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Article

Vaccine Hesitancy: When Political Miscommunication Replaces Scientific Benefit/Risk Assessment

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Around the world, scientists, manufacturers and governments jumped into the race to develop a vaccine to combat COVID-19 and its associated lockdowns. A global response was required since defeating the pandemic requires global alignment. The availability of COVID-19 vaccines has always been a major concern for the WHO particularly in low and middle-income countries. While the vaccine development programs moved successfully forward, another problem, vaccine hesitancy, became a worrying factor in the movement towards herd immunity in many countries. Several factors contribute to this predicament.[1]

First, there is confusion between *vaccines* and *vaccinations*. Many people refuse to accept "mandated" vaccination, because they consider their health decisions to be a personal choice and a matter of individual dignity. Government mandates have revealed a deep disconnection between the government and society. The problem is not exclusively the safety and efficacy of any one vaccine *per se*, but a backlash against a public health intervention that is viewed as coercive.

Experts give their informed, evidence-based opinions on vaccines, yet vaccination programs are political decisions made in consideration of national and global public health perspectives. The decision to recommend and/or mandate vaccination is not only a benefit/risk assessment but also factors in societal, economic and other related issues deemed important by political leadership. These non-health related factors are complex and difficult to explain to the general population as they rely on information and interests from different areas of society and are not always immediately clear in their motivations and broader purposes.

Second is the ability of national, regional and global pharmacovigilance (PV) systems to provide a clear and united vision of the efficiency and safety of COVID-19 vaccines. Currently PV systems are oriented to the detection, via large databases, of side effects using automatic signal detection based on statistical disproportionality, resulting in the identification of short-term, high level clinical events. However, in some cases the clinical relevance and the broader public health impact is unclear. "Black Swan" clinical events can easily be taken out of context and misused and manipulated for other purposes in various media platforms like social media. Other tools like pharmacoepidemiologic studies should be promptly implemented in order to provide a nuanced and realistic vision of reality. The use of pharmacoepidemiologic tools is needed in more local settings as well to accurately assess the impact of Black Swan-like signals in specific national and regional contexts. "Detailing the facts" will aid in both developing and optimizing the local response and communications.

We believe that miscommunication is a major component of global vaccine hesitancy for many reasons. The spread of misinformation plays a dangerous role, particularly as anti-vaccination campaigns play politics with the public health and magnify the mistrust of many people[2]. The appearance of rare unforeseen side effects, like thrombotic events, are disproportionally magnified by the media, raising undue public concern. Appropriate due diligence of all side effects is needed, but so is a clear communication of the data and facts available from trustworthy organizations

with little delay.[3,4] This can only be done in partnership with public health authorities, healthcare providers and the media. Lack of a consolidated and coordinated reaction to an identified Black Swan event and its legitimate place in the benefit/risk analysis hampers the successful implementation of vaccination strategies. Inconsistency, lack of proportionality and lack of clarity in the communication of available facts must be urgently avoided.

These issues are not unique to low-and-middle-income nations. As such, global cooperation is the order of the day. Ecosystem problems require ecosystem solutions. The real formula is well known – dedication and a lot of effort from healthcare professionals, patients, academicians, transnational organizations and, yes – even politicians from every corner of the globe. Easy to articulate but difficult to implement.

A "one-size-fits-all" strategy, where the impact of any individual signal is considered relevant for all contexts, is no longer valid or productive. Communications measures should be aimed at protecting and supporting the trust of the public and ensure that a problem like vaccine hesitancy cannot derail efforts to defeat a global pandemic – where every jab counts.

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Article

Value over Volume: Maximizing Resources by Prioritizing Value: The Dubai Healthcare Experience

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ABSTRACT

The mission of the Dubai Health Authority is to transform healthcare delivery by fostering innovative and integrated care models and enhancing community engagement. The Authority's programs are designed to move the emirate's healthcare system forward by being mutually supportive, constituency inclusive, accountable and outcomes-based. Dubai's healthcare policy leadership has adopted a strategy to drive and ensure compliance and accountability through an innovative health governance framework. At its core, Dubai's healthcare strategy begins with its Care Model Innovation Program. This key initiative is designed to promote innovation and efficiency and ensure that Dubai residents (citizens) and visitors (non-citizen residents) have access to high quality services across the continuum of care.

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INTRODUCTION

Dubai is often known as the "home of superlatives:" the biggest malls, the tallest building, the newest technologies. But the most important (and often unrecognized) local trait is speed to best practice implementation. In more Western parlance, the emirate isn't just about indoor skiing in searing summer heat. It's public policy action. Consider Dubai's healthcare delivery system. The emirate talks the talk and walks the walk. Mandatory health insurance was enacted in 2014 requiring that by 2016 every employee and dependent residing in Dubai must be medically insured.[1] Four years later, close to 100% of Dubai's population is now covered and have financial access to health care. (See Figure 1) And it's not just about a speed trophy – the results are also impressive.

The mission of the Dubai Health Authority is to transform healthcare delivery by fostering innovative and integrated care models and enhancing community engagement. The Authority's three goals (see Figure 2) are designed to move the emirate's healthcare system forward by being mutually supportive, constituency inclusive, accountable and outcomes-based.

The Authority strives to reach these goals through six core values:

1. Customer centricity
2. Efficiency
3. Engaged and motivated workforce
4. Accountability and transparency
5. Innovation
6. Excellence

Dubai's healthcare policy leadership has adopted a strategy to drive and ensure compliance and accountability through an innovative health governance framework. At its core, Dubai's healthcare strategy begins with its Care Model Innovation Program. This key initiative is designed to promote innovation and efficiency and ensure that Dubai residents (citizens) and visitors (non-citizen residents) have access to high quality services across the continuum of care.

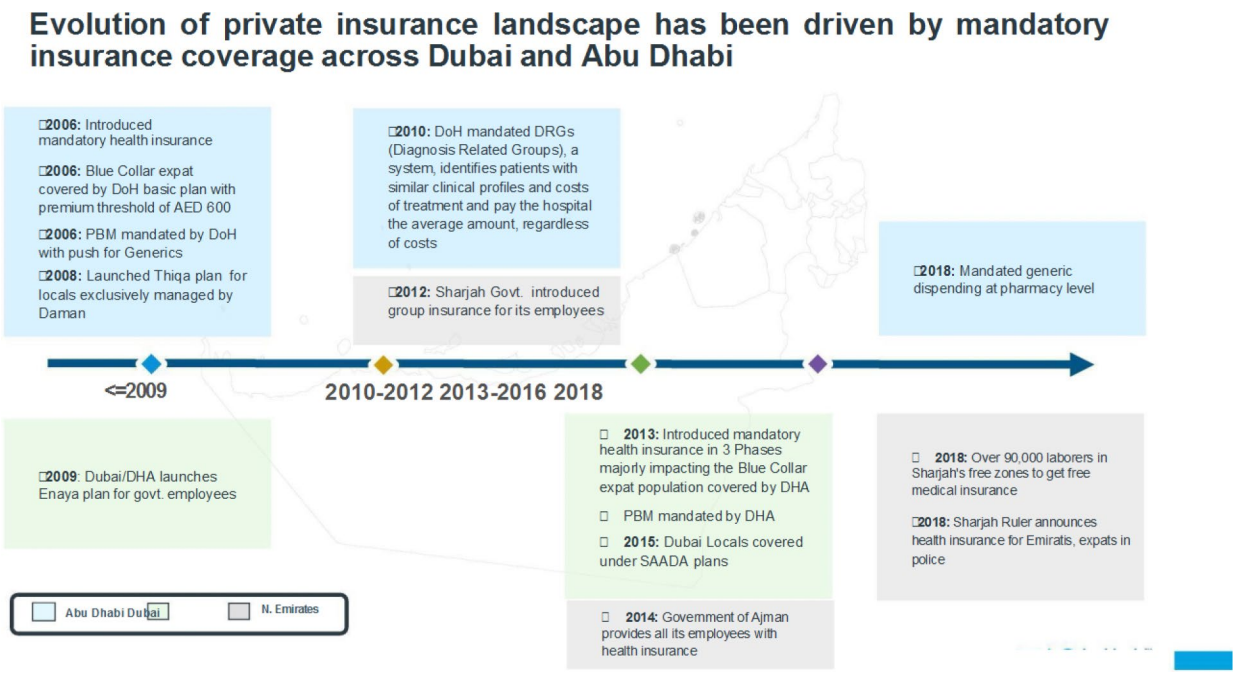

Figure 1

Figure 2

The strategy introduces innovative care models to fill existing care delivery gaps and enable an integrated cost-effective, patient and innovation-oriented care delivery system.

Dubai's Care Model Innovation design contains ten distinct aspects:

1. Develop and implement a strategy for special-needs patients
2. Innovate in the delivery of ambulatory surgery
3. Introduce and promote the use of telemedicine solutions

4. Introduce innovative medical technologies in the provision of healthcare services
5. Promote innovation culture
6. Enhance home and remote care
7. Reinforce the use of patient engagement tools
8. Develop pharma interventions to provide solutions beyond the pill
9. Innovate in the delivery of rehabilitation care
10. Continually innovate the healthcare delivery ecosystem

VALUE OVER VOLUME

At DUPHAT 2021 (the largest pharmaceutical event in Middle East and Africa)[2], Dr. Mohamed Farghaly (head of the Dubai Health Authority's insurance medical regulation department) outlined both the strategic implications and tactical realities of pharmaceutical costs on Dubai's health insurance system. The key "red thread" of his presentation was "value over volume" – that cost, while receiving the lion's share of healthcare headlines, is only one of many above the line variables with value (defined as positive patient outcomes) the driving "bottom line" denominator of the healthcare equation. (See Figure 3).

Dr. Farghaly began his presentation by making clear what volume-based cost-containment options were off the table: Brand-to-generic substitution at point of dispensation (pharmacies) and non-medical switching from brand to generic drugs or innovator biologics to biosimilars, mandatory step therapy, or in any way interfering with a physician's authority to practice medicine as she sees fit for any given patient. According to Dr. Farghaly, empowered physicians deliver better results and, hence, greater value to both their patients and the healthcare system in Dubai.

In a recent study of German cardiologists[3], researchers found that more than 14% of physicians in the quantitative study and over one third of physicians in the qualitative study chose not to participate in a government-initiated cardiology program because of concerns related to freedom – especially out of fear for their own professional autonomy as such or in relation to prescription regulations as well as the patients' free choice of medical practitioners. As one physician commented, "I think professional autonomy is heavily threatened here by the cardiology program." They especially perceived an emergence of unilateral dependence instead of cooperation. This is likely based on the imbalance of power within the program.

Research from other national programs reinforce the concept of rewarding positive patient outcomes versus tertiary savings based on formulary restrictions and impinging upon the prescribing authority of a physician.[4] A disempowered physician is likely to provide fewer medical services – including more aggressive use of innovative medical technologies, including diagnostics,

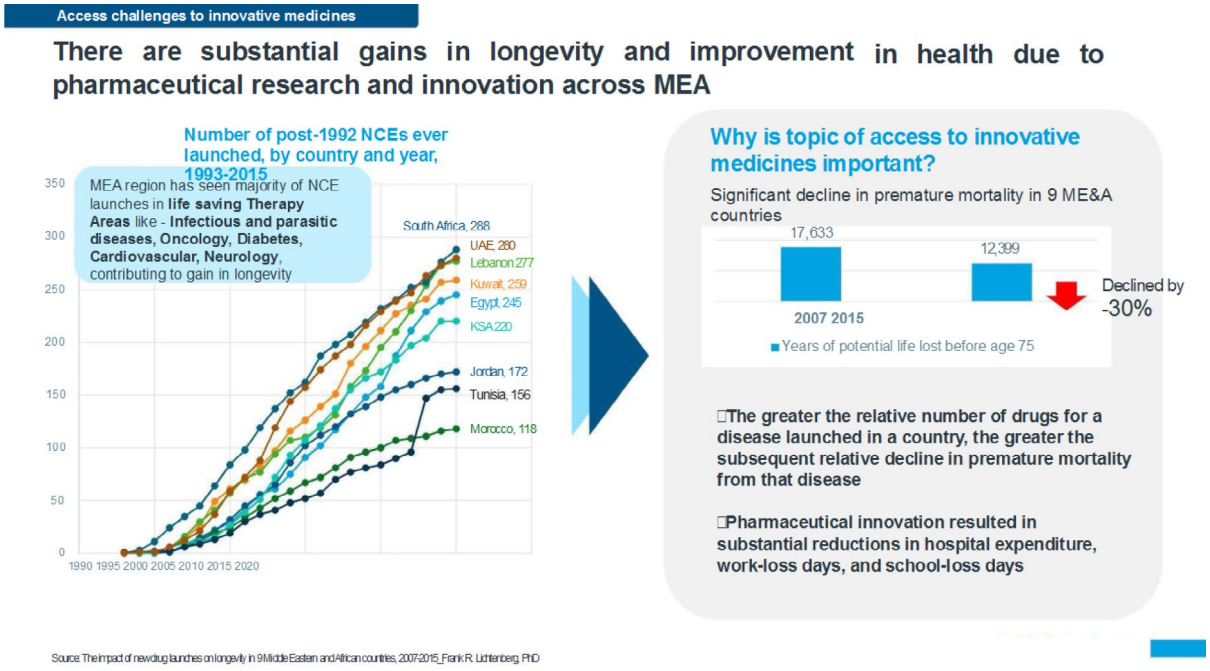

Figure 3

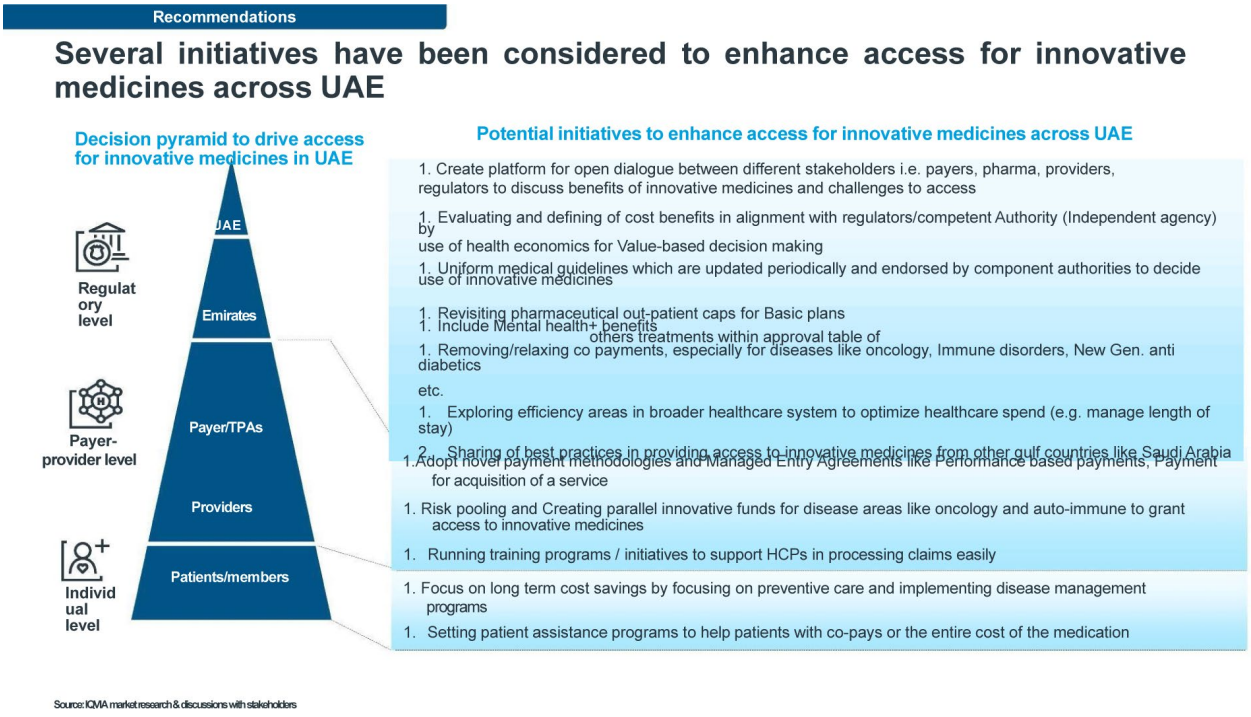

Figure 4

devices and therapeutics. The increasing pressure of non-medical budgetary constraints has a direct impact on the value of any given healthcare provider's lifetime of experience and hands-on patient contact.

Another foundational concept that is helping to propel the UAE's healthcare system forward is open, honest and regular communications with the various parts of their healthcare ecosystem. (See Figure 4).

An important lesson is that dialogue counts. The UAE has been particularly good at managing an open-door policy with the innovative biopharmaceutical sector, maintaining a good dialogue with the industry on policies that could affect patients or the sector. And this extends to the emirate level, with Abu Dhabi setting up a new industry-government Advisory Council to collaborate on policies to boost investment, employment and innovation in the sector.[5] As per Dr. Farghaly, achieving "value over volume" is contingent on driving timely positive patient outcomes – and that's a team effort. "Value" as the denominator of the healthcare equation demands that multiple voices be heard – and heeded.

LESSONS LEARNED FROM THE COVID-19 EXPERIENCE

"Value over Volume" recognizes that, when it comes to advancing the public health, whether in the East, West or the Gulf Peninsula – we are all in this together. Get ready world, the "Gulf Tiger" is poised for global leadership in the smart and savvy delivery of cost-effective, patient-focused healthcare.

ENDNOTES

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Article

A Systematic Review of Bioentrepreneurship Education

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ABSTRACT

Bioentrepreneurship education is the academic sub-field concerned with programs or courses designed to teach the knowledge, skills, and attitudes required for biotechnology entrepreneurship. This paper reviews the developments in bioentrepreneurship education, based on journal articles, editorials, books, book chapters, theses, and conference proceedings. The results indicate the field continues to develop, is represented by studies from multiple regions, and involves partnerships between university departments and between universities and the local biotech sector. Three themes are put forward and discussed with regards to developing the sub-field. These are (1) programmatic versus embedding approaches, (2) the need for industry stakeholder views on bioentrepreneurship education, and, (3) development toward a common (but not the same) bioentrepreneurship curriculum.

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Keywords: Bioentrepreneurship, Bioentrepreneurship education, Instructional design

INTRODUCTION

Biotechnology (biotech) entrepreneurship, according to Shimasaki, refers to "the sum of all the activities performed through a team of individuals, working together over time, to build an enterprise that creates and commercializes life-changing products through the melding of scientific and business disciplines"[1] and Meyers and Hurley say that bioentrepreneurship education is generally understood as the programs or courses designed to teach the knowledge, skills, and attitudes required for those activities either by the entrepreneurs or by those interested in life science commercialization[2]. This paper is about the state of the field of bioentrepreneurship education.

Over the past three decades, the need for bioentrepreneurship education has developed in response to the emergence and growth of the biotech field. Initially, the founders of biotech start-ups were scientists who learned on-the-job the business of science[3]. As the industry grew, so too did the need for scientists who understood the entrepreneurial process. Programs in bioentrepreneurship began to appear at universities where biotech start-ups were being founded by faculty and students. Initially and predominantly, this was in The United States of America, but over time programs were established in other countries too. As the biotech field developed and new technical sub-fields evolved (drug development, diagnostics, medical technology, agrotechnology, nanotechnology, digital healthcare), so too have the educational offerings and the professional activities, such as societies and conferences, leading Meyer to describe bioentrepreneurship education as an "emerging field" that is involved a "global effort of students, faculty, administrators, and their partners in offering training and education to those interested in creating and learning bioscience companies" [4].

Such a claim is to say that bioentrepreneurship education displays at least some of the characteristics associated with academic fields, including an object of research and an accumulated specialist knowledge about that object that is not generally shared with another discipline, including theories and concepts, specific terminologies, and methods. And most crucially, academic fields have some institutional manifestation in the form of subjects taught at universities or colleges, respective academic departments, and professional associations connected to it and who build and sustain it[5,6]. So, more than ten years since Meyers' claim, *is bioentrepreneurship education still emerging as an academic field? How global is that effort? Which partnerships do we know about?* And *what is needed to move is forward?* Addressing these questions is the aim of this paper.

THE REVIEW APPROACH.

Searches of *Google Scholar* and *Scopus* for publications using the terms "bioentrepreneurship education", "bioenterprise education", "biotechnology entrepreneurship" or "bioentrepreneurship program" returned 99 results. Excluding those where the terms appeared in reference lists only (n=25), in passing remarks (n=2) or other publications on the same page (n=2), and those written in languages other than English (n=3), provided a data set of 67 results that were reviewed.

Each result was coded for its general aim, educational context (program or course level, target learner, credit/curricula or non-credit/extra-curricular), instructional design (explicit or implicit), and regional focus (e.g. The United States of America, Europe-United Kingdom, Asia-Pacific, multiple regions).

Analyzing the coding for field emergence characteristics, three key patterns emerged: (1) programmatic versus embedding approaches, (2) the need for industry stakeholder views on bioentrepreneurship education, and, (3) development toward a common (but not the same) bioentrepreneurship curriculum. To address the question, *what is needed to move it forward?* these themes are discussed in the final section.

FINDINGS

The findings from the literature review are presented to address three sub-questions about field emergence, global reach, and partner involvement in bioentrepreneurship education.

Is bioentrepreneurship education still an emerging academic field?

Most results are articles or commentaries published in academic journals (n = 55). The other types of publications are books and book chapters (n = 7), conference proceedings (n = 4), and a Master thesis (n = 1). Moreover, 61 of the 67 results have been published since bioentrepreneurship education was characterized as an emerging field[2]. 143 results appeared in 2009, with eight of those in the first bioentrepreneurship education special issue in the *Journal of Commercial Biotechnology*[4]. Since 2014, publication rates have been consistent with two to six publications each year. The exceptions to this were 2014 when there were 9 publications and 2017 when there were 11 publications, with eight of those being in the second bioentrepreneurship education special issue published in *Technology Transfer and Entrepreneurship*, including Gunn's [7] guest editorial. The pattern indicates that bioentrepreneurship education continues to develop.

These results indicate that bioentrepreneurship education is the core topic in most of the results (n = 50). Within those results, the issues covered included the development of new courses and programs aimed at learners with various disciplinary backgrounds, the challenges of a multidisciplinary teaching, balancing the teaching and assessment of (business) practice and (business) theory, the production of learning materials and learning experiences that reflect the biotechnology industry, and the perennial issues of academic-industry collaboration and intra-university coordination. Broad statements about the role of education and wider biotechnology trends or a bioentrepreneurship class being the context for other subjects were the two ways that bioentrepreneurship education appeared as a peripheral topic (n = 17).

The education levels reported in the results range across the education system; High school (n = 3), Undergraduate/Bachelor level (n = 6), Graduate/Master level (n =29), MD or PhD (n = 5), Other studies referred to higher education generally or across all educational levels, such extra-curricular and professional training (n = 11), or not specified (n = 13).

How global is that effort?

Expectedly, most of the results focused on bioentrepreneurship education in The United States of America (n = 33) or The US was one of several contexts studied (n = 2). This is expected given the central role that the US clusters played in the emergence and development of the global biotech field. What these studies offer are the descriptions of various programs and the experiences of several teaching initiatives to adapt general entrepreneurship methods to the biotech context.

What is surprising is the range of studies covering most regions and multiple countries with those regions. European experiences of bioentrepreneurship education are described in studies from Belgium, The Netherlands, Finland, Lithuania, Poland, Portugal, Sweden, and Switzerland. A common feature of these studies is the European paradox, which is the failure to translate scientific advances into marketable innovations, as a driver for bioentrepreneurship education. African experiences include Nigeria and multiple papers about the South African context. What is common in these studies is the argument that bioentrepreneurship can improve the economic situation and deliver local solutions. From the Asia-Pacific region, studies include a five-country comparison, multiple studies of Indonesia, Australia, and a comparison of a New Zealand and a

Table 1: Summary of chronologically ordered Bioentrepreneurship Education Publications

Author	Year	Title	Source	Focus	Edcontext	Regional Focus
Tang et al.	2003	Realizing potential: The state of Asia bioentrepreneurship	Nature Biotechnology	P	Not specified	Asia
Collet & Waytt	2005	"Bioneering" - Teaching biotechnology entrepreneurship at the undergraduate level	Education and Training	C	UG	Australia
Cooke	2007	European asymmetries: A comparative analysis of German and UK biotechnology clusters	Science and Public Policy	P	Not specified	United Kingdom and Europe
Friedman	2008	Best practices in Biotechnology education	Book	C	Other	Australia, Canada, New Zealand, South Africa, The USA
Ketolainen	2008	Designing a model for business training in Finnish biotechnology companies	Master thesis	C	Other	Finland
Meyers & Hurley	2008	Bioentrepreneurship education programmes in the United States	Journal of Commercial Biotechnology	C	Grad	The USA
Allan et al.	2009	Bioscience enterprise: Postgraduate education at Cambridge and Auckland	Journal of Commercial Biotechnology	C	Grad	United Kingdom, New Zealand
Back	2009	The Bioentrepreneurship MBA	Journal of Commercial Biotechnology	C	Grad	The USA
Brown & Kant	2009	Creating bioentrepreneurs: How graduate student organisations foster science entrepreneurship	Journal of Commercial Biotechnology	C	Other	The USA
Conroy & Khan	2009	Integrating virtual internships into online classrooms	Journal of Commercial Biotechnology	P	Grad	The USA
Crispeels et al.	2009	Best practices for developing university bioentrepreneurship education programmes	Journal of Commercial Biotechnology	C	Grad	Belgium
Gravagna	2009	Creating alternatives in science	Journal of Commercial Biotechnology	C	MD/PhD	The USA
Iyer & Fitzgibbon	2009	Building the future biotechnology workforce: A University of Houston model	Journal of Commercial Biotechnology	C	UG	The USA
Langer	2009	The implementation of a proseminar course to lead change in the MS.MBA biotechnology programme at Johns Hopkins University	Journal of Commercial Biotechnology	C	Grad	The USA
Meyers	2009	Editorial -Special Issue	Journal of Commercial Biotechnology	C	Not specified	Not specified
Meyers et al.	2009	Open content textbooks: Educating the next generation of bioentrepreneurs in developing economies	Journal of Commercial Biotechnology	C	Grad	Not specified

Author	Year	Title	Source	Focus	Edcontext	Regional Focus
Tirrell & Thomas	2009	Team-based learning in Keck Graduate Institute's professional Master of Bioscience programme	Journal of Commercial Biotechnology	C	Grad	The USA
York et al.	2009	Teaming in biotechnology commercialisation: The diversity-performance connection and how university programmes can make a difference	Journal of Commercial Biotechnology	C	Grad	The USA
York et al.	2009	Building biotechnology teams: Personality does matter	Journal of Commercial Biotechnology	P	Grad	The USA
Salgaller & Marincola	2010	Biotechnology entrepreneurship - where no research has gone before	Journal of Translational Medicine	P	Not specified	The USA
Hestness et al.	2011	Day Startup: Molding student entrepreneurs for fun and non-profit	INTED2011 Conference Proceedings	C	Other	The USA and Europe
Boni & Weingart	2012	Building teams in entrepreneurial companies	Journal of Commercial Biotechnology	C	Not specified	The USA
Meyers	2012	The Birth of a Discipline	Journal of Commercial Biotechnology	P	Not specified	The USA
Parthasarathy et al.	2012	The University of Colorado Certificate Program in Bioinnovation and Entrepreneurship: An interdisciplinary, cross-campus model.	Journal of Commercial Biotechnology	C	Grad	The USA
Sammut & Boni	2012	The biotechnology entrepreneurship boot camp: From lectern to printing press	Journal of Commercial Biotechnology	C	MD/PhD	The USA
Gunn et al.	2013	An Agile, Cross-Discipline Model for Developing Bio-Enterprise Professionals	Journal of Commercial Biotechnology	C	Grad	The USA
Guldemont, et al.	2014	Entrepreneurship and Technology Transfer Education at the Vrije Universiteit Brussel	Book chapter	P	Grad	Belgium
Gunn & Lorton	2014	Measuring the Effectiveness of Global Immersive Study Tours to Attract Non-Scientific Working Professionals to the Bio-Enterprise	Technology Transfer and Entrepreneurship	C	Grad	The USA
Iltchev & Marczak	2014	Business plan financial model in teaching medical students' entrepreneurship	Book chapter	C	Grad	Poland
Khuntia et al.	2014	The University of Colorado Digital Health Consortium Initiative: A Collaborative Model of Education, Research and Service	Journal of Commercial Biotechnology	P	Not specified	The USA
Langer	2014	Building a curriculum for bioentrepreneurs	Nature Biotechnology	C	Grad	The USA

Author	Year	Title	Source	Focus	Edcontext	Regional Focus
Maia & Claro	2014	Biodesigning with European undergraduates: Adaptation, trade-offs, and outcomes	Conference Proceedings	C	Grad	Portugal
Meyers	2014	Bioentrepreneurship Education and Training Trends	Journal of Commercial Biotechnology	C	Other	Not specified
Meyers & Castro	2014	MD/PhDs or MD/MBAs: which do we need more to innovate in	PMFA News	C	MD/PhD	The USA
Shimasaki	2014	Biotechnology Entrepreneurship: Starting, Managing, and Leading Biotech Companies	Book	P	Not specified	The USA
Uctu et al.	2014	Bio-entrepreneurship as a bridge between science and business in a regional cluster: South Africa's first attempts	Science and Public Policy	C	Other	South Africa
Langer	2015	Correspondence	Nature Biotechnology	C	Grad	Not specified
Meyers	2015	Bioentrepreneurship: opportunities and challenges	Book chapter	P	Not specified	Not specified
Parthasarathy et al.	2015	The University of Colorado certificate program in bioinnovation and entrepreneurship: An update and current status	Journal of Commercial Biotechnology	C	Grad	The USA
Rosier & O'connell	2015	Nuances in the entrepreneurship training tool box	Nature Biotechnology	C	Not specified	Not specified
Gunn	2016	When science meets entrepreneurship	Journal of Entrepreneurship Education	C	Grad	The USA
Gunn	2016	Perception Over Fact: A Media Case Study of the Life Sciences Cluster in Puerto Rico	Technology Transfer and Entrepreneurship	C	Not specified	Puerto Rico
Gunn et al.	2016	The BIEM Verification Study: Experienced Venture Capitalists Assess a Biopharmaceuticals Innovation Expertise Model.	Journal of Commercial Biotechnology	C	Grad	The USA
Kazakeviciute et al.	2016	Curriculum development for technology-based entrepreneurship education: A cross-disciplinary and cross-cultural approach	Industry and Higher Education	C	UG	Lithuania
Martin et al.	2016	Teaching public health professional entrepreneurship: An integrated approach	Journal of Enterprising Culture	C	Grad	The USA
Retra et al.	2016	Educating the science–business professional	Industry and Higher Education	P	UG	The Netherlands
Anderle & Huynh-Do	2017	Educating Scientists in Translational and Entrepreneurial Medicine: Unmet Needs and Challenges	Technology Transfer and Entrepreneurship	C	Grad	Switzerland

Author	Year	Title	Source	Focus	Edcontext	Regional Focus
Ardhiansyah	2017	Critical thinking skill of XI grade students Sma Muhammadiyah 1 Purwokerto with bioentrepreneurship based learning	Proceedings of International Conference on Indonesian Islam, Education and Science (ICIIES)	P	UG	Indonesia
Bridge	2017	The Struggle to Establish Bioentrepreneurship Education Programs: An Australian Perspective	Technology Transfer and Entrepreneurship	C	UG	Australia
Cullis	2017	Biotechnology Entrepreneurship Graduate Education Based in a Biology Department-Case Western Reserve University	Technology Transfer and Entrepreneurship	C	Grad	The USA
Gunn	2017	Introduction to the 'Bioentrepreneurship Education' Issue	Technology Transfer and Entrepreneurship	C	Not specified	Multiple
Gunn & Langer	2017	One Course, Two… Four Courses–A Bioentrepreneurship Concentration-Case Studies: Johns Hopkins University and the University of San Francisco	Technology Transfer and Entrepreneurship	C	Grad	The USA
Gunn et al.	2017	Gender Differences in Graduate Bioentrepreneurship Education-A Case Study: University of San Francisco	Technology Transfer and Entrepreneurship	C	Grad	The USA
Jamison-McClung & Kjelstrom	2017	A Cross-Disciplinary Doctoral Emphasis in Bioentrepreneurship: A Case Study of the University of California Davis Biotechnology Program	Technology Transfer and Entrepreneurship	C	MD/PhD	The USA
Jansson & Lek	2017	A Corporate Entrepreneurship Approach to Bioentrepreneurship Education at the Karolinska Institutet	Technology Transfer and Entrepreneurship	C	Grad	Sweden
Langer	2017	Developing Global Biotechnology Enterprise, Entrepreneurship and Regulatory Science Programs: Profile from the Center for Biotechnology Education at Johns Hopkins University	Technology Transfer and Entrepreneurship	C	Grad	The USA
Warra	2017	Entrepreneurial biotechnology: A resource to Nigeria economy	Journal of Microbiology and Biotechnology Reports	P	Other	Nigeria
Ulfa et al.	2018	Developing creativity and entrepreneurial values in high school student through project based learning model on biotechnology concept	EDUSAINS	P	HS	Indonesia

Author	Year	Title	Source	Focus	Edcontext	Regional Focus
Zajicek & Meyers	2018	Digital Health Entrepreneurship	Digital Health	P	HS	The USA
Boni et al	2019	Transforming Technology into High-Value Solutions for Compelling Biomedical Needs: Bio Entrepreneurship Bootcamp 2.0	Journal of Commercial Biotechnology	C	MD/PhD	The USA
Cullis	2019	Developing collaborative international biotechnology entrepreneurship programs	Conference Proceedings	C	Grad	The USA
Natadiwijaya et al.	2019	Preservices creative thinking skills on biotechneur programs	Journal of Physics: Conference Series	P	Other	Indonesia
Ectu & Essop	2020	Identifying the strength and weaknesses of the South African tech-based industries: Insights from the Swiss South African business development programme	African Journal of Science, Technology, Innovation and Development	C	Other	South Africa
Ectu et al.	2020	Evaluating South Africa's tech-entrepreneurship programme for venture creation through the eyes of the participants	Industry and Higher Education	C	Other	South Africa
Fayolle et al.	2020	Effective models of science, technology and engineering entrepreneurship education: current and future research	The Journal of Technology Transfer	P	Not specified	Not specified
Oguntuase	2020	The Effectiveness of Student Worksheet (Project-Based Learning) Based on The Values of Islamic Boarding School for The Biotechnology Subject to Train High School Students with Bioentrepreneuship Skills	Jurnal Inovasi Pembelajaran Biologi	C	HS	Indonesia
Oguntuase	2020	Academic Entrepreneurship, Bioeconomy, and Sustainable Development	Book chapter	C	Other	Not specified

Key Focus: C=bioentrepreneurship education is the core topic in the publication. P= bioentrepreneurship education is a peripheral topic in the publication
EdContext=Educational Context: HS=High school, UG=Undergraduate/Bachelor level, Grad=Graduate/Master level, MD/PhD=Doctoral, Other= other studies referred to higher education generally or across all educational levels, Not specified= the level of educational study is not specified.
Regional focus: The USA= The United States of America, Multiple=multiple regions listed by the authors, Not specified = the country or region is not specified.

United Kingdom program. They have similar arguments about the potential of bioentrepreneurship to drive economic growth and they highlight the institutional factors inhibiting the industry's growth and the role of education.

Strikingly missing are studies of bioentrepreneurship education in Latin America, the Middle East, and the wider United Kingdom. The biotech sector in these regions has received industry, academic, and public policy attention for some time[8,9], and multiple initiatives have supported the establishment of bioentrepreneurship education. Studies that describe and evaluate these efforts and compare them to educational efforts in other jurisdictions are yet to appear.

Which partnerships do we know about?

Industry-university, public-private, pharma-biotech, start-up-incumbent, and clusters, consortia, and constellations are all forms of partnerships regularly used in the biotech field despite the known challenges of

collaboration[10]. When it comes to bioentrepreneurship education, partnership models are apparent too.

Various intra-university arrangements between schools of science, engineering, business, and law to deliver multiple-disciplinary bioentrepreneurship education have reported the benefits and challenges from learning and organizing perspectives. On the learning side, the benefits include more integrative learning experiences that better reflect work in the biotech sector and expose students to and prepare graduates for entrepreneurial careers[11,12], but the challenges include teaching bioentrepreneurship to students from different disciplinary backgrounds and different career aspirations of working *as* the bioentrepreneur as opposed to *with* or *for* the bioentrepreneur[13–15]. On the organizational side, the benefits of cross-faculty arrangements include developing internal capacity to service the growing interest in and demand for bioentrepreneurship education and helping to legitimize the commercialization of science. However, the organizational challenges are multiple. Perennial issues of control of decision-making and internal competition for student enrolments are reported in multiple jurisdictions[16,17]. Moreover, bioentrepreneurship programs report challenges of securing appropriate adjunct staff with appropriate industry and teaching experience[18].

Looking at the partnerships between educational institutions and the biotech sector, there appears to be a set of common conduit activities that connect bioentrepreneurship education and the ecosystem. Guest speakers, site visits, company projects, international study tours, and internships have all been reported as valuable learning activities and assessment tools in bioentrepreneurship education curricula. On this, two points are noteworthy. First, multiple studies indicate that the demand for and success of bioentrepreneurship education is shaped by the activity in the local environment[2,12,13,19–26], suggesting that bioentrepreneurship educators and administrators should understand the value their local biotech sector gain from their programs. Second, given the dynamic nature of biotech ecosystems[27], it is important that educators and administrators of existing bioentrepreneurship education review and update their programs to reflect local developments, as well as global trends.

DISCUSSION

To the question *what is needed to move bioentrepreneurship education forward?* three themes emerged from the review. These are discussed next.

1. Programmatic and embedding approaches to bioentrepreneurship education

A recognized set of subjects, teaching approaches, and assessment methods is a feature of an academic field[5] and when it comes to bioentrepreneurship education, there appear to be two schools of thought. One first school of thought can be classified as the 'programmatic' approach and it is characterized by programs of study designed primarily as accredited qualifications in bioentrepreneurship. They tend to be targeted at learners with science disciplinary backgrounds and are designed to teach the business of biotech in dedicated modules and courses.

Myers and Hurley's 2008 web-based survey of bioentrepreneurship programs in The US identified eight of 18 schools with these types of offerings. Since then, other North American examples described in the literature include the biotechnology doctoral program at the University of California Davis[28], Case Western Reserve University's masters in biotechnology entrepreneurship degree program[11], multiple qualifications offered at The Johns Hopkins University[18,24], the biotechnology specialization in the Master of Science in Information Systems degree the University of San Francisco[29,30], and the professional master program at Keck Graduate Institute of Applied Life Sciences[31].

Examples in other regions include Karolinksa Institute's master of bioentrepreneurship program in Sweden[23], the bioengineering master program in the Faculty of Engineering of the University of Porto[32], the master degree launched by the Swiss Institute for Translational and Entrepreneurial Medicine[33], the biotechnology program in the master degree at Free University of Brussels in Belgium[34] and the Master of Bioscience Enterprise programs at Cambridge University in the United Kingdom and The University of Auckland in New Zealand [19]. Programs at the undergraduate/bachelor level identified in the results were the University of Houston College of Technology's biotechnology degree program[13], QUT's Bachelor of Biotechnology Innovation in Australia[35], and bachelor's program at Vrije Universiteit Amsterdam in The Netherlands[25].

The second school of thought can be classified as the 'embedding' approach and it can be characterized as bioentrepreneurship education that tends to be embedded in wider programs of study either as elective courses or majors within general degrees, such as an MBA. Also, in this approach are some non-credit or extra-curricular initiatives that provide professional training. The offerings are generally targeted at learners with several disciplinary backgrounds including engineering, medicine, and business, as well as science. They tend to emphasize the value of learners' prior knowledge, deliver content in ways that reflect what learners bring to the program,

and employ multi-disciplinary learning designs whereby teams can leverage the members' different skillsets.

Examples include the University of Colorado Denver's certificate in bioinnovation and entrepreneurship based on a combination of core and additional courses[15,36] and business plan teaching within the Medical University in Łódź in Poland[37]. Gunn and Langer[22] reported the use of this approach in the initial stages of establishing bioentrepreneurship at the University of San Francisco and Johns Hopkins and before programmatic qualifications were launched, but those courses were incorporated in the new qualifications. At the undergraduate/bachelor level, the program at Kaunas University of Technology in Lithuania illustrates this model for students enrolled in science, health, engineering, design, information technologies and other related fields[38] and the University of New South Wales in Australia has reported experimenting with this approach too[16].

Examples of extra-curricular initiatives that provide professional development include the 18 student-run life science organizations that Brown and Kant[39] identified in their 2008 web-based search, some of which have been described in more detail, including the Ph.D. science club at the Graduate School at the University of Colorado Denver[40]. The extra-curricular program for graduate students in public health at DePaul University in Chicago offers another example[41].

Professional development initiatives include the 3 Day Startup (3DS) model developed at the University of Texas at Austin and run in the US and Europe[42] and the two-day Biotechnology Entrepreneurship Boot Camp that has run at the annual BIO conference since 2005[43–45]. Also, described are several initiatives under the "Cape Biotech" strategy that develop business skills and mentoring [26].

Both approaches operate in multiple regions and respond to the needs of the local biotech sector and university structures and politics. Moreover, both models share similar learning activities and assessment tools, including guest speakers, site visits, and company projects. But, what is not clear is the relative effectiveness of each model in these different contexts or if and how they complement each other. For instance, in comparing the Cambridge University (United Kingdom) and University of Auckland (New Zealand) programs, Allan and her colleagues[19] recognized that differences in internship choices, thesis topics, and postgraduate employment opportunities were explained by differences in contextual factors. Similarly, the models at the Johns Hopkins University and the University of San Francisco[22] reflect the demand for technologists and medical professionals, whereas the corporate entrepreneurship focus in the Karolinska program reflects the Swedish industrial setting[23]. Therefore, closer attention is needed to understand the benefits, limitations, and trade-off of these different approaches both in terms of the learning experience and career prospects for the participants and for the local biotech sectors who hire and/invest in the graduate of these programs.

2. Industry stakeholder views on bioentrepreneurship education

The extant literature demonstrates the crucial role of the biotech industry in bioentrepreneurship education. The emergence and growth of new courses and programs are strongly related to the local industry's development, with programs strongly related to biotech start-up activity and research universities. It is apparent that the local biotech industry is involved in credit and non-credit offerings in multiple ways, including guest speakers and panelists, providing projects and hosting internships, and as adjunct instructors bringing industry trends and practices into the classroom. However, industry stakeholders are more than peripheral contributors who illustrate for learners how theory is applied in practice. Rather the industry is a key partner in the bioentrepreneurship education endeavor. Business practices in the biotech sector are dynamic and employers and investors want graduates with content knowledge that is relevant now and skills and attributes to see and act on opportunities (i.e. an entrepreneurial mindset)[25]. So, as well as evaluating how bioentrepreneurship education serves learners, bioentrepreneurship educators and administrators need to understand the value they offer our industry partners too. Here, two lines of work appear to require attention.

First, more work is needed to understand how industry partners judge current bioentrepreneurship offerings. It is rare for studies to report industry views in program evaluation and it is unclear why this is this case. Is it because educators and program managers are not asking them? Or, is it that they are not taking seriously industry views? Or, is that they know the views of the industry, but are not disseminating their learning to the wider bioentrepreneurship community? Whatever is the reason, knowing the industry's views can assist in the development of bioentrepreneurship education.

Second, more work is needed to understand what models are used to ensure that developments in the biotech sector are introduced into the curriculum. Building and maintaining instructor teams that involve research-active faculty and adjust staff with relevant industry experience and leveraging relationships with various ecosystem actors (e.g. the investment and consultancy communities, incubator, accelerator, and technology transfer intermediaries, and the like) are identified as elements of the bioentrepreneurship education field.

More intentional use of them to ensure the curriculum remains current would be beneficial. Moreover, models of how such relationships are developed and add value for all the partners involved.

3. Development of a common (but not the same) bioentrepreneurship curriculum

A common curriculum is a manifestation of an academic field[6] and as a step towards defining a body of core knowledge and learning objectives that satisfy the needs of the market (i.e. learners and the industry who employ them or fund their ventures) and various accreditation agencies, Meyers and Hurley offered a comprehensive curriculum as a first step[2]. Drawn from learning outcomes and topic lists of bioentrepreneurship syllabi provided others, the initial curriculum included multiple learning aims and objectives on the topics of the legal environment, marketing, finance, international trends, the regulatory environment, new product development, clinical trials and validation, business development and planning, manufacturing, technology management and commercialization, leadership, management, communication, and emotional and social intelligence skills.

To date, bioentrepreneurship educators and researchers have reported techniques for teaching some topics and have offered primarily learners' perceived satisfaction scores or fast feedback as evidence of their effectiveness. However, the value of such activities is the impact they have on learning. From an instructional design perspective, to evaluate the impacts of bioentrepreneurship learning outcomes, there is a need for authors to go beyond describing program initiatives and reporting perception data[46]. Such data are needed to examine and debate what makes up the bioentrepreneurship curriculum and what sets of techniques and methods are shown to be most effective for teaching and assessing it. Along these lines, bioentrepreneurship education educators and researchers would benefit from employing educational and instructional methodologies such as pre-and post-test surveys, action research, peer evaluation, reflection, and triangulation[47] to build a rich picture of the field's development.

From a field evolution perspective, field changes have flow-on effects and that includes what specialist knowledge is deemed important in the curriculum[6]. On this point, there has been little debate about what should (and should not) be in a common bioentrepreneurship curriculum. On the one hand, a common curriculum establishes what is generally recognized as the special knowledge, skills and abilities learned in a subject. While it is not a definitive list and nor does it specify the assessment tools for demonstrating knowledge, a common curriculum indicates some agreement in the field. On the other hand, as the previous sections established, bioentrepreneurship education is often a response to local industry needs, so parts of a common curriculum appear to be more (and less) relevant and other local needs are not in the common curriculum at all. Thus, more work is needed to debate what are the elements of a common bioentrepreneurship curriculum, recognizing they evolve as the industry evolves, and examining the different instructional approaches that support it. In this regard curriculum mapping, benchmarking, and comparative case analysis offer useful tools.

Related to the field development, a contemporary picture of the programs that universities offer, both in The United States and elsewhere, and what professional bodies support bioentrepreneurship education is needed for comparative analysis. Establishing subjects and programs of study in universities and creating professional associations are key characteristics of academic field building[5,6]. Beyond being proxies of field development, understanding what subjects and programs have launched (and terminated), where they are located, who they target, how they are delivered (in-class, online, hybrid), with whom (industry partners and other university partners), and, if and how their experiences differ from the early-movers are important in understanding how the field is developing. Practically, it tells educators and program managers what works and what doesn't. Similarly, understanding the work of professional associations such as the Society of Bioentrepreneurship Education and Research (www.siber.bio)[17] is another important step on the path of developing bioentrepreneurship education that is relevant to both learners and the industry.

CONCLUSION

Bioentrepreneurship education is intimately related to the biotechnology sector. This paper aimed to review the state of the field and to discuss where to next.

The field is developing, evidenced by the results since an initial bioentrepreneurship curriculum was sketched out in 2008, with the representation of experiences from multiple regions, and partnership activities within university departments and between universities and their local industry.

Three areas were outlined where more work is needed: (1) programmatic versus embedding approaches, (2) the need for Industry stakeholder views on bioentrepreneurship education, and (3) development toward a common (but not the same) bioentrepreneurship curriculum.

Finally, the limitations of the study should be noted. First, the search method is replicable, but the results may

omit other outputs that are relevant, especially conference proceedings that are not indexed for searching. Searches were run in *GoogleScholar* and *Scopus* to overcome this. Second, in focusing on three key themes in the Discussion, it is probable that there are other recognizable themes. On this point, the paper motivates readers to put forward other themes that they see as relevant, as well as take up and address some of the ones offered here.

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Educators' Corner Perspectives

Innovations arising from post-COVID-19 in Bioentrepreneurship Education

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INTRODUCTION

That COVID-19 has changed multiple facets of our working and social lives is a claim that few would challenge. COVID-19 also changed the focus of the business of biotechnology and how business is done[1,2]. New collaborations rapidly formed and cooperated openly, collegially, and virtually in ways rarely seen in a field where intellectual property rights loom large[3]. The papers published from these collaborations mapped out key features of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that have helped to identify drug candidates. In turn, incumbents of different sizes – from the multinational pharmaceutical corporations, through to small and medium-sized biotech firms – tapped the new streams of resources to redirect their portfolios and capabilities towards antiviral drugs and biologics, diagnostics, and vaccines. Media interest in vaccine development and the commercialization implications of upscaling production on a global scale has seen growing investor interest in R&D[4].

At the same time bioentrepreneurship education, and more precisely the learners, educators, administrators, and firms who participate in delivering programs that help prepare the field's next generation of leaders, were affected too. Like education in almost every corner of the world, early 2020 saw bioentrepreneurship educators and program administrators scramble to transform lectures, laboratories, case discussions, presentations, and other 'traditional' brick-and-mortar education into online learning. Moreover, our industry partners – the pharmaceutical firms, life science start-ups and university spin-offs, venture capital firms, public research organizations, and biotech consultancies – who host internships and site visits and provide industry guest speaker sessions and company-sponsored projects that keep bioentrepreneurship education at the edge of the field's evolving needs, helped us to pivot.

Bioentrepreneurship education is generally understood as the programs or courses designed to teach the knowledge, skills, and attitudes required for those activities performed either by entrepreneurs or by those interested in life science commercialization[5]. Bioentrepreneurship education grew out of the need for people who could bridge science and business[6] in an emerging field. What and how educators teach and what students learn and how they demonstrate their knowledge mirrors the growing and changing needs of the biotech field. Now, nearly twenty-four months since the World Health Organization declared a pandemic, we start to prepare for a post COVID-19 world. As vaccination rates rise so too do the restrictions that blocked on-campus learning, international travel and face-to-face collaboration, but how the experiences in dealing with the COVID-19 restrictions will reshape bioentrepreneurship education is just starting.

As bioentrepreneurship educators who have started to grapple with this subject, we notice growing interest in the post-COVID curriculum with commentaries and webinars and several online conference streams providing advice and debate on post-COVID education[7–9]. Similarly, discussions in professional societies, such as the Society of International Bioentrepreneurship Education and Research (SIBER)[10] indicate that post-COVID bioentrepreneurship education means more that 'just' returning to the "hybrid" classroom, where the traditional learning experience is now mixed with

new online teaching practices. The contribution of this educators' piece is to prompt engagement and discussion among and between educators and other key biotechnology partners in sketching out the needed changes in bioentrepreneurship education due to COVID-19. In this piece we outline how COVID-19 has shaped how bioentrepreneurship is taught and why we might want to maintain some of those practices as part of the future curriculum, namely of internships and company-sponsored projects, site visits and industry guest lecturers, and cross-institutional exchanges/joint programs. We summarize the importance of these changes for learners and for the biotechnology field. We also consider the challenges these might present for educators too.

THE ROLE OF INTERNSHIPS AND COMPANY-SPONSORED PROJECTS

Internships and company-sponsored projects are common features of many bioentrepreneurship programs because they offer learners first-hand local industry exposure and the opportunity to network and develop soft skills. Likewise, internships and company-sponsored projects provide firms access to cutting-edge science and an informal way to test the prospective graduate recruits in a competitive labor market[11]. While online bioentrepreneurship internships and company-sponsored projects existed before COVID-19[12], the dominant model was the in-person experience where learners worked at the firm's premises or visits for meetings. COVID-19 challenged the use of internships and company-sponsored projects due to both financial uncertainty and practical challenges of delivering them, with some estimates indicating that 22-39% of US college internships were cancelled in 2020[13]. However, firms and universities pivoted to provide online experiences and finding new ways to offer internships and company projects[12]. How these virtual experiences are being run offers new ways to leverage them in a post-COVID-19 world.

First, virtual internships and company projects are teaching students virtual networking skills. Biotechnology is global and hubs around the world are connected through multiple professional networks. Through virtual experiences, students are learning skills of networking virtually. The practical skills of reaching out to strangers through LinkedIn, professional association membership, and emails, and establishing relationships on Zoom, Skype and the like are the soft skills needed for working in a global field irrespective of a pandemic. Second, virtual internships are showing us that some tasks traditionally performed at work can in fact be completed elsewhere. Similarly, they offer students first-hand experience of what it means to collaborate virtually and use cloud-based project management and writing tools. This opens up new possibilities about the types of projects firms can offer and broadening the types of tasks they ask students to perform. On the student side, virtual experiences offer students first-hand experience of remote working. Third, virtual internships open up the opportunity of global internships. Where the traditional internship model privileges working for local firms to understand their local ecosystem, what virtual internships are teaching us is that firms can recruit students from anywhere, thus expanding their potential graduate labor pool. Similarly, for students, the opportunities of global virtual internships offers the prospect of exposure to several biotech ecosystems. Of course, different time differences present a new set of challenges, but again, developing the soft skills to work across time zones is a reality of professional life in a global industry.

SITE VISITS AND INDUSTRY GUEST LECTURERS

First-hand industry exposure is a key characteristic of bioentrepreneurship education[5] and site visits and industry guest lectures are two methods for achieving this. Site visits involve physical inspection of a workplace for the purpose of observing and learning. While site visits vary in length from hours at an individual company to week-long study tours meeting several firms[14], site visits provide learners the opportunity to explore and identify a multitude of career paths[15]. Industry guest speakers involve experts imparting their knowledge and lived experience directly to learners[16]. Common to the methods were the opportunity to students to learn others' first-hand experiences and the direct interaction with people in the local industry.

COVID-19 restrictions have had contrasting effects on these methods. Where site visits became all but impossible, the transition to Zoom and other online video technologies made industry guest lecturers more common with the creation of the "webinars". Similarly, the individual guest lecture often became the panel discussion as many in industry started to appreciate how challenging it is engage a bunch of strangers down the barrel of a laptop camera. Hundreds of guest lectures and panel discussion were recorded and many were shared publicly via Vimeo and YouTube, creating a rich source of materials for asynchronous learning. The advantage for learners has been two-fold and the benefits of these are still being leveraged. Beyond the opportunity to engage with speakers and panelists from around the world during webinars (either by unmuting

to talk or via chat or posting in the Q&A), students have been able to engage with other participants on the call. Subsequently, it is not just speakers or panelists who are participating from across the globe – it is also the audience. Not only can learners engage with guest lectures and audience in the live setting, the sharing of recordings provides students the opportunity to re-watch and deepen their exposure. Finally, it has opened up the potential for students to watch different recordings on the same topic. This type of exposure to the breadth of experiences from different biotech regions and different actors (founders, investors, managers, regulators and the like) is on a scale not available pre-COVID. Even for those well-endowed institutions situated in areas with well-develop biotech hubs, the length of the semester and number of teaching contact hours has always constrained the number of industry guest speakers that students are exposed to. COVID-19 has changed that calculus to the number of hours students can spend watching them on YouTube!

CROSS-INSTITUTIONAL EXCHANGES/JOINT PROGRAMS

Joint program across education institutions that co-teach biotechnology either within the same country or across countries have been important for bioentrepreneurship students for at least two reasons. They embed students in different professional networks that offer employment prospects [17] and they expose students to different subject expertise[18,19]. For programs that involve physical travel, COVID-19 travel restrictions has seen such programs stop. In contrast, programs that were delivered online, such as Johns Hopkins Master of Biotechnology Enterprise and Entrepreneurship[20] reported enrolment growth during COVID-19. Similarly, interest in bioentrepreneurship courses offered through Coursera, FutureLearn, EDx and other online providers grew[21]. Moreover, many extra-curricular programs, such as MIT Boot Camp[22] and ASCB's week-long biomedical business event[23] remain online.

The growing demand for bioentrepreneurship education, especially in given interest as a result of COVID-19[24], and the growth of offerings from different providers present new opportunities for universities to re-think their joint programs. The traditional reasons for overlooking online joint programs – students don't want to learn online and our institutions do not have online courses – do not seems to hold any longer. Moreover, the other reasons – the demand for such learning is low or we do not know how to collaborate virtually with other partners – have been challenged by the individual and organizational behaviors we have all recently observed and participated in. That leaves a further set of reasons – how to align learning outcomes and timing of the delivery of such courses – as ones that we can grapple with (and would come to better outcomes if we grappled with openly and collaboratively).

CONCLUSIONS

Our aim in writing this piece was to prompt engagement and discussion among and between educators and other key biotechnology partners in sketching out the needed changes in bioentrepreneurship education due to COVID-19. None of us have all the answers because the impact of COVID-19 will be felt for years to come. However, all of us have first-hand experiences of how COVID-19 impacts our working and social lives, and we have the privilege of talking of a post-COVID-19 world where we return to classroom, travel for meetings and conferences, and visit collaborators at their places of

Method	Importance for learner	Importance for the biotech field	Post-COVID Educator Challenges
Internships	First-hand experience Network building Soft skills	Informal job test Access to cutting-edge research Knowledge inputs	Topic expectation mgmt. Time differences
Company-sponsored projects	Academically bounded real-world problems	Controlled knowledge inputs	Expectation mgmt. Time frame alignment
Site visits	Vicarious learning Confidence	Promote the business	Engagement with virtual reality
Industry guest lecturers	Different perspectives Inspiration	Reciprocity Increase expert status	Audience priming
Cross-institutional exchanges/joint programs	Different institutional experiences Network building	Globally oriented graduates	Alignment of learning aims across programs

Figure 1. Summary of key Bioentrepreneurship teaching methods affected by COVID-19.

business (when many of our family, friends, colleagues and students who died from COVID-19 don't). Also, we have the ability to examine what happened and considered which of those lessons provide us ways to improve future bioentrepreneurship education. The COVID-19 pandemic resulted in previously unimaginable industry collaborations where due to intellectual property and proprietary information occurred, fueled by new resources. Can we take a lesson from and provide a global environment for biotechnology entrepreneurship education which can raise all of our programs considering the need for graduates in this sector? SIBER intends to lead this global effort.

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Article

Platform technology management of biotechnology companies in Japan

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ABSTRACT

This study quantitatively and chronologically analyzed the technology management of Japanese biotechnology companies using the patent application data of platforms and products, including patent categorization methods. Nine listed platform companies were analyzed. The results showed that most of the companies continuously maintained their initial platform technologies by filing updated patents, but without filing patents of new platform technologies. Their business models were shifted from a platform model to a platform-product, hybrid model and not a product-focused model. Their product patents generated from platform technologies were mainly for tools, diagnostics, and cell processing technologies, not therapeutics, except in one case; related therapeutics patents were mainly filed by corporate partners. Existing papers that analyzed Japanese biotechnology companies were verified to be partially correct based on our high-resolution patent categorization data; these results supported the usefulness of our approach.

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INTRODUCTION

BUSINESS MODEL CLASSIFICATION OF BIOTECHNOLOGY COMPANIES

Many biotechnology companies have followed the path of Cetus and Genentech since their establishment in the 1970s.[1] Such biotechnology companies characteristically start off with clear business ideas and straightforward funding purposes. However, their business models become un-workable once these initial ideas or purposes are fulfilled.[2]

Many researchers have used various perspectives and classification methods to categorize the business models of biotechnology companies depending on the purpose of the analysis. According to a literature review of studies on biotechnology in the past 15 years, business models of biotechnology companies were categorized into 22 classifications.[3] However, business models of biotechnology companies can be broadly categorized into three classifications: platform, product, and hybrid business models.[4] Case studies taken from several countries classified the business models of biotechnology companies in each country with platforms/products categorization methods.[5,6,7,8]

The product business model generates revenue by developing and commercializing drugs with or without corporate partners.[4] This is a high-risk, high-return business model as drug development requires a large amount of money and longer development duration while the expected revenues are high after the drug is launched or licensed.[4] On the other hand, the platform business model generates revenue by providing platform technologies such as research tools for drug development in pharmaceutical companies.[9] High throughput screening, combinatorial chemistry, and, ribonucleic acid (RNA) interference are examples of platform technologies provided as research tools or contracted services.[1] Platform technologies are also applied to a broad range of diseases and generates drug or diagnostics candidates.[3] The platform business model is considered a low-risk, low-return business model since platform technology can be developed with lower costs and in a shorter amount of

time. Compared to that of products, the revenues from platform technologies are lower.[4] Moreover, platform technologies cannot attract investment since patent-protected final products are valued higher while the platform technology that was used to generate the products is relatively valued lower.[1,4]

The hybrid business model is a combination of the platform and product business models as it provides platform technologies for pharmaceutical companies as a research tool and developing their own products. This business model earns revenues from pharmaceutical companies and by raising funds from investors. The money from these two sources is then directed to drug pipelines,[3,5,6] which are generated from their own platform technologies or in-licensed products from other companies.[4] If the products and platform technologies are relevant, there will be a synergistic effect on business expansion. Thus, among platform, product, and hybrid business models, the hybrid business model receives the largest amount of investment.[4] However, even with the hybrid business model, the revenue earned from platform technology is insufficient for product development.[5]

Further classifications include a distinction between "early drug developers" and "advanced stage drug developers." The former develops products until phase I/II, while the latter develops them at least up to phase III.[10] In other sub-classifications of product business model, companies that develop drugs for the mass market (e.g., diabetes or asthma) are classified as "development companies," while those that develop drugs for oncology or orphan diseases are classified as "specialty marketing companies."[9] In addition to the drug development process, if the company's activities cover manufacturing drugs, marketing, and sales, then the company is categorized as a "vertical integrated business model".[1,3,4]

MANAGEMENT OF BIOTECHNOLOGY COMPANIES IN EACH BUSINESS MODEL

For the product business model, the product sources, project management of drug development, and Life Cycle Management (LCM) have been analyzed. The inventors of drugs approved by the U. S. Food and Drug Administration from 1998 to 2007 were analyzed based on patent data. Over half of the innovative drugs reviewed under the priority review status have originated from biotechnology companies or universities and not pharmaceutical companies.[11] Innovative drugs tend to be generated from biotechnology companies or public research organizations since their high-risk tolerance allows them to initiate such projects.[12] A drug development process can be regarded as the project management of virtual companies since development projects are managed in the same way, whether they are run by pharmaceutical companies, biotechnology companies, or contract research organizations with or without collaborators.[13] Drug LCM could be further regarded as a part of management options for the product business model. The challenge in LCM is to maintain market exclusivity against competitive brands and generic drugs by extending the exclusive terms through the addition of new indications, formulations, and dosages, using additional patent protections and regulatory exclusivities.[14,15]

For the platform business model, we analyzed the relationship between patent and monopoly, differences in patent management between product and platform technology, sustainability of competitive advantage, and classifications of platform management. The historical trajectory of the Polymerase Chain Reaction platform technology is an example of a "virtual monopoly" where a single company owns all the key patents for innovative and unique platform technology.[16] Regarding the difference in the patent strategy between product and platform technologies, it is indicated that patent protection for a product is crucial in excluding competitors from drug sales. Meanwhile, the patent management of platform technology has become more complex than that for product since the former consists of technology elements that sometimes include a strategy not to patent as a means to maintain secrecy from competitive companies.[17] As for the sustainability of technology platforms, a case report, which selected eight biotechnology companies with at least five years of operational history in Sweden or Australia, proved that initial technology platforms were insufficient for business continuation, and new capabilities needed to be obtained. Among these eight companies, six abandoned their initial technology, and seven obtained new platform technologies or products.[18] A further classification of platform technology management was proposed: "initial platform technology updates, ,"applying initial technology for a new area," and "obtaining other platform technology;"[9] however, these were based on the opinions of an industry expert and did not provide any evidence beyond their expert opinion.

A report that analyzed the relationship between business model selection and funding sources in biotechnology companies between 1980 to 2009 pointed out that biotechnology companies established in the 1980s had obtained funds mainly from the stock market. Leveraging public funding after a long period of drug development was possible after positive results from a phase II study. However, after the 1990s, we note that funding from the stock market decreased while venture capital investments increased. We posit that this caused the redemption period to become shorter and the business model of biotechnology companies shifted from

product development to platform development to adapt to the shorter term.[19]

Business model classification was noted for the analysis of partnership structures as well. A paper which analyzed the alliances of biotechnology companies between 1974 to 2002 found that pharmaceutical companies were partners, and biotechnology companies provided drug targets and drug candidates to pharmaceutical companies. Then alliances between biotechnology companies and other biotechnology companies increased, and provided platform technologies in the 1990s. [20] In analyzing the alliance of 325 global biotechnology companies between 1973 to 1997, the number of products developed proved to be maximized when the alliance number per company was moderate.[21] This trend was a common feature regardless of the alliance characteristics (i.e.upstream or downstream) in the value chain, from early to later stage manufacturing and marketing. Comparison of the number of alliances of 87 European and American companies, showed that companies with hybrid business models had a larger number of alliances, suggesting to us that the management team could gain more investments by adopting a hybrid business model.[22]

Compared to product-based business models, few studies were conducted from the management perspective of platform technologies, except for three categorizations of platform technologies.[9] Since technologies were varied and platform technologies were rarely classified, these studies were qualitative observations of cases, based on interviews, expert opinions, or published data. Moreover, there was no chronological analysis based on quantitative data, such as patent data.

CHRONOLOGICAL BUSINESS MODEL CHANGE OF BIOTECHNOLOGY COMPANIES

Biotechnology company business models are not static and they change over ime. Thus, two dynamic concepts were proposed: "obtaining another platform technology"[9] and "shifting to product business model from a platform business model."[4,23] Since drug development has immense costs, biotechnology companies do not have sufficient funds, and therefore, tend to begin their business based on developing a platform technology.[3,9] One reason business models shift from platform to a hybrid or product business model is risk management; investor's risks can be reduced by the stable income generated by low-risk platform technology, while anticipating higher returns from product related technologies.[3,4,9] Another reason for the shift is the technological sustainability, as biotechnology companies often abandon their initial outdated technologies and shift business models to accommodate new platform technologies or products.[18] From our interview survey, an industry expert insisted that the reasons for this shift toward a product business model were investors' preferences and the biotechnology company's choice to gain investment.[9]

In American genomic companies, the main reason for the business model shift from platform to hybrid was to bring further investment, since the value of the drug candidate goes up along with clinical trial development from phase I to phase III.[24] In 7 of 75 biotechnology companies in Germany, the reason for the shift was to gain more licensing income from products once its platform technology began to earn income; furthermore, older companies tended to shift more, compared to younger ones.[5] However, a rare reverse case was reported that described the chronological business model shift of one biotechnology company in Finland, which initially aimed to develop a fully integrated business model that covered development, manufacturing, and marketing. However, they switched to a hybrid business model by obtaining platform technology, and eventually chose a platform business model by putting product developments aside.[6] These studies were based on interviews and qualitative data; however, no research was conducted by quantitatively observing chronological business model shifts. Thus, the reality of this shift remains uncertain, and will require further studies.

ISSUE OF BIOTECHNOLOGY COMPANY'S MANAGEMENT IN JAPAN

In the beginning of the 2000s, Japanese biotechnology companies demonstrated a tendency to focus on platform technologies due to constraints in investment , and thus, provided technologies to pharmaceutical companies in partnerships.[26] A company's platform technology cannot keep its competitive advantage forever. Therefore, the company's technology should be updated according to the competitive companies' activities and technological progress in the industry.[2,9] However, 80% of Japanese biotechnology companies in the Japan Biotechnology-industry Association's questionnaire survey in 2015 stated that their core technology had not changed since they began operating.[27] To examine the competitiveness of Japanese biotechnology companies, the quality of their initial technologies was compared with the USA, based on the forward citations of patents. It was found that forward citations were lower in Japan than in the USA, and the citations were corelated with the companies' growth in the USA, but not in Japan.[28] Regarding the profile of products in Japanese biotechnology companies, the analysis of the licensed out products of 16 listed Japanese biotechnology companies was conducted with classifications into small molecule or new modalities,

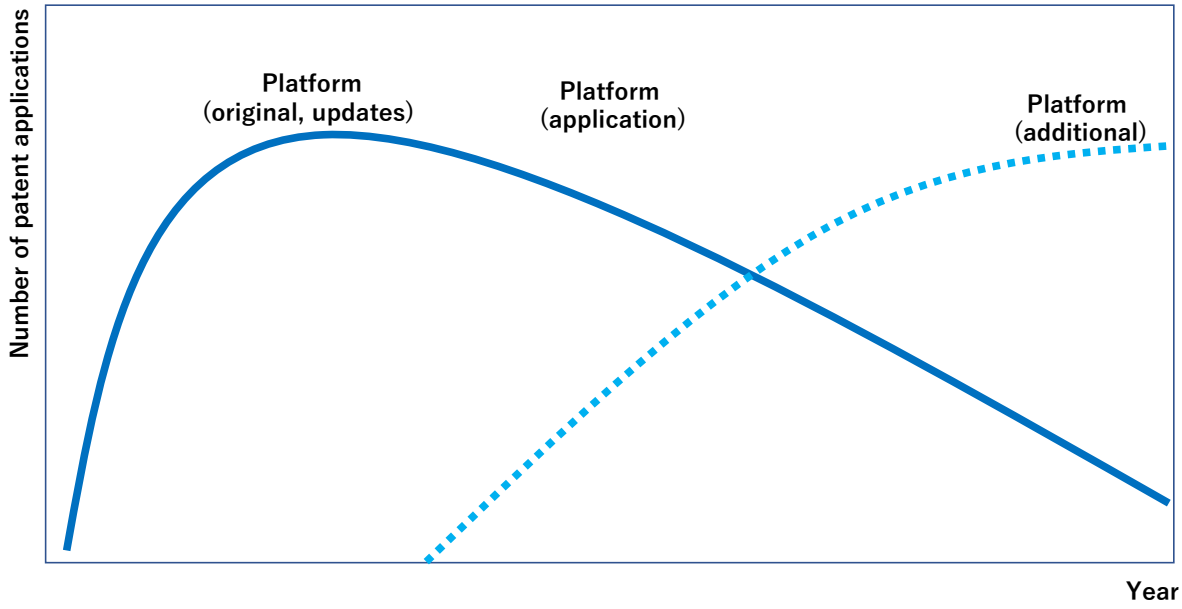

Figure 1 Hypothesis of platform patent applications

and self-developed or in-licensed.[29] Most of these drugs were 1) not innovative, 2) improved from existing products with same mode of actions, expecting low risk and high probability of licensing out, and 3) not generated from their own technology platforms.

These existing studies suggest that Japanese biotechnology companies tended to be established with a platform technology business model, and the initial technologies and products were less competitive compared to the USA. They also suggest that initial technologies were usually not updated and new, additional platforms were not introduced. Most of these studies are based on qualitative analysis (ex. questionnaire survey); therefore, it is necessary to analyze Japanese biotechnology companies more quantitatively based on objective data, to confirm these existing findings.

In this study, the management of the platform-type biotechnology companies in Japan was analyzed, chronologically distinguishing the technology between platforms and products using the improved quantitative patent analysis method for platform technology companies.

ANALYTICAL FRAMEWORK FOR DYNAMIC CHANGE OF TECHNOLOGY PORTFOLIO

In this research, the three categories of platform technology management proposed by Thong[9] were adopted in order to construct an analytical framework for observing the time series changes of technology categories and the dynamic change in the technology portfolio. The three existing categories were (1) "version updates," (2) "finding new areas of application," and, (3) "adding other platforms". Related patent applications that support platform technologies are sorted into each category. The three categories were just conceptual , not based on data such as period of filing, maintenance, and acquisition of patents. The framework in this research provides a chronological analysis of these three categories of concrete evidence for platform technology management using patent data.

"Version updates" could be observed when the original platform technology of a company is kept and updated (solid line, Figure 1). "Finding new areas of application" could be observed when the company adds applications generated from the technology platform, which claims specific and limited usage, but does not claim the product itself (broken line, Figure 1). "Adding other platforms" could be observed when the patent is applied in a different technology field (dotted line, Figure 1).

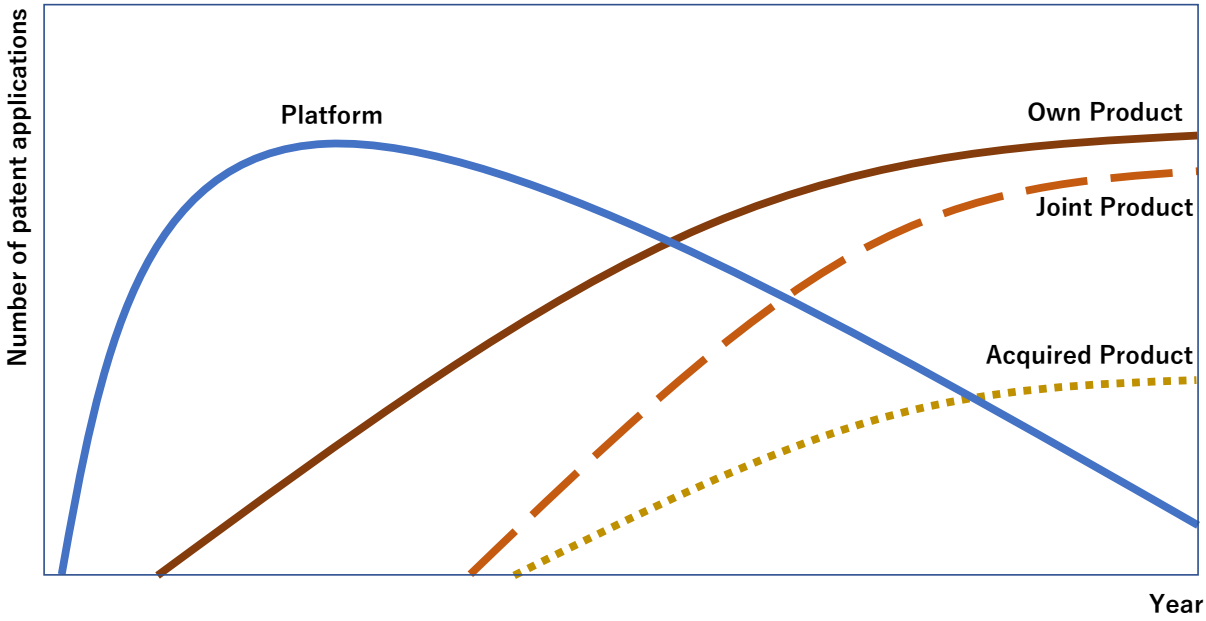

Figure 2 Various emerging patterns of product patent applications in the platform technology company

A platform patent can be applied for by a platform company alone, or with another company or public research organization, i.e. coinventorship. In this study, such platform technologies were considered the platform company's technology regardless if they were co-patented with other companies or not. Platform technologies cannot keep their competitive advantages because biotechnologies are continually progressing, causing the original platform technology to become outdated. Since patent applications in each category require maintenance costs, unnecessary patent applications are not maintained, and the number of patent applications maintained in each category show peak values. These are observed as a decrease, as shown in the curves of Figure 1.

Platform technology companies often change to the hybrid type that holds product patents in various patterns. After the establishment of platform type companies, product patents could be filed as outcomes of platform utilization, for simple licensing, co-development with pharmaceutical companies, or sometimes, for product development of in-house projects. Such product patents are categorized into two types in this study: the first type is called Own Product and is filed by the company alone (solid line, Figure 2) as outcomes of an internal project. The second type is called Joint Product and is co-patented with other companies as an outcome of collaborations (broken line, Figure 2). The choice to prioritize product project or partner projects as well as the choice to seek a hybrid-oriented model or not at the early phase of financing depends on the company's style. On the other hand, product patents which could be acquired from third party companies (dotted line, Figure 2) are called Acquired Product. In any case, product patents are obtained after a platform patent stream emerges over time. Once product patents become unnecessary, they are not maintained; this is observed in decreased patent numbers in Figure 2.

In this analytical framework, three types of platforms and three types of product patent applications are simultaneously observed in the same time course chart.

METHODS FOR CASE SELECTION AND PATENT ANALYSIS

Company Selection: In this study, we analyzed Japanese biotechnology companies listed until 2015 due to their good information disclosure practices. Among 29 listed biotechnology companies, we only focused on the companies established before 2007 since it would be difficult to observe technological changes in young companies. Furthermore, contract research organizations, subsidiary companies of pharmaceutical companies, and biotechnology companies that do not have their own platform technology were also excluded. Thus, only nine companies were selected for this study. They were university-originated companies that were funded based on drug discovery platform technologies.

Patent data source: Our dataset was extracted from a database of Japanese patent applications, CyberPatent Desk[30] in 2019. The data until 2016 were used for analysis. The data format included the title of the invention, applicant(s) (original and current), inventor(s), filing date claims, final decision, and date of cancellation.

Patent application counting: We counted the total number of "live" patent applications every year for each company based on its legal status. Three legal statuses of patent applications included, 1) filed, 2) under request for substantive examination, and 3) under maintenance, were regarded as "live," while other legal statuses, such as 1) withdrawals, 2) refused by Japan Patent Office, and 3) cancelled without paying annual fee, were regarded as "not live."

Patent type categorization: The patent applications were categorized as product or platform by referring to the claims of each patent application. The product patent applications were identified in case claims including contents related to therapeutic and/or diagnostic products, with information on targeted diseases and/or modalities. Furthermore, product patent applications were categorized according to its applicant(s), Own Products, Joint Products with collaborators, or Acquired Products from third parties. The platform patent applications were identified based on the claims that included research tools and/or enabling technologies.[3] Furthermore, platform patent applications were categorized according to claims regarding "version updates," "finding new areas of application," and "adding other platforms," and by comparing earlier patent applications. Although each company's technology platform was defined on its website, the originators of these inventions were usually university or public organization researchers. Thus, in addition to researching companies as applicants, the key scientists of each company were researched as inventors as well to detect related patent applications.

RESULTS

The profiles of nine companies are summarized in Table 1. There was no apparent correlation between the companies' existence period and the number of patent applications.

Figure 3 shows the number of "live" patents for the nine companies in chronological order. Platform patent applications were further classified as "version updates" (shown as "original and updated"), "finding new areas of application" (shown as "application"), and "adding other platforms" (shown as "additional"). Product patent applications were classified as Own, Joint, and Acquired Products.

OncoTherapy Science, Inc.

Most claims in patent applications were drug target genes, related tools, and modalities with reach-through claims on the targets for cancer treatments. These claims were regarded as "finding new areas of application." The patent applications were filed continuously during our research term. The methodology for finding targets was laser microbeam microdissection that obtained a high purity population of cancer cells from cancer tissues and genome-wide cDNA microarray;[32] however, the company did not file this technology and kept it as "a know-how" (or trade secret), so that no original and updated platform patents were detected. Although vaccines and small molecules were clinically developed based on platform patents through corporate alliances, few product patents, such as Own or Joint Product, which claimed to be a small molecule, were detected using the company's name as that of the applicant; however, their corporate partners filed these product patents.

CellSeed Inc.

CellSeed Inc.'s platform technology was based on culturing cells in sheets using temperature-responsive cell cultureware.[33] The cell culturing technology has been improved and updated by filing patents, which are indicated by the solid blue line in Figure 3. Based on the original platform technology, patent applications were filed as patents of "finding new areas of application," which claimed for specific types of cell culture. The chromatography technologies were applied as additional platforms. Furthermore, patents that claimed specific types of cell cultured products using cell sheet to treat diseases were filed as "Own and Joint Products." By filing patents that cover an original platform with updates, applications, additional platforms, and products, the company made full efforts to increase the value of their technology portfolio.

DNA Chip Research Inc.

DNA Chip Research Inc.'s platform technologies included Gene expression profiling and computer programing for DNA microarray.[34] Initially, the company kept their original platform technology portfolio and updated platform patents; however, they later discarded half of these without acquiring new applications and additional platforms. Instead of platform-related applications, product patent applications, which claimed diagnostic kits, were instead increased. It may be because the development costs of diagnostic products are cheaper than that of therapeutics, allowing them to file and keep these patent applications even with limited funding. All their platform patent applications were related to DNA

Table 1 A list of the nine companies analyzed

Company name	Year of company established	Year of stock listing	Platform technology	Total number of patent application
OncoTherapy Science, Inc.	April 2001	December 2003	Laser microbeam microdissection and cDNA microarray to identify the target gene	236
CellSeed Inc.	May 2001	March 2003	Cell sheet engineering for culturing cells in sheets using temperature-responsive cell cultureware.	96
DNA Chip Research Inc.	April 1999	March 2004	Gene expression profiling and computer programing for DNA microarray technology	55
NanoCarrier Co.,Ltd.	June 1996	March 2008	Micellar nanoparticle technology, which encapsulates various substances into nano-sized micelles	54
REPROCELL Inc.	February 2003	June 2013	Production of pluripotent stem cells (iPS cell)	27
Trans Genic Inc.	April 1998	December 2002	Genetically engineered mouse production technology	26
RIBOMIC Inc.	August 2003	September 2014	Drug discovery technology of RNA molecules, named aptamaer.	19
Chiome Bioscience Inc.	February 2005	December 2011	Antibody generation technology , named ADLib® system	13
PeptiDream Inc.	July 2006	June 2013	Peptide Discovery Platform System(PDPS) technology, which discovers peptide and small molecule therapeutics	8

microarray technology, and not any other technology field.

NanoCarrier Co., Ltd.

The company's platform technology was a micellar nanoparticle technology, which encapsulated various substances into nano-sized micelles as a Drug Delivery System.[35] As platform patent applications, these claimed to encapsulate a broad range of molecules with a combination of various types of drugs. The platform technology portfolio was to keep the original and updated patents continuously with a few additional platform patents. Product patent application claimed specific drugs as encapsulate substrates, such as Cisplatin and Docetaxel. Some products were clinically developed with corporate partners. They maintained and updated the original platform patents continuously, which strengthened their micellar nanoparticle technology.

REPROCELL Inc.

The company's platform technology involved the production of pluripotent stem cells.[36] The improvements on the cell culture method are regarded as "platform updates," and applications for treatment or specific types of cell culture are regarded as "new application." The platform technology strategy was to keep the original and update the platform strongly, while discarding half of these with a few additional platforms. We categorized two patent applications as product, one was a small molecule for disease treatment, and the other was gene therapy.

Trans Genic Inc.

The company's platform technologies included gene modification and knockout mouse production.[37] These two gene recombination technologies were related to each other and were used to obtain a genetically engineered mouse. The "original" platform technology portfolio was continuously maintained and "updated" for knockout mouse production, with one "new application" and one "additional" platform for the evaluation of environmental pollution, which was discarded in 2011. Own Product patents are mainly for tumor marker antibodies, which were not related to their platform technologies. The total number of patent applications increased due to both platform and product patents.

RIBOMIC Inc.

The company's platform technology involves a method to derive aptamers, which are short, single-stranded RNA sequences.[38] The platform for molecular discovery is called the Ribomic Aptamer Refined Therapeutics (RiboART), a system with no patent applications and therefore remains undetected. Furthermore, all patent

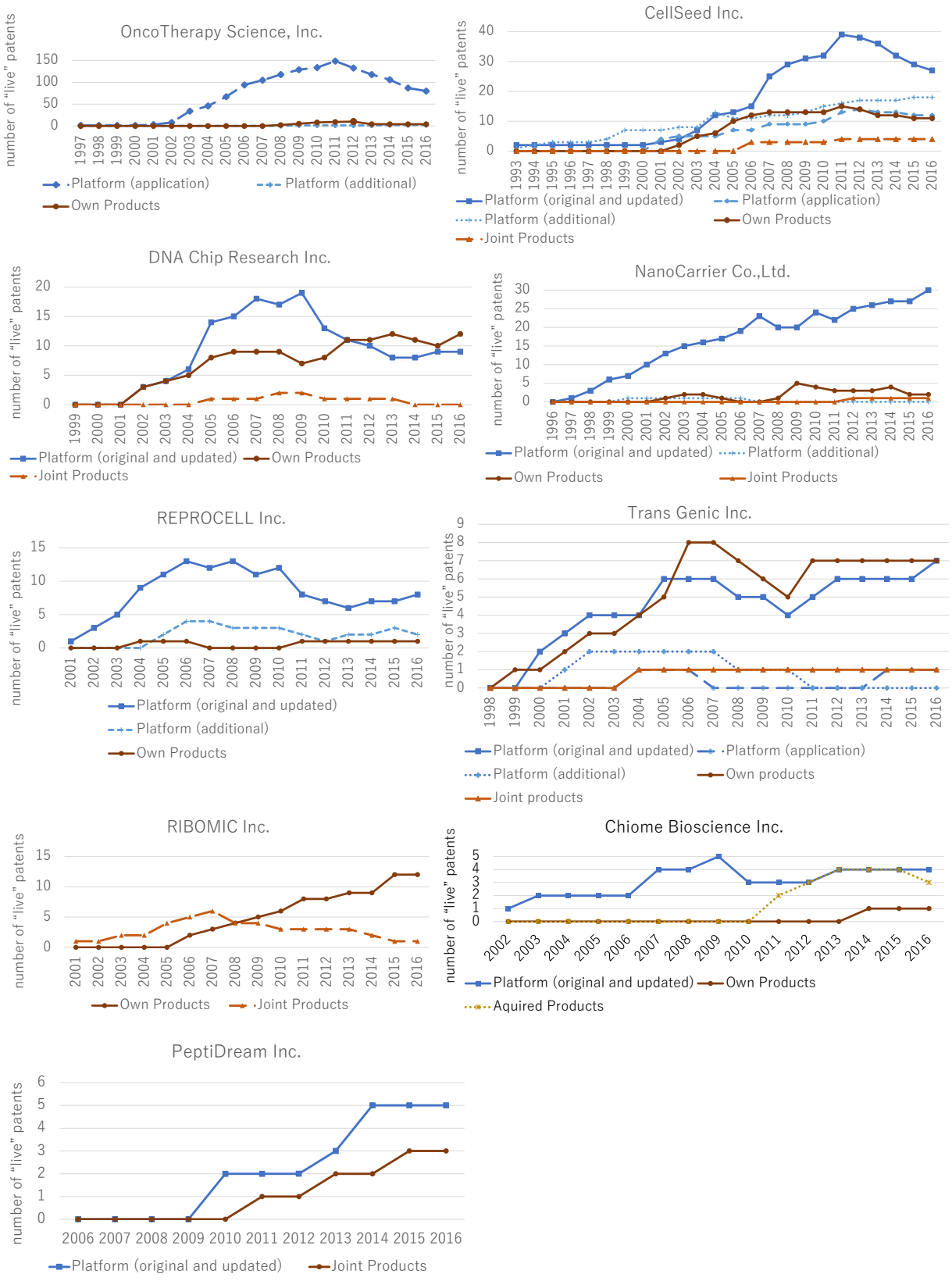

Figure 3 The number of "live" patent applications overtime in each year

applications claimed aptamers as products generated based on the platform technology.

Chiome Bioscience Inc.

The company's platform technology involves an antibody generation technology named ADLib® system.[39] The platform technology portfolio maintained the original ADLib® system and updates it from chicken antibodies to a humanized antibody, without filing new applications for the platform and additional platforms. The company clinically developed antibody pipelines with patent applications, which were acquired from another company through mergers and acquisitions. These acquired products might be an indicator of an original platform technology, which did not work sufficiently enough to generate promising products.

PeptiDream Inc.

This company's platform technology is called Peptide Discovery Platform System (PDPS), which is used to discover peptide and small molecule therapeutics.[40] The platform technology portfolio maintained the original PDPS and updated it without filing new applications for original and additional platforms. All the product patents were applied as therapeutic peptides.

PLATFORM TECHNOLOGY RELATED PATENTS

Eight companies had platform technologies with patent protections when the companies were established. These companies could be divided into three groups: the first group (i.e., DNA chip, REPROCELL, Transgenic, Chiome, and PeptiDream) has less than ten live platform patents, which are updates on the original platform patents to protect a single and narrow concept; the second group (i.e., CellSeed and NanoCarrier) has filed over 30 updated platform patents on the original core platform patents to protect a wide concept; and a single company (i.e., OncoTherapy) has filed over 100 application type platform patents, which mainly claim a drug target and its related rights without original and updated platform patents.

CellSeed and REPROCELL have filed for additional platform patents; however, the patents were few and their roles were limited to complementing the original platforms. Meanwhile, RIBOMIC Inc. did not apply for any platform patents and has only product patent application which was filed shortly after the company was established.

There are two reasons attributed to the decrease in the number of live patents: refusal and withdrawal. Refusal means the patent did not align with the company's intention and was therefore refused by the patent office. Meanwhile, withdrawal was based on the company's intention. There were a total of 92 withdrawals and 19 refusals for OncoTherapy Science, and 4 withdraws and 18 refusals for CellSeed, by 2016. Thus, the reasons for decreasing live patents were different in two companies.

PRODUCTS RELATED PATENTS

The above results were based on patent applications, which were searched using company names as applicants. No Joint Product patent applications from pharmaceutical companies were found, except in a few cases. To detect the product patent applications derived from platform technologies that were filed by corporate partners, the names of the key scientists for these platform companies were searched as well. However, no product patent applications were detected. This suggests that product patents that were outcomes of an alliance with platform technologies were filed only by partner companies, and Joint Product patents were rarely detected. Conversely, a relatively large number of product patent applications were filed as Own Products by DNA Chip Research, Trans Genic, and RIBOMIC. These patent applications were specifically for products like DNA microarray diagnostic kit, antibody, and short RNA sequence. These products all have lower costs for concept proofing as compared to those of therapeutic products. The properties of Joint Products differ in each company. All the Joint Product patent applications of DNA Chip Research, RIBOMIC, and PeptiDream were co-patented with public research organizations, while CellSeed's were co-patented with pharmaceutical companies. Trans Genic and NanoCarrier filed patent applications with both pharmaceutical companies and public research organizations.

DISCUSSION

In this study, we quantitatively and chronologically observed the portfolio management, which included filing, maintenance, and cessation of patents of platform and product patents, of Japanese biotechnology companies to precisely analyze each company's action with high resolutions. Three categories were introduced for platform patents (i.e., "version updates," "finding new areas of application," and "adding other platforms"), while three categories were introduced for product patents (i.e., "Own Products," "Joint Products," and "Acquired Products"). Based on the newly developed classifications, we have formulated the following observations regarding the platform technology management of Japanese biotechnology companies that we analyzed:

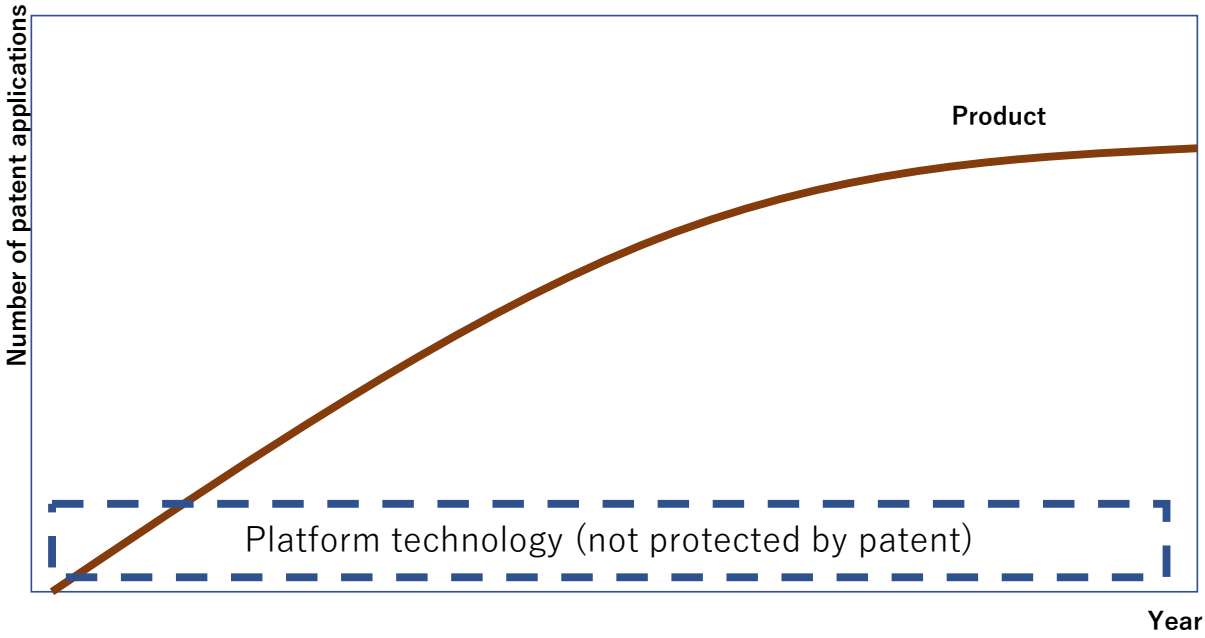

Figure 4 The pattern of "know-how based" platform technology management

First, depending on whether platform technologies were supported by patents or not, two types of platform technology companies were identified; this status affected their product patenting situations as well. Seven companies filed and maintained original and update platform patents cumulatively, and one company filed so many "new areas of application" type platform patents continuously, including target related antibodies and vaccines claims, without support from the patents of the original platform technology. These are regarded as "patent protected" platform biotechnology companies.

A small number of product patent applications (i.e., Own Products) were observed in all eight companies, most of which were claims for tool, cell processing, and diagnostic products. Few drug patent applications were detected as Joint Products, which were results of the alliance partner's sole patent filing.

To maintain technical advantage, it is sometimes a better to deliberately refrain from using patents to protect platform technologies.[17] For instance, a company without any platform technology patent was regarded as a "know-how based" platform biotechnology company. In this case, product patent applications were filed cumulatively as outcomes of platform technologies that were not protected by patents (Figure 4), and their corporate values were only based on these product patents.

Since two patterns were observed from the Japanese cases and the relationship between platform and product patents were affected by the financing situation of each country, our observed patterns may not be generalizable until additional evidence is gained from other countries.

Second, by observing the technology platform of companies with the three platform patent categories proposed by an existing paper,[9] we could successfully profile what kind of platform the company operated and show the effectiveness of this method. By focusing on "version update" platforms chronologically, the number of these and its continuity indicate the seriousness of the company to maintain the competitiveness of the platform. A relatively large number of these mean that the strategy secured a wide range of related patents, and a small number suggests the protection of a specific area by basic patents. Data on "finding new areas of application" shows how companies attempt to add value to the original platform. Data on "adding other platforms" provides information about the company's dependence on the original platform and the possibility of acquiring complemental technological assets. This newly developed method is broadly applicable to cases in other countries, to observe the management of platform technologies.

Third, by observing the product patents of platform technology companies using three categories (Own, Joint, and Acquired Products), we could quantitatively and chronologically analyze whether companies shifted their business model from platform to hybrid or product. In the case of all the nine companies, a shift to the hybrid model was observed. However, we could not find a radical shift to the product-focused model, such as abandoning

an initial technology platform, which was reported in the existing literature.[4,5,18,24] Among the nine companies, DNA Chip Research Inc. and Trans Genic Inc. filed a relatively large number of product patents compared to platform patent applications, which claim mainly low development cost products such as diagnostics. Thus, the lack of large-scale financing for drug development to biotechnology companies in Japan might have caused these limited moderate shifts.[24]

Finally, this study validated the characteristics of Japanese biotechnology companies, as reported by existing literatur From the case profile of our samples, former observations about platform technology companies in Japan[26] were revised due to the emergence of product-focused companies. The result of this study was similar to the one that reported that 80% of Japanese biotechnology companies did not change their core technologies[27]; eight of nine companies continuously added platform patents and did not discard the core technologies with low activities to acquire additional platform technologies. The previous report that compared the quality of initial technologies using patent forward citations[28] did not distinguish products and platforms and did not use credible examiner's citations instead of normal forward citations.[31] It is not appropriate to obtain results with such unreliable parameters and coarse resolutions in analyzing patents. The existing results that licensed out products from Japanese biotechnology companies were not innovative and not regarded as first in class[29] were partially denied due to the existence of two types of innovative products, newly identified cancer drug targets of OncoTherapy with new mode of actions and newly synthesized artificial peptides of PeptiDream containing brand-new structures.

CONCLUSIONS

The technology management of Japanese platform biotechnology companies was analyzed quantitatively and chronologically using the patent application data of platforms and products. Most of the companies continuously maintained their initial platform technologies by filing updated platform patents in addition to new platform technologies and shifting to a platform-product hybrid model. Existing papers that analyzed Japanese biotechnology companies were verified to be partially correct based on the high-resolution patent data; these results validate the usefulness of our approach.

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Article

Consensus on Metrics for the Assessment of a Medical Science Liaison Using the Delphi Method

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ABSTRACT

The determination of the metrics to evaluate the figure of medical science liaison (MSL) presents certain difficulties, as there is a great deal of variability. Therefore, the aim of the present exploratory study is to evaluate the metrics for evaluating MSL performance that are currently being used by the medical departments of the pharmaceutical industry in Spain by using the Delphi methodology with two rounds of participation. Moreover, the study aims at providing an expert consensus about which metrics should be used and how they should be evaluated in order to be as appropriate and feasible as possible.

After the first round, experts reached a consensus in 20 (38.5%) of 52 items: 18 in agreement and 2 in disagreement. In the second round, they established consensus in 8 (25.0%) of the remaining items. Overall, consensus was met in 28/52 (53.8%) items: 23 in agreement (44.2%) and 5 in disagreement (9.6%). No consensus was reached in 24 items (46.2%). On the general metrics, there was consensus agreement that the weight of each of these metrics should vary according to the product life cycle (96%), and disagreement that performance assessment should be done through a combination of quantitative (92%) and qualitative (80%) metrics.

This study provides the company with greater knowledge to establish and adapt its strategies without losing focus on delivering value in the relationships with healthcare professionals and patients.

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Keywords: Medical Science Liaison, Metrics, Quantitative, Qualitative, Delphi, Key opinion leader.

INTRODUCTION

Medical Science Liaisons (MSLs) are professionals with both high educational and scientific qualifications who work in companies in the pharmaceutical, biotechnology and other health-related fields[1]. Their role was created to serve as a link between the industry and the health professional. The first MSLs were selected from sales representatives who had a solid scientific background and were able to provide a higher clinical and educational expertise to medical professionals[2]. The MSL role has changed over the years, even the involved departments inside the companies. For instance, 27% of MSLs belonged to sales departments in 2004, whereas in 2010 the percentage dropped to 2%[3]. In most companies, MSLs do not receive incentives

depending on sales or market share[4]. Furthermore, MSLs do not have a sales or marketing role, despite being in contact with marketing teams to guarantee that messages are precise and consistent[5]. MSLs are involved in product life cycle processes and cover a very wide range of therapeutic areas. Their main mission is to build trust on a scientific level between the company and the health professionals, by carrying out training activities, research (clinical trials, CTs), dissemination of scientific evidence, etc[1,6]. In recent years, the number of MSLs has increased considerably and they have become a strategic element in the companies' medical departments[1]. Despite this, published literature about the role of MSLs, as well as their relationship with health professionals, is very limited[6-14].

Additionally, given the important contribution that the MSLs provide to the industry, the complexity of their work, and the wide range of issues they address, attempts have been made to measure their role qualitatively and quantitatively. In the past, quantitative metrics have been preferred as they are considered more objective, fact-based, potentially unbiased, and easier to analyse[15]. These metrics include time spent in the field or the number of interactions with medical key opinion leaders (KOLs) in that sector. In contrast, qualitative metrics are more difficult to measure and the resulting objective rationale of the value of MSL has traditionally been considered insufficient[6]. In addition, determining these metrics presents certain difficulties, due to the wide range of variability. Two frequently used qualitative metrics are: the skills and competencies of the MSL; and the interaction, discussion, and engagement with the KOL. Objectives and activities in MSLs are not guided by marketing or sales goals, but by medical needs instead[4]. For this reason, metrics applied to sales representatives are not adequate for MSLs. To date, there is no consensus on MSL metrics. Therefore, the aim of the present study was to analyse the available metrics for assessing the MSL and to provide an expert consensus about which ones should be used and how they should be evaluated in order to be as appropriate and feasible as possible.

METHOD

Study design

This was a nationwide exploratory study conducted by a panel of experts following the online modified Delphi methodology with two rounds of participation. The first round was held from 18th to 29th May 2020 and the second round from 5th to 23rd June 2020. The project was devised and coordinated by the MSL METRICS working group of the Association of Medicine of the Pharmaceutical Industry in Spain (AMIFE), consisting of four MSL/MSL managers. The criteria to define the panel of experts were the following: MSL manager with >2 years in the position; MSL with > 5 years in the position; medical directors; representing companies of different sizes (from micro-businesses with ≤ 10 employees, to large companies with more than 250). In order to build an expert panel of more than 20 members, the steering group invited a total of 48 experts to participate, who were identified analysing their LinkedIn profile. By using LinkedIn website, the steering group sent a mail to experts explaining the project. The recruitment period lasted one month.

Questionnaire

The steering group developed a questionnaire based on: internationally available literature about MSL metrics; their experience as MSLs; and metrics developed by the main MSL associations[16-20]. Initially, a PubMed search was carried out using the keywords: "medical science liaison" and "metric", however, no results were obtained. For this reason, the information held by the MSL associations themselves had to be accessed. After developing different constructs and items, two independent (not involved in the project) experts in the field revised them to ensure that they were fully understood and valid for the questionnaire. The questionnaire consisted of 52 items, divided into 3 domains, according to the type of metric: quantitative, qualitative, and general. To avoid misunderstanding, a short definition and an example was enclosed with each item.

Determination of the degree of consensus

A 5-point Likert scale was used for the responses to each item: strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree. After the first round, the percentage of each response was determined for each item. A second round was held in order to obtain consensus on those items where there were discrepancies. A consensus of agreement was established when more than 75% of the participants responded with 'agree' or 'strongly agree' for the corresponding item (Figure 1).

In the same way, a disagreement was defined when more than 75% of the participants answered 'disagree' or 'strongly disagree' to the corresponding item. When the two possible consensus options were not met, it was established that there was no consensus on the corresponding item.

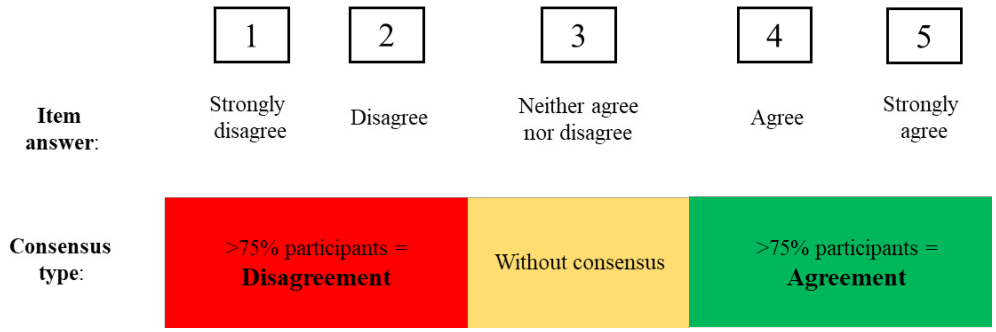

Figure 1. Types of answers for each of the items and established consensus.

RESULTS

A total of 28 out of the 48 experts who were contacted started the Delphi process. One medical director, 11 MSL managers and 16 senior MSLs from 19 different pharmaceutical companies participated. The response rate in the first round was 89% (25 out of 28 experts) and 100% in the second round (25 out of 25). After the first round, the experts reached consensus on 20 (38.5%) of the 52 items evaluated: 18 with an agreement and 2 with disagreement. The degree of consensus for the metrics assessed in the two rounds of the Delphi method is shown in Figure 2.

An agreement on quantitative metrics was reached in 10 of the 27 items (two items on number of interactions with KOLs, two items on number of interactions with other health professionals, one item on research support, two items on conference support and attendance, two items on internal support, and one item on dissemination of scientific information). An agreement was reached on qualitative metrics in 7 of the 22 items (one item on skills and competencies, two items on *stewardship*, one item on *internal feedback*, one item on *external feedback* and two items on *insights*). In the general metrics, there was an agreement on item 50 ("The measurement of each of these metrics should vary according to the product life cycle") and disagreement on items 51 ("The application of quantitative metrics is sufficient to assess MSL performance") and 52 ("The application of qualitative metrics is sufficient to assess MSL performance").

In the second round, the experts reached consensus on another 8 (25.0%) of the remaining 32 items. Five were in agreement (three quantitative items: one on number of interactions with other health professionals and two on dissemination of scientific information; and two qualitative items: internal *feedback* and *advocacy*) and three in disagreement (two on quantitative items: research support and conference support and attendance; and one qualitative item: skills and competencies). Thus, consensus was reached on a total of 28 (53.8%) of the 52 items: 23 in agreement (44.2%) and 5 in disagreement (9.6%). No consensus was reached in 24 (46.2%) of the items. The metrics that produced the greatest variety of opinions were those relating to time in the field (reaching consensus on none of the three items), *external* feedback *(reaching consensus on two of the five items) and* internal feedback (reaching consensus on only one of the four items).

DISCUSSION

Assessing and determining the role of an MSL is as important as it is difficult. To date, there is no consensus on the evaluation of MSL metrics. The only available literature comes from non-indexed journals or surveys conducted by MSL associations, where each of them offers its own metrics, but without offering a global consensus approach to the assessment of MSL performance[16-20]. All the publications highlight the need to design a metric system that reliably represents the work of the MSL.

About a decade ago, the industry started to use the combined model of quantitative and qualitative metrics when communicating the value of the MSL to internal *stakeholders*[21]. Since then, whether due to the heterogeneity in the functions of the MSL or the changing environment and regulations in which it is involved, truly diverse metrics have appeared and the quality of the MSL's work has not been clearly identified. According to a 2010 survey, MSLs believe that the metrics currently established by companies do not adequately represent their roles or contributions[22].

Although our study has reached a consensus that many metrics should be implemented, the difficulty of doing so has become apparent. On the one hand, quantitative metrics are generally more obvious and more widely used. They make it easy to determine whether or not a goal has been achieved, but do not provide information on the reason behind it. The number of MSL interactions with KOLs and other HCPs in a given time are the most commonly used quantitative metrics in the pharmaceutical industry[23,24] and they encompass face-to-face

	Metric type	Item	Statement	Round 1 (%)	Round 2 (%)
Time in the field	QUANTITATIVE	1	MSL field time reflects the value of the MSL profession or activity	36	28
		2	MSL field time should be a metric that is part of the assessment of MSL performance	60	68
		3	MSL field time must be a predefined value	40	40
Interactions with KOL		4	The total number of interactions (face-to-face and virtual) of the MSL with KOLs should be a metric that forms part of the assessment of the MSL's performance.	76	-
		5	Face-to-face interactions of the MSL with KOLs carry the same weight as virtual interactions (calls, video calls, etc.) as long as there is scientific exchange	76	-
		6	There must be a predefined minimum number of MSL interactions with KOLs per unit of time	60	68
Interactions with healthcare providers		7	MSL interactions with other HCPs (other healthcare providers who are not KOLs) add value to the company	96	-
		8	It is necessary to measure the number of interactions of the MSL with other HCPs (other health providers who are not KOLs)	88	-
		9	The number of interactions of MSL with other HCPs (other health professionals who are not KOLs) has the same relevance as the number of interactions with KOL	36	32
		10	MSL face-to-face interactions with other HCPs (other health professionals who are not KOLs) carry the same weight as virtual interactions (calls, video calls, etc.) as long as there is scientific exchange	68	88
Research		11	The number of IIT/CTs-related interactions (including follow-up) should be measured to assess MSL performance	76	-
		12	The number of research proposals made or endorsed by the MSL should be measured	56	68
		13	There must be a minimum number of research proposals made or endorsed by the MSL	72 (-)	88
		14	The impact of the research proposals made by the MSL should be measured	64	72
Conferences		15	The number of conferences attended should be measured to evaluate MSL performance	52 (-)	80
		16	Whether the MSL is involved in the organisation of scientific activities related to the conference (symposia, round tables, medical stand) should be measured	76	-
		17	The number of conference sessions attended by the MSL should be measured	48	56
		18	The number of conference interactions between the MSL and KOLs, other HCPs or other *stakeholders* should be measured	84	-
In-house support		19	The number of MSL interactions with in-house staff should be used to assess MSL performance	56	72
		20	The number of internal trainings provided by MSL to in-house staff should be used to assess MSL performance	88	-
		21	The contribution of the MSL to the development of the company's strategy should be measured	92	-
Dissemination of scientific information		22	The dissemination of scientific information of the MSL should be measured by the number of sessions delivered by the MSL	56	68
		23	The number of requests for information to the MSL from KOLs or other *stakeholders* should be measured	60	96
		24	The number of sessions delivered reflects the impact of the MSL	44	36
		25	The number of HCP attending the sessions delivered by the MSL should be measured to assess MSL performance	32	24
		26	The weight of the MSL in the dissemination of scientific information should be measured	96	-
		27	The number of MSL scientific dissemination activities per time period (speed/time until impact) should be measured	72	80
Skills and competencies	QUALITATIVE	28	MSL skills and competencies are a qualitative metric to assess	88	-
		29	The correct way to assess MSL skills and competencies would be through regular exams or tests	64 (-)	84
		30	The correct way to assess the skills and competences of the MSL would be through the evaluation of the training activities on a yearly basis	44	48
Stewardship		31	The contribution of the MSL to proactively develop or update the KOL file is a qualitative metric to be assessed	84	-
		32	Assessing the updating of the KOL file would be a qualitative way of measuring *stewardship*	56	64
		33	The development or updating of the KOL file should be carried out by the MSLs according to their criteria	56	68
		34	One way of assessing the KOL file would be to evaluate the suitability of the KOLs included in the file in terms of the company's needs	80	-
		35	The MSL is required to use specific software for KOL identification	44	44
		36	Feedback from internal stakeholders on the scientific activity of the MSL should be a qualitative metric to assess MSL performance	68	76
Internal feedback		37	Feedback from internal stakeholders should be measured through a survey of MSL activity	44	52
		38	The evaluation of the MSL's performance through global surveys by internal stakeholders is objective and valid	32	24
		39	The evaluation of MSL performance through global surveys by internal stakeholders has to be based on objective questions	96	-
		40	The evaluation of MSL performance by the internal *stakeholders* should be measured through specific satisfaction surveys (for each common project or activity)	44	36
External feedback		41	The *feedback* from KOL or other HCPs on the MSL's scientific activity should be a qualitative metric to assess MSL's performance	84	-
		42	The *feedbacks* of KOLs and other HCPs collected by the MSLs themselves are a valid metric	40	60
		43	The *feedback* from KOL and other HCPs should be proactively collected through satisfaction surveys	44	56
		44	A spontaneous feedback from a KOL and other HCPs has the same weight as one proactively requested by the company	44	48
Insights		45	The *insights collected* and conveyed by the MSL should be a qualitative metric to assess MSL performance	88	-
		46	The number of *insights* per unit of time is a valid metric to evaluate MSL performance	28	24
		47	The value provided by the *insight* (collected and conveyed by the MSL) to the objectives of the company must be weighted	80	-
Advocacy		48	Change in KOL attitudes or beliefs based on interactions with the MSL should be measured to assess MSL performance	72	72
		49	To assess *advocacy* objectively (interaction, discussion and engagement with the KOLs), the degree of compliance should be measured against a previous *advocacy* plan for each KOL or group of KOLs	68	76
GENERAL ASPECTS		50	The weight of each of these metrics should vary depending on the life cycle of the product	96	-
		51	The application of quantitative metrics is sufficient to assess MSL performance.	92	-
		52	The application of qualitative metrics is sufficient to assess MSL performance.	80	-

Figure 2. Degree of consensus for the metrics assessed in the two rounds of the Delphi method.
MSL, medical science liaison; KOL, key opinion leaders; HCP, healthcare provider; IIT, investigator-initiated trials; CT, clinical trial; stakeholder, external and internal parties of interest to the company
Green represents a consensus of agreement, red represents a disagreement, and yellow represents no consensus. In the latter, the negative sign within a parenthesis means that the answer is in the direction of disagreement (in the rest of the percentages where there are no parentheses, the answer is in the direction of agreement).

or virtual interactions, the interaction type, and even the location of the interaction. Our study clearly shows the agreement that both quantitative metrics should be measured, and that virtual interactions have the same weight as face-to-face interactions with both KOLs and HCPs. Given that our study was conducted after several months of lockdown during the coronavirus pandemic, it is quite possible that this had an impact on the change in perception of virtual interactions, which are now on a par with face-to-face interactions. Time spent in the field is another quantitative metric. MSLs distribute their working time on administrative and updating tasks, preparation, self-training, and internal and external relations, using both through face-to-face and virtual contacts. Companies may establish this 'time' by considering all of these characteristics or only some (travel times, waiting times, time spent in direct interaction, virtual interactions, etc.). Despite being one of the most widespread metrics which is never missing in any reporting system, our study did not reach a consensus on it being a necessary valuation metric. This is evidence of the "serious" lack of homogeneous and complementary understanding of this important metric.

Other widely used quantitative metrics are: the number of interactions with other *stakeholders* (such as the nursing, pharmacy, administration staff, with the exception of KOLs); support for research and clinical trials (number of CTs or studies in which the MSL is involved, completed in a period of time, number of interactions related to these trials or studies, etc.); support and attendance at conferences over a period of time (number of events attended, whether they are international, national, regional or other); internal interactions with other departments (number of training sessions, presentations, responses to queries, or different meetings); or the dissemination of scientific information to external *stakeholders* (number of sessions in hospitals, health centres, number of conference presentations or participation in other events, or number of external stakeholders reached through these sessions).

Regarding research support, considering both investigator-initiated studies and CTs, our study underlines

the agreement that the MSL should be acting as support and, therefore, that it should be considered as a metric. However, there is no agreement on how to measure it. Also, there is consensus that there should not be a minimum number of research proposals presented or endorsed by the MSL[25,26]. In the case of conference support and attendance, there is no agreement as to whether the number of conferences attended by the MSL should be measured. In fact, the majority of participants in our study (80%) rejected such an idea, presumably because, although attendance at conferences forms a part of the MSL's role, the metric should focus on analysing the capture of *insights* rather than solely on the number itself. Furthermore, the MSL's attendance at conferences is often limited by internal company policy[15]. Internal support to other departments is also important in assessing MSL performance. Our study shows that the contribution of the MSL to the development of the company's strategy as well as that related to internal support (training, doubt resolution, internal scientific reference, etc.) should be measured. Regarding the dissemination of scientific information, a fundamental pillar of the MSL's role, there is no consensus that the way to measure this relevant metric is in terms of the number of sessions but rather in the importance of such dissemination and the number of scientific dissemination activities per unit of time.

On the other hand, qualitative metrics are a challenge for the industry, as they are difficult to assess and take longer to measure. They tend to be fewer in number than quantitative metrics and with a higher degree of heterogeneity[21,25]. Nevertheless, they provide significant information on the value provided by the MSL. One of them is the determination of skills and competencies, including scientific knowledge, communication skills, clarity of exposition, ease of making presentations, public speaking, social skills, efficient networking, or the ability to analyse the territory and selecting KOLs[15,26]. The qualitative metrics used are shown in Figure 2.

In our study, the first qualitative metric to be included was the assessment of the MSLs skills and competencies and it received a high degree of acceptance (88%). The metric skills and competencies encompassed the qualitative assessment of the MSL's skills through his/her daily activities, and included scientific background, training, communication skills, public presentations, implementation and management of scientific projects. Given that certain competencies and skills are required for the role of MSL, determining how they evolve and improve is a useful and reliable way to assess their performance. However, our study also showed that the right way to assess them is not through regular exams or tests. It is important to bear in mind that in Spain as in other countries, MSLs do not always receive specific training programmes to become experts in their therapeutic areas and in the skills needed to perform their duties[23,27,28]. The second qualitative metric used in our study was the *stewardship*, which would be the qualitative assessment of territory management. It may include the compilation or analysis of the KOL file, establishment and updating of the list or ranking, dynamic management of the KOL file and the achievement of associated goals. It represents the pillar on which a company's entire medical plan is based. We found a high consensus regarding considering it a metric for assessing the MSL (84%) and that the KOL file should be assessed according to the needs of the company (80%). There has been no consensus on whether it should be based on the MSL criteria or whether specific software should be used. An important question in this regard is how to develop a KOL ID that is effective and efficient. Our third qualitative metric was *feedback* from internal *stakeholders*. This is quite a controversial topic as it involves the evaluation of MSL's performance by colleagues from other departments. This metric obtained a high consensus for its implementation, especially if it is carried out through global surveys and objective questions (96% of participants). However, no consensus was reached on the proposed forms of evaluation. Similarly, the *external* feedback qualitative metric (from HCP and KOL) also achieved a high degree of consensus (84%) on its suitability for use, but not on how it should be performed. For example, it is not clear if *feedback* collected by the MSLs themselves is a valid metric, or whether satisfaction surveys on a proactive basis should be used. There are also doubts as to whether a proactive survey and spontaneous *feedback* by the health professional hold the same weight. The next qualitative metric was the management of *insights*, which produced a high level of agreement (88%) in assessing the role of the MSL as well as to the value it provides to the company's objectives (80%). On the contrary, the number of *insights* per unit of time was not considered to be a valid metric for assessing MSL performance. The last qualitative metric evaluated in our study was *advocacy*. This metric determines the influence of the MSL in the KOL, as a result of their interaction, through discussions and argumentation conveyed by the MSL to the KOL and adopted by the KOL. Having an *advocacy* plan is identified as paramount to assessing the quality of the MSL. A change in trend caused by the MSL should always be measured, however they are difficult to measure as these changes are not sudden. Our study found an agreement (76%) that for *advocacy* to be assessed objectively, the degree of compliance with a previous plan should be measured.

In our opinion, qualitative metrics are perhaps more valuable than quantitative metrics, as they relate to the MSL's competitive intelligence and, to a large extent, the *insights* gathered from their interactions with KOLs. Given the great diversity of existing metrics, our study's main purpose was to provide a consensus that can be

used as a reference by the medical departments of different companies. It is important to underline the consensus that MSLs should not be assessed by quantitative (92% of participants) or qualitative (80%) metrics alone, making it clear that a combination of both metrics is necessary to understand MSL performance.

In our study, some of the items did not reach consensus, and thus they probably do not represent adequately the performance of an MSL. However, the discrepancy in opinions among experts, for some items, could derive from the (large) variability in the MSL job description for each MSL, making difficult the generalization of the MSL performance by some measures. In addition, none of the experts suggested poor understanding with an item (and asked for feedback).

Also, numerically, there was more lack of consensus in task-based metrics. What our results really reflect is a profound need to revise the actual metrics system as both qualitative and quantitative are controversial. The present study shows that there is a generalized failure to reach an appropriate balance between task – or strategy-based metrics when measuring MSL performance. This fact directly highlights the difference between quality and quantity, and the complexity of these measurements.

In conclusion, the present study offers a consensus with a comprehensive approach to the assessment of MSL performance through quantitative and qualitative metrics. The improvement in determining the role of the MSL through established and broadly defined metrics is directly proportional to the professional growth of the MSL and this approach provides the company with greater knowledge to establish and adapt its strategies without losing focus on delivering value in the relationships with healthcare professionals and in the health and quality of patients' lives.

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