian College of Kuwait

The first step in building knowledge-based economies requires governments to create clear national development plans. A good example that demonstrates serious steps toward reform is in the national reform strategy adopted by the State of Kuwait. In 2018, the Kuwaiti government unveiled a long-term development plan titled 'New Kuwait Vision 2035' (or the Vision) as depicted in Fig. 5. The plan aims to transform the country into a regional, financial, commercial, and cultural hub within seventeen years. The plan aims to attract foreign investors, strengthen public and private sectors, diversify skills, and advance knowledge, growth, and the economy. Two of the seven pillars in the Vision for 2035 identify investment in human capital and economic diversification as crucial elements to reduce the country's dependency on oil export revenue. The Vision seeks to reform the education system to prepare Kuwait's youth to become competitive and productive members of the workforce.

Within this framework of reforms, the higher education sector in Kuwait has taken serious steps to align their strategies with the national development plan. ACK is one of the private higher education institutions in Kuwait that has adapted its programs to ensure they serve the needs of the nation.

As part of its commitment to serve its community, ACK has redesigned its strategy and governance framework to align them with the New Kuwait Vision 2035. It

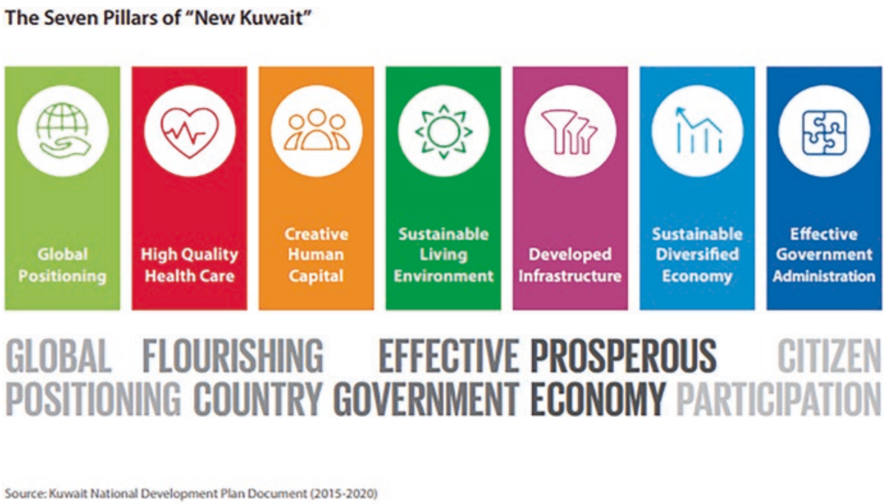

Fig. 5 New Kuwait Vision 2035' (or the Vision)

has sought to reform its landscape to integrate R&D as a critical pillar in its strategic planning. In order to do so, the College has developed an integrated framework to establish a solid foundation for research, development, opportunities, resources, and innovation. The adaptable framework is based on four main dimensions: Teaching and Learning; Service to the Community; Innovation and Entrepreneurship; and R&D.

6.1 Teaching and Learning

The transition to become more research focused meant that ACK had to re-evaluate its existing teaching and learning methodologies. And to ensure that students graduate with the ability to think critically, analyze and solve problems, implied that ACK had to align its research and teaching to suit the students' development. ACK had to make sure that its pedagogical framework was innovative and based on sound scientific knowledge. Research was integrated into teaching. By linking research output with teaching and learning, research-informed teaching became a critical aspect of this process. Continuous research is also conducted to ensure that the programs offered meet the needs of the market and that the skills of the graduates are in-demand locally and internationally.

Integrating research into the teaching and learning process has not been straightforward. The College had to implement a range of strategies encompassing professional learning opportunities for academics, sharing good practices, engaging discussions, and providing useful resources. The College has also launched specialized centers such as the Teaching and Learning Center and the Project Based Learning Center in order to provide the necessary support to faculty.

In parallel, ACK has emphasized through its policies and strategic planning the opportunity for students to engage in research. The student-centered approach adopted by the College uses project-based learning to allow students to work in teams and/or individually to research an industry or a business issue and then proceed to develop strategies, processes, and products as solutions. In addition, all students are required to research and present a major graduation project to demonstrate synthesis of individual aspects of learning during their studies and apply this to an approved workplace project or challenge. Upon completion, these projects are exhibited to showcase the industry and service sector innovative solutions to everyday issues. Several graduation projects have been successfully adopted by the industry. These projects are developed based on the Conceive-Design-Implement-Operate (CDIO) criteria which emphasize students' ability to analyze, synthesize, and test.

Wherever possible, students are encouraged to liaise with local workplaces or research organizations in the development of their project and in many instances, this has led to continuing research and/or graduate employment.

In order to facilitate continuous research, centralized databases are being established within both the Schools of Engineering and Business so that the work and contact information of past students remains accessible. At the same time, these databases will enable faculty to maintain contact with former students who wish to continue their association with the advancement of their own graduation project work beyond their time at ACK.

Students also have the opportunity to engage in research with their faculty and through internships and work placements as part of their programs of study. There are many benefits for undergraduate students to engage in internships. Unfortunately, not a lot of attention is given to the benefits of undergraduate internships. Internships improve students' professional growth and development. Such opportunities supply valuable real-life experiences to students and allow them to smoothly transition to the workplace. These experiences will enhance their practical knowledge and expose them to different areas of R&D. It will also teach them to balance collaborative and individual work and become contributors in the production of knowledge.

6.2 Service to the Community

As a provider of higher education, ACK considers itself an active member of the local community. The College positions itself as a hub within the community where research experts, teaching, faculty, industry, and student learners meet for the purposes of sharing and expanding knowledge for the betterment of individuals, economies, communities, and the environment. With that in mind, the College, through its strategy, has placed particular emphasis on its role within the community.

Serving the community meant that ACK had to diversify its approach to maximize its local impact. It has become involved in research projects that directly serve the needs of the community. This has been conducted through collaborations with local institutions such as the Kuwait Foundation for the Advancement of Sciences (KFAS) and the Kuwait Institute for Scientific Research (KISR). On a weekly basis, the College has organized seminars which are open to the public, where faculty have the opportunity to discuss their research results and disseminate their findings within the community. Through its different schools, ACK also invites keynote speakers from various disciplines to discuss and present their latest studies which are beneficial to the faculty and community.

An important aspect of the College's service to the community is the transfer of knowledge. Knowledge should not remain confined within the walls of the institution. The most effective mechanism to transfer knowledge in a higher education institution is through students, academics, and graduates. By supplying the market with highly skilled graduates, the College is playing a significant role as a key player in the process of upskilling, which will in turn be a driver for economic growth. ACK continuously performs research and data analysis on the needs of the market to ensure that all of its offerings are relevant to the local needs. The College firmly believes that the success of its graduates in their careers allows ACK to continuously attract better students who in turn will serve their communities.

Through its lifelong learning and e-learning activities, the College seeks to continuously create learning opportunities for its community and graduates. It also provides a platform where ideas can be shared and transmitted to other universities locally and internationally with the aim to advance education in the region and put forward solutions to the challenges faced in the Arab region. ACK established its Corporate Training Center in order to continuously update the knowledge and practices of professionals while emphasizing the importance of lifelong learning.

Prior to the COVID-19 crisis, which paralyzed the higher education sector, ACK organized a conference in collaboration with KFAS where experts from around the region and the world were invited to discuss the importance of introducing e-learning in the Arab region. By organizing sessions, conducting community research, and writing press releases, the College was able to raise awareness within the community and introduce e-learning at large.

6.3 Innovation and Entrepreneurship

Innovation is key at ACK. As the Arab region faces immense challenges on the social, economic, and environmental fronts. The College conducts research to find innovative solutions to these challenges. As the universities' role in knowledge creation and advancing innovation becomes more pivotal, ACK's position as a higher education provider is becoming crucial in creating innovation networks and producing the next generation of innovators and entrepreneurs.

Moreover, since the Kuwaiti government is reducing its reliance on oil, diversifying sources of income can be achieved through innovation and entrepreneurship. In parallel, education plays an important role in teaching students about new business ventures and startups. To this end, in order to be adaptable to the needs of the country and the market and strategically focused, ACK has systematically transformed itself to allow it to produce and share knowledge, devise processes for knowledge creation, and as stated earlier, integrate research into teaching as well as educate students to develop research. This has meant that ACK had to widen its networking platform locally, regionally, and internationally to become a facilitator in innovation. Integrated leadership and an openness to innovation led the College to establish the Innovation and Entrepreneurship Center. The Center is intended to produce entrepreneurs who can secure funding for their projects from the government and the private sector.

By harnessing innovation, entrepreneurs are key to economic growth, diversification, and job creation. To this end, ACK has developed a pedagogy that serves to transfer practical knowledge and develop relevant skills that support entrepreneurs. The College engages students in learning experiences that foster an entrepreneurship mindset and considers its applied education model the foundation for developing entrepreneurial skills.

Recently, the College published a book chapter titled "The Role of Faculty Members in Building an Entrepreneurship Culture in Higher Education: The Case of the Australian College of Kuwait" [26]. The chapter explored the importance of faculty involvement in university activities and teaching methodologies that promote a culture of entrepreneurship.

Innovation and entrepreneurship are implemented in the College through its 5 year strategic plans which are pursued along the following five lines:

1. Develop curricula that support innovation and entrepreneurship and supplement each curriculum with graduation projects that can be converted to startups and small and medium enterprises;
2. Promote activities that foster a culture of innovation and entrepreneurship;
3. Focus on strategic and financial partnerships that reinforce knowledge and sharing expertise with universities such as Central Queensland University in Australia. Locally, reinforce partnership with the Kuwait National Funds for Small and Medium Enterprises, Kuwait Banking Association as well as private angel investors;
4. Encourage academic research in entrepreneurship and business model innovation; and
5. Provide special services needed for startup businesses such as intellectual property, legal services, feasibility studies, business plans, and startup incubation [26].

On an annual basis, the College organizes an exhibition where entrepreneurs are given the opportunity to showcase their businesses and start-ups to ACK's community.

6.4 Research and Development

Research at ACK has undergone a fundamental transformation within the last few years. The College has redesigned its strategy and governance framework to ensure that research with impact becomes a core function and a strategic priority. The research vision serves to enhance the profile of ACK as a higher education institution that contributes to the pursuit of original research aimed at extending the boundaries of applied knowledge.

The vision aims to have a transformative impact on society through innovation in education, research, creativity, and entrepreneurship. In support of that, a set of clear policies and procedures have been drawn up to safeguard ACK's research system and ensure the principles of transparency, fairness, and ethical conduct are not comprised. The overarching strategy is composed of four main goals:

1. Establish thematic research areas with a strong association to national priorities;
2. Build research capacity amongst the College constituents;
3. Enable access to infrastructure supportive of the research ecosystem; and
4. Develop and maintain effective and efficient research systems.

An important component of ACK's research strategy has been the establishment of a research governance model where a Research Council and a Research Center were created in 2016. The Research Council, which is headed by the President, oversees the implementation of the research strategy and engages the College's senior leadership and faculty in the refereeing process to ensure funded projects are of a high caliber and are within the research themes identified by the College. Since its establishment, the Research Center has been working on building an environment that allows the College to elevate its research profile.

Through the Research Center, the College has sustained thematic lines of applied research that address priority areas aligned with the National Research Priorities identified by KFAS. These priorities include: Energy; Water; Environment; Innovation and Entrepreneurship; Mechatronics and Automation; Business Development; Learning Philosophies and Frameworks; and Marketing Communications. The Research Center works on research projects in close partnerships with KFAS, governmental bodies, and international universities. In particular, ACK faculty submit proposals annually to KFAS. These include a number of research applications in collaboration with international universities in areas related to national priority.

As part of its research and development reform, the College has established national and international partnerships to strengthen its research capabilities. These partnerships have provided the College with access to resources and networks. For instance, the College has signed agreements with its international partners to allow faculty to collaborate in joint research. The College is currently engaged in a number of multidisciplinary research projects in USA, Canada, Europe, and Australia. Since ACK's research themes are also aligned with its strategic partner CQUniversity in Australia, a joint research council has been established. And the title of adjunct research professor is awarded to collaborators from ACK and CQUniversity. ACK is also in the process of seeking partnerships within industry to utilize their equipment and laboratory facilities to conduct industry-led research.

To promote a conducive research environment, the College has established an internal Research Fund which is managed by ACK's Research Council. The College's grant schemes fund multidisciplinary research that focuses on key national priority issues. To further support its research drive and enhance the quality of research output, ACK has increased its budget for research and faculty development. It has also reduced the faculty's teaching load to allow them to conduct research. Furthermore, incentive plans have been introduced to encourage faculty to engage in research and publication in quality journals. These plans award faculty a percentage of the grant upon completion of the project. The College also organizes a dinner, on an annual basis, to recognize faculty members with outstanding research. Faculty are given financial rewards for their research contributions including recognition certificates.

As part of the College's initiative to create a research intensive environment, clear progression and promotion plans were drawn for faculty. These plans are not limited to R&D activities and publications, but also require faculty to be active members in the editorial boards of international journals. With respect to the required manpower, the College has recruited faculty with a strong background in applied research. Faculty are the backbone of the research community, hence, the College places importance on enhancing their capabilities.

In short, the College's senior leadership provides unconditional support to all research endeavors. The College has created two positions for post-doctoral fellowships in engineering and business in order to develop new research ideas. These positions are recruited based on international criteria and the selected candidates' contracts are renewed on an annual basis. The purpose of creating these positions is to allow faculty to interact with international peers and create research groups with an international dimension.

To supplement its research efforts, the College established specialized engineering workshops and laboratories that are staffed by experienced multinational teaching assistants and technicians. These facilities have been equipped with state-of-the-art tools. The workspaces for Project-Based Learning (PBL) engage students and faculty in experience-rich inquiry, critical thinking, research, and innovation. In addition, in 2014, ACK established an Industrial Advisory Board at different levels (College and Schools). The Board is comprised of industry professionals from the private and government sectors and provides strategic advice in areas of research, development, and curricula. Such alliances ensure that ACK not only delivers industry-aligned skills but also produces research that is beneficial to the development of economy and society.

As a result of nurturing an inclusive environment that produces multidisciplinary research, attracts international collaborators, uses high-end resources, and maintains the highest standards of ethics, the College achieved a sharp increase in funded projects and research output published in Q Journals.

7 Conclusions

Achieving sustainable economic growth is not possible without R&D. As the economy in the Arab world is becoming more knowledge-based, effective attempts to reform research has never been more pressing. There are many reforms required for R&D within the Arab region. From governance to organizational challenges, they all need to be tackled. This includes the issue of brain drain as human capital is critical for any R&D reform. Taking a macroscopic perspective, the Arab region should examine successful R&D models in countries like Denmark, Singapore and South Korea and endeavor to develop similar strategies and reforms over the next two to three decades. This region could also benefit from developing an Arab Digital Library, an Arab Bureau of Higher Education and Research Statistics, National Labs, Arab World Journals, R&D Chairs, Multinational Companies and Research Findings, an Arab World Center for Patents and an Arab World Machine Translation Company.

This chapter sheds light on the reforms required by the higher education sector in the Arab world. Governments in this region need to invest more in R&D as they seek to diversify their sources of income. More importantly, the higher education sector within this landscape must place particular emphasis on reforming their R&D environment. Such reforms will also allow universities to compete on the global platform and achieve higher rankings for their institutions.

There are many challenges that universities face that makes the process of reforming R&D challenging. These include the lack of government support, poor funding, insufficient collaboration, human capital issues, dearth of full-time researchers, and the absence of proper research infrastructure. Such impediments present serious challenges to the reform process. Reforming R&D within a university is not an easy process. It requires a horizontal and vertical collaborative effort involving all members of the university. However, with the right leadership and a connected approach, many universities have been able to establish themselves as research powerhouses.

This chapter presents an adaptable framework based on four main dimensions: Teaching and Learning, Service to the Community, Innovation and Entrepreneurship, and R&D that can be adopted by universities seeking to develop their R&D.

What is certain is that a shift in the university's paradigm from a traditional teaching model to a teaching and research model will ensure that graduates have the required skills needed by industry. Also, such a shift will ensure that universities become drivers for innovation and economic growth. Sustained innovation can be achieved through the higher education sectors' impact on R&D.

Moving forward, reforming R&D requires a shift in the university's mission. This calls for an institutional and regional strategy that recognizes research as a priority area. Also required are an appetite for interdisciplinary research, a systematic approach to development and exchange of knowledge, human capital, proper networking, and a supporting infrastructure.

The recommendations expressed in this chapter draw mainly on the evolutionary experience of ACK.

On a final note, the below points present a summary of the research infrastructure that was incorporated into ACK's landscape and therefore allowing it to create a sustainable research ecosystem:

- The College redesigned its strategy and governance framework to align them with the New Kuwait Vision 2035.
- By integrating research into teaching, ACK's pedagogical framework is based on sound scientific knowledge.
- The College established the Teaching and Learning Center and the Project Based Learning Center to train its faculty on the most updated teaching and learning materials and to teach them the methods of integrating research into teaching in order to implement research-informed teaching.
- The College implemented a student-centered approach by using the PBL pedagogy as the main method to enhance students' attributes toward research and development.
- Students are required to present a major graduation project geared toward national development plans.

- The College is an active member in the CDIO initiative which moves ACK toward becoming an engine for economic development.
- Students have the opportunity to engage in research alongside their faculty and through internships and work placements as part of their programs of study.
- The College has introduced the working student initiative to provide students with the opportunity to work closely with faculty members in their research projects. It also provides support for students to participate in national, regional, and international development competitions.
- The College, through its comprehensive strategy, has placed particular emphasis on its role within the community.
- The College is involved in research projects that directly serve the needs of the community and has partnered with local institutions such as KFAS and KISR to conduct research to that end.
- Through its highly skilled graduates, the College is playing a significant role in the process of upskilling and development of the country.
- ACK established the Corporate Training Center to support professionals in their lifelong learning journey and through de-learning and re-learning.
- ACK, through its Innovation and Entrepreneurship Center, has revised and enhanced the role of its faculty in order to develop the students' abilities to think and act as entrepreneurs.
- The College has established an alumni network where alumni have the opportunity to present their successful achievements to ACK's community.
- The College's research strategy and governance framework ensure that research with impact is a core function within ACK.
- ACK's research strategy is streamlined with the national strategy developed by KFAS.
- The College's Research Center and Research Council oversee the implementation of research and ensure that funded projects are of high caliber and meet the priorities of the nation.
- The College has established national and international partnerships to strengthen its research capabilities, provide international research opportunities for faculty, and exchange knowledge.
- Since ACK's research themes are aligned with its strategic partner CQUniversity in Australia, a Joint Research Council has been established.
- Incentive plans have been drawn to encourage faculty to engage in research. Faculty who secure external funding for their research will receive a specified percentage of the grant upon completion.
- The College organizes annual dinners to recognize and reward faculty with outstanding research in particular those who publish in Q1 and Q2 journals.
- Faculty are also supported to present their research findings in international conferences and are also encouraged to patent their achievements.
- The College has created positions for post-doctoral fellowships in engineering and business with the intention of developing research groups who will serve the national plans.

- The College's recruitment and appointment policy have clear selection criteria based on research contributions for the appointment of new faculty of all ranks (instructor to professor).
- The College established the Industrial Advisory Board at the School and College level. The Board, whose members are comprised of industry professionals from the public and private sectors, provides strategic advice on areas of research, development, and curricula.
- ACK has received the ISO certification. This ensures that ACK's quality assurance practices are in line with international standards.

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Three Decades and Beyond of Strategic Planning for Research and Development in Kuwait: The Case of Kuwait Institute for Scientific Research

Samira A. S. Omar

Abstract Strategic planning at Kuwait Institute for Scientific Research (KISR) defines the path toward investment and balanced distribution of resources to meet the institute's mission and goals. Strategic plans are founded on national development demands, prioritizing research and development (R&D) to provide solutions to society's critical problems. Strategies are vital in identifying strengths, weaknesses, opportunities, and threats (SWOT) and evaluating key performance indicators. From a small research institution to a renowned R&D institute, KISR initiated its first five-year strategic plan (1980–1985), progressing to the current ninth strategic plan (2020–2025).

Kuwait's Vision 2035 showcases a knowledge-based economy, with the private sector as driving force to prosperity. Aligning this Vision with the Kuwait National Development Plan (KNDP) was considered in the 2015–2020 eighth strategic plan. And subsequently, in the 2020–2025 ninth strategic plan focused on how KISR can best serve and contribute to KNDP's main pillars, namely energy, living environment, infrastructure, economy, and human capital. In conjunction, KISR's research centers ventured into integrating their programs in line with this vision.

As stewards of Kuwait's applied R&D, KISR brings to the fore science and technology to bear on the challenges implied in Kuwait's Vision 2035 via research and innovation around flagship programs, artificial intelligence, Big Data, and business technology innovation. KISR remains committed to meeting the science and technology needs of clients and stakeholders and to becoming a celebrated international center of excellence for science, technology, and innovation, across multidisciplinary research programs.

Keywords Research and development · Strategic planning · Science · Technology · Innovation · Knowledge-based economy · Kuwait's Vision 2035

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1 Introduction

Institutional strategic planning is the lifeblood of any scientific institution. It is also a fundamental approach to define the path and methodology to be followed toward an ideal investment and a balanced distribution of available resources to realize the institution's mission and goals. It is a process of anticipating change, identifying new opportunities, and effecting strategies [1]. Strategic plans should focus on data and how these data could be used to propound realistic policies and goals [1]. Given the great need for information that supports real-time strategic decision-making, it is imperative for institutions to advance beyond providing traditional static data, and instead, be actively engaged in contemporary analytical methods and be the lead in this area [2]. Planning, if properly implemented, can have a powerful impact on advancing and transforming both academic and scientific institutions [3].

The Kuwait Institute for Scientific Research (KISR), which was established by an Amiri Decree in 1967, has since been formulating its five-year strategic plans, starting in 1980 in collaboration with international institutions such as the Battelle Memorial Institute, Ohio, USA. Since the first strategic plan, KISR has continued to develop and implement strategic plans at five-year intervals even in the wake of the devastation that hit its research facilities during the 1990–1991 Iraqi invasion of Kuwait. KISR has then, without delay, regained the helm of leadership as an applied research institution in the country and in the region.

During its initial construction and subsequent development, KISR has sought to attract qualified and capable scientists, especially Arabs and expats, to participate in its research activities and train Kuwaiti nationals. KISR has been keen in honing national expertise in scientific research both through in-house activities and trainings abroad, and by providing scholarships for graduate and post- graduate education.

Announced in 2010, Kuwait's Vision 2035 describes a nation's dramatic transformation for the better over the next 15 years. The Vision showcases a knowledge-based economy, in which the private sector is the driving force for financial prosperity and for providing bigger opportunities, working alongside the government, efficiently and effectively to confront the nation's most crucial problems. It is a Vision that highlights new infrastructures, with a vibrant economy as well as healthy and sustainable communities, in a well-protected and well-preserved environment [4].

The process of aligning the vision of KISR with the Kuwait National Development Plan (KNDP) has been initiated in KISR's eighth strategic plan (2015–2020), emphasizing on the advancement in science and technology.

In 2017, KISR celebrated its 50th anniversary, which gave the institution the prospect to look back at the numerous significant accomplishments and contributions to its stakeholders and the nation. The institute's contribution to the realization of the nation's Vision 2035 and the need to develop its capacity in digital technology will require in the realm of science, technology, and innovation.

2 The First Six Strategic Plans

At its inception in 1967, KISR was as a small research institute with a limited number of personnel, mainly from Japan and Kuwait. It was established as part of an offset program between the Government of Kuwait and the Japan-Arab Oil Company, focusing mainly on petroleum, agriculture, and fishery research studies. The institute was initially managed by an administrative system headed by Japanese leaders until 1970, when the first Kuwaiti Director General, Dr. Mohammed Al Shemali was appointed. He set up a simple research and development system that requires preparation of research proposals with workplan, budget and schedule for implementation. He also established laboratories for conducting applied research in the areas of agriculture, petroleum, and fishery. The number of employees at that time did not exceed 50. The institute was later inaugurated by Government officials, following an Amiri Decree issued in 1981 that put forward the charter, which recognizes KISR as an independent research institution in Kuwait with flexible policies for institutional management and operation.

KISR's mandate underlined the research areas that the institute should conduct relative to its R&D plan. These included, but are not limited to food, agriculture, marine science, energy, petroleum, and water. The first (1980–1985) and second (1985–1990) strategic plans focused on research programs in the fields of agriculture, petroleum, and techno-economics. The third (transitional, 1992–1995) strategic plan was about re-establishing the institute after its complete inflicted damage during the Iraqi invasion of Kuwait in 1990 and 1991. The institute developed a three-year Transitional Strategic Plan (1992–1995) to recover resources and restore the damaged laboratories and buildings with a message to stakeholders and the community at large on keeping 'Partners in Reconstruction'. It was not until the fourth strategic plan (1995–2000) that the institute started to expand its resources and its R&D programs based on the national government priorities. KISR established five scientific divisions (Food Resources and Marine Sciences Division, Water Resources Division, Petroleum Research and Studies Center, Engineering and Urban Development Division, and the Techno-Economics Division) in addition to other technical and administrative support divisions. KISR employed over 809 staff members of which 95% were either Ph.D., MSc (or MA), BSc (or BA) or College Diploma holders [5].

KISR's fifth strategic plan (2000–2005) constituted a transformational step with a vision for the new Millennium and aiming at keeping abreast with scientific and technological developments around the globe. It reflected great harmony with the current and even the yet-to-be realized technological and scientific developments, while coordinating the economic, productive, and developmental priorities of the State of Kuwait. The fifth strategic plan was about carrying out R&D in the divisions that were established as part of the fourth strategic plan. About 97% of the set goals were reached by executing 194 research project contracts, of which, 69% were financed by beneficiaries, in a rundown as follows: 65% from the government, 16% from the private sector, and 19% from international agencies. In addition, 50 internal research projects, more than 73 scientific consultations, and more than 6000 technical services were carried out during that same period. The outcomes of these executed research projects were given excellent reviews by international referees.

Some of the most remarkable accomplishments embodied in KISR's fifth strategic plan were the following: a revision of the hierarchy, resulting in the reduction of the number of research divisions from six to five and the organizational units from 21 to 14; the merging of the Computer Unit with the National Center for Scientific and Technological Information; the development of financial and purchasing procedures; and the automation of operational procedures, resulting in greater control, facility, and flexibility in staff performance .

During the preparation of the sixth strategic plan (2005–2010) [6], the emphasis was on curtailing the institute's weaknesses by: putting more efforts on effective marketing of its research outputs; developing a system for dealing with compensation and service requests; engaging a pool of researchers and specialists with the needed expertise; compensating for difficulties in marketing scientific systems and innovations in the absence of technological and scientific incubators; and improving its limited long-term planning capabilities. This is due to the lack of a national policy for scientific research, controlled financial allocations to scientific research by the government and private sectors (not to exceed 0.3% of the national income), and the failure of government authorities to abide by the Council of Ministers' decree about KISR's scientific services and consultations, as required by such authorities.

Accordingly, a document referred to as 'Present and Future Trends' was released in the sixth strategic plan, disclosing what needed to be looked into relative to the national R&D situation. These constituted the following: a dearth of clear scientific and technological policies; suitable mechanisms for connecting scientific research activities and outcomes with technology transfer needed for national development; investment incentives for scientific R&D outcomes, in order to face unfair competition from products and commodities produced in the developed world, dependence on foreign expertise, and a relatively small local market; and finally, infrastructure shortfalls in meeting the demands and requirements of scientific research playing a greater role in the various areas in need of development.

Overall, detailed goals and measures were called for to mitigate existing deficiencies and at the same time, to achieve the specific targets within the planned period. Specific targets encompassed the research units, human resources, knowledge management, scientific consultations and technological services, administrative organizations, information and communications technology, and regional and international cooperation.

By and large, performance indicators also had to be prioritized: to attain high quality levels of research activities and consultative services (such as scientific production, scientific quality of outcomes, human resources, administration, media, and finance); to establish an efficient scientific research framework supported by efficient human resource management, infrastructure, research facilities and databases; to become a reference for science and technology and a think-tank to support Kuwait's decision makers; to promote KISR's position in the local, regional, and international arena; to enhance scientific and technological cooperation and partnerships with regional and international institutions; to increase KISR's customer database; and to be able to develop individual financial revenues.

3 The Transformation Plan

The seventh strategic plan (2010–2015) [7] was a fundamental rethink of KISR's mission and vision for the future. In developing a new vision for KISR, several key objectives were identified. First and most important, the vision should seek to build consensus and it must state the purpose of KISR and where KISR can add value to its chosen markets, while being novel, ambitious, and satisfying the aspirations of all its stakeholders. With these objectives in mind, and after reviewing vision statements from leading international research technology organizations, the following vision statement was adopted:

KISR VISION
By 2030, KISR will be internationally acknowledged as the region's most highly respected science and technology institution and knowledge gateway and recognized as a driving force for sustainable economic prosperity and quality of life.

In developing KISR's mission statement, some general principles were complied with. For the most part, the framework for the mission statement was set according to the Amiri decree aiming at conducting research, promoting science and technology, and providing advice and services.

KISR MISSION
KISR leads and partners internationally to develop, deploy, and exploit the best science, technology, knowledge, and innovation to public and private sector clients, for the benefit of Kuwait and others facing similar challenges and opportunities.

To achieve the new and ambitious vision and accomplish KISR's expanded mission, the 7th five year strategy was developed that provided a clear focus on KISR's applied research activities, taking into consideration long-term technological challenges. This strategy also included a well-defined priority for critical support to national policy making. The strategy is based on five thrusts as shown in Fig. 1 and described as follows:

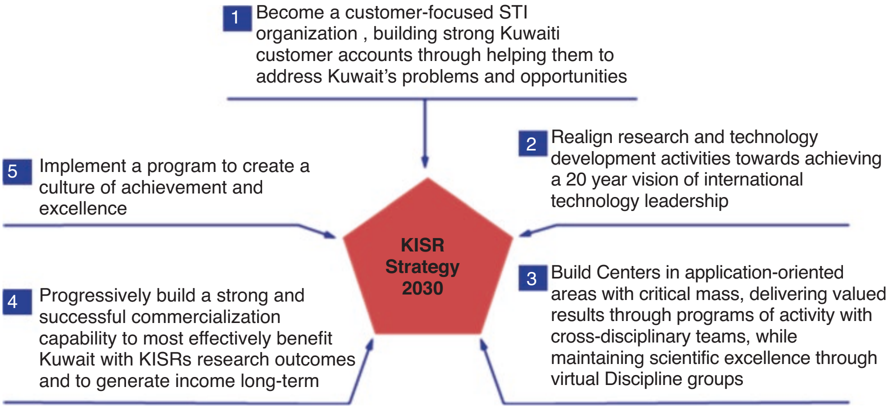

Fig. 1 The five thrusts of the seven strategic plan of Kuwait Institute for Scientific Research (KISR)

(i) To become more customer focused, employing the outside-in approach

- KISR will concentrate more on a small number of key topics where the application of science technology and innovation will help customers address Kuwait's challenges.
- Promptness in the delivery of services and outputs, and consistent quality will be emphasized, particularly in the core project development and delivery cycle.
- Closer customer partnerships will be fostered through a formal marketing and client engagement process with key accounts.
- KISR's formal performance management process will drive and reward performance, in alignment with a customer focused approach and a broader vision, mission, and strategy.

(ii) To achieve international technology leadership

- Kuwait's national challenges are also global in nature. For its success, KISR will augment its science technology and innovation capabilities by coupling with the efforts of others to deliver solutions or insights for effective policy. The institute's capabilities encompass the following:
- KISR will focus on demonstrating technology leadership in chosen areas.
- A higher bar will be geared up for the impact of KISR's R&D and new guidelines have already been expounded for publication in high-impact journals.
- KISR will partner locally, regionally, and internationally, hosting collaborative multidisciplinary research programs with highly trained scientists and technologists.
- An extensive modernization and facilities development program will be implemented to provide a state-of-the-art support to scientists and engineers working at KISR.

(iii) To set-up centers in application-oriented areas
- In the near-term, four Centers of Excellence will be established, namely: Petroleum; Energy and Buildings; Water; and Environmental and Life Sciences. Over the long-term, other centers will be planned for to support national priorities.
- R&D in each center will be based on strategic programs designed to support solutions to national priorities by working closely with key clients (see upcoming section on National challenges)
- Each center will be semi-autonomous, exclusively guided by an Advisory Council, comprising key clients, scientists, and stakeholders with the expectation that they can break off and form independent research centers in the future.

(iv) To set up a solid and thriving commercialization capability
- KISR will focus on the potential for commercializing efforts from each of its program initiatives.
- Appropriate legal frameworks, mechanisms, and processes to enable commercialization will be developed.
- KISR will create a pipeline that provides a flow of technology and business opportunities.
- Specialized resources (funds, intellectual property management, etc.) and corporate venturing/incubator facilities will be pursued.

(v) To nurture a culture of achievement and excellence
- A new generation of leaders who adopt KISR's new values and who intend to serve as role models will be worked up.
- Performance management will be instituted to add in setting performance objectives at the senior management level fixed on the five strategic thrusts, and reinforced by an aligned performance planning, appraisal, and development process for all staff.
- Management will highlight its efforts on proactive institutionalization of this culture of achievement by serving as role models and fostering a motivated supervision and reward system to encourage appropriate behavior of the staff.

The developed strategy would require that KISR should also develop the capability to initiate new thrust areas, prioritize current ones, and rethink the manner it conducts current activities. This would entail the redesigning of an organizational structure that supports transformational change. After considerable assessments, the decision has been to organize KISR's research and technology capability into four centers that aim to contribute solutions to national challenges. These centers include: Petroleum; Water; Energy and Building; and Environment and Life Sciences (Fig. 2).

In addition to the existing Administration and Support Services, two new sectors have been established, as such: Science and Technology Sector (STS) and Marketing and Commercialization Sector (MCS). The STS leads the development and

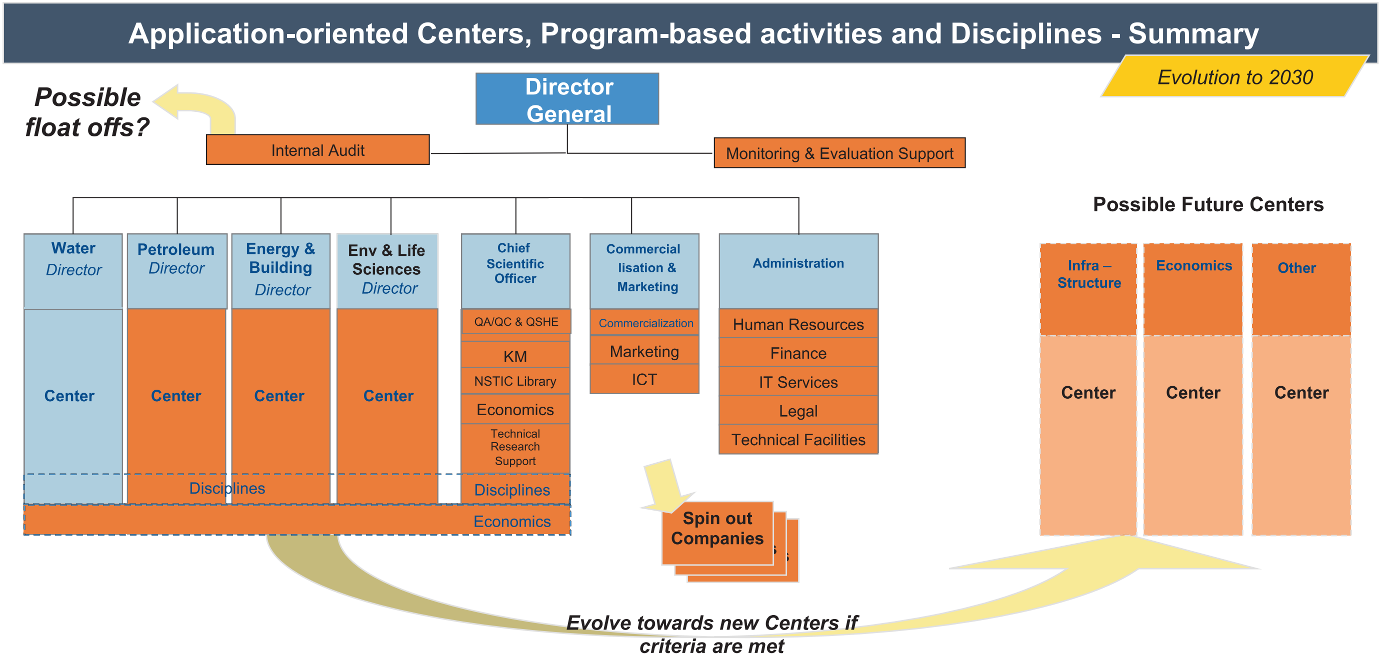

Fig. 2 Organizational structure of Kuwait Institute for Scientific Research in the seventh strategic plan

implementation of KISR's long-term science and technology strategy, ensures that KISR develops and maintains its scientific excellence, and incubates new centers for the future, such as techno-economics (TED). Currently, the TED was established to develop a strategy for the Economic Public Policy and Private Sector Development programs. Meanwhile, the MCS supports the development of client-engagement processes, as well as the exploitation of KISR's research for commercial purposes.

The new structure is directed at growth and evolution and geared towards incubating new centers, such as Infrastructure and Buildings center and spinout companies to meet Kuwait's developing needs.

4 Steps in Strategic Plan Development

The planning process of the 7th Strategic Plan began with an assessment of the current situation. The senior leadership and the Board agreed that a systematic appraisal of KISR's current effectiveness would be essential if a robust vision and plan were to be developed for the future. KISR has contracted with an outside firm, specialized in working with research and development organizations, to help conduct this assessment, which included a detailed analysis of the stakeholder's technology requirements and the alignment of KISR's activities with those requirements. Such an evaluation had to include a detailed look at KISR's internal policies and procedures, and their impact on both client and staff satisfaction and effectiveness. Concisely, the results strongly indicated that a major transformation of KISR would allow it to provide services necessary to meet KISR's priority needs, satisfy clients, and make KISR the workplace wherein the best scientists and engineers recognize their potential and use their talents.

Following the assessment, the next step in the process was to put together and execute a plan for accomplishing the necessary transformation. Key elements of this work phase included reflecting on KISR's mission and vision, defining the core values that demarcate KISR's desired culture, identifying the strategic changes (thrusts) that would be necessary to achieve the desired transformation, creating a new organizational design, and assessing the requirements for the strategic changes to make KISR a more effective organization. Most of the changes have been implemented as part of the strategic planning process; other modifications will be implemented in the coming years.

Conclusively, the key part of the process was to reorganize KISR's applied research programs and translate them into a set of sector-oriented centers of excellence to effectively meet the needs of stakeholders and clients. By working with clients, stakeholders, and outside experts, KISR has identified twenty-eight priority applied research programs to be grouped into four Research Centers and one additional unit/division, hosting two programs, these are: Petroleum Research Center, Environment and Life Science Research Center, Water Research Center, Energy & Building Research Center and Technoeconomic Division. The 25 programs are

Table 1 Research Centers and Research Programs in the seventh and eighth strategic plans of Kuwait Institute for Scientific Research (KISR)

Centers	Programs
Water Resources Research Center (WRC)	1. Wastewater Treatment and Reclamation Technologies
	2. Water Resources Development and Management
	3. Thermal Desalination Technologies
	4. Innovative Desalination Technologies
Petroleum Research Center (PRC)	5. Corrosion Assessment and Mitigation Technology
	6. Improved Oil Recovery
	7. Optimization of Petroleum Refinery Processes
	8. Polymeric Products Enhancement and Customization
	9. Refining Capacity Expansion and Flexibility
Environment & Life Science Research Center	10. Coastal Management
	11. Aquaculture
	12. Biotechnology
	13. Crisis Decision Support
	14. Desert Agriculture and Ecosystem
	15. Environmental Pollution and Climate
	16. Food and Nutrition
	17. Ecosystem-based Management of Marine Resources
Energy & Building Research Center	18. Energy Efficiency Technologies
	19. Renewable Energy Technology
	20. Construction and Building Materials
	21. Sustainability and Reliability of Infrastructure
	22. Nanotechnology-Advanced Materials
Technoeconomic Division	23. Economic Public Policy
	24. Private Sector Development
	25. Feasibility and Business Support

listed in Table 1. Detailed strategic plans were then developed for each center and program, drawing on input from clients, stakeholders, and outside experts. An example of this strategic plan is presented in Fig. 3 for the Environment and Life Sciences Research Center (ELSRC).

Completing the assessment process emphasized on the role of KISR in using research to generate practical applications. As a partial response to this challenge, special attention was given to increasing the sophistication and impact of KISR's marketing and commercialization activities.

It was also determined that virtually every process within KISR should be re-engineered to support KISR's vision and mission to be better aligned with the new organizational structure. A team consisting of employees from KISR, and consultants was deployed to develop "to-be" models and implementation plans for

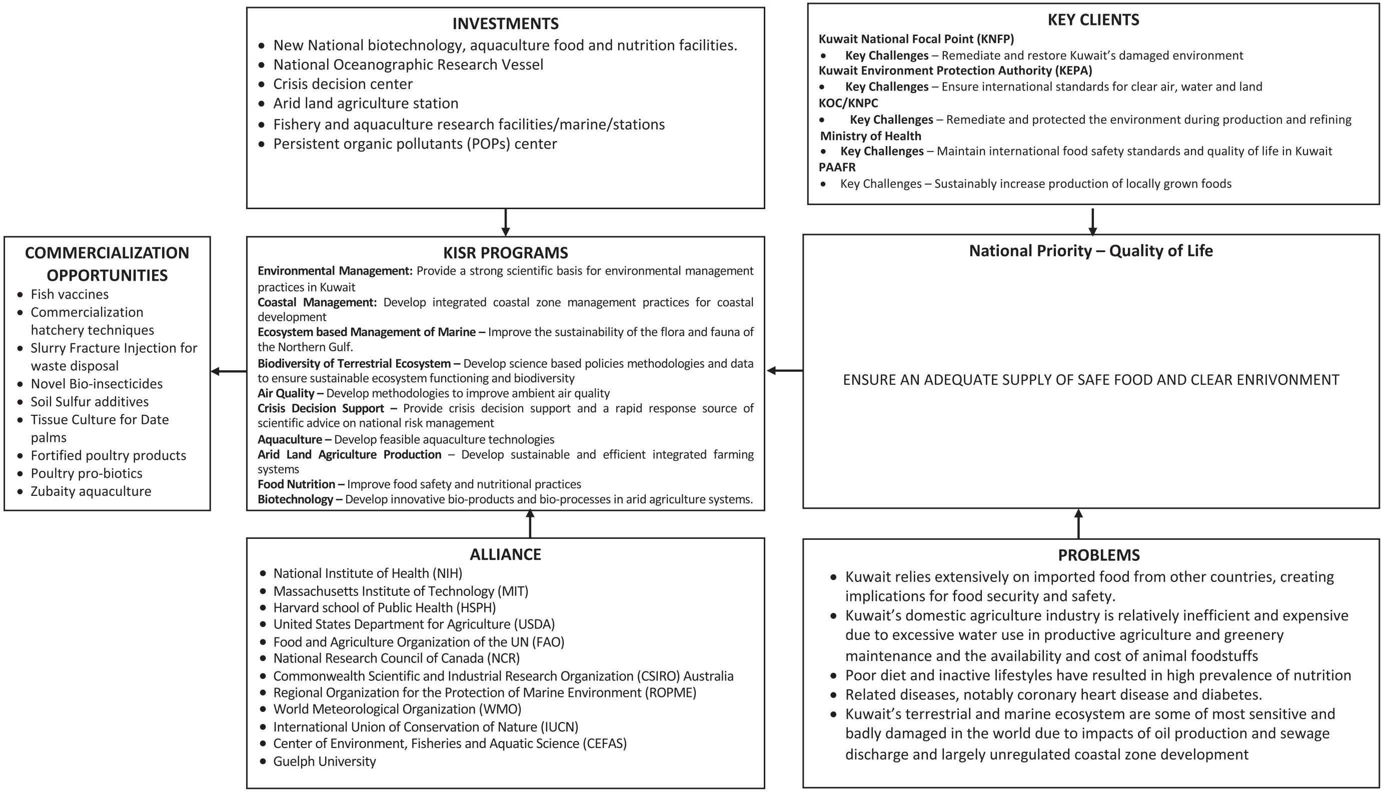

Fig. 3 Outline of the Environment and Life Sciences Center Strategic Plan in relation to the national priority – quality of life

processes related to finance, purchasing, human resources, research management, and performance management.

At length, these systems and activities are being put in place to make ~~of~~ KISR the best workplace for attracting and supporting talented scientists, engineers, and administrative staff in Kuwait and in the region. Our ability to invest in, motivate, reward, and support our people will ultimately determine whether this transformation effort would indeed be successful for Kuwait, KISR clients and stakeholders, as well as the institute itself.

5 Evaluation of KISR's Current Effectiveness in Supporting Kuwait

Before addressing the future of KISR, its vision, mission, and strategic direction in the 7th Strategic Plan, a comprehensive review of KISR's current effectiveness in providing value to the state of Kuwait was conducted. The evaluation process consisted of four elements: (1) an external and internal assessment of KISR's current performance by key stakeholders; (2) a self-assessment of KISR's current capabilities and constraints; (3) a benchmark study, comparing KISR with comparable international research and technology institutes; (4) and an analysis of the challenges faced by key sectors of Kuwait's economy and quality of life. This set of information has helped to formulate the new vision, mission, and strategy.

5.1 Assessment of KISR by Key Stakeholders

The first step in the strategy development process was to interview both internal and external stakeholders to obtain a clear perspective on the key issues and priorities to be addressed. Sixty-five internal and twenty-five external stakeholders pre-approved by senior management were interviewed using a formal interview protocol. Interviews were conducted with all key parts of the institute, including research and administrative support. External stakeholders consisted of key clients of each of the research divisions.

External stakeholders had a shared standpoint that while KISR has somehow maintained its brand image, there are areas that still need to be addressed and worked on. These include improving service delivery, particularly delving on core development and delivery cycle; using a more client-focused approach; showing consistency in the high quality of the outputs of the institute; focusing on key topics, aimed at creating a difference; having a brand image as a provider of research; and showing positive goodwill, which is substantial but contingent on expected improvements in KISR's research and service delivery processes.

On the other hand, internal stakeholders suggested that the key processes driving KISR's organizational performance need upgrading and that cultural barriers within departments have led to poor teamwork and low morale.

The implications of these findings have been incorporated into the new strategy. These include the need to have more focus in KISR's research activities and better prioritization of efforts, which will eventually provide substantial benefits to Kuwait. This intensified focus will need to be balanced against the continuing need for KISR to play a broad role within the nation's science, technology, and innovation framework, given the relative scarcity of other institutions to play that role. An urgent priority will be to emphasize on client service delivery that will require increased client focus and implementation of process improvements. Finally, there is a need to create a more open institute, by conducting objective and transparent performance reviews.

5.2 Institutional Self-Assessment

The next step in the strategy development process was to obtain information on each of KISR's divisions and gain perspective on their performance, capabilities, and resources. Each division generated a self-assessment report, highlighting its historical strengths and achievements, future ambition, and barriers to attaining this ambition, and current resources and performance. A series of meetings were held to review current activities and assess the value they were adding to identified clients.

The highlights of the self-assessment report covered the following:

- KISR work has focused on applied research.
- Resources are spread too thin across many sectors.
- There has been uneven distribution of resources across divisions; and the allocation of resources has not been aligned with Kuwait's priority needs.
- Except for the Petroleum Research Center, there has been an increase in project funding from internal KISR sources (as opposed to client funding).
- Significant differences exist in scientific outputs between Kuwaiti and expat researchers.
- There has been a lack of effective collaboration across divisions (e.g., no incentives or policies for matrixing).
- Some areas of KISR that are below critical mass required additional manpower.
- The proposal development process is slow.
- There has been a lack of available skilled technicians to maintain facilities.
- There is low recognition of the importance of R&D in Kuwait.

The implications of these findings were also important in developing KISR's 7th five-years strategy. Specifically, there is a need to effectively allocate limited resources and prioritize them to promote cross-functional teams and application-oriented programs to break down barriers between and among divisions and departments. KISR also needed to reinforce a culture of achievement throughout its operations.

5.3 Benchmarking KISR with Comparable International Research and Technology Institutions

Five listed R&D institutions in developed countries were selected for the international benchmarking comparisons study. The five organizations represented modern good practice and have similar functions to KISR (in relation to providing support to industrial innovation, technological services and support to policy making). The five selected instructions are listed as follows:

- The Danish GTS system of nine institutes, focused on providing technical services and R&D to industry
- SINTEF, Norway's largest polytechnic research institute
- IRECO, the umbrella organization of the Swedish applied research institutes, (consolidated into four over the last five years)
- The Fraunhofer Society (FhG), a large network of applied research institutes in Germany
- TNO, the Dutch applied industrial research institute, which is a large, multidivisional, multi-technology institute

The aim of these comparisons was to evaluate relative resources and staffing levels; performance indicators, such as scientific and patent outputs; and the effectiveness of different organizational models. The scope was intended to set the scene for the strategic plan review, rather than to provide a comprehensive set of benchmarking comparisons.

Some results of the study with international organizations in developed countries (the first five institutions) showed that KISR's promotion of R&D staff was compatible with other institutions and that the turnover per employees was similar. In respect to funding, KISR showed much higher core funding at around 80% than the other five institutions. However, while KISR has R&D potential, it lagged behind the others in terms of scientific outputs and patents in 2007, when the comparative study was conducted. KISR was delivering some 0.1 scientific and conference papers per employee, with only a handful of patents in total. This indicated that progress still needs to be made at KISR in terms of outputs [7].

5.4 Analyzing Key Sectors and Addressing Kuwait's National Challenges

A high-level analysis of Kuwait's challenges was conducted in terms of its economy, society, and environment to gain an understanding of the relative importance of the issues faced by the country and the region. This analysis was important to identify priority research areas that KISR should focus on in its transformation strategy. It showed the need to focus and emphasize on projects dealing with the country's national challenges as this is the fundamental mission of KISR. The analysis showed that KISR needs to be customer focused, as it is KISR's clients who will implement the research results produced. Moreover, KISR outputs need to provide more tangible value to Kuwait in terms of social and economic impact and that the outputs must meet international standards.

6 The Eighth Strategic Plan

The eighth strategic plan (2015–2020) [8] could be considered a transformational plan that has led to a broader and more ambitious strategy, focused on Kuwait's National Strategy, and witnessing reorganization, a new leadership, and the development of improved processes for KISR. At the core of the eighth strategic plan was the endorsement of the applied research areas that KISR should focus on and the identification of the type of organizational and supporting processes indispensable to promoting KISR's success. The eighth strategic plan also envisioned the longer term development process of KISR as illustrated in Fig. 4. As indicated in the Figure, over the course of 20 years, KISR has since aspired to become an international center for excellence in applied research and technology focusing on areas of strategic importance to Kuwait and the region.

For the eighth strategic plan, much effort was expended on determining the general scope of KISR's research programs, its major client sets, and the optimal organization for meeting the needs of these clients. This effort included extensive engagement of KISR stakeholders, benchmarking of important research and technology organization structure and processes, and development of a new mission, vision, and values for the institute.

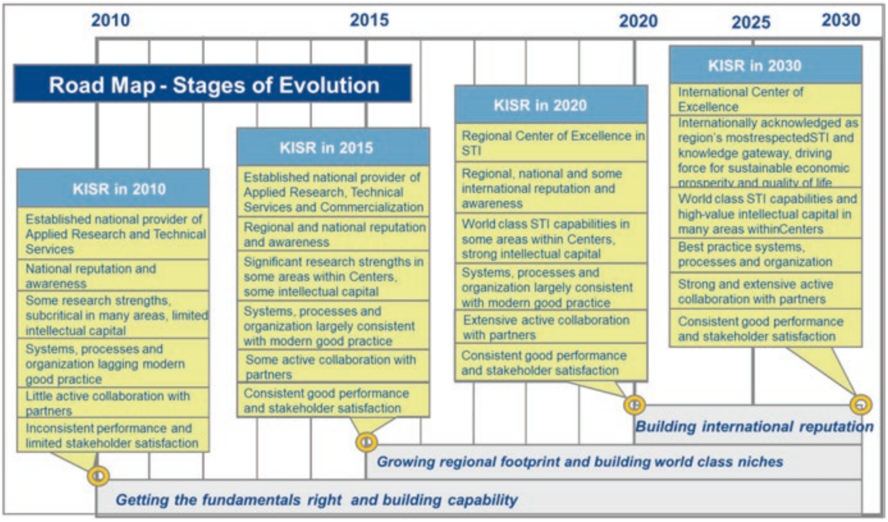

Fig. 4 Kuwait Institute for Scientific Research (KISR) road map focus for the ninth strategic plan. (Modified from [11])

However, KISR faced challenges during the first two and a half years of its eighth strategic plan implementation that were mainly due to external macro-economic developments leading to lower oil prices, and consequently, to new government policies that have adversely impacted KISR's budget and operations. In addition, the closure of both the Wafra Joint Operations and Khafji Joint Operations in Kuwait since 2015, has also affected KISR's petroleum research revenues. These were exacerbated by several internal challenges that spanned organizational-related issues including the following: appointment of new managers, difficulty retaining and attracting new R&D talents, limited availability of R&D funds from the private sector, and shortcomings in the implementation of new processes that hampered operational excellence. In addition, KISR's management had to deal with some of the past problems, as well as the new restrictive directives/policies of the regulatory government institutions, all of which have negatively encumbered the institute's operations.

7 Evaluation of KISR's Accomplishments – SWOT Analysis

To evaluate KISR's accomplishments, a SWOT analysis was undertaken to highlight the strengths, weaknesses, threats, and opportunities of KISR's achievements and progress during the eighth strategic plan (2015–2020).

- In view of the major **challenges** that have been facing KISR during the implementation period of 2015–2020, the Upper Management, supported by the Research Centers and divisions, succeeded in addressing many of them through several initiatives/actions spanning KISR organization and processes, capacity building, KISR clients and stakeholders, and operational excellence.
- **Weaknesses** were mainly related to the macro-economic developments and lower oil prices that have adversely affected and continue to affect KISR's budget and operations. Simultaneously, KISR has been facing other internal challenges, some of which have been dragging for some time before the new management took charge in February 2016. These have all negatively weighed down KISR's overall productivity during the first two years of the eighth strategic plan implementation, which included the following: high staff turnover and difficulties of retaining competent staff, Kuwaitis and non-Kuwaitis; difficulty in recruiting new proficient talents; cuts in government budget and limited private sector's R&D funds; lower number of R&D activities due to inadequate funding, which has hindered a number of projects, and consequently, the number of publications in internationally-refereed journals; cancellation of new government initiatives for infrastructure improvement and development projects that were originally approved, thus adding to the reduction of the 2018/19 budget; inadequate number of senior scientists to help mentor junior staff; elimination of incentives, thus, adversely affecting the research staff morale and negatively obstructing the culture of achievement; and shortcomings related to the implementation of some of the new processes that were developed in line with the new organizational structure.

- **Strengths** included: KISR's outreaching efforts to expand its client base that have ended in fruition, particularly the cultivation of new clients, such as the Kuwait Direct Investment Promotion Authority and bolstering R&D/technical services through collaboration with the Kuwait Petroleum Corporation and its subsidiaries, results of which will be more evident in the upcoming few years; resumption of the activities of the Kuwait Environmental Remediation Program with the Kuwait National Focal Point with expected significant revenues; embarking on strengthening strategic alliances with the private and public sectors; and initiation for the establishment of a business unit to augment KISR's revenues. In addition, several initiatives undertaken by the Upper Management contributed to the improvement of KISR's operations including: the development and approval of new policies; the streamlining of operational processes to facilitate the operation of research centers; the development of an institute-wide Quality Management System and a Laboratory Information Management System, starting with the Petroleum Research Center; the establishment of an occupational safety system; the initiation of a structured plan for management and early-career technical staff career development; and the upgrading of KISR's infrastructure.
- KISR still faces several **threats** related to the uncertainty in the allocation of KISR's R&D budget due to the fluctuation of oil prices, new restrictive government policies related to hiring of competent talents. The entanglement of KISR with the constricting rules and regulations of the governmental, financial, and legislative institutions also adversely affected KISR's flexibility to exercise its role as an independent institution, as well as inhibiting its productivity.
- On the other hand, KISR has potential **opportunities** that the institute can benefit from, including but not limited to: strengthening its technical outputs and innovative products and processes through the implementation of high-national impact flagship projects, in collaboration with local and international alliances; promoting engagement with external stakeholders through the establishment of the KISR Advisory Council, KISR Research Centers Advisory Boards and KISR/Kuwait Foundation for the Advancement of Sciences (KFAS) chairs of distinguished scholars; enhancing KISR's innovation ecosystem through the establishment of specialized centers and increasing KISR's revenues via the creation of a new business unit and technical incubators.

Information generated from the Mid-Term Review of the eighth strategic plan, along with the lessons learned during the first two years of the implementation of KISR's eighth strategic plan, provided significant insights on the necessary actions that KISR should undertake to move forward during the remaining period of the eighth strategic plan. It also provided good judgment on how to optimize the impact of KISR's ninth strategic plan (2020–2025), as well as on how to enhance the contributions of the institute at the national level.

8 Way Forward in Strategic Planning

The ninth strategic plan (2020–2025) [9] has laid out an integrated approach for achieving the important institutional goals as follows: continuing to provide services to KISR clients and stakeholders with high value; providing high quality solutions to their crucial problems, addressing the priority objectives of the National Development Plan in areas where KISR has comparative edge; contributing significantly to enhancing KISR's R&D and innovation products and services; optimizing KISR's resources; improving income generation; and continuing the institute's efforts to boost up its international reputation and its impact in applied science and technology.

The ninth strategic plan emphasized on issues and concerns that could not be addressed systematically during the seventh and eighth transformation strategic plans. These issues and concerns are:

- Research Centers and research programs are expected to direct their resources to meet the priorities set in their strategies and to show a high level of commitment and a firm resolve to supporting more important activities. This resulted in a reduction in the number of research programs from 25 to 15 as shown in Fig. 5.
- Centers are also demanded to consciously select a portfolio of activities across their research programs:
  - To provide innovative solutions to important client or market sector problems within the five year-period of the plan. The Centers must commit to and actively manage the development of innovations that will have a positive impact on key clients and stakeholders and give KISR the reputation as an innovative institute positioned for longer-term success.
  - To tailor high-quality and near-term delivery of research and services that meet the priority needs of key clients. The Centers and program strategies must include elements designed to elevate the relationship between KISR and its key clients to the level of at least 'preferred provider' and preferably, a strategic partner.
- The steps for executing the proposed strategy are foreseen to be more specific and detailed with greater attention paid to the factors that may enable or disable the strategy. Particularly, it is anticipated that the strategy will be supported by something closer to an implementation or project plan, with respect to process improvement within the sectors and capacity development in every organizational unit.

As for the way forward, it is anticipated that KISR's ninth strategic plan will be aligned with Kuwait's national priorities as reflected in Kuwait's development plan (KNDP), goals/objectives, and vision of 2035. Close cooperation with the Supreme Planning Council/Ministry of Planning for Sustainable Development were sought after. However, in preparing the plan, due consideration were given to worldwide trends and leaping advancements in technology development and their

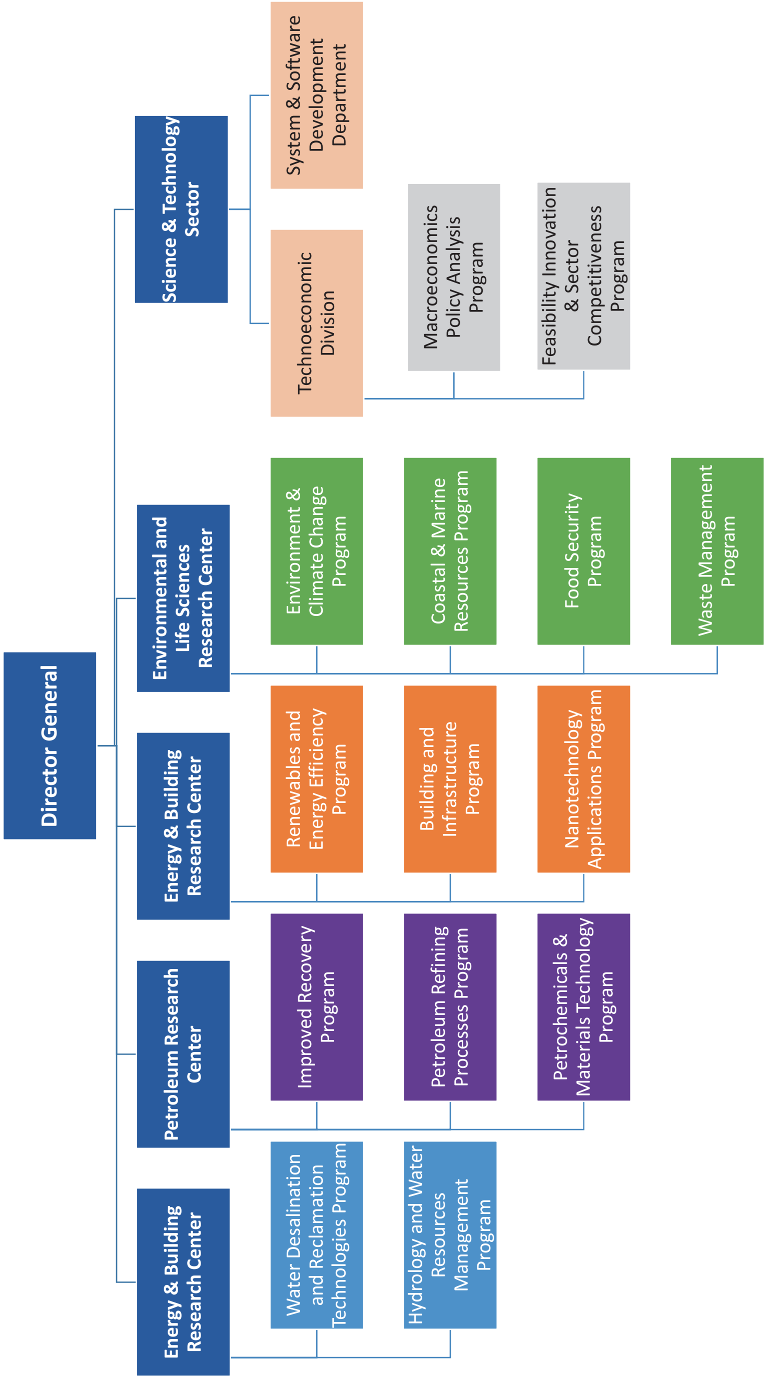

Fig. 5 Research Centers, Science and Technology Sector and Research Programs in the ninth strategic plan of Kuwait Institute for Scientific Research (KISR)

implementation, in addition to the international competitiveness arena and the information age mindset toward open innovation that runs counter to secrecy and silo mentality.

KISR's ninth strategic plan should focus more on innovation, while stressing on international collaboration and allocation of the essential resources to ensure its successful implementation. In addition to its commitment in providing technical development support to its clients, KISR's strategic plan should focus mostly on how KISR can expand its intellectual property (IP) portfolio and enhance its commercialization activities through the execution of flagship projects that have significant bearing at the national level. Execution should be carried out via a structured matrix system, internally, as well as at the national level, and in collaboration with international alliances.

Correspondingly, KISR should breed the appropriate and relevant technology platforms that will support KISR's cross-cutting capabilities, such as computational science (Big Data analytics) and simulation, separation technologies, etc., that would allow the institute to meet national needs. Entrepreneurship should be given due consideration and instituted through the development of appropriate incentives to encourage the culture of innovation at KISR. The Centers and programs have to be the driving force behind increased openness and in embracing internal and external cooperation. All of KISR's organizational units and available resources should be aligned and managed through a collaborative framework in line with the institute's set objectives and expected deliverables. Close cooperation with the business community is required, and KISR should dwell on the promotion of business incubators in collaboration with the private sector.

9 Conclusion

Five-years strategic plans are important for R&D institutions like KISR. They provide a road map for prioritizing research programs that are targeted towards achieving national development strategic goals. They provide proper guidance for efficient utilization of resources such as manpower and laboratories as well as increasing productivity and revenues. For the State of Kuwait to meet the Sustainable Development Goal (SDG 9) Target 9.5, which states—

> "*Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular, developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending*"—

it is necessary to develop a national policy for R&D and science, technology, and innovation. Kuwait Foundation for the Advancement of Science (KFAS) and the Secretary General of the Supreme Council of Planning and Development are currently working with multifarious relevant institutions to provide an international perspective on the Kuwaiti science, technology and innovation system and policies in collaboration with the Directorate for Science, Technology, and Innovation of the Organization for Economic Cooperation and Development (OECD). The OECD will review the innovation policies in Kuwait to offer a comprehensive understanding of the strengths and weaknesses of a national innovation system and the opportunities to enhance it through government policy. It is also envisaged that this review and its recommendations will impart vital international perspective for developing priorities in R&D for KISR's ninth strategic plan (2020–2025).

The Arab Strategic Plan for science, technology and innovation recommends that Arab countries augment their R&D expenditures [10]. The source of KISR's budget is from both the Ministry of Finance and Client/Customer income. However, the annual generated income is fully transferred to the Ministry of Finance, which allocates its annual budget based on the expenditure and income generated annually. Therefore, it is necessary for KISR to upgrade and design its financial system to allow efficient management of financial-related matters in the strategic plan. Increasing income could be achieved through improving, not only the relationship with clients/partners but also, the quality of products and research outcomes. Although commercialization of KISR outcomes was markedly specified in the objectives of KISR's seventh and eighth strategic plans, heightened efforts are imperative to succeed in achieving this objective in the ninth strategic plan. And human resources call for quality recruitment, training, and competent leaders who can offer the best solutions and productivity in a healthy environment.

Strategic planning emphasized flagship projects that will draw the talent and know-how from across KISR to address the enormous complex challenges identified in Kuwait's Vision 2035. In these programs, and in every endeavor, KISR's success will depend on each and everyone, and on promoting a culture of open communication, mutual respect and support, continuous learning and improvement, and client service. Recruitment of young Kuwaiti scientists and provision of the state-of-the-art training in R&D and innovation will also be a priority goal in this ninth strategic plan.

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Higher Education in the Arab World: Research and Development from the Perspective of Oman and Sohar University

Hamdan Al Fazari

Abstract Arab states face challenges in many fields and sectors as they seek to move up the value chain and develop a knowledge-based economy. Increased investment in Research & Development (R&D) across all sectors is essential to provide solutions to these challenges and move beyond an oil-based economy. R&D in the higher education sector has an important role to play in solving the challenges facing Arab countries. The Ministry of Higher Education, Research, and Innovation has a responsibility in Oman for driving research and innovation through the development of national strategies along with funding key aspects of work linked to the Oman Vision 2040. Accordingly, higher education institutions in Oman, and Sohar University in particular, have established research platforms and centers focused on strategically important fields. In Oman, The Research Council (TRC) works to build research capacity, create a supportive environment for research, and provide funding to researchers. The aim is to enhance the quality of higher education and build confidence with stakeholders to support innovation across all sectors.

Sohar University allocates about 5% of its annual revenue to support research and development. This approach is intended to build research capacity by supporting university staff to undertake research and knowledge transfer. In addition, through a number of partnerships, Sohar University has contributed to attracting local and Direct Foreign Investment (DFI) as part of its research and development. Examples include: (A) work with WR GRACE (USA) to establish one of the three qualitative testing laboratories of catalysts in the world used in the oil industry; a project that involved an investment value of $3.5 Million; (B) establishment of a $13 Million Advanced Manufacturing Research Center in partnership with the Ministry of Commerce, Industry and Investment Promotion as part of the Sultanate's program to implement the diversification of the economy; (C) funding from the British government as part of the UK-GCC research grants for the establishment of a food growing plant to localize advanced food technologies and support food security in Oman. These projects have contributed to the growth of the quality of research

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and development in Oman and demonstrate the importance of working in partnership across sectors. These projects have increased local value-added, have attracted local and foreign investment, supported innovation and creativity, created jobs for Omanis, and enhanced research and development capabilities.

The investment in these projects has been impactful with the results demonstrating the validity of this partnership approach focused on strategically important challenges. They have also supported Sohar University in obtaining professional accreditation from organizations such as the Oman Academic Accreditation Authority and Engineers Australia. It is anticipated that the impact of this approach will contribute to R&D in the wider Omani context and establish Sohar University as one of the Sultanate's leading R&D institutions.

Keywords Research and development · Innovation and creativity · Research platforms · Investment · Efficiency and productivity · Building research capacity

1 Introduction

The challenge of developing a robust research and development (R&D) sector is common to all Arab states. It takes years and significant effort to build the confidence and capacity in R&D that is required to establish any country as a leader in these areas. The fierce international competition within the R&D sector puts pressure on higher education institutions to guarantee the quality of their academic delivery and to build innovation and creativity around the areas of education that can lead to investment. To support development of high quality R&D, governments and higher education institutions need to overcome the challenges of funding and access to finance and, most importantly, adopt focused and realistic strategies that will allow them to become competitive. Arab states need to evolve from countries that consume knowledge to those that produce new knowledge. In this way Arab states, including Oman, can enhance innovation and creativity to the levels that their higher education sectors require to support growth and international competitiveness.

The sustainable economic growth of developing countries depends on the extent of industrialization and its impact on the Gross Domestic Product (GDP). Oman, a member of the Gulf Cooperation Council (GCC), is a fast growing industrial economy where 86% of the national revenue was generated by the oil and gas industry according to the 2014 Congressional Budget Office (CBO) report [1]. In order to reduce the dependence on non-renewable oil sources, Oman has started diversifying investments in other industrial sectors including manufacturing, agriculture and fisheries. In addition, high technology industries developed have been creating more employment opportunities and self-sustaining the economy [2].

Oman, like several other Arab states, has government-led research funding authorities that provide research funding to support projects aligned with strategically important sectors in the Sultanate. The aim is to build research capacity aligned to local challenges. Oman formerly had The Research Council (TRC) responsible for supervising the R&D sector. It was later placed under the Ministry of Higher Education in August 2020 as part of a restructuring process. The new name of the ministry is now the Ministry of Higher Education, Research and Innovation. The ministry, under its new structure, is responsible for higher education, research, innovation and vocational education.

Most, if not all, higher education institutions in Arab states get modest government support for research whereas the private sector receives very limited core research funding. In many cases, governments offer financial support to these institutions by providing project grants for researchers and students, allowing them to investigate issues related to the relevant country. The type of support varies from one country to another, so in Oman TRC supported projects related to the identified research priorities of Oman. For the last 10 years, TRC in Oman has funded many small and medium size projects to enable researchers and students to carry on their research work. In general, however, the funding is modest compared to international standards.

2 Challenges Facing R&D in Arab Countries and Oman

The higher education sector has an important role in building a credible R&D foundation in Arab nations. Compared to Europe and the USA, the higher education sector in the Arab states is relatively young and still developing. Challenges facing Arab states include: access to research funding, developing an innovation ecosystem, low levels of business investment in R&D, and the fierce international competition in this field. Arab countries have invested in their citizens by providing access to higher education at home and overseas but now need to migrate from being consumers of knowledge to producers of knowledge through direct research and knowledge transfer investment in the higher education sector in their home states. Arab countries should assist in funding R&D through the enhanced provision of research grants; promote research pooling to build critical mass at a national level; expand the extent of R&D and innovation support; adopt major projects in strategically important specialisms to focus their research efforts and support innovation in key clusters. These initiatives would enhance the profile of Arab states, support improvement in the global innovation index, and provide a basis for long-term competitiveness in international markets.

Some Arab states currently face difficulties such as political instability and limited budgets for R&D projects, reducing opportunities to attract domestic and foreign investment. Paradoxically, this has had some beneficial effects, as it has forced industrial companies to utilize expertise available in-country rather than relying on external expertise. This factor, in turn, has supported the development of the Arab world's core base, thereby encouraging investment and increasing the capacity to engage with qualitative research. Although legislations in the fields of technology and innovation are present in some Arab countries, there is an urgent need to review and develop them further.

For Oman this legislation needs to be compatible with Oman Vision 2040. Oman has supported R&D and innovation through TRC, the Centre for Industrial Innovation and other funds such as the R&D Fund in collaboration with Riyada (SME network), the Oman Technology Fund, and more recently, the Innovation Development Oman (IDO). However, there is a compelling case to draft legislation establishing a national body to regulate and supervise all the sponsors of research, development and innovation. A coherent national approach can be achieved by placing them under a single authority to allow for the monitoring and performance evaluation. Government agencies should adopt major projects according to their specialty to focus effort and energy on research, development and innovation thus creating an environment conducive to supporting Oman's rise in global research and innovation rankings. For example, if the electric car components project is adopted and integrated into industrial activities in the Duqm region, the results of innovation in this sector will be enhanced by its direct benefit to the industry. Duqm will then have the opportunity to become a magnet for foreign and domestic investment. There are also competencies in terms of an able workforce, and if these are adopted, developed and taken into local ownership, they will have the required capacity and competence to become active researchers and support R&D and innovation and creativity in the Arab states. Moreover, to build a solid foundation for R&D, the private sector needs to further engage in this field and become an effective booster and contributor.

Furthermore, Arab states should focus on investing in modern technologies rather than on technology that relies on an unskilled foreign workforce. This requires legislation to provide incentives for investment in the rapidly evolving technology fields. In addition, the new investment laws in Arab states represent a significant shift in attracting direct foreign capital, but the returns are limited and there is a need to create a suitable environment and a solid investment base.

3 R&D Initiatives at Sohar University

Sohar University was the second university to be established in Oman and it was the first private university in the Sultanate. The University's mission is "to provide access and opportunity to build a knowledge nation" while its vision is "engaging minds, transforming lives and serving the community". Student numbers continue to grow, and Sohar University currently has over 6200 undergraduates and 300 postgraduates registered in a range of disciplines. The University also hosts an Arabic Language Centre, which attracts students from a growing number of non-Arab countries. The Centre currently hosts Chinese, Taiwanese, Mexican, Korean, and Australian students who wish to learn Arabic in an immersion setting. In addition, the University offers a broad portfolio of Continuing Professional Development courses to meet the needs of Omani business leaders and the wider community. The

University is not yet empowered to award PhD degrees but it has submitted proposals for PhD programs and is waiting for approval from the Ministry of Higher Education, Research and Innovation. The University has a substantial General Foundation Program and six Academic Faculties [3].

When the University was established in 2001, it was with the guidance of the original Ministry of Higher Education and supported by the University of Queensland, Australia one of the world's top 100 research universities. Sohar University is a progressive, modern institution that meets the needs of a contemporary society and contributes to the economic and cultural wellbeing of the city of Sohar, to the Sultanate and Oman's neighbors. Sohar University is committed to:

- Providing outstanding learning opportunities to enable students to achieve their full potential
- Developing research that delivers global impact
- Working with business and community partners to support social, cultural and economic development
- Supporting students to succeed as entrepreneurs and have meaningful careers with the skills necessary to make an immediate impact

The University's management has always been keen to have academic staff with a high level of competence and scientific expertise. It has laid great emphasis on the importance of applying the principles of comprehensive quality, which is regarded as the principal factor in contributing to the achievement of the objectives of the University. Those objectives are primarily to ensure that Sohar University graduates are confident and skilled individuals who are able to make a positive contribution to their community and to the Omani society at large. The University employs international staff from over 30 countries, bringing a wealth of experience to Oman. The combination of well-qualified Omanis allied to the international profile of the academic staff has allowed the University to develop challenging and innovative programs of study and to enhance its research contributions.

One of the main objectives of the University, as stated above, is in "developing research that delivers global impact". This, of course, is strengthened by the University's world-class campus, providing students and staff with modern, purpose-built facilities necessary to support learning, research and enterprise. Significant investment has been made in laboratories to support academic research and undergraduate students' projects. Moreover, the University continues to develop the campus, providing excellent facilities for education and magnificent laboratories for research. Sohar Univeristy is committed to continue developing the campus and to providing excellent facilities for education, research, and community engagement.

To support this research engaged institution, there has been extensive investments in information services to ensure that Sohar University is a digitally-connected institution and to embrace the opportunities presented by technology in supporting the learning processes. Even so, continued investment is required in spaces conducive to innovative teaching and social learning and research. The services for technology support have increased every year, and these services are directly linked with research capabilities. At the same time, robust financial planning, with a long-term commitment to securing the University's position as a leading contributor to research in Oman, has been evidenced through the financial sustainability and growth of Sohar University in recent years.

Sohar University conducts research with impact, which is intended to support the strategic priorities of Oman. Furthermore, Sohar University has attracted partnerships and both direct foreign investments and domestic investments as part of its research and development. For example, W.R. GRACE from the USA established one of the three qualitative testing laboratories of catalysts in the world used in the oil industry with an investment value of $3.5 million. The W.R. GRACE project is supported by OQ and financed by W.R. GRACE in partnership with Sohar University, which has increased the local value-added of the company's services and has provided job opportunities for Omanis. In addition, the W.R. GRACE laboratories provide oil sampling services to OQ, GCC and the MENA countries. As a result of the technical and practical success of W.R. GRACE laboratories, the company is currently considering increasing its investments and expanding these laboratories at the University. The $13 million grant has been obtained from the Ministry of Commerce, Industry and Investment Promotion in Oman as part of the Omani government's program to diversify the economy, and to establish two major projects to serve the country's advanced manufacturing industries. There is also the funding that has been obtained from the British government as part of the UK-GCC research grants for the establishment of a food growing plant to localize advanced food technologies and support food security in Oman. The funding has established a fully equipped agriculture technology unit (agricultural incubator) which is aimed at localizing advanced technologies to support food security in Oman in collaboration with the University of Sheffield. This has undoubtedly contributed to the growth and quality of research and development in the University.

The University has an important role in encouraging investment and innovation and it will continue its efforts to adopt strategic projects that contribute to the growth and development of Oman's economy. One of the roles of universities is to contribute to innovation and find solutions to dilemmas, and this in turn will contribute to the creation of funding for research projects.

4 Comparison of Arab and Omani Research and Development with Some Other Countries

Comparisons among Arab states, including Oman, and other countries, requires a procedural approach for analyzing the current scenario based on: evaluating scientific research activities, innovation activities, comparing and analyzing the performance indicators of scientific research and development, and identifying the gaps with the highest ranked countries worldwide. The relationship between innovation and GDP can be shown using the Global Innovation Index as indicated in Fig. 1, in

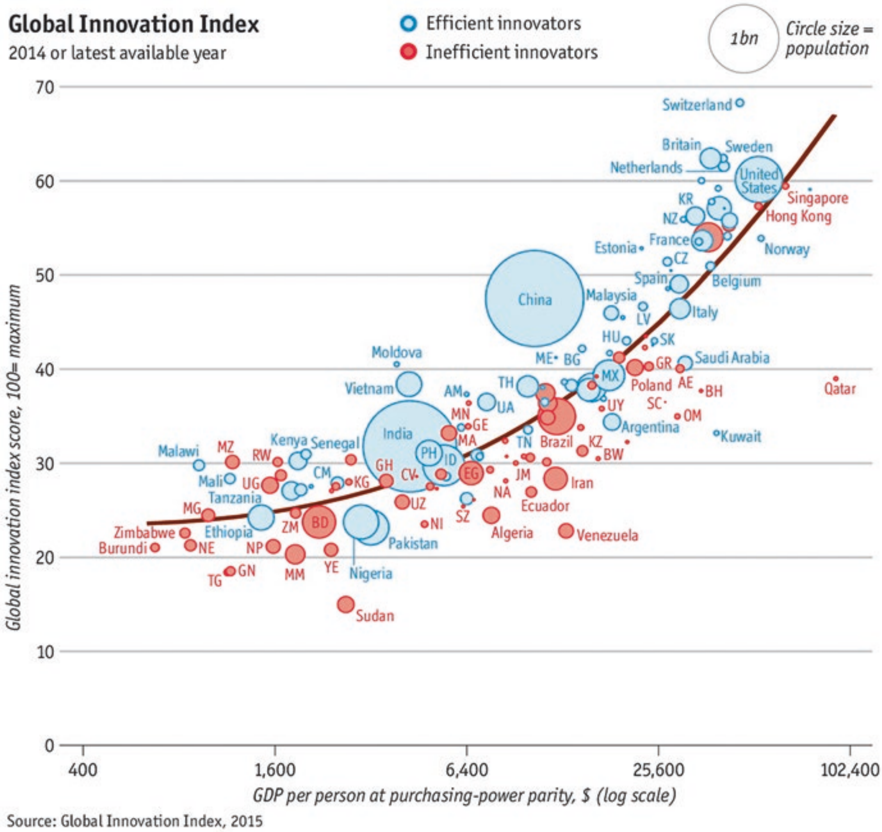
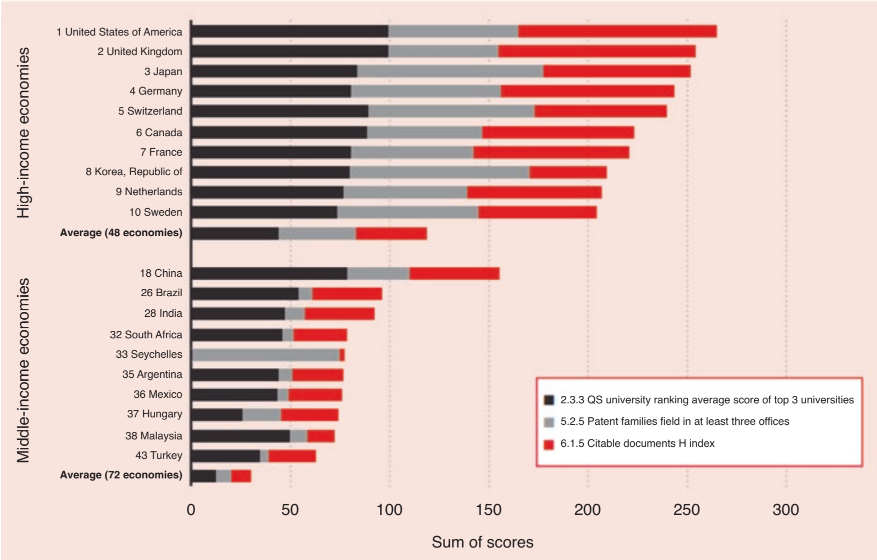


Fig. 1 Global Innovation Index

terms of innovation expenditures, percent of GDP [4]. The figure shows that the Arab countries have high a GDP/capita ratio but not a high level in innovation, and that they lag behind similar economics in terms of innovation. The UAE and Qatar lead in the Arab Gulf but they still have a long way to reach the top countries in innovation worldwide. The figure also indicates that the countries that are leading in the innovation index like Switzerland, Britain and Sweden have high levels of education and innovation, noting that some of these countries are limited in natural resources but are successful in innovation. Figure 2 shows that high income countries are those countries that have: (A) good universities; (B) good number of patents; (C) good paper citations, and most importantly these countries are counted as leading in innovation quality which Arab countries are lagging behind [5]. And Fig. 3 shows the R&D expenditures (percentage GDP/Capita) from 2011 to 2018 for some Arab states including Oman. The UAE is the region's best performer but still only has 1.3% GDP/capita spent on R&D with Oman at 0.27% GDP/capita. The EU aims to have 3% GDP/capita spent on R&D with the USA being similar

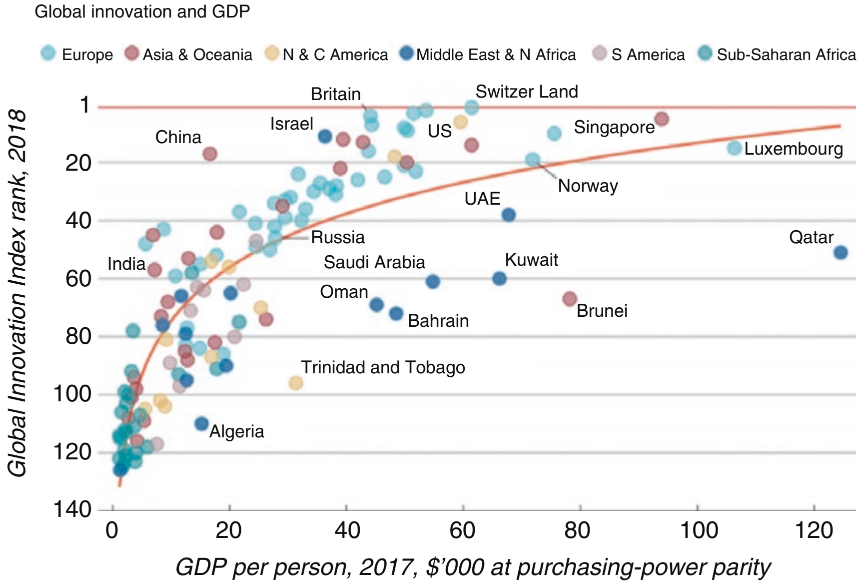


Notes: Numbers to the left of the economy name are the innovation quality rank. Economies are classified by income according to the World Bank Income Group Classification (July 2013). Upper- and lower-middle income categories were grouped together as middle-income economies.
Source: Global Innovation Index

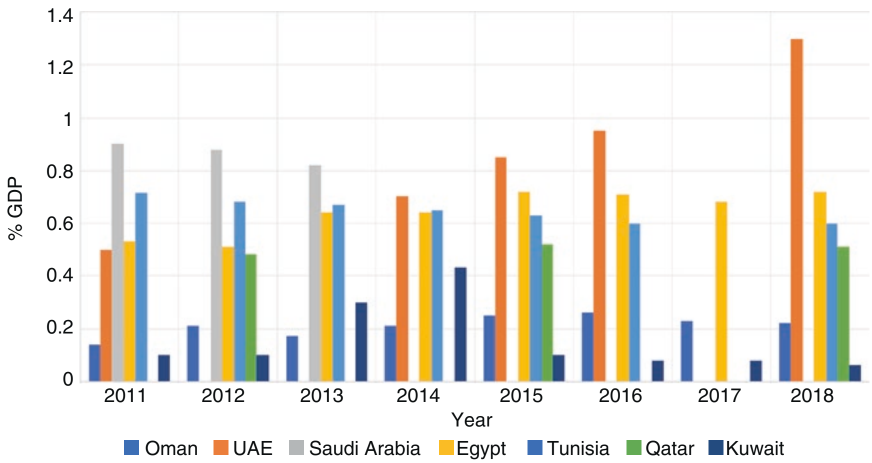
Fig. 2 Innovation quality: Metrics for quality of innovation

while some Far Eastern countries exceed this level of expenditure. Investment in R&D is a major contributor to long-term economic competitiveness and the Gulf states are lagging behind other major economies in the world [6].

In the Omani context, the National Strategy for Research and Development (NSRD) 2040 is vital for academic institutions. This strategy aims to prepare an integrated national strategy for research and development that is informed by global experience and is responsive to local needs, aligning research priorities with Oman Vision 2040 and other national strategies to enhance the role of R&D in addressing current and emerging challenges. The strategy will provide support and a research environment that will be beneficial to the academic sector [7]. The National Symposium on NSRD 2040 that was conducted on 15th December 2019 in Muscat and addressed the goals of preparing an integrated national strategy for R&D. In addition to addressing current and emerging challenges, it also developed an implementation plan that facilitates institutional integration, participation and efficiency, and enforces the efforts regarding raising awareness of the R&D culture and its importance in the transformation of Oman towards a knowledge-based economy. The NSRD 2040 was conducted in a participatory approach and was led by TRC teams, in collaboration with government, private and academic institutions.



Source: Global Innovation Index



Source: TheGlobalEconomy.com, Business and Economic Data for 200 Countries

Fig. 3 R&D Expenditures (percentage GDP/Capita) 2011 to 2018 for Some Arab States

There is a need to create a suitable environment and a solid foundation on which to base the development of scientific research development activities in Oman. Government support and funding is essential. Additionally, allowing higher education institutions the freedom to govern the development of programs and areas for research will be helpful in stimulating and facilitating research.

5 Analysis and Findings

This study has investigated the issue of R&D in Arab states from the perspective of Oman and Sohar University. It also attempted to offer recommendations for the improvement of this sector. It can be concluded that all the research initiatives whether they were internally-based (in Oman) or externally-based (external partnerships and external collaborations) which have been experienced at Sohar University were aimed at building capacity and aligning the contribution of the research base to help the development of the Omani economy. This included: supporting the Small and Medium Enterprises (SMEs) by finding solutions to problems, increasing the manufacturing sector's contribution to GDP, increasing local value added, encouraging investments in projects, building capacity in advanced manufacturing, creating new jobs, promoting innovation, and using local natural materials available in Oman. A focus on "Designed in Oman" and "Made in Oman" has highlighted the importance of addressing local issues with global reach. In addition, Sohar University has been working to ensure a holistic approach to integrate enterprise, innovation, consultancy and knowledge transfer into its academic delivery.

The Lambert Review 2003 as in Fig. 4, indicates that universities or R&D centers with partnerships show a double efficiency in terms of: (A) Increased range of goods and services; (B) Opened new markets and increased market share; (C) Improved quality of goods and services; and (D) Reduced unit labor costs [8]. Thus, the link with businesses improved with having partnerships. Also, it is important to have an innovation ecosystem in place in the Arab states to enhance the industrial

	Increased range of goods and services	Opened new market, increased market share	Improved quality of goods and services	Reduced unit labour costs
No Partnership	42%	40%	46%	33%
Partnership	82%	81%	85%	65%

Source: Lambert Review 2003

Fig. 4 Business – University interaction research and solve the issues and challenges in these countries by having a sound education and training system that caters for knowledge transfer and innovation.

There are opportunities in Oman and in particular in Sohar for the enhancement of the In-Country Value (ICV), which led the award of *Tanfeedh* (Implementation) funding by the government to the University. Qualification for this award requires an applied research center taking research to the point where it becomes useful to industry. Translation to business requires an incubator with offices and workshop facilities and a training facility tied to the university, together with sufficient land to support new factories in the longer term. The development of such center is designed to support the development of a highly competitive manufacturing capability in Oman through:

(a) Technological capacity for advanced manufacturing through world-class facilities for design, machining, prototyping and proving pre-mass production;
(b) Capacity building and the delivery of technical skills training programs for human resource development and Omanisation;
(c) Development of the Omani private sector by investing in manufacturing;
(d) Supporting foreign direct investment by providing access to technical skills, machining and automation know-how and proving pre-mass production.

The higher education sector in most of the Gulf and certainly in Oman is relatively new (less than 30 years) and the challenge is to build stakeholder confidence in the qualifications awarded from higher education institutions. Furthermore, governments have invested in building capacity and capability in citizens through scholarships for overseas education and also in-country education. This takes time to show positive results and has needed major investment and commitment from the governments. It is now the time for all the Arab states to commence their participation in the fields of R&D, innovation, and creativity.

Institutions have quality assurance and management systems in place and they can use international benchmarks to measure progress. However, world league tables show that the universities in the Arab states still do not feature in any significant way. The Arab states and in particular the states of the GCC have the resources and the population to compete with Europe and the USA. There will be however some inevitable delay as the higher education sector is still developing, but taking the above steps and working towards overcoming the challenges facing the Arab states would lead to realistic progress. There are no obvious factors that would hinder progress, and a good example is that of the Chinese universities and other Asian universities, which have made rapid progress and which now feature in the higher education and R&D league tables. These higher education institutions have a developed the higher education sector, and most importantly a good base for R&D. This has led to the construction of commercial and industrial hubs in these countries that have further led to significant investment and increased their financial income.

A major feature in measuring universities' performance is research capacity (generating new knowledge). The GCC has invested in its citizens and the countries of the GCC should have enough human resources to build a research base and start to generate new Intellectual Property (IP). This may be linked to applied research or regional research. Climate change, global warming, petro-chemical economies, global trade, Islamic finance, cultural issues, the blue economy, health issues, aging populations, and epidemiology in new health sectors offer scope for R&D. The governments of the GCC states have focused on building a higher education sector of quality and they have taken a conservative approach to building capacity. In Oman this has been achieved but allowing private higher education institutions to award PhD degrees will be a vital step in building confidence in the sector.

Research will support the Omani 2040 vision related to diversifying the economy. The *Intaj* (Production) project at Sohar University, for example, shows how it is possible to work with business and bring new higher level skills to the region. This requires a partnership between the government, businesses and universities. Universities also need to build trust and show that they can deliver. This will then lead to an IP ecosystem to support research, entrepreneurship and innovation and consequently further projects and investments.

If research capacity can be built along with good quality assurance in the region, the R&D sector will see improved rankings in the international league tables for both the higher education and R&D sectors. This will enhance overseas student recruitment as stakeholders will have confidence in the awards. One advantage in Oman and in most Arab states is that the medium of instruction is English. There should be a national effort in Oman (led by the government) to develop the Sultanate as a destination for higher education and R&D. Building on the Sultanate's reputation as a safe and welcoming country with higher education quality assured to international standards would bring investment into the country. If Oman can attract international talent and retain it, then the country will flourish, and this is similar to the experience of Europe and the USA, both of which offer opportunities to international talent as well as to their own citizens.

The increasing number of international students will also help to raise league table rankings, and in the long term their experiences will build confidence in the sector. Joint international research projects such as the Sohar University-UK grow dome project will bring benefits to both sides and more investments to promote international collaboration that would benefit Oman and the Arab states. It is, in fact, noticeable that the higher education and the R&D sectors are both advancing quickly on the international stage, therefore Oman, the GCC and the Arab states need to increase their pace of change in order to compete before time runs out. Of course there is a need to assure quality in both sectors but this does not require an overly conservative approach. The Arab states need to build confidence in the quality of higher education and R&D in relatively new and developing sectors. This will only happen by linking that quality with global issues in terms of building confidence in their academic provision. National initiatives are required to build the capacity of Arab states in R&D.

To summarize, the policy at Sohar University is about bridging the gap between industry and academia, and creating the conditions to help develop the Omani economy. R&D supports *Innovation*, *Innovation* leads to *Investment, Investment* leads to *Projects* that can, in turn, lead to the enhanced *Welfare of the wider Communities and Countries.* This is explained in Fig. 5 – the R&D Welfare Model as proposed by the author.

Fig. 5 R&D Welfare Model

Source: Author's Proposed Model

The following are some proposals and mechanisms to help develop the R&D sector in Arab countries and Oman:

- Moving from consumers of knowledge to being creators of knowledge
- Building confidence and research capacity by establishing a sound academic base
- Restructuring programs to meet and anticipate market needs
- Ensuring that the Research Centers in the Arab states work with government institutions and private companies to find joint financing sources
- Encouraging collaborative research, whether between higher education institutions, between companies or between companies and higher education institutions, will improve and develop the types of research and thus will contribute to innovation, which will then lead to the creation of investment opportunities
- Striving to develop international partnerships through joint projects which are mutually beneficial
- Establishing greater collaboration in terms of joint research projects and exchange of information and data regarding R&D
- Extending collaboration in conducting research workshops and training
- Full use should be made of key international organizations, especially UNESCO, Arab learned societies, the leading quality-assurance bodies, funders of collaborative research projects and student exchanges, the Arab Academy of Sciences, and other research and educational agencies. In addition, it is essential to find the right funding for research, development and innovation. Thus, the UNESCO, as the regional bureau for education in Arab states, needs to take a lead in the development, enhancement, and improvement of the R&D sector
- Accepting that there is an urgent need for building confidence and facing the numerous challenges in many fields and sectors. In this way, the Arab world will

be enabled to play a full role in the global knowledge economy, attract investments and build knowledge-based nations. It will be necessary to implement reforms that address a wide range of major issues in improving innovation, creativity, investment, the welfare of countries and any other issues that directly affect R&D

- There is a need for transparency, diversity of sources and scale of funding and partnerships for R&D
- Better liaison is required between the Arab states in academia. This will enable universities to overcome the challenges that many Arab universities face when adapting to new realities such as (A) e-learning and online teaching; (B) virtual campuses and classes; (C) meeting societal needs for advanced practical skills and competencies; and (D) producing graduates capable of meeting the needs of the Fourth Industrial Revolution and other challenging issues
- Constructive proposals are needed from Arab states to improve and enhance the R&D sector and to encourage the adoption of best practices
- Government research institutes should be co-located with universities and some public universities should be merged with private universities to ensure cross-fertilization of staff, students, concepts, and a more efficient use of expensive facilities and laboratories. This will build a critical mass to create larger size institutions in order to achieve economies of scale through shared resources and services
- There is a need to urge industrial companies to benefit from the expertise available within the country instead of relying on external expertise. This, in turn, will develop the country's core base, thereby encouraging investment and increasing the capacity to engage with qualitative research
- Encouraging large local companies to operate R&D centers that can be linked to higher education institutions and to allocate a percentage of the funds designated for research, training, innovation, and consultancy through the current educational institutions at both local and national levels rather than spending it at the international level
- The Oman Vision 2040 Research Strategy is important because research is an integral part of what academics do in higher education institutions and it is required to enrich academia and students. The Vision also leads to innovation, creativity and investment, which would otherwise not be obtained, and creates a positive environment for R&D
- Facilitating the procedures in the process of partnerships and investments for local and foreign institutions, which will contribute to the creation of projects and jobs

It must be noted that it is possible to implement all of the proposed recommendations that have been listed above. The infrastructure already exists. These recommendations are not costly, and all that is required is the determination for meaningful change that can establish the Arab states as leading countries in the R&D sector.

6 Conclusions

In summary, Arab higher education institutions in general, and Sohar University in particular, strive to enhance academic delivery to support R&D. Some of the main challenges that R&D face in the Arab world and in the Omani higher education institutions include funding and building confidence. In addition, the Arab countries tend to be consumers of knowledge and not producers of knowledge. The lack of funding for R&D will impede long-term economic development and diversification, and reduce opportunities to attract direct foreign investments. Sohar University has made every attempt to build research capacity and has tried to develop international partnerships and collaborations. This is the start of the process and efforts will continue to work with partners for the long-term benefit of Oman. It can be concluded that the R&D of higher education in Oman and Sohar University:

- Needs to be reflective; in terms of capacity building, the domain and type of R&D to invest on
- Needs to be collaborative
- Needs to be further supported by the government in terms of funding and providing an appropriate infrastructure
- Requires more support from the private sector. The private sector should be a leading player, as this sector creates investments that leads to projects and production
- Needs to build a broader and deeper base by having strong academic programs that meet the business markets with strong professional development in place to develop a good cadre
- Remains in the process of improvement and development

All the issues mentioned above are applicable across the Arab world, but some still require resolution. Common efforts and harmonization processes are required for the R&D of Arab higher education institutions. This is important as R&D plays a key role in innovation and creativity in higher education institutions and in the maintenance of academic standards. Finally, the R&D base needs to be supported by sound and appropriate policies and regulations that meet the needs of the researchers, investors, governments, private sector and other stakeholders. In this way, the Arab higher education sector will be able to provide outstanding R&D that allows students to innovate and be creative; to focus on providing access and opportunities to build knowledge-based nations; to be creators of knowledge rather than consumers of knowledge; to develop institutional research capacity with impact; to build strategic alliances with national, regional, and international partners and communities in the field of R&D; to engage with local communities; and to support student experiences by engaging minds, transforming lives, and serving those communities. This will lead to investments that can create jobs for the region's young citizens. Moreover, "*R&D* can lead to *Innovation*, *Innovation* can lead to *Investment, Investment* can lead to *Projects* that can lead to the enhanced *Welfare of local Communities and of Countries at large",* as described in the R&D Welfare Model (Fig. 5).

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Managing Creativity on a Budget: The Future of Academic Research and Development in Lebanon

Elie D. Al-Chaer

Abstract The central mission of a university is the discovery, dissemination, and application of new knowledge. In this regard, research is key to a university's reputation and gradually becoming the basis of its academic and financial success. Research and innovation are critical for expanding the knowledge base and the stream of highly educated individuals who, in turn, can provide economic vigor and competitiveness to their society. Although the main focus of this chapter is on Lebanon, the challenges outlined, and solutions proposed may apply anywhere else, particularly in developing countries, since Lebanese academic research institutions are a magnified microcosm of academic centers around the world. Lebanon may be home to some of the earliest founded modern universities in the Middle East and the Arab World, with a few constantly affirming their leading position among the best universities in the world through competitive cutting-edge research. However, the preeminence of research as a substrate for academic excellence in Lebanon's universities is at risk particularly without sustained investment in public and private academic institutions. In the COVID era and when Lebanon's economy is in freefall and the government is unable to increase spending on higher education, the survival – not to mention growth – of research universities is threatened, unless purposeful national research strategies are developed that guide more investments into higher education, and unless universities become more efficient and focus their research on national priorities and goals. In light of the many economic and global challenges, a new roadmap is needed to revive the role of the university in research and development. This chapter highlights the problems that plague academic research and development in Lebanon as well the challenges faced by higher education in that regard and proposes realistic solutions to tackle these challenges. These include research strategies focused on national needs, communication about the value of research universities, proper infrastructure to provide material resources, collect and analyze data,

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scarcity of resources (human and material), understanding the complexities of research administration and leadership, balancing academic freedom with societal, cultural and institutional expectations, standardized performance metrics, regulatory compliance and indirect cost allocation. Once the challenges are recognized and addressed, and a national research agenda is developed, the human capital – arguably the most valuable innovation resource – can be developed to maximize the use of material resources and purpose them towards national priorities.

Keywords Lebanon · Academia · Higher education · University · Research · Development · Financial crisis · COVID-19 · Economy · Budget · Creativity · Management

1 Introduction

1.1 Academic Research and Development

From Plato's academy, founded circa 387 BC [1], to the Peripatos or Aristotle's school of philosophy [2] to the early modern institutions of higher learning, the mission of universities seems to revolve around a central theme and that is to afford pupils a healthy skepticism and a solid foundation of sound knowledge and learning. Very little has changed in terms of the mission since Plato. Today, a university's central mission is the discovery, dissemination, and application of new knowledge. Research is a tool at the heart of this mission; it is essential to a university's reputation and its academic and financial success. Beyond this, research universities have steadily become critical to the economic and social success of society, especially in the United States and Europe.

The expectations are high that academic research and development (R&D) will continue to play a key role in addressing current and future national and global challenges. However, the pace of change in the scope and scale of the academic research enterprise has accelerated and appears likely to change direction. The global pandemic, the economic conditions and the erosion of public and political confidence in university-based research have clouded the future of the research university. As universities seek to increase and diversify revenue streams and reduce their dependence on government appropriations, and with exorbitant tuition rates in some of the private prestigious institutions, externally sponsored research gains greater prominence.

Over the past two decades, the research funding landscape has become highly competitive, and this will only increase given the financial situation in many countries. Creating and managing a research portfolio is not that simple for the individual expert and can be even more difficult for the institution. Furthermore, research has become more global and collaborative, making the development and management of any research enterprise increasingly complex.

1.2 Lebanon's Institutions of Higher Education

Lebanon's higher-education system is one of the oldest in the region. One of the earliest professional centres of higher learning around the Mediterranean was the Roman Law School of Beirut, which gained so much recognition as the preeminent centre of jurisprudence of the Roman Empire [3] that Beirut became known as the "Mother of Laws". With the dark ages, education in Lebanon regressed and it wasn't until the sun began to set on the Ottoman Empire that modern higher education came to the country. In 1866, missionary Daniel Bliss founded the American University of Beirut [4]. This was followed, in 1875, by the University of Saint Joseph founded by the Jesuits [5], then by the Beirut College for Women in 1948, which became later the Lebanese American University [6]. The Lebanese University was founded in 1951 [7]. Up until 1960, there were nine officially licensed universities in Lebanon: eight private ones and the national Lebanese University (public). While these institutions made great scholarly contributions to the fields of arts and humanities, science-oriented research was quite scant and limited to a handful of universities, namely the American University of Beirut, the Lebanese University and Haigazian University.

Following the 15-year war of 1975, the private sector flourished in a sudden and rapid expansion. A great number of "universities" were licensed and spread throughout Lebanon, some of them to cater to sectarian interests, others to accommodate political wishes. The process lacked a clear national vision to guide higher-education policy. Although higher education became available to all Lebanese youth, in the north and the south, it was without dependable standards of accreditation or emphasis on the role of research in the generation and dissemination of knowledge [8]. The increase in the number of universities did not necessarily have a positive effect on the country's research and development, as many of these universities could not or did not want to undertake serious research and link it to their teaching activities. In fact, Lebanon's dispersed institutional landscape is distributed over more than forty universities and higher education institutions (twelve of them with science and/or technology faculties) and six research centers. However, most Lebanese research takes place in four universities, accounting for nearly 84% of the overall number of publications [9]. Actually, "more than 50 per cent of the total number of publications is concentrated in only one institution: the American University of Beirut, the oldest and most visible university since it fully integrated a 'publish or perish' culture and has the largest institutional research budget in Lebanon" [10]. This being said, a number of other private institutions started to get on board the research enterprise as an ostentatious statement of keeping up with the times, rather than a dedicated pursuit of knowledge advancement and learning. These numbers are based on random estimates reported by a number of agencies and investigators, as Lebanon lacks a central database for R&D in the country, and data on the distribution of the academic R&D effort is scarce. In fact, many of the global R&D databases do not even list Lebanon among the countries engaged in the conception or creation of new knowledge, products, processes, methods, or systems; for example, see [11]. To make matters worse for Lebanon, a great number of universities instituted over the past two decades in neighbouring Arab countries are campuses of West European and North American institutions with generous endowments for research. In the absence of cooperation protocols, they competed with and, in many instances, off-staged historic Lebanese institutions in their outreach to international students and the impact of their research. In a recent review of Lebanon's government and governance, special emphasis was placed on the historic and future role of higher education in lifting up society and the economy with a section dedicated to the pivotal role of the university in the transition to enter the global knowledge economy [12].

This compels a major review and significant reforms of the higher-education sector in Lebanon, to survive the tidal wave of changes sweeping higher education around the world and to emphasize the importance of R&D in academic hubs. Many of the laws and regulations that govern this sector are dated and holding back universities in Lebanon from keeping up with the demands of a twenty-first century university education. A simple example is the law regarding remote education, which has come to attention particularly during the COVID-19 pandemic and as the need for online teaching became more urgent. The Lebanese government does not recognize online degrees; this means that students – even during the ongoing coronavirus pandemic – cannot pursue online studies if they wish to enter the job force in Lebanon after graduation. At the onset of the pandemic and instead of enacting policy changes to allow students to obtain degrees online, the government stopped short of that and only authorized a few months' worth of online coursework to be recognized [13]. Another example is the lack of uniform regulations and national standards for integrating research and development into higher education and allocating resources needed for academic research according to a national priority schedule.

1.3 Status of Research and Development in Lebanon

Much like other developing countries, Lebanon stands to benefit a lot from the socioeconomic advancement and participation in the modern global knowledge economy. Between 2005 and 2018, Lebanon made small yet significant advances in innovation largely in the private sector. However, the institutional framework to properly govern these strides remained to a large extent underdeveloped. Many of these initiatives were undertaken by private individuals or institutions operating according to convenient international standards, but in a relative policy vacuum as the central government lacked the organizations, the budget, the administrative capacity and arguably the vision and the will to plan and assist. The complexity of R&D activities, the need for a large number of actors to be involved and the strategic importance of this issue nationally, demand a critical role of the Lebanese government to formulate a clear vision and put in place efficient policies that propel R&D contribution to Lebanon's economy and Lebanon's contribution to the global knowledge economy. Unfortunately, successive Lebanese governments, after the end of the war, did not show an understanding of the complexities of the rapidly evolving marketplace and of the role of competitive R&D therein resulting in a failure to have coherent long-term strategies to guide the process.

Most scientific research in Lebanon is concentrated in a small number of higher education institutions incapable of accommodating all the Lebanese scientists. According to one estimate, more than half the Lebanese scientists are outside Lebanon [9]; a figure further aggravated by recent political and socioeconomic unrest in the country.

2 Lack of Research Strategies Focused on National Needs

Economic growth and related enhancement in living standards require a certain number of fundamentals that include increases in workers' skills, capital accumulation, and a number of other functional factors such as the quality of the legal and regulatory frameworks. Two factors that are undoubtedly central to the growth process are innovation and technological advancement; economic policies can directly affect those in many ways. For example, policies directed at the protection of intellectual property rights and the promotion of R&D, promote innovation and technological advancement more directly.

In many countries, governments provide direct support for scientific and technical research, through grant-providing agencies or through tax incentives. In addition, many governments run their own research facilities, including facilities focused on nonmilitary applications such as health. The primary economic justification for a government role in R&D is that the private market would not effectively fund specific types of research without government intervention. This is particularly true when it comes to basic or fundamental research, since the full economic value of a scientific advance is not always available to its discoverer, especially if the new knowledge can be reproduced or distributed at low cost. A similar argument may be made with regard to R&D of basic societal needs. If many people can exploit, or benefit from, research done by others, then the collective social return may be higher than the private gain of those who bear the costs and risks of innovation. As a result, market forces favor underinvestment in R&D from society's private perspective and support a strong argument for government intervention.

In that sense, Lebanon needs a national strategic planning effort to define the priorities and targets of any R&D effort undertaken by its institutions. Incentivizing private research along those strategic priorities is likely to help societal needs on the long run. In the sixties, the government of Lebanon, under President Charles Helou, recognized the need for scientific development in the country. At the time, it proposed to lay down concrete policies defining the obligations and rights of the state with regard to industrial growth, services, trade, and the encouragement of entrepreneurial enterprises. The proposal further suggested that businesses should be made partners with the state in any program for research and social development, by requiring them to support programs that set as their targets the improvement of the workers conditions [14]. Very little of that, if any, was put to action. The country would be faced in 1967 with a massive influx of displaced Palestinian refugees and the dawn of an era of political uncertainty and security breaches that culminated in the 1975 war. Unfortunately, consecutive governments in the postwar era were more interested in currying favors with regional and sectarian powers, through a system of clientelism, and didn't do much to rectify the shortfalls besieging the advancement of the research university or R&D in the country, in general.

2.1 Poor Communication About the Value of Research Universities

In contrast to a growing list of countries in the Middle East and North Africa (MENA), Lebanon lacks a cohesive national strategy to promote or sustain its research universities, many of which are arguably the best in the region. At the same time, universities often lack their own realistic research outreach strategies. Many of these institutions, deluded by western models and metrics of success, have bitten more than they could chew in trying to grow their research portfolio locally. Many others have engaged in not much more than wishful thinking in hopes of maintaining their research enterprise. They would all be put to the test in the fall of 2019 as the country entered yet another period of political unrest and the biggest economic downturn since the end of the war. In the absence of specific and strategic institutional and national research policies or priorities, most universities are no longer in a position to maintain their research portfolios and many have already been forced to reduce internal investment in their research or shut it down totally. This comes at a time where the importance of research in the collective social awareness is almost absent. Between the arrogance of long-established research universities – trading off their societal reputation without any meaningful outreach to promote their mission or the importance of research to their mission – and the ignorance of nascent institutions whose idea of research is just a promotional tool to polish their public image, the public and its representatives in government are left largely unaware of the value of research and its possible contribution to the economy; ergo without a robust tangible justification for investment in and funding of academic research.

2.2 Lack of Proper Infrastructure to Provide Material Resources, Collect and Analyze Data

The innovation infrastructure is a key determinant in a nation's ability to be competitive in an ever-more competitive world. It may be easy to understand the physical infrastructures that underlie national economies; for example, highways, communication networks and power supply help define a nation's capacity to produce and transport goods and services. In direct analogy to the physical infrastructure, there exists an "innovation infrastructure", which defines a nation's capacity to innovate. Examples of this infrastructure include the education system, public investment in basic science, worker training and retraining, and policies that incentivize private investment in R&D [15]. When it comes to the Lebanese education system, it is worth noting that an estimated two-thirds of Lebanese students attend private schools [16]. In April 2015, then Minister of Education, Elias Bou Saab, acknowledged many of the challenges and gaps that exist in the Lebanese school system, and the public schools, particularly. While the Lebanese law stipulates that the national curriculum should be updated every four years, it has not been updated since 2000. Plus, because of the national disagreement over Lebanon's modern history, history textbooks cover historical events before 1943 only [17]. Other components of the innovation infrastructure do not fare better than the education system. In April 2006, a newly formulated five-year Science, Technology and Innovation Policy (STIP) was officially launched in Beirut in collaboration with the United Nations Educational Scientific and Cultural Organization (UNESCO). STIP was designed to enhance and diversify science, technology and innovation input in economic activities resulting, ultimately, in the creation of high-quality jobs and investment opportunities. It called for the National Center for Scientific Research (CNRS) to lead in refocusing research programs and priorities to directly benefit Lebanese services and productive sectors. Unfortunately, efforts to implement the STIP were initially slowed down by military conflicts, and ultimately by the little and insignificant steps made by the CNRS in that regard [18]. These major gaps in the innovation infrastructure, along with the lack of initiatives to support worker training and retraining, and of tax policies to foster private sector investment in R&D [19], combined to create a perfect storm when the economic cataclysm of 2020 hit.

3 Lack of Proper Understanding of the Complexities of Research Administration and Leadership

In recent years, higher education institutions around the world, were required to undertake radical responses as a result of significant pressures from reduced research funding, increased regulatory requirements, mounting public calls for accountability, and growing questions about the utility of a traditional college/university degree [20]. With COVID-19 and global lockdowns, the utility of these responses was put to task like never before.

For higher education leaders, this environment can be overwhelming as traditional approaches for managing institutions seem unequipped to meet the economic, social, and technical changes [21]. The relationship between the research activity and the administrative support organization is largely based on the historical norms of a given institution, with the administrative support lagging behind. This support is often inadequate and not sufficiently responsive to provide faculty with a competitive advantage in their efforts to attract external funding or in the management of funded research programs. As a result, the resiliency of research universities is increasingly at risk. Without adequate updates to keep up with research advancement, research administration can become a drag on research programs, especially as the number and complexity of these programs increase. “Rarely are research administrative offices adequately staffed, creative enough, or proactive enough to fully enable the success of the faculty” [22].

The complexity faced by research institutions is compounded by the ever-changing role of colleges and universities in a society that has long been experiencing disruption and transformation. A good framework to address it may be found in the integrative approaches and core principles of complexity science [23]. In pre-COVID times, it would be unusual for anyone living in Beirut not to be stalled in traffic on the way to work and to wonder about ways to solve the traffic problem. ‘*If only drivers were a bit more civilized. If only there were a good public transport system, and more people took public transport. Wouldn’t these actions resolve the problem?*’ In short, no. Traffic, like higher education, is a complex system. Imposing actions or designing for strict management of human behavior does not always lead to direct linear outcomes. The relationships between jobs, neighborhood, families, housing, work regulations, government policies, access to education, tax processes, criminality, psychology, environment, and urban planning interact and converge in defining the intricacy and flexibility of the system. The actions and interactions of these factors are often independent and arbitrary. Thus, the complexity inherent in these systems relates to more than just the number of the interacting factors. It becomes the theory that defines how change occurs within systems as well as the principles and mindsets needed to adapt and prosper in turbulent environments. This is particularly important when implementing large-scale transformations in higher education [24]. In a society where all of the above factors are poorly defined, and many are non-existent, a diligent planning process is needed to restructure not just the higher education system and academic research but also good governance and the overall approach to government [12, p.253].

4 The Creative Capital and the Scarcity of Human and Material Resources

One of the greatest challenges facing R&D in Lebanon, prior to 2019, was the scarcity of human and material resources. Besides shortage in supplies, equipment and infrastructure, there has always been a growing need for highly qualified R&D staff. These deficiencies were further aggravated by a series of catastrophes that beset the country starting in 2019, including – besides COVID-19 – social unrest, popular uprising, economic collapse, the Beirut Port explosion and the massive devaluation of the national currency.

4.1 People: The Creative Capital

Education and professional expertise provide a sound basis for a knowledge-based economy. Having qualified staff is key to any company's ability to develop and implement innovations and thus to enhance its competitiveness. This is even more significant when it comes to the university as a hub of R&D. The quality of human resources defines the quality of research performed and is the precondition for the development of new knowledge and new technologies. In fact, the most important asset in a knowledge-based economy isn't raw materials, transportation systems, or political influence; it's the creative capital. Simply put, an arsenal of creative thinkers whose ideas can be turned into valuable products and services.

What constitutes creativity in the context of modern research? At the basis of the creative genius is a mastery of the foundations. The physicist Richard Feynman who, more than any of his peers, mastered the basics had re-performed all the great experiments on his learning journey [25, 26]. So, when he was working on higher order experiments, he knew what worked and what didn't... Mastery of the foundations was key to his ability to innovate and succeed. "*In the beginner's mind there are many possibilities, but in the expert's, there are few*" [27].

On the other hand, development of innovation systems can be hampered by low interest in engineering and science subjects, a limited number of qualified women and men in research, the brain drain abroad and a general lack of public awareness about the importance of R&D. Additionally, a lack of scientific career options and the limited mobility between academic research and industry can be a problem. This conundrum may not be unique to Lebanon, but it presents a particularly intense challenge for a society plagued with instability, poverty and bleak prospects for its youth. In fact, shortage of talent and properly trained support staff is one of the main challenges that has always faced academic R&D in Lebanon. At the root of this problem is a seeming inability to locally produce highly qualified scientists who can go on to become independent academic researchers and leaders in their fields.

Some attribute this problem to the lack of a culture that believes in, and is committed to, research on a long-term basis. They explain the shortage of good students interested in research by the lack of a collective 'reading' culture in the country. For a society living at the base of the pyramid of needs, this presents an opportunity to invest in education and in R&D of basic needs and to build collaboration bridges with the world. However, the investment in education and research is subject to the complexity outlined in Sect. 3 (above). At the same time, foreign opportunities for collaboration may not always be appropriate; they require a careful and strategic exploration as wealthier collaborators and research-advanced societies may have different priorities when it comes to the research agenda and allocation of resources.

Thus, many academic institutions rely on the recruitment of a few innovative and dynamic individuals who build on their earlier achievements abroad and want to return to the motherland, where they champion some productive research. Still, this approach lacks a guiding vision that prioritizes local needs in the recruitment process, both at the national and institutional levels, and constantly depends on the continued commitment of key recruits with skills that are uniquely valuable to the institution's success. The dependence on a keyperson presents a major risk that puts progress and development at the mercy of key individuals who may decide to leave, taking with them the institutional knowledge. This keyperson-risk requires proper management to mitigate it, either by securing competitive retention packages that keep the talent from leaving or by having the keyperson commit to generate local creative capital during their tenure; and although the understudies may not be as talented as the lead, their level of performance should be adequate enough to allow the show to go on. Unfortunately, the keyperson risk is often poorly managed with no investment in developing local talent committed either to research or to the institution [28].

4.2 Material Resources

Institutions of higher education in Lebanon as well as the Lebanese government have inadequate and insufficient fiscal and material resources; therefore, any realistic R&D plan must adhere to the principles of working within limited capabilities and attending to national priorities while setting other projects aside. Concentrating financial and material resources to ensure development in key areas is a strategic policy decision for national economic development and also a guiding principle that institutions of higher education must adhere to [29]. Without priorities, it would be impossible to efficiently direct efforts; however, ignoring comprehensive development could also result in production imbalances.

In a society living at the base of Maslow's pyramid [30], where basic needs of running water, sewers, power, roads, transportation and public works infrastructure are lacking, some research topics may become a luxury and it would be difficult to imagine allocating resources to them given the unmet basic needs of the population. That's why, efforts need to concentrate, firstly, on the most important and essential products and the most crucial technologies, where breakthroughs that can spur overall development are possible at affordable costs.

A first step in that direction is the coordination of efforts among academic institutions and at a national level to pool resources towards the establishment of dedicated, well-staffed, continuously updated facilities outside the exclusive control of any one institution. One of the important roles of such facilities should be providing service and support, through state-of-the-art instrumentation and skilled personnel. Many of the basic personnel and equipment resources needed for dynamic academic R&D programs could be funded, at least in part, by joint university-industry research grants. This would benefit both universities and industry, in particular small industrial firms. It would also help to keep university researchers up to date on current industrial challenges, as well as assist in keeping industrial personnel abreast of the latest ongoing academic research.

The growing sophistication and cost of equipment and supplies used in modern research laboratories add to the problems facing academic R&D in the twenty-first century. Much of these resources are too costly for most universities and, in some instances, for even the largest companies. A conceivable solution would be to establish main hubs for sophisticated state-of-the-art equipment and instrumentation, permanently staffed by dedicated and expert personnel, with satellite research laboratories centered in major universities campuses. Funds for the training and employment of personnel should be appropriately anticipated and budgeted with costs allocated to various stakeholders including the government, the private sector and participating academic institutions. These research centers, with specialized equipment, would also offer short courses and training programs to educate potential users and mitigate the key-person risk. The provision of support for visiting scientists to learn how the instrumentation operates may also be considered as it would provide an additional source of income.

5 Innovation and the Balance Between Academic Freedom and Culture

Academic freedom in the twenty-first century is such an elusive concept that defining it has to take into account the interests of society, institutions, students and faculty. However, at the heart of academic freedom, lies the promise of unleashing the creative potential of faculty and students by giving them the right to break the mold and be all they can be without fear of repercussion from society. Ironically, many advocates of academic freedom have been diligently working to promote it through the development of more policies, procedures, rules and prohibitions [31] so much so that the notion of academic freedom itself became so encumbered with the need for compliance and political correctness as an old ship accumulates barnacles [32].

Arguably, the challenge to academic freedom is felt most in academic research, where on top of policies and regulations, the scientists have to content themselves with available sources of funding. Long gone is the era where Christopher Columbus could get funding from Ferdinand of Aragon and Isabella of Castile to explore new routes to the old world [33]. Today, proposals that get funded are, supposedly, hypothesis-driven proposals, with enough statistically significant preliminary data to report in a peer-reviewed publication, and resounding conclusions that satisfy the existing expectations of a complacent research environment. Anything short of that will put its writer at a tremendous disadvantage in the scientific community, from lack of funding to denial of publication in reputable journals and subsequent implications on academic standing, and promotion; challenges that threaten any researcher's ability to survive at a modern university.

In fact, many scientists question whether there is real freedom in academic research to be creative and argue that academia, these days, stunts creativity when it needs to nurture it. Those who succeed in advancing to leadership positions in academic institutions have often been cautious, making few enemies and stirring little controversy in their career. But such a strategy does not necessarily generate the insights that drive science forward. The history of scientific research is rich with mavericks who refused to accept the prevailing theories and challenged the status quo. In the field of infectious diseases, for example, those scientific mavericks included Louis Pasteur [34], whose germ theory was initially ridiculed, Joseph Lister [35], who promoted the concept of sterilization, and others.

On the other hand, to enhance the output of R&D, one needs to balance creativity and practicality; a valid counterargument often proffered in defense of the status-quo. In balancing these two, one cannot ignore the role of culture, which may affect both sides of the scale. Certain practical aspects of R&D, such as budgets, applications and return on investment, may be enhanced by culture. Others, such as ideas and innovation may be deterred. Ethical considerations, which vary between cultures, may also affect the scale, regardless of societal development. Examples include the controversies that deterred Human Embryonic Research in the USA for a long time [36], and numerous studies in the Arab and Islamic worlds that have tackled the impact of "fasting" during Ramadan on health outcomes [37]. This balancing does not necessarily ascribe creativity and practicality strictly to academia. Ideas and innovation can be generated in any R&D sector not just academic arenas.

6 Lack of Standardized Performance Metrics

A marker of research productivity of a higher education institution is the productivity of its faculty members; thus, gauging the productivity and competencies of faculty is important in tracking institutional success. It would be wonderful to have some sort of a foolproof competency-measurement tool that could automatically conduct competency and performance assessment. Unfortunately, that is not the case especially when it comes to academic research. While some tools do exist, a thorough assessment would require considerable reliance on the "human element", where the judgement and experience of an evaluator are employed in assessing the new recruit or evaluating the established investigator.

When assessing new recruits, a set of standard proxies for competency are usually used. They include education, training, certification, skills, and experience. Variations in education are quite common between new recruits, especially when they come from different educational backgrounds and systems around the world. These variations make for a tricky evaluation of documents and can be very difficult from a credential-evaluation perspective. To streamline these multiple systems, the Lebanese Ministry of Education and Higher Education (MEHE) relies on an Equivalence Committee, set up in 1962. The committee acts as "the only [official] reference for … recognition of certificates and the equivalency for education levels in various domains (general education, higher education, and technical and vocational education)" [38]. As for the remaining proxies, they are left up to individual institutions to assess taking into consideration, sometimes, the institution's specific needs or, some other times, more subjective and often biased conventions, where competency may be assumed by virtue of lineage, family ties, sectarian or religious affiliations.

A similar approach is adopted towards performance appraisals. On the surface, it seems to espouse international standards but at the core it is as much subject to traditional local considerations as the recruitment competencies. Much like academic research centers around the world, the top research universities in Lebanon have adopted appraisal standards that encourage faculty to spend time writing, submitting and procuring research grants with key performance indicators focused on published papers, funding and number of students graduated. Whereas these metrics may be easy to document, they tend to suppress academic freedom and do not necessarily yield a reliable appraisal of performance aligned with the mission. On one hand, they deflect the most talented people from creative and meaningful pursuits, to grant writing and increasing the number of publications in their portfolio, and on the other, they increase the insecurity of employment. A meaningful system of appraisal would focus more on tangible outputs with real measurable impact rather than on virtual impact factors. In fact, the inappropriate use of impact factors compelled certain scientists, groups, institutions and publishers to come together and sign the San Francisco Declaration on Research Assessment (DORA), a declaration that rejects the use of impact factor in determining one's scientific merit and accomplishment [39]. The question then becomes: how does one determine a scientist's accomplishments? The answer seems simple. In order to assess the scientific achievements of a scientist, focus should be on the content of the papers, the level of research, and the importance of the outcome of the studies. In a country with depleted resources, the primary focus should be on the application of research and the benefits that it would bring to the society. This would align research goals with the set of national priorities, which to a large extent should reflect market requirements. To that end, a comprehensive assessment should take into consideration the impact of the creative works on the immediate and medium-term needs of society, make room for people management, and provide a faster pace of career advancement tied to more basic performance indicators such as product, individual, and sector development.

7 Compliance and Indirect Cost Recovery

An important criterion in assessing the success of regulatory reform is whether regulatory systems accomplish their policy objectives. Despite a massive increase in regulation and government-imposed formalities in Lebanon, especially after the end of the 1975 war, results have too often been disappointing. In many other countries, this would have prompted governments to examine how they can achieve their policy objectives more cost-effectively through better regulation and different mixes of policy tools. Although this expansion of national focus appeared to be aligned with the OECD approach to regulatory reform, which in the 1990s turned from deregulation to regulatory quality management (*improving the efficiency, flexibility,* *simplicity, and effectiveness of individual regulations and non-regulatory instruments*), it did not keep up with OECD regulatory reform, which is now entering a third phase: the management of regulation (*to improve the total impact of regulatory systems in achieving their social and economic goals*) [40].

7.1 Compliance

Research compliance is one of the most pressing concerns of university leadership today, driven mostly by governmental regulations and adherence to accepted standards. In a small country, impoverished by years of corruption, scientists – with no meaningful recourse to national funding – are left at the mercy of foreign grant agencies. To make matters worse, the regulatory requirements vary widely across agencies making academic institutions in Lebanon subject to regulations imposed by a myriad of foreign governments and organizations around the world. This gradual, ever-increasing growth of regulation and reporting requirements can exacerbate institutional financial stress and divert faculty time from research. At the same time, the cost of doing research is not fully recoverable from sponsors. When scientists are spending most of their time chasing security of their employment in securing grant funding and complying with administrative regulations, little time is left for creativity.

The amount of funding available to support academic research is unlikely to increase in the coming years; if anything, it is more likely that it will suffer from a significant decline given the severe economic crisis in the country and the colossal inflation driven by the loss of the local currency value by comparison to the US dollar (just shy of a 1000% loss of value as this chapter is finalized). In fact, just on the basis of an adjusted inflation, the declines have been so gigantic that any meaningful research is almost impossible to take place. At the same time, reporting, accountability and compliance requirements are likely to continue to increase. On one hand, this is driven by pressure from sponsors to comply with growing regulations and to provide detailed quantitative data on the results of funded research. On the other hand, the increasingly collaborative, inter-disciplinary and global nature of research is reinforcing regulatory and administrative complexity. As a result, there is a large and rising burden on faculty and research administration, diverting faculty time from innovation and education, and depressing faculty morale.

The lack of capabilities to manage the growing complexity of compliance requirements is not always a case of administrative inefficiency, but a result of the cap on overhead recovery associated with increasing administrative costs to keep up with cost of research compliance and reporting requirements.

7.2 Indirect Cost Allocation and Recovery

The Department of Labor in the United States defines indirect costs as expenses of doing business that are not readily identified with a particular grant, contract, project function or activity, but are necessary for the general operation of an organization and the conduct of activities it performs [41]. In theory, costs such as heat, light, janitorial services, accounting and secretarial support might be charged directly if little meters could record effort in a cross-cutting manner. Practical difficulties preclude such an approach. Therefore, cost allocation plans, or indirect cost rates, are used to distribute those costs to helping revenue sources [42]. Without indirect costs, academic research centers would have to fully subsidize any research project, whether it is funded by a private organization or the government. Indirect costs on government grants provide a means to support academic R&D through an indirect national investment in research. Academic research centers in Lebanon do not receive indirect costs on projects funded by government agencies, such as the CNRS, or by many other funding agencies. This means that for every project or activity receiving extramural funding, academic institutions have to provide cost-sharing coverage. Cost-sharing commitments can be met using direct or indirect costs that are permissible, applicable, practical, and accounted for. It is divided into two types: (1) direct costs (faculty effort, research staff salary, equipment, and other direct expenses) and (2) indirect costs (unrecovered overhead on sponsored expenditures, overhead on cost-shared University resources, and costs normally considered indirect). Given the dire financial times that the country is going through, one way to support academic research, besides providing funding for projects, would be to provide some indirect costs to the host institutions.

8 A Wicked Problem in Need of Creative Solutions

Academic R&D faces a great number of challenges, worldwide, and particularly in Lebanon. These challenges may be national, governmental, institutional and cultural and are intertwined with the complexity of the problems facing the country as a whole. Knowledge of and information about these challenges are either incomplete or contradictory. With the great number of "experts" involved, the number of opinions proffered, the prohibitive economic burden, and the interconnected nature of these problems with other regional problems, the issue of academic R&D, in general, and in Lebanon in particular presents the perfect *wicked problem* [43].

National and governmental challenges are exceptionally pertinent in Lebanon given the political, economic, and demographic instability of the country and the recurring internal and regional threats to its security. With law enforcement practically non-existent and public works infrastructure mostly lacking, people are forced to find solutions to daily problems, at the base of Maslow's pyramid [44]. This solution-oriented and resilient attitude is the human capital that drives innovation in this conflict-ridden land. It needs to be embraced and capitalized upon in ways that are scaled to its genius but also to its needs. The one-size-fits-all international standards of R&D may not be necessarily suitable for Lebanon's innovators, be they academic researchers or micro-entrepreneurs. In a twenty-first century society, where the scientist is asked to get out of bed in the dark because there is no power, hedge the option of a morning shower on the availability of running water, walk through a street riddled with trash and uncollected garbage to catch a cab or get to an old clunker, and then drive through one or two hours of traffic to get to the research institution, only to struggle for another half-hour to find a parking spot, self-realization may be a far-fetched aspiration. Basic needs must be met first and competencies must be evaluated accordingly!

If we were to consider Rostow's stages of development over time [45–47], Lebanon, much like many other developing countries in the Arab World, would be a *Traditional Society* characterized by a substantial, agriculture-based economy, with rigorous labor and low-level trading, and a population that lacks a significant scientific perspective on the world and technology. Yet, much like many of its neighbors, the Lebanese society has leaped prematurely to the *Age of Mass Consumption* without going through the *Preconditions to Take-off* where society begins to develop manufacturing, and a more national/international, as opposed to regional, outlook. The Lebanese economic development seemed to have skipped also the *Take-off* stage, which typically involves properly planned urbanization, upgraded public works infrastructure, strategic and sustainable industrialization, and bypassed the *Drive to Maturity*, where standards of living rise, use of technology increases, and the national economy grows and diversifies. These levels of development are usually tied to and reflected in the reasonable increase of income per capita (Fig. 1). Perhaps these sudden and steepish leaps explain the recurring economic problems of Lebanon and the recent collapse of the Lebanese currency.

Institutional challenges, although not necessarily exclusive to academic research in Lebanon, are largely magnified for Lebanese universities compared to the rest of the world. Shortages in well-trained human capital and essential material resources (see Sect. 4, above), scant budgets, skewed metrics and inapt regulations are rampant and common to many societies in the developing world but addressing them alone, without mentioning the cultural challenges, would only scratch the surface of the problem.

Cultural challenges are not strictly the societal ethical considerations or the lack of a "reading" culture committed to research on a long-term basis. They extend to political and religious interference in the academic process in general, and in R&D in particular. This is hardly a new phenomenon or one exclusive to Lebanon. In fact, the suppression, manipulation, disrespect, and disregard of science and scientific opinions are widespread and pervasive [48]. However, for Lebanon, these challenges come with an added element of contempt towards competence, innovation and academic freedoms in favor of allegiance to sect or clan leader. This general disposition attitude has, unfortunately, permeated academic institutions and centers of R&D, where loyalty to the "chief" and to senior administrators has become an

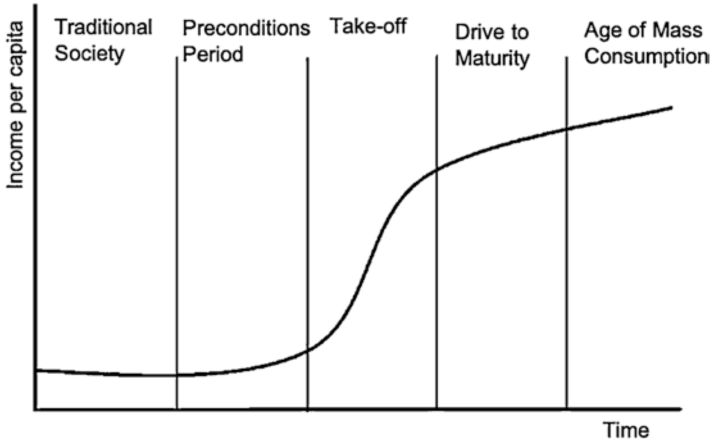

Fig. 1 Income per capita across Rostow's stages of Development

unspoken proxy for competency, often substituting for aptitude and performance [49–51].

Overcoming these challenges and streamlining policies, regulations and thereof are crucial to the advancement of science. Science and public policy are mutually dependent; yet, they have a complex and often difficult relationship. In free societies, they share the core values of openness and transparency. Exchange of ideas and information, independent verification, reliable peer review, and integrity of publications are hallmarks of the scientific enterprise, fundamental to its success and progress. In the same way, the credibility, legitimacy and authority of our policies depend on the public's trust in the validity of the processes that produced them. Thus, compromising the integrity of academic processes, including R&D, for personal, administrative or political expediency, can have a devastating effect on the public policy and subsequently on society.

9 Managing Creativity on a Budget

If creativity had a child, it would be innovation. There are two types of innovation: *incremental* and *radical*. *Incremental* innovation exploits existing findings and technologies. It either improves upon an outcome that already exists or reconfigures an existing technology to serve a different purpose. In this sense, it is innovation at the margins. In contrast, a *radical* innovation brings about a new outcome into the world and involves a departure from existing technology or methods. Despite the advantage of radical innovation, it is often risky and expensive and could take many years to produce concrete results. On the other hand, *incremental* innovation is safer cheaper and more likely to produce results within a reasonable time. An often overlooked third type of innovation is *process* innovation. This one helps streamline operations, ramp up productivity and increase public trust in academic proposals [52].

Academic research institutions are the hubs of the creative capital and innovation is fundamental to their mission. One may argue that they have an ethical responsibility to innovate and come up with solutions to societal problems, but universities alone cannot solve all society's problems. In fact, most social problems – such as inequality, political instability, death, disease, or famine – are wicked and cannot be "fixed." Yet, academic R&D can play a role. By adopting an empathetic design [53] academic research institutions can follow a five-step process to help find solutions to basic societal problems. The five steps include observation of the problem, capturing data related to the problem, reflection and analysis, brainstorming, and developing solutions. Whereas inequality, political instability, health and disease are important challenges, a focus on more tangible and needed basics may yield a more immediate and essential return. Starting with the design and development of infrastructure can alleviate the negative consequences of wicked problems and steer the overall trajectory of culture in more desirable directions. This would shift the role of academic R&D in many societies, like Lebanon, to emphasize standard solutions to known engineering issues (for example, design, build, and maintain public works) at first, and then to identify local issues with regional impact, such as food security, poverty, education, and health, and seek to partner with willing collaborators to solve them.

Even if Lebanon's universities have the collective human capital and combined capacity to conduct world class research on their own, they cannot afford it. Instead, their immediate focus must be on establishing and maintaining the integrity of their internal processes and adopting more humane and culturally attuned, yet objective, standards in resourcing, as well as developing and retaining local talent. This is a first step in restoring the public trust in any proposal that relies on academic input. Without it, any incremental or radical innovation will remain wanting. Many of the challenges faced by these institutions, although not unique, are wicked in nature and may not have definitive formulation. Thus, the standardized metrics used in the US, Europe or even the rest of the MENA region, for the development and retention of talent, may not be appropriate for the growth of R&D in Lebanon.

In tandem with this self-reflection and internal reforms, academic R&D needs to refocus on two types of creative strategies: (a) local solutions to local problems and (b) international collaborations for extra-local challenges. Sadly, local problems for Lebanon are very rudimentary; they start at the level of designing, building and maintaining civil engineering works to secure food, water, warmth and shelter, electrical power stations, fresh water supply, garbage disposal and clean environmental practices, as well as many other basic purposes such as safety and security, etc. These represent strategic priorities without which there is no way for any society to climb the advancement ladder. Other more advanced challenges will need to be addressed in collaboration with regional or international partners, taking advantage of one location with the invested infrastructure and material resources, and global on-site or virtual teams with the knowledge and expertise.

10 Conclusions

Collecting reliable R&D indicators in developing countries (such as Lebanon) is a challenge in and by itself, in the absence of a dedicated national institutional unit. This has implications that affect any proposal for strategic reforms. The paucity of reliable, up-to-date statistical information on human resources and research budgets, despite funding by the European Union (EU) to describe the scientific and technological capabilities in many of the developing MENA countries [54], makes it very difficult to put in place a reliable process plan. However, indicators, alone, cannot fully reflect the characteristics of R&D in developing countries, where systems' dynamics, idiosyncratic practices, informal behaviors and unexpected changes can affect the picture. Additional information is needed to better understand the local R&D; it includes: (1) contextualization of science and innovation within the broader political, economic, educational and social systems; (2) history of science in the country; (3) governance of science and available policy documents; (4) indicators on human resources with considerations for research as a profession (status, salaries, etc.); (5) funding agencies; (6) research outputs (postgraduates, publications, papers and patents) and (7) cooperation agreements.

With all the societal, cultural, organizational, budgetary and institutional challenges facing academic R&D in Lebanon, a roadmap that protects academic freedom is needed to prioritize the national goals and allocate the required funding. Policy makers need to become better informed about the national importance of a strong commitment to R&D by investing more heavily in targeted capacity building and the expansion of opportunities for research in universities. While global research trends, policy settings and funding arrangements are important to keep in mind, the priority would be for policy makers and institutional leaders to acquire skills in developing R&D policies based on evidence and informed by national strategic considerations. Additionally, they will need to develop an appreciation of the training needs of researchers in universities and research institutes concerning the processes of commercialization. Although many private institutions of higher education enjoy a relative autonomy when it comes to policy makers, this is not the case for the Lebanese university, the largest and only public institution of higher education in the country. A better appreciation of how the importance of institutional autonomy and independence from public interference is needed, if universities in general, and the Lebanese University in particular, are expected to make a significant contribution to R&D.

In addition to national mobilization, institutional development of R&D processes and priorities is needed. Research managers and administrators within universities and research institutes will require more support with the development of knowledge and skills related to their responsibilities, so that they can be held accountable for their duties.

The steps above will address some of the basic needs for local research. But there will remain gaps when it comes to building regional and international collaborations across countries to improve transnational R&D management. These collaborations are important outlets for the creative genius of local experts interested in global problems. They would require bilateral or multilateral frameworks of co-operation at policy and intuitional levels, giving the countries access to a regional network of resources, experts and professionals in this domain.

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Academic Research in Support of Post-Conflict Recovery in Syria

Wael Mualla

Abstract The nine-year-old conflict in Syria has had profound impact on all national sectors, including the higher education sector and research facilities. The damages inflicted on the sector can be described as huge and enormous, and include: losses of higher education infrastructure and research facilities (many facilities were looted and destroyed), loss of intellectual capital (higher education expertise and researchers), significant drop in academic research output caused by the loss of experienced qualified staff and by limited higher education funding allocated to research as funds were diverted to support other urgent priorities. And now, as the crisis appears to be nearing its end, one of the important topics that is currently debated in Syria is how can academic research play a significant role in supporting the post-conflict recovery process in Syria whether on the social, economic or political front. In this chapter, the status of scientific research in Syrian universities and research centers prior to 2011 are highlighted. The impact of the crisis on research facilities and research output are also presented and discussed. Finally, a new vision on how academic research can support the post-conflict recovery process in Syria is presented.

Keywords Syria · Conflict · Higher education · Research facilities · Recovery

1 Introduction

Syria has been experiencing a severe conflict since 2011, which has affected all economic and social sectors in the country, including the higher education sector and research institutions. The damages inflicted on the sector is described as huge and enormous. It includes losses of higher education infrastructure and research facilities (many facilities were looted and destroyed), loss of intellectual capital (higher education expertise and researcher), significant drop in academic research

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output caused by the loss of experienced qualified staff, and limited higher education funding allocated to research as funds were diverted to support other urgent priorities and as a result of economic sanctions imposed on Syria.

As the crisis appears to be nearing its end, one of the most important topics that is currently debated in Syria is how can academic research play a significant role in supporting the post-conflict recovery process in Syria whether on the social, economic or political front.

In this chapter, the national system for science, technology and innovation in Syria is described. The status of scientific research in Syrian universities and research institutions prior to 2011 are highlighted including their points of strength and weaknesses. The impact of the crisis on research facilities and research output are also presented and discussed. A new vision on how academic research can support the post-conflict recovery process in Syria is presented.

2 The National System for Science, Technology and Innovation in Syria

The national system for science, technology and innovation in Syria consists of: higher institutions for managing and developing scientific research and technological development, scientific research bodies (i.e. all public and private institutions that carry out scientific research or studies, such as research and studies centers, universities, higher education institutes, etc.), technical productive enterprises, and intermediate and supportive institutions [1, 2].

3 Syrian Institutions of Scientific Research

National Syrian institutions of scientific research consist mainly of scientific research institutions that are within the higher education sector and scientific research institutions outside it. Institutions within the higher education sector include: 8 public universities, 23 private universities, 4 public higher institutes and 58 technical institutes [2]. It is worth mentioning that research output in terms of quality and quantity varies considerably across the sector. Well-established institutions, such as Damascus University and Aleppo University, have significantly higher research output than others.

National research institutions that are outside the higher education sector include: the Centre for Scientific Studies and Research, the Atomic Energy Commission, the General Authority for Scientific Agricultural Research, the General Authority for Remote Sensing, the National Commission for Biotechnology, the National Centre for Energy Research, and the Syrian Commission for Family Affairs and Population [2, 3].

Intermediate and supportive entities include the Industrial Research and Testing Center, the Syrian Arab Organization for Standardization and Metrology, the National Agricultural Policy Center, and the *National Standards and* Calibration Laboratory [2].

4 International Research Centers Located in Syria

In addition to the national centers for scientific research, there are two international centers that carry out intensive research in Syria; these are the International Centre for Agricultural Research in the Dry Areas (ICARDA) and the Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD).

ICARDA is an international organization undertaking research for development, providing innovative science-based solutions for countries across the non-tropical dry areas [4]. Its research activities include the development of new crop varieties, water harvesting, conservation agriculture, the diversification of production systems, integrated crop/rangeland/livestock production systems, and the empowerment of rural women.

ACSAD is a specialized regional center for research studies on the development of the arid and semi-arid areas in the Arab World. It works within the framework of the League of Arab States, and aims at unifying national efforts to develop scientific agricultural research in the arid and semi-arid areas [5]. Its research activities are in fact similar to ICARDA.

5 The Status of Research and Innovation in Syria

A review of a number of sciences, technology and innovation indicators shows that Syria has fallen behind most Arab countries in several areas during the past decade. For example the WIPO/INSEAD Global Innovation Index ranked Syria in the 110th position (out of 125 countries) in 2011 [6], which is an unsatisfactory position in comparison with other Arab countries (Jordan was ranked 33, Lebanon 41, and Egypt 89). In 2012, Syria's slipped to the 123th position in the Global Innovation Index ranking (out of 141 countries) [7], and in 2013 it slipped further to the 134th position (out of 142 countries) [8]. From 2014 onward, as the war took its toll on all Syria's economic sectors, Syria went out of the Global Innovation Index ranking.

Even the Arab ranking systems put Syria in a backward position. Arab countries were ranked according to the Composite Arab Index for Research, Development and Innovation (Table 1). The research, development and innovation index is determined by a number of inputs for each country (such as spending on research and development, human resources for research and development, sources of financing and development) and outputs (represented by scientific publications, patents, and the balance of payments for advanced technology products). Arab countries were

Table 1 Ranking of Arab countries according to the Research, Development and Innovation Index 2016

Arab Countries	Ranking according to the Research and Innovation Composite Index	Ranking according to research and development	Ranking according to innovation	Ranking according to enabling environment and infrastructure
UAE	1	1	1	2
Qatar	2	2	6	1
Saudi Arabia	3	3	2	3
Tunisia	4	6	5	6
Kuwait	5	7	11	4
Lebanon	6	5	3	11
Bahrain	7	15	4	5
Jordan	8	10	7	9
Oman	9	8	13	8
Morocco	10	16	9	7
Egypt	11	4	14	13
Djibouti	12	14	8	15
Palestine	13	11	12	17
Syria	**14**	**13**	**15**	**16**
Algiers	15	17	16	12
Mauritania	16	18	10	18
Yemen	17	9	17	20
Sudan	18	12	18	19
Libya	19	19	19	10
Iraq	20	20	20	14

classified into three homogeneous groups that have similar performance. The first group, consisting mostly of Gulf states, is characterized by political and social stability, and is witnessing remarkable levels of economic growth. Syria was classified in the third group, which included countries with weak economic growth and in a state of conflict (such as Yemen, Iraq and Sudan) [9].

The status of research within the Syrian higher education sector is characterized by the absence of a research strategy that links research institutions with the industry and other economic sectors, and is associated with modest research output (although this varies considerably across the sector). Low research output in academic institutions is caused by limited research funding, over-emphasis on teaching, inadequate forms of research training and lack of incentives for academic staff to conduct research. Research is mainly conducted by academic staff for the purpose of academic promotion or research dissertations. Additionally, most research does not meet the needs of the society or the economic sectors [10].

Statistics provided by the Syrian Ministry of Higher Education shows that Damascus University, considered the most prominent university in Syria, awarded

118 PhD degrees and 418 Master's degrees in 2015, all of which involved research work. However, their impact on the number of patents was negligible [3].

Most of the projects carried out by the various research bodies focus on agriculture, engineering, and medical and basic Sciences. For example, agriculture and agro-industries made up the largest part during the years 2014–2015, reaching 32% of the total research projects implemented, while projects related to renewable energies did not exceed more than 0.5% [2, 3].

6 Research Funding in Syria

It is widely accepted that the amount a country spends on scientific research in relation to its national income is considered a basic indicator of the country's development. If the level of spending on scientific research is less than 1% of the gross domestic product (GDP), research performance is considered very poor and unproductive. Whereas, if the level of spending is from 1.6% to 2% of GDP, research is considered to be at a good level to serve development in the country. If the level of spending exceeds 2%, the research performance is considered at the right level required for developing sectors and creating new technologies [2].

Although Syria ranks well among Arab countries in terms of spending on education (exceeding 6% of GDP in 2009), its spending on scientific research in the pre-2011 era was estimated at 0.12% of its GDP which was unsatisfactory. This figure dropped even further to 0.01% in the post-2011 era because of the war [2].

Analysis carried out by the Syrian Higher Commission for Scientific Research in 2015 of the sources of funding for research projects revealed that most of the funding came from the government. Private sector share, whether domestic or external, in the financing of research projects has been very poor (9%) (Fig. 1) [3].

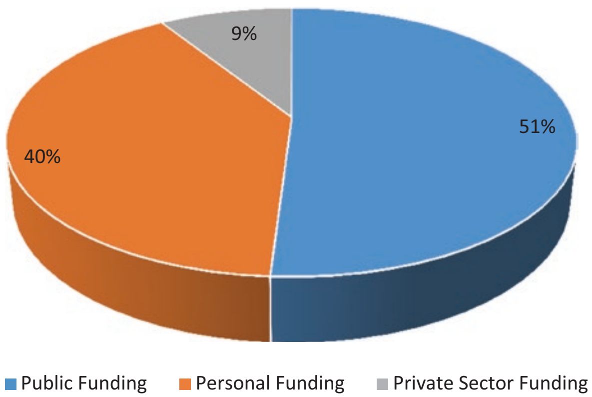

Fig. 1 Distribution of funding sources for scientific research projects and activities for the year 2014

7 Networking and Interconnection Between Scientific Research Bodies and Development Sectors

Science, technology and innovation in Syria suffers from major shortcomings, including weak relationship, cooperation and coordination among its components. This is due mainly to weak institutional structures and legislations that enhance this relationship. The importance of coordination and networking between scientific research bodies is reflected in the strengthening of the technology transfer system. In Syria, the lack of coordination between research centers is a major weakness of the science, technology and innovation system which often resulted in the duplication of research efforts as well as waste of time, efforts and resources [2].

8 Impact of the Crisis on the Higher Education Institutions and Research Facilities

The nine-year old conflict in Syria has had devastating impact on all national sectors, including higher education institutions and research facilities. The damages can be described as huge and can be summarized as: losses of infrastructure, especially in areas that went out of government control; loss of intellectual capital (academics and researchers); limited funding available for research, as funds were diverted to support other urgent priorities.

Although there is no official assessment to date on the material and non-material damages inflicted on research facilities in Syria as a result of the ongoing crisis, the Higher Commission for Scientific Research reported in 2017 that the damages to infrastructure have been huge and include complete destruction of a large number of scientific research sites, including the destruction of a large part of documents, records, scientific references and laboratory equipment [3]. It is worth mentioning here a project conducted recently by UK NARIC and the UNESCO Beirut Office describes the impact of the conflict on Syrian higher education provision and the key challenges the country needs to address on the road to recovery, but does not cover the impact of the war on research facilities [11].

The damages sustained at both ICARDA and ACSAD are good examples of the war impact on research facilities in terms of buildings, infrastructure and laboratories. The headquarters of both ICARDA in Aleppo and ACSAD in Damascus countryside were both looted by armed groups, stealing lab equipment, computers, cars, trucks, air-conditioners etc. The gene bank, which was considered once ICARDA's "crown jewel" was also stolen. Staff, both international and national, were eventually moved to other locations inside and outside Syria. Similar damages have been witnessed at the Syrian Arab Organization for Standardization & Metrology, the General Authority for Agricultural Research, and the Faculty of Chemical and Petroleum Engineering at Al-Baath University [3].

Regarding the loss of intellectual capital (or “brain drain”), the National Report on Scientific Research in Syria published by the Higher Commission for Scientific Research indicated that between 2011 and 2015 as much as 3298 academics and researchers working in scientific research institutions left their jobs for various reasons, mainly immigration. This number represents 36.6% of the total number of research staff, with most of them working in engineering sciences (41%), agriculture (18%) and medical sciences (15%). It is worth mentioning here that over 50% of the research staff who left were PhD holders which is a significant loss for Syria [3].

The report also indicates that 293 out of 367 research assistants (i.e. 68%) who were sent abroad to participate in PhD programs at prestigious institutions as part of scholarship programs run by universities and research intuitions and covered by the government, did not return to Syria in 2014 to re-join their institutions, in breach of their contracts [3].

Economic sanctions imposed on Syria as a result of the war had significant impact on scientific research in the country as well. Syria’s cooperation with a number of international organizations has been cancelled. For instance, the ban imposed by the International Organization for Standardization (ISO) made obtaining international standards difficult. The ISO has cancelled Syria’s membership in the organization which prevented the Syrian Arab Organization for Standardization & Metrology (SASMO) from obtaining important standards and updates which negatively affected the performance of SASMO. Moreover, a number of bilateral cooperation agreements have been suspended, such as the scientific collaboration agreement signed with the German government on establishing the Higher Institute of Water Management, whose mission included training, teaching and research. This suspension strongly affected the performance of the institute which relies heavily on foreign expertise in performing its duties. Furthermore, the difficulty in obtaining and importing materials for scientific research have affected the progress and outcome of numerous research projects. Another negative impact of the economic sanctions has been regarding the access to information. Research institutions witnessed difficulties in accessing digital libraries, modern scientific journal publications necessary for their research projects. Syrian researchers have also experienced great difficulties in publishing in prominent scientific journals [3].

9 How Can Academic Research Support Post-Conflict Recovery in Syria

Higher education institutions, academics, and domestic researchers can contribute towards recovery through basic and applied research, plus other knowledge services such as consultancy in a wide range of areas of relevance to reconstruction, state-building, peacebuilding, and development. However, internationally led post-conflict interventions and northern-dominated academic research on conflict, too often neglect domestic research in affected societies, with harmful consequences for rebuilding research capacities and promoting genuine national ownership [12].

9.1 Reconstruction and State-Building

Post-conflict reconstruction includes both short-term humanitarian relief works and long-term strategies to promote sustainable development and to integrate the country into the global economy [13]. A shared vision among all sectors of the country that includes broad agreements on the major aspects of recovery is a vital element in effective post-conflict reconstruction.

It is important to note that the success of post-conflict recovery depends not only on the amount of financial resources available but also on the fostering of a sustainable base of human capital [12]. Post-conflict countries generally face a skills gap at a time when human capital is in high demand [14]. It is evident that higher education can support building the human resources base through its basic teaching (or training) function by producing skilled graduates to rebuild a domestic skills base, which was weakened due to a variety of factors that depleted managerial and technical personnel, such as war deaths and injuries, or immigration [12].

However, in addition to its contribution to building the human resources base, the expertise embodied in higher education can play a role during the reconstruction phase, through applied research and consultancy, such as planning, implementing, monitoring, and evaluating reconstruction programs [12].

9.2 Peacebuilding

Furthermore, research on peacebuilding that is carried out by academic institutions can foster or support sustainable structures and processes which strengthen the prospects for peaceful coexistence. It can also decrease the likelihood of the outbreak, reoccurrence, or continuation of violent conflict [15]. Experiences drawn from conflict-affected regions indicate that major themes for research that support peacebuilding in post-conflict era include [16]:

- Identity, pluriculturalism and multiculturalism
- Intercultural dialogue and cooperation
- Intergroup contact
- Reconciliation
- Youth activism and empowerment
- Prosocial behavior psychology

9.3 Economic Recovery

Post-war economic recovery faces complex challenges including entrenched war economies and economic crises requiring responses that demand expertise including macro-economic stabilization, regulating extractive industries, international negotiations, and participation in global governance regimes [12]. Skills shortages and weak institutional capacity may hinder Syria's efforts to effectively navigate these transitional processes. Needless to say, that Syrian higher education institutions could aid economic recovery by carrying out research on these challenges and by supplying skilled graduates (particularly postgraduates) in relevant disciplines such as law and economics that would enable a long-term sustainable approach to building economic governance capacity.

Higher education experts can also play a significant role in post-conflict economic recovery through applied research related to post-war challenges specific to the Syrian context, such as:

- The role of private, public and NGO sectors in post-conflict reconstruction of the Syrian economy
- The returning of Syrian refugees and their role in economic development
- The role of small and medium enterprises in post-conflict economic reconstruction
- Emergency plans to rebuild the global trust in Syrian goods

9.4 Rehabilitation and Restoration of National Heritage

Perhaps one of the most important areas of research where academic researchers can contribute in the post-conflict era is in the area of rehabilitation and restoration of the national heritage. For Syria is a land of glorious cultural heritage. It is home to the oldest and culturally rich cities and archaeological sites in the world. It has currently six UNESCO Word Heritage sites, namely Damascus old city, Palmyra, the ancient city of Bosra, Aleppo, the Krak des Chevaliers, and the ancient villages of Northern Syria. Ebla, which is a city-state founded around 3500 BC, is rich with archaeological heritage from the Sumerians, Ablates, Acadians, Assyrians, Hittites, Hurries, Mitanni, Amorites and Babylonians. It illustrates the amazing Syrian cultural heritage, and shows the amount of effort that should be deployed on both national and international levels to rescue such a rich and diverse culture that overcame disputes and differences throughout history [17].

As stated earlier, the nine-year old conflict in Syria has had devastating impact on all national sectors. The cultural sector was not an exception, especially archaeological sites. Syrian cultural heritage suffered huge damages mainly due to the systematic clandestine excavations carried out by professional armed gangs and the deliberate damage to Syrian cultural landmarks in areas of conflict. In addition, cross-border smuggling of cultural objects grew remarkably. Some archaeological sites have also become battlefields, which had disastrous effects on historic buildings and ancient citadels. Archaeological statues and mausoleums have been particularly targeted by fanatics, whose distorted interpretation of Islam deems the veneration of tombs and non-Islamic vestiges as idolatrous. Sites have been destroyed and precious manuscripts and archives have been burned for purely ideological reasons. All six aforementioned world heritage sites were placed on UNESCO's Endangered World Heritage Sites list. Syrian archaeological authorities have not been able, so far, to do a full inventory count of the damages done to the glory and magnificence of this archaeological and historical heritage, which in fact belongs to humanity as a whole.

Academics working in the field of archaeology can contribute toward the post-conflict recovery period in many ways. First, by performing their basic function of teaching and training, they can introduce relevant courses in the archaeology program, such as "Protecting Cultural Heritage in Armed Conflict". They can also participate in providing other knowledge services such as consultancy on how to prepare for and conduct essential restoration works in damaged archaeological sites. They can also have important contribution in essential projects planned by the Ministry of Culture and the Directorate General of Antiquities and Museums such as the Project for the Digitization and Documentation of Artifacts (museums contents) in all governorates, and the Built Urban Heritage Documentation Project, which documents historical cities and important historical and archaeological buildings in all governorates of Syria. Their main contribution could be through training the teams to provide the required scientific work, as well as setting the required standards for documentation and digitization.

Academics can also play an important role in applied research by performing research that is important to the post-conflict recovery period such as:

- How to ensure the return of local communities to historic cities
- The role of local communities in preserving cultural heritage (Palmyra model)
- The role of local communities in reviving cultural heritage after wars
- The impact of reviving traditional handicrafts in achieving sustainable development of cultural heritage after wars
- The impact of the rehabilitation of historic cities on human development (Aleppo as a model)
- Protecting and preserving intangible heritage
- Setting up standards for safeguarding intangible heritage

10 Crucial Steps to Be Implemented

There are crucial measures that need to be implemented to pave the way for the post conflict recovery period, and to enable academics and researchers to contribute effectively to the recovery process. These steps include:

10.1 Rebuilding the Human Resources Base

As stated earlier, one of the most negative impact of the conflict in Syria has been the loss of well qualified academics and researchers. Therefore, in order to rebuild the human resources base, policies aiming at reversing the "brain drain" from academia and research facilities should be adopted and implemented in the higher education sector and research institutions [10]. Incentive schemes designed to attract staff back home should be designed and implemented. Syrian academic immigrants should be regarded as assets for Syria. It is of paramount importance to attract them back or to build partnerships with them and their institutions abroad.

10.2 Research Strategy

Developing a research strategy that links higher education institutions and research centers with the industry and the various economic and social sectors is of paramount importance. This role should be played by the Higher Commission for Scientific Research which was established in 2005 and whose mission includes drawing up a comprehensive national policy for scientific research and technological development, coordinating research activities between the various national research bodies, linking them to the actual needs of the society, and creating an enabling environment that supports scientific research and stimulates researchers [18].

Academic staff should be encouraged to engage in research and publish in high impact research journals through generous incentive schemes [10]. Reward policies for highly distinguished applied research and registered industrial patents should be established.

10.3 Enhancing Research Funding

As stated earlier, even in the pre-conflict period, the amount of spending on scientific research in Syria was estimated at 0.12% of its GDP, which is considered unsatisfactory by international standards (any spending less than 1% of the GDP is considered very poor and unproductive). Therefore, enhancing research funding from both the private and public sectors should be of paramount importance as well. This could be achieved through incentive schemes (such as tax incentives), adopting policies and legislations that support research in private sector companies including incentives that encourage research and development within this sector, and establishing a national innovation fund financed by the private sector.

10.4 Intellectual Property Policies

In Syria, there is no unified system for the protection of intellectual property and official responsibility for it is divided between the Directorate of Commercial and Industrial Property Protection, which is affiliated with the Ministry of Internal Trade and Consumer Protection, and the Directorate of Copyright Protection, which is affiliated with the Ministry of Culture. This role is also absent in universities and other research centers, and there is no official intellectual property policy [2]. Some of the important measures that need to be implemented which will have positive impact on research output include:

- Establishing intellectual property policies within universities and research centers, including establishing regulations for ownership of research results
- Creating offices specialized in technology transfer in universities and research centers
- Introducing legislations that allow universities, research centers, and their employees to establish and manage technology companies based on the outcome of their research
- Restructuring the intellectual property protection system and the national innovation system, unifying its components, and organizing its association with technology transfer offices in universities and research centers

11 Conclusions

Academic research should contribute towards recovery in Syria through basic and applied research in a wide range of areas of relevance to reconstruction, statebuilding, peacebuilding, and development. Investing in domestic research institutions such as universities and research centers for the production of knowledge in recovery-related fields would enable Syria to assume genuine ownership of reconstruction by producing and disseminating knowledge of local context, conflict, and recovery. Crucial steps need to be implemented first to pave the way for recovery. These include rebuilding the human resources base, enhancing and diversifying research funding, and establishing intellectual property policies.

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Challenges and Opportunities of Multi-Disciplinary, Inter-Disciplinary and Trans-Disciplinary Research

Abdallah Shanableh, Semiyu Aderibigbe, Maher Omar, and Ahmad Shabib

Abstract Disciplinary approaches have advanced the frontiers of knowledge in the various disciplines. Multi-disciplinary methods have enhanced understanding of observed phenomena from multiple perspectives. Inter-disciplinary approaches integrate disciplines and allow a more holistic understanding of phenomena. Trans-disciplinary approaches engage stakeholders in interdisciplinary teams and integrate practical considerations and impacts in developing and applying knowledge. Increasingly, advancing scientific knowledge demands a combination of approaches to address complex issues involving technical and societal concerns. Integrating ideas, expertise, and practices offer many opportunities and have proven highly effective and successful in various fields, especially concerning enhancing fundamental understanding and developing innovative solutions to complex problems. However, adopting this approach may be hampered by different technical, institutional, personal, communication, practical, and educational challenges. In this article, an assessment of the challenges and opportunities associated with implementing multi-disciplinary, inter-disciplinary, and trans-disciplinary research approaches are presented and discussed within the context of the University of Sharjah.

Keywords Research · Research paradigm · Disciplinary research · Multi-disciplinary research · Inter-disciplinary research · Trans-disciplinary research

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1 Introduction

Research is pivotal for making evidence-based decisions, understanding societal issues, as well as sustaining growth and development. Using disciplinary oriented approaches have advanced knowledge and professional insight for strengthening professional practices in society's various fields and sectors. More so, disciplinary research guided by different research paradigms has been established to propel specific agendas and goals in various professional domains. For instance, natural sciences and engineering mostly adopt positivism, drawing on natural laws as a research paradigm driving data collection and analysis by using quantitative, observational and experimental processes [1, 2]. Simultaneously, humanities and arts mostly employ interpretivism to recognize subjective thoughts and social context peculiarities using qualitative approaches, including interviews, focus group discussions, and ethnography to explore issues. Cohen et al. [3] explained that researchers adopting the interpretive paradigm offer the chance to see issues from the participants' views other than those of the researchers.

The body of theoretical and applied knowledge in the various disciplines continues to expand with research and development. However, knowledge worthy of exploration exists in between disciplinary fields. Such in-between knowledge may best be approached by multi-disciplinary or inter-disciplinary researchers, which opens doors for exploring knowledge not usually accessible through disciplinary research, enhances understanding, consolidates knowledge, induces creativity, and dissolves boundaries. The need to better understand complex phenomena demands synergy between and among various disciplinary areas. Hence, multi-, inter-, and trans-disciplinary research with a blend of ideas from different fields and disciplines emerged. With the emergence of this approach, the mixed methods movement among researchers agreed that methods (objective and subjective) and ideas from different fields could be tapped to understand complex issues [4]. Researchers subscribing to these research approaches recognize the need for combining efforts, specialized disciplinary knowledge, and diverse research methods to explore issues and develop new ideas.

Despite gaining currency and considered beneficial, inter-disciplinary approaches are not without some challenges [5–7]. Therefore, this chapter discusses the opportunities and challenges of the multi-, inter- and trans-disciplinary research approaches drawing on the experience of the University of Sharjah (UoS). In the next section, we present the conceptual discourse, followed by the opportunities and challenges of the methods using UoS as a case study. In the last section, we present the conclusion, state the implications for practice, and share a framework for enhancing the adoption of multi-, inter and trans-disciplinary research.

2 Conceptual Discourse

The following conceptual discourse covers previously published discussions and conclusions in the literature regarding the key concepts related to this study. Namely research paradigm, multi-disciplinary research, inter-disciplinary research, and trans-disciplinary research.

2.1 Definition and Types of Research Paradigm

The research paradigm concept has been extensively discussed in the literature, with its definition, importance, and features clarified. In Kivunja et al. [8], it is explained that a paradigm represents the principles used by researchers selecting the appropriate methods for conducting their studies. Researchers sometimes encounter challenges in their research due to the lack of knowledge of paradigm types and their implications [9]. Thus, it is essential to understand and explicitly clarify the paradigm followed in research proposals and projects to determine the strategies for collecting and analyzing data.

As Lincoln and Guba [10] contended, a paradigm is characterized by four main elements – epistemology, ontology, methodology, and axiology. In terms of types, many have been proposed in the literature. For instance, paradigms were initially grouped into three main categories: (1) positivist, (2) interpretivist/constructivist, and (3) critical/transformative paradigms [11]. Researchers then proposed a fourth paradigm type combining the three components mentioned earlier: (4) the pragmatic paradigm [12].

The positivist paradigm is known as the scientific method of investigation [8]. This type of research is based on logic, hypothesis formulation, testing, and various mathematical operations to derive conclusions. The interpretivist/constructivist paradigm is mainly based on understanding the subjective world of human experience, which emphasizes on comprehending the subject's viewpoint under observations rather than the observer's perspective [10]. A theory is then generated based on the data from the conducted work. The critical/transformative paradigm involves research work undertaken to promote social justice and address economic, social, and political issues related to marginalized and underprivileged individuals [8]. The pragmatic paradigm was proposed in order to establish a paradigm that involves a combination of all these methods aiming at understanding human behavior and complex issues in a pragmatic way [8].

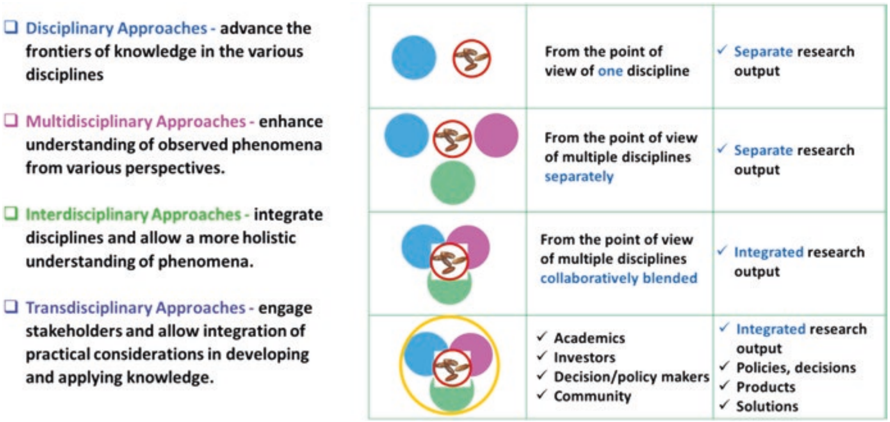

Fig. 1 Illustration of the disciplinary, multidisciplinary, interdisciplinary and transdisciplinary research approaches

2.2 Conception, Opportunities and Challenges of Different Research Approaches

An illustration showing the basic definition of the disciplinary, multi-disciplinary, inter-disciplinary, and trans-disciplinary research approaches is presented in Fig. 1.

2.2.1 Multi-Disciplinary Research

Multi-disciplinary research features a combination of knowledge from various fields and disciplines to help understand more complex phenomena. In multi-disciplinary research, scientific and social challenges are independently addressed by two or more disciplinary domains [13]. In other words, research is considered multi-disciplinary when researchers from diverse fieldwork collaborate, but within the limits of their fields [14]. Research in the environmental area is a prime example of multi-disciplinary research, where engineering, ecology, geosciences, physics, and other disciplines can independently, yet collectively, aid in the solution of environmental challenges. Besides, most well-known universities worldwide became involved in multi-disciplinary research to establish collaborative work in medicine and other clinical health care fields [14]. An example of multi-disciplinary research outcome was identifying approximately 25,000 genes in human DNA, which resulted from co-operative work between engineers, biologists, bioinformatics specialists, and other scientists [14]. Moreover, multi-disciplinary research has been widely implemented between anthropologists and psychologists, which resulted in fundamental theoretical advances [15].

Even though adopting the multi-disciplinary approach in research work enables advanced investigations of more complex cases, such an approach faces multiple challenges [6]. One main challenge facing multi-disciplinary research is that independent contribution of the participating discipline may restrict achieving the intended results. Thus, it is sometimes required to create new concepts based on shared knowledge in an inter-disciplinary manner [14]. Another challenge is related to the data-collection requirements of each researcher, which usually requires some trade-offs, thus hindering the team's ability to meet all the needs of the researchers [6].

2.2.2 Inter-Disciplinary Research

Inter-disciplinary research could be conceptualized as integrating the analytical strengths of multiple distinct disciplines to solve a given problem [16]. Such integration leads to eliminating the commonly faced gaps and challenges in terminology, approach, and methodology. The main difference between multi– and inter-disciplinary research is that the latter relies on shared knowledge created upon the direct interaction between disciplines, rather than the independent nature of multi-disciplinary research [13].

Inter-disciplinary research has gained significant ground over the years due to the nature of interactive work that results in accomplishing further objectives and obtaining better outcomes. For instance, research work conducted in the nanoscience field is directly based on the interactive work from chemical synthesis and physics disciplines [13]. Besides, molecular biologists, behavioral scientists, and even mathematicians could combine their knowledge to solve complex health issues, such as obesity and pain causes [16]. Moreover, one major scientific field is sustainability science, a field aimed at combining multiple disciplines to aid sustainable development, and which is considered either inter- or trans-disciplinary, rather than multi-disciplinary [17]. Perhaps, this is because it may be challenging to realize the goals of sustainability science without the synthesis of ideas from many disciplinary domains.

The engagement of researchers in inter-disciplinary research has undoubtedly increased over the past years, shown in a study conducted by Silva et al. [7], where it was quantitively confirmed that science fields are becoming more inter-disciplinary. In this study, the degree of inter-disciplinarity showed a strong statistical correlation with the strength and impact of the publishing journals. Also, Carr et al. [5] reported that inter-disciplinary collaboration in publications is rising, based on the analysis of publications in the Institute for Scientific Information (ISI) journals. However, inter-disciplinary research could face a few challenges in implementation, mainly due to the disciplinary boundaries limiting communication between team members and stakeholders [18].

2.2.3 Trans-Disciplinary Research

Trans-disciplinary research is considered similar to inter-disciplinary research, as both are based on the interactive work between researchers from various disciplines, and sharing their knowledge beyond their specializations. However, the main difference between both types is that inter-disciplinary research primarily merges the work of academics in developing an integrated research output and product [19]. On the other hand, trans-disciplinary research encompasses different contributors (stakeholders) working collectively to utilize the knowledge outside their academic scopes, such as generating practical solutions, products, or policies to resolve issues [19].

One of the advantages of trans-disciplinary research is the ability to resolve highly complex and interdependent problems, where issues are unpredictable, not associated with a particular sector/discipline, and require the contribution from multiple stakeholders outside academia for decision-making purposes [20]. For instance, trans-disciplinary research could resolve various societal problems, which constitute significantly high complexity [21]. In such a case, the research results can be integrated with an action-oriented process among the stakeholders involved in providing practical solutions. The efficiency of trans-disciplinary research has been proven in multiple fields, where human interaction with natural systems or significant technical development is required [21].

One main field that requires trans-disciplinary research is sustainable science, which often requires either inter- or trans-disciplinary research, but mostly tends to need the second of the two [17]. Sustainability research problems are significantly considered complex, as they represent several problems and sub-problems belonging to various distinct sectors and disciplines and are constantly changing [17, 21]. Therefore, trans-disciplinary research offers the opportunity to combine different knowledge systems, leading to more effective collaboration between science, policy, and society, resulting in more appropriate solutions to the sustainable science field [22].

As mentioned earlier, one of the merits of trans-disciplinary research is combining the knowledge and efforts of a wide range of stakeholders, along with those of the researchers, to reach practical solutions. However, such an advantage could potentially create multiple challenges for conducting trans-disciplinary research. In particular, the wide variations in values, preferences, and beliefs of decision-makers and stakeholders could further escalate the complexity of problems [21].

2.2.4 Examples of Research Approaches and their Collaborative Activities

The clarification of the various research approaches can be deduced from the research tasks associated with exploring the use and impact of chemicals extracted from plants, as an example. A chemist may study the chemical composition of the plant extracts, which requires several preparation steps, such as grinding and extraction of active ingredients from plants, developing and applying analytical testing methods, and identifying and classifying chemicals according to types and quantities. Microbiologists may assess the antibiotic properties of plants, which requires preparation steps similar to those used by the chemists studying the chemical composition of the extract. Additionally, the pharmacists are needed to assess the anti-cancer properties of plant extracts and biotechnologists to study the genetic effects of plants extracts. Chemists, microbiologists, pharmacists, and biotechnologists can generate research outcomes separately. However, microbiologists utilizing cook-book chemical techniques may not directly benefit from the expertise of a chemistry specialist in a team of chemists and microbiologists.

On the other hand, a team of chemists, microbiologists, biotechnologists, and pharmacists may work in an inter-disciplinary team focusing on the common goal of producing medical preparations from the plant extracts, as shown in Table 1. In such an inter-disciplinary team, the various team members bring the benefits of their expertise to produce a more scientifically sound and comprehensive outcome. Furthermore, inter-disciplinary collaboration makes researchers more aware of the various field tools, which provides opportunities for adopting such tools in their own disciplines. For example, an environmental specialist working on the production of biofuels from plant waste material may observe microbial inhibition due to the presence of antimicrobial agents in the plant material, which can then be further confirmed and understood through testing the anti-microbial, anti-cancer, and genetic effects of such materials.

Table 1 Example of research tasks exploring the use and impact of chemicals extracted from plants

<table>
<tr><th rowspan="2">Task No.</th><th rowspan="2">Task</th><th rowspan="2">Common Tasks</th><th colspan="3">Research Nature and Output</th></tr>
<tr><th>Multi</th><th>Inter</th><th>Trans</th></tr>
<tr><td>1.</td><td>Grinding & extraction</td><td rowspan="3">Common to tasks 4, 5, 6, 7 & 8</td><td rowspan="3">Chemistry</td><td rowspan="8">Various combinations, (i.e., chemistry+ microbiology + pharmacy) with common purpose of testing a potential medicine from plant extract</td><td rowspan="8">Various combinations (i.e., scientists, community, government, business & industry) depending on desired outcome</td></tr>
<tr><td>2.</td><td>Preparation of chemicals</td></tr>
<tr><td>3.</td><td>Testing chemical composition</td></tr>
<tr><td>4.</td><td>Testing anti-microbial effects</td><td></td><td>Microbiology</td></tr>
<tr><td>5.</td><td>Testing anti-cancer effects</td><td></td><td>Pharmacy</td></tr>
<tr><td>6.</td><td>Characterizing genetic effects</td><td></td><td>Biotechnology</td></tr>
<tr><td>7.</td><td>Conducting clinical trials</td><td></td><td>Medical, social</td></tr>
<tr><td>8.</td><td>Producing biofuel from waste</td><td></td><td>Environment</td></tr>
</table>

The benefits of multi-disciplinary and inter-disciplinary research collaboration extend to reducing efforts through sharing common tasks leading to various shared outputs involving various discipline foci. An example of such benefits and outcomes is illustrated in Table 2 [23–25]. The project described here aims at assessing the presence, fate, and potential impacts of emerging contaminants in wastewater in Sharjah, United Arab Emirates. In this case, the project team involves a chemist, a pharmacist, an environmental specialist, a plant biologist, and a public health expert. Since the team members focus on common goals and objectives, the contribution of the team specialists are negotiated and agreed upon in an attempt to maximize and share benefits. The results of such combined effort will lead not only to enhanced understanding of the phenomena, but also to shared publications and research grants among the team members that otherwise would not have been possible.

3 Research Context of University of Sharjah

In 2014, the University of Sharjah (UoS) opted for reorganizing research management around three research institutes serving researchers and students from the various colleges despite the tendency to maintain research managed by the academic colleges and departments. The Medical and Health Sciences Research Institute serves four medical and health colleges. The Research Institute of Sciences and Engineering serves the sciences, engineering and computing colleges. And the

Table 2 Examples of multi-disciplinary and inter-disciplinary team collaboration project

Task	Task	Common tasks	Team	Publications
1.	Development of novel analytical methods	Common disciplinary task Inter-disciplinary orientation	Chemistry, pharmacy, environmental science, engineering, plant biology & public health	"Simultaneous determination of pharmaceuticals by solid-phase extraction and liquid chromatography-tandem mass spectrometry" [24].
2.	Identification and quantification of chemicals			
3.	Analysis of wastewater treatment plant performance	Inter-disciplinary		"Contaminants of emerging concern in Sharjah wastewater treatment plant, Sharjah, UAE" [25].
4.	Analysis of human health risk from exposure	Inter-disciplinary		"Human health risk assessment of pharmaceuticals in treated wastewater reused for non-potable applications in Sharjah, United Arab Emirates" [23].
5.	Uptake of pharmaceuticals by plants	Inter-disciplinary		Uptake of select pharmaceuticals by leafy plants (under review)

Humanities and Social Sciences Institute serves five colleges: Arts, Humanities and Social Sciences; Business Administration; Communication; Law; and Sharia and Islamic Studies. The main purpose of this organization was to encourage cross-disciplinary collaboration through funding multi-disciplinary and inter-disciplinary research groups. Each research institute coordinates and funds research, providing opportunities for different research initiatives focusing on multi-disciplinary and inter-disciplinary studies. Since 2015, a total of 27 research groups/lines were formed in the Research Institute of Sciences and Engineering. Figure 2 indicates the number of academic departments involved in the various listed research groups/lines. A few research groups consist of researchers from one discipline. For example, researchers in the Civil Engineering Department formed two groups, with one focused on structural systems and the other on infrastructure. The various subdisciplines involved in the infrastructure group are shown in Fig. 3, which illustrates that seemingly disciplinary groups are in fact multi-disciplinary in the new research structure. In fact, the UoS research outcome has increased since this reorganization as evidenced by the number of research publications in the various research databases.

Apart from research activities, UoS is moving towards establishing unique multi-disciplinary/inter-disciplinary graduate programs to support research in the aforementioned centers and groups. For example, the Research Institute of Sciences and Engineering initiated various programs in collaboration with the concerned academic colleges and other UoS research institutes. Such programs include MSc. in

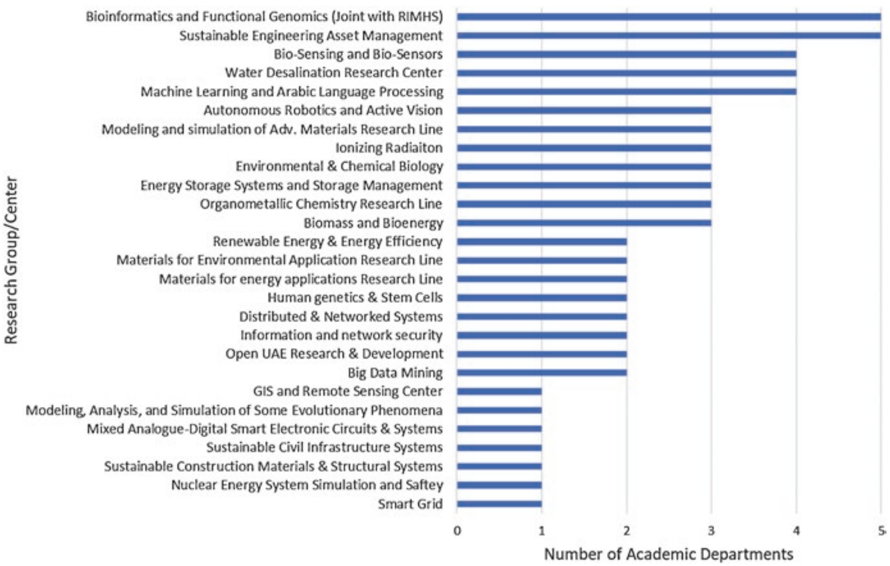

Fig. 2 Number of academic departments from the three colleges of Sciences, Engineering and Computing and Informatics represented in the various research groups/lines in the Research Institute of Sciences and Engineering at UoS

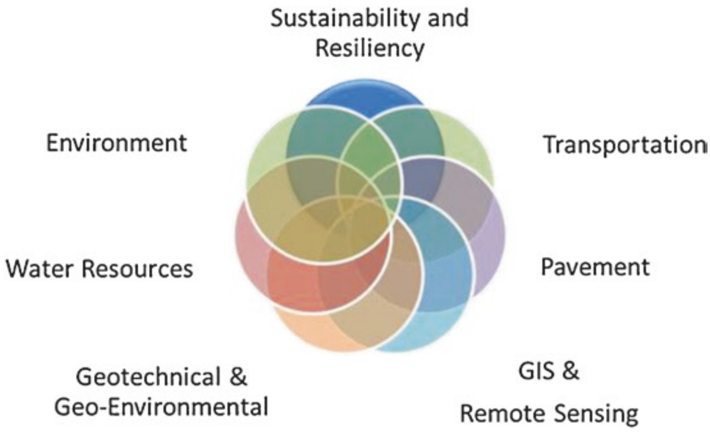

Fig. 3 Disciplines in the infrastructure research group in Civil Engineering Department at UoS

Environmental Sciences and Engineering; MSc. in Geographic Information Systems and Remote Sensing, and MSc. in Biomedical Engineering.

4 Opportunities in Multi-Disciplinary and Inter-Disciplinary Research

As stated earlier, a combination of methods grounded in different disciplinary philosophies offers many opportunities to strengthen research output and sustainable impacts. Some of these are:

- Meeting the personal interests of researchers to solve complex societal problems
- Potential for increased production and impact through collaborative endeavours
- Enhanced quality and citations of research publications
- Reduction of efforts through sharing common research resources and tasks
- Reduction of stress through team support and networking opportunities
- Opportunities to deal with complicated and real-life problems in society
- Participation in multi-and inter-disciplinary funding opportunities [13, 19, 22]

As drawn from the experience of the Research Institute of Sciences and Engineering, these research approaches increase the quality of research output and citations, thereby strengthening the institution's research reputation. Combining efforts and harnessing resources, including project software and required acumen, also save time, energy, and research assets. The approaches promote team and network building, both internally within the university and externally with other organizations. Through group and network building, faculty and researchers build synergy and access to more collaborative funded research and projects.

As Table 2 indicates, many research projects have been successfully conducted using different research orientations at the Research Institute of Sciences and Engineering, and findings were published in reputable journals. Despite the multi- and inter-disciplinary research opportunities, it is essential to acknowledge the inherent limitations and possible challenges to these research approaches.

5 Limitations and Challenges to Multi-Disciplinary and Inter-Disciplinary Research

The lack of clarity on rules and responsibilities, actual or perceived, can cause conflict and possibly resentment [26]. Roncaglia [26] identified four risk factors in multi-disciplinary teamwork: communication barriers; accessibility and availability of resources; group size; and accountability. The same limitations may also apply to inter-disciplinary teamwork. Communication barriers may be attributed to team members prioritizing their disciplinary contributions and lacking agreement on common aims and goals. Sharing available resources promptly and communication of data about resources are essential to nurturing teamwork and collaboration. Team size is another issue that may threaten collaboration, sharing of resources, shifting responsibilities, and productivity. The risk of misjudgment may also arise when team members from different disciplines differ in their approach and assessment, or when interdependence among team members results in ambiguity in terms of rules and responsibilities.

The following are possible challenges and limitations to multi-disciplinary and inter-disciplinary research [6, 14, 18, 21, 27, 28]:

- The dominance of disciplinary academic systems: Although all scholars acknowledge the need for collaborative research in concept development and innovation, it was found that some disciplines dominate others, thereby discouraging scholars from some fields.
- Administration and organizational boundaries: Some regulations and boundaries are considered favorable to some disciplinary areas, which may discourage collaboration among scholars from different fields.
- Promotion and incentives bias against other disciplines: Negative sentiments about co-authors may discourage scholars from being engaged in collaborative research of multi or inter-disciplinary nature.
- Publication obstacles: Some journals do not accept papers and findings emerging from multi- and inter-disciplinary research, perhaps because of preferences for specific disciplinary-focused publications. Differences in referencing style could also pose challenges for some scholars, which could discourage them from engaging in multi- and inter-disciplinary studies.
- Available funding opportunities: There are also limited funding opportunities for collaborative research. More so, some focused disciplinary studies are sometimes

promoted through institutional policies, which could be influenced by some perceived societal needs for scientific innovations.
- Skills needed for engagement in integrative research: Limitations in the research skills to employ and integrate different research philosophical paradigms and methods are also challenges hindering collaborative research.
- Time factor: Lack of enough time to plan and engage in multi-disciplinary research, possibly because of some official duties, may hinder the scholars' involvement in collaborative research. These may include teaching course loads and engagement in committees. Differences in time zone may also hinder valuable international collaborative research for educators.
- Reliance on technology: Over-reliance on technological tools as one of the conditions for funding and perceived effectiveness of inter-disciplinary research may discourage some scholars from collaborative research. For some scholars, they may not need technological tools. Still, funding for research assistants and the misconception about using technology could discourage those scholars from applying for collaborative research funding.

6 Skills for Multi-Disciplinary and Inter-Disciplinary Research

Nolan [29] suggested that inter-disciplinary and multi-disciplinary approaches require overcoming professional boundaries and rely on trust, tolerance, and sharing of responsibilities. The following are a set of skills required for successful multi- and inter -disciplinary research [26, 30–32]:

- ***Effective leadership:*** In any multi- or inter-disciplinary research, there is a need to have leaders with sufficient skills to ensure the participation of all team members and efficient sharing of resources and responsibilities, which is essential to improve processes and outcomes.
- ***Overcoming professional boundaries:*** Multi- and inter-disciplinary research require overcoming professional boundaries between members through showing respect for the various disciplines and trust in each other's roles and competencies, as well as the willingness to share responsibilities and outcomes.
- ***Communication:*** Researchers need to clearly communicate the contribution of their disciplines to other members from different fields. Effective communication requires team members to agree on common aims and goals and to recognize the contributions of other team members and their disciplines.
- ***Trust and tolerance:*** It is required to establish a level of trust between members in each other's competencies and accept the perspectives of other members.
- ***Self-management and adaptability:*** Researchers need to carefully identify their research priorities and to adapt to the way other members from different disciplines evaluate problems.

- ***Non-technical skills:*** Being able to establish good relationships with other members is essential for every researcher in order to have better communication, conflict management, and producing high-quality deliverables.

7 Conclusion

This chapter explored the opportunities and challenges in collaborative research endeavors using the inter-disciplinary and multi-disciplinary approaches. We looked into the extant literature on this subject and offered insight into the experiences of UoS. And drawing on the perspective from the Research Institute of Sciences and Engineering specifically, we concluded that multi-disciplinary and inter-disciplinary research have immense benefits to scholars and the community in addressing complex problems. We contended that using either of the two research approaches is not without some challenges and hindering factors. As such, stakeholders such as researchers, institutional leaders, and funding bodies need to keep exploring strategies for enhancing research grounded in the pragmatic paradigm using a combination of expertise and specializations. Table 3 shows the possible measures and efforts required for promoting and strengthening multi-disciplinary and inter-disciplinary research. Working with colleagues from other fields can foster research effectiveness for resolving complex issues, and enhance the adoption of collaborative research.

Management teams in institutions have to create a culture of collaboration, supported by appropriate policies and to raise awareness about the prospect of collaborative research along with adequate training. Besides, they need to provide essential

Table 3 Framework for promoting and strengthening multi-disciplinary and inter-disciplinary research

Faculty	Management	Funding agency
Appreciating teamwork and collaboration Respecting and showing interest in other disciplines and their contributions Showing openness to learn new research-focused skills and benefit from other disciplines Willingness to share knowledge & compromising in collaborative research Dedicating scheduled time for collaborative research where responsibilities are shared	Inducing cultural change and removing unproductive boundaries Balancing disciplinary and collaborative research through leadership, policies and incentives Ensuring consistent strategies and policies Raising awareness and training Providing incentives (e.g., teaching load reduction), infrastructure and funding Reducing pressure to publish in top foreign journals and in foreign languages	Setting clear goals, objectives and expectations while proving adequate resources Having benefits directed towards social knowledge and technology-based economies Supporting the publication of findings from funded projects Offering training opportunities both locally and internationally Promoting collaboration among researchers to foster cross-fertilization of knowledge

incentives, funding, and faculty resources to tap on multi- and inter-disciplinary research. With the need for research visibility fostering impacts and promoting institutional images, management needs to encourage faculty to publish in reputable journals, but this needs to be done moderately. The funding bodies also need to set clear rules and policies encouraging multi-disciplinary and inter-disciplinary research proposals. They need to promote research that focuses on different societal dimensions, tapping into the scholars' knowledge and expertise with various disciplinary orientations.

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