







RESEARCH ARTICLE

Mapping validated Lebanese core and specialised pharmacy competencies to global frameworks

Aline Hajj^{1,2,3} , Hala Sacre² , Marwan Akef² , Rony M. Zeenny^{2,4} , Zaheer-Ud-Din Babar⁵ , Pascale Salameh^{2,6,7,8} 

¹ Faculty of Pharmacy, Université Laval, Québec, Canada

² INSPECT-LB (Institut National de Santé Publique, d'Épidémiologie Clinique Et de Toxicologie-Liban), Beirut, Lebanon

³ Oncology Division, CHU de Québec-Université Laval Research Centre, Québec City, Canada

⁴ Department of Pharmacy, American University of Beirut Medical Centre, Beirut, Lebanon

⁵ College of Pharmacy, Qatar University, Doha, Qatar

⁶ Gilbert and Rose-Marie Chagoury School of Medicine, Lebanese American University, Beirut, Lebanon

⁷ Faculty of Pharmacy, Lebanese University, Hadat, Lebanon

⁸ Department of Primary Care and Population Health, University of Nicosia Medical School, Nicosia, Cyprus

Keywords

Advanced competency
Competency framework
Core competency
Global framework
Lebanon
Mapping
Specialised competency

Correspondence

Hala Sacre,
INSPECT-LB (Institut National de Santé
Publique, d'Épidémiologie Clinique Et de
Toxicologie-Liban)
Beirut
Lebanon
hala.sacre@inspect-lb.org

Abstract

Background: The pharmacy education landscape is transforming rapidly, driven by advancements in healthcare delivery, technology, and patient-centred care. This evolution highlights the need for core and specialised frameworks to guide curriculum development, competency assessment, and professional standards and influence the quality of pharmacy practice and patient outcomes. **Objective:** To map the validated Lebanese core and specialised pharmacy competencies with existing global core, advanced, humanitarian, and education frameworks. It also sought to suggest new domains, considering current and potential future health challenges. **Methods:** In this work, validated Lebanese pharmacy competency frameworks (core and specialised) were mapped to four FIP frameworks, i.e. the Global Core Competency Framework (GbCFV1, optimised in GbCFV2), the Global Advanced Development Framework (GADF), the Global Competency Framework for Educators and Trainers (FIP-GCFE), and the Global Humanitarian Competency Framework (GbHCF). **Results:** The findings underscore enhancing competencies across digital health, public health, emergency readiness, and pharmaceutical care domains in various curricula and frameworks. **Conclusion:** This study revealed several opportunities for improvement, highlighting the importance of revising and incorporating new competencies, such as digital health, emergency preparedness, and public health practice, into the Lebanese core competency framework. These competencies would enable pharmacists to adapt to rapidly evolving practices and assume new roles.

Introduction

The pharmacy education landscape is transforming rapidly, driven by advancements in healthcare delivery, technology, and patient-centred care. This evolution highlights the need for competency-based education in pharmacy, using validated core and specialised frameworks (International Pharmaceutical Federation (FIP), 2022; McMullen *et al.*, 2023). The latter would guide curriculum development, competency assessment, and professional standards and influence

the quality of pharmacy practice and patient outcomes (Medina *et al.*, 2013).

The pharmacist's role has extended beyond traditional medication dispensing and management to meeting the modern pharmacy concept (Sam & Parasuraman, 2015). Building upon the World Health Organisation's (WHO) vision of the seven-star pharmacist model involves additional roles, i.e. researcher and entrepreneur. This model has extended and reached ten stars in some settings (Kremin *et al.*, 2023),

highlighting the positive change brought by pharmacists. Pharmacists now play an essential role in improving medication therapy, medication adherence, and patient education while contributing to interprofessional healthcare teams (Kehrer *et al.*, 2013; American College of Clinical Pharmacy, 2023). In some countries, such as the UK and Canada, pharmacists can even prescribe medications (Faruquee & Guirguis, 2015; Owczarek *et al.*, 2023), in addition to some relatively new roles such as mail-order pharmacy (Howk, 2023) and speciality pharmacy (Suchanek, 2005).

Additionally, pharmacists must have relevant competencies in digital health technologies, humanitarian and crisis management (International Pharmaceutical Federation (FIP), 2021a), and emergency preparedness, given the rapid advancement in these fields (International Pharmaceutical Federation (FIP), 2017b). Competency frameworks must evolve to incorporate these emerging areas, enabling pharmacists to use digital tools, telehealth, and data analytics to improve patient care and medication management (Ronquillo *et al.*, 2024). They must also equip pharmacists with the knowledge and skills to respond effectively to public health emergencies and crises (International Pharmaceutical Federation (FIP), 2016, 2017a; Aruru *et al.*, 2021). The need for skilled and adaptable pharmacists able to practice in these diverse roles is further increased by the complexity and patient-centred nature of healthcare systems.

Despite the acknowledged importance of these frameworks, substantial gaps remain, and these frameworks still need to be validated at local, regional, and global levels. While several countries have developed their core competency frameworks, such as the pharmacist core competency framework from Lebanon (Zeenny *et al.*, 2021; Hajj *et al.*, 2021) and similar initiatives from other countries (Suwannaprom *et al.*, 2020; ; Al-Haqan *et al.*, 2021; Dobrova *et al.*, 2022; Alfaifi *et al.*, 2022), many frameworks lack validation or have undergone incomplete or locally limited validation, leading to inconsistencies in learning outcomes and competency expectations among pharmacists worldwide (Hogan & Agnello, 2004; Fries *et al.*, 2011). The reliability and relevance of these frameworks are thus in question because of these discrepancies.

Using frameworks without adequate validation or implementation has far-reaching consequences. In such cases, training and education may rely on incomplete or outdated competency models, leading to gaps in pharmacists' knowledge and skills, which in turn, would affect their abilities to provide optimal

patient care, adapt to evolving healthcare practices, and contribute effectively to interdisciplinary healthcare teams (Kallio *et al.*, 2021). Bridging these gaps is imperative to address these challenges; it would ensure standardised and effective pharmacy education globally (Hajj *et al.*, 2022), enhance the professional development of pharmacists, improve patient care, and contribute to advancing the pharmacy profession.

In light of the changing landscape in the pharmacy profession, it is crucial to acknowledge the emergence of new specialities and innovative roles for pharmacists, requiring more skills- and clinically-focused education including managerial roles that extend beyond sales and marketing, positions in regulatory affairs, medical affairs, and digital health services. Adapting competency-based educational programmes to tackle these changes would equip pharmacists with the necessary skills for their societal role, ultimately enhancing patient care and safety (Bruno *et al.*, 2010; Nash *et al.*, 2015). Therefore, this work aimed to map the validated Lebanese core and specialised pharmacy competencies with existing global core, advanced, humanitarian, and education frameworks. It also sought to suggest new domains, considering current and potential future health challenges.

Methods

Definitions

Advanced competencies are overarching competencies necessary for any middle-to-late-career pharmacist, regardless of the practice field (Meilanti *et al.*, 2023), while specialised competencies are applied to a specific field of pharmacy practice (Penm *et al.*, 2016). Furthermore, a domain is a cluster of competencies, while a framework is a group of domains. For this document, a concept is considered to be indirectly mentioned whenever it is addressed in the framework without having a dedicated domain.

Frameworks used for the mapping

At the global level, the International Pharmaceutical Federation (FIP) has developed four global frameworks: the Global Core Competency Framework (GbCFV1, optimised in GbCFV2) (Bajis *et al.*, 2023), the Global Advanced Development Framework (GADF) (Meilanti *et al.*, 2023), the Global Competency Framework for Educators and Trainers (FIP-GCFE) (Meštrović *et al.*, 2022), and the Global Humanitarian Competency Framework (GbHCF) (International Pharmaceutical Federation (FIP), 2021a). Their contents were

qualitatively validated, but quantitative validation or pilot assessment in specific settings is still necessary.

In Lebanon, ten specialised competency frameworks have been developed, validated, and piloted based on the needs identified by a previous study (Sacre *et al.*, 2020). These comprehensive frameworks, tailored for pharmacists practising in various settings, regardless of their hierarchical position, included digital literacy and emergency readiness. Only the framework for pharmacists holding managerial positions in sales and marketing can be considered advanced, as it is intended for high management ranks. These competency frameworks relate to community pharmacists (Sakr *et al.*, 2023), hospital and clinical pharmacists (Chamoun *et al.*, 2023), academic pharmacists (instructors, researchers, and clinical preceptors) (Safwan *et al.*, 2023), industry pharmacists (Sacre *et al.*, 2023), sales and marketing pharmacists (Namnoum *et al.*, 2023), and pharmacists in managerial positions in sales and marketing (Sacre *et al.*, 2023).

Principles and procedures of the mapping

After a thorough literature search, the competency domains/clusters were compared, resulting in four groups of frameworks:

Core competency frameworks (including early career and advanced competencies);

Specialised frameworks in pharmaceutical care settings (including humanitarian, community, hospital, and clinical settings);

Specialised frameworks in academia (including global educators and trainers and specialised frameworks for preceptors, instructors, and researchers);

Specialised frameworks in the pharmaceutical industry and marketing settings (including managers).

Based on the Lebanese and the FIP existing frameworks (Table I), ten domains were identified and distributed as follows: fundamental knowledge, specialised fields of practice, pharmaceutical care (including the safe and rational use of medicines, clinical skills, and patient-centred care), management, professional skills, personal skills (including leadership and working with others), public health, research, education, and emergency readiness.

Table I: Frameworks to be mapped, types, and sources

Framework name	Framework type	Source	Reference
FIP GBCFv2 Early career	Core competencies; any setting	FIP Global Competency Framework: Supporting early career training strategy (Version 2).	(1)
Advanced FIP GADF	Core competencies; any setting	FIP Global Advanced Development Framework (GADF): Supporting the advancement of the profession	(2)
Core Competency Framework (Lebanon)	Core competencies; any setting	Developing Core Competencies for Pharmacy Graduates: The Lebanese Experience	(3)
FIP Global Humanitarian Competency Framework (GbHCF)	Pharmaceutical care setting	FIP Global Humanitarian Competency Framework (GbHCF): Supporting pharmacists and the pharmaceutical workforce in a humanitarian arena (Version 1)	(4)
Community (SCF-CP)	Pharmaceutical care setting	The specialised competency framework for community pharmacists (SCF-CP) in Lebanon: Validation and evaluation of the revised version.	(5)
Hospital (SCF-PHS-H)	Pharmaceutical care setting	Validation of the specialised competency framework for pharmacists in hospital settings (SCF-PHS): A cross-sectional study.	(6)
Clinical (SCF-PHS-C)	Pharmaceutical care setting	Validation of the specialised competency framework for pharmacists in hospital settings (SCF-PHS): A cross-sectional study.	(6)
FIP Global Competency Framework for Educators and Trainers (FIP-GCFE)	Academia, Teaching and/or Research setting	The FIP Global Competency Framework for Educators & Trainers in Pharmacy (FIP-GCFE).	(7)
Preceptor (SCF-AS-P)	Academia, Teaching and/or Research setting	Academic pharmacist competencies in ordinary and emergency situations: content validation and pilot description in Lebanese academia. Clinical preceptor competencies for a better pharmacy education: A suggested framework for Lebanon.	(8, 9)
Instructor (SCF-AS-I)	Academia, Teaching and/or Research setting	Academic pharmacist competencies in ordinary and emergency situations: content validation and pilot description in Lebanese academia.	(8)

Framework name	Framework type	Source	Reference
Research (SCF-AS-R)	Academia, Teaching and/or Research setting	Academic pharmacist competencies in ordinary and emergency situations: Content validation and pilot description in Lebanese academia.	(8)
Industrial (SCF-IP)	Pharmaceutical Industry and Market setting	The specialised competency framework for industry pharmacists (SCF-IP): validation and pilot assessment.	(10)
Sales & Marketing (SCF-PSM)	Pharmaceutical Industry and Market setting	Assessing and validating the specialised competency framework for pharmacists in sales and marketing (SCF-PSM): a cross-sectional analysis in Lebanon.	(11)
Sales & Marketing Manager (SCF-PMSM)	Pharmaceutical Industry and Market setting	Specialised competency framework for pharmacists in managerial positions in sales and marketing (SCF-PMSM): development, validation, and correlates.	(12)

The mapping was executed and then scaled accordingly, using the following measures that were developed by the team of experts constituted for this purpose: no mention (0), indirect mention (1), direct mention (2), specially dedicated domain (3), and field of speciality (4). Two authors, who are experts in competency development and validation, performed it separately, and consensus resolved discrepancies. Examples of differences included divergence in opinion regarding some items (direct versus indirect mention, mainly) or classification of items involving multiple activities within domains (missing domains, primarily). A third author reviewed and cross-checked the final maps.

Results

The Lebanese core competency framework places more emphasis on fundamental knowledge, less on specialised practice (including pharmaceutical care) and emergency preparedness, and equal emphasis on management, personal, and personal skills compared to the global early-career and advanced competency frameworks developed by the FIP. Public health is directly mentioned in the Lebanese and early-career frameworks but not in the advanced framework. Research and education are directly mentioned in the Lebanese framework, with more emphasis on this domain than in the early career framework but less in the global advanced framework (Table II).

Table II: Core (early career and advanced) competencies

Framework	Core competency domains/clusters	Fundamental knowledge	Specialised field of practice	Pharmaceutical care*	Management	Professional skills	Personal skills**	Public health	Research	Education	Emergency readiness
FIP GBCFv2 early career	1- Pharmaceutical public health; 2- Pharmaceutical care; 3- Organisation and management; 4- Professional/Personal skills	2	1	3	3	3	3	3	2	1	2
Advanced FIP GADF	1- Expert professional practice; 2- Working with others; 3- Leadership; 4- Management; 5- Education, training, and development; 6- Research and evaluation	2	2	2	3	3	3	0	3	3	0
Core competency framework (Lebanon)	0- Fundamental knowledge; 1- Professional practice; 2- Personal skills; 3- Medicines supply; 4- Safe and rational use of medicines; 5- Pharmaceutical public health; 6- Organisation and management	3	1	2	3	3	3	2	2	2	0

*Pharmaceutical care encompasses the safe and rational use of medicines, clinical skills, and patient-centred care

**Includes leadership and working with others

0=No mention; 1=Indirect mention; 2=Direct mention; 3=Special dedicated domain; 4=Field of speciality

The FIP Global Humanitarian Competency Framework is the closest to the Lebanese specialised competencies in community pharmacy, although the latter emphasises more fundamental knowledge and emergency readiness. The Lebanese specialised framework for hospital pharmacists is also close to the

community framework, with a direct managerial aspect (but not a dedicated domain) and no mention of public health. The Lebanese clinical framework is close to the hospital pharmacy framework, with slightly more emphasis on research and personal skills and less on professional aspects (Table III).

Table III: Pharmaceutical care setting competencies

Framework	Core competency domains/clusters	Fundamental knowledge	Specialised field of practice	Pharmaceutical care*	Management	Professional skills	Personal skills**	Public health	Research	Education	Emergency readiness
FIP Global Humanitarian Competency Framework (GbHCF)	1- Pharmaceutical public health 2- Pharmaceutical care 3- Organisation and management 4- Professional and personal skills	2	4	3	3	3	3	3	2	2	2
Community (SCF-CP)	0- Fundamental skills; 1- Safe and rational use of medicines; 2- Pharmacy management; 3- Professional skills; 4- Public health fundamentals; 5- Emergency preparedness and response (EPR)	3	4	4	3	3	2	3	2	2	3
Hospital (SCF-PHS-H)	0- Fundamental skills; 1- Safe and rational use of medicines; 2- Patient-centred care; 3- Professional skills; 4- Emergency preparedness and response (EPR)	3	4	4	2	3	2	0	2	2	3
Clinical (SCF-PHS-C)	0- Quality improvement; 1- Clinical knowledge and skills; 2- Soft skills; 3- Ability to conduct clinical research; 4- Ability to provide effective education; 5- Use information technology to make decisions and reduce errors; 6- Emergency preparedness and response (EPR)	3	4	4	2	2	3	0	3	2	3

*Pharmaceutical care encompasses the safe and rational use of medicines, clinical skills, and patient-centred care; **Includes leadership and working with others
 0=No mention; 1=Indirect mention; 2=Direct mention; 3=Special dedicated domain; 4=Field of specialty
 GbHCF=Global Humanitarian Competency Framework (FIP); SCF-CP=Specialised Competency Framework – Community Pharmacists (Lebanon); SCF-PHS-H=Specialised Competency Framework – Pharmacists in Hospital Settings – Hospital (Lebanon); SCF-PHS-C: Specialised Competency Framework – Pharmacists in Hospital Settings – Clinical (Lebanon)

The academic-setting competencies are described in Table IV. The Lebanese competency framework for preceptors is broadly similar to the FIP framework, except it directly mentions public health (versus no mention) and emphasises more fundamental knowledge, pharmaceutical care, and emergency readiness. The Lebanese researcher and instructor

frameworks strongly emphasise the research and teaching aspects compared to the preceptor competency framework. They also mention pharmaceutical care and public health without dedicating specific domains to these concepts (indirect mention).

Table IV: Academia, teaching, and research setting competencies

Framework	Core competency domains/clusters	Fundamental knowledge	Specialised field of practice	Pharmaceutical care*	Management	Professional skills	Personal skills**	Public health	Research	Education	Emergency readiness
FIP Global Competency Framework for Educators and Trainers (FIP-GCFE)	1- Education, training, and development 2 -Research, evaluation, and scholarship 3 -Expert professional practice 4 -Working with others 5 -Management, strategy, planning, and leadership	2	4	2	3	3	3	0	3	4	2
Preceptor (SCF-AS-P)	0 -Professional development; 1- Supervising and teaching skills; 2- Facilitating learning; 3- Clarity, organisational/time management skills, and enthusiasm; 4- Interpersonal and communication skills; 5 -Cultural competency skills; 6- Leadership skills; 7- Knowledge and clinical skills; 8 -Research and project management; 9- Emergency preparedness and response (EPR)	3	4	3	3	3	3	2	3	4	3
Instructor (SCF-AS-I)	0- Design, plan, and organise teaching and learning opportunities, and courses; 1- Teach and/or support learning; 2- Assess student learning and provide feedback to ensure student advancement; 3- Create effective and innovative learning environments to optimise learning. 4- Provide effective student support/guidance; 5- Professional development; 6- Emergency preparedness and response (EPR)	2	4	1	2	3	2	1	0	4	3
Research (SCF-AS-R)	0- General research and soft skills; 1- Expertise in fundamental science; 2- Expertise in interventional trials; 3- Expertise in applied pharmacy research; 4- Professional development; 5- Emergency preparedness and response (EPR)	3	4	1	2	3	2	1	4	0	3

*Pharmaceutical care encompasses the safe and rational use of medicines, clinical skills, and patient-centred care

**Includes leadership and working with others

0=No mention; 1=Indirect mention; 2=Direct mention; 3=Special dedicated domain; 4=Field of specialty

FIP- GCFE=FIP Global Competency Framework for Educators and Trainers; SCF-AS-P=Specialised Competency Framework in Academic Setting – Preceptor (Lebanon); SCF-AS-I: Specialised Competency Framework in Academic Setting – Instructor (Lebanon); CF-AS-R=Specialised Competency Framework in Academic Setting – Researcher (Lebanon).

Finally, as shown in Table V, frameworks for pharmacists in industrial and marketing settings indirectly mention pharmaceutical care, public health, and education, emphasising specialised practice and management (particularly for marketing managers). In

all three frameworks, fundamental knowledge and research are directly mentioned, emergency readiness is highlighted, and personal and professional skills are included.

Table V: Industry and market setting competencies

Framework	Core competency domains/clusters	Fundamental knowledge	Specialised field of practice	Pharmaceutical care*	Management	Professional skills	Personal skills**	Public health	Research	Education	Emergency readiness
Industrial (SCF-IP)	0- Research and development; 1- Pharmaceutical and industrial development; 2- Analytical development; 3- Industrial pharmaceutical production; 4- Quality assurance and control; 5- Quality management; 6- Emergency preparedness and response (EPR)	2	4	1	3	2	2	1	2	1	3
Sales & Marketing (SCF-PSM)	0- Pharmaceutical knowledge; 1- Professional communication skills; 2- Organisation and management skills; 3- Professional practice; 4- Personal skills; 5- Emergency preparedness and response (EPR)	3	4	1	3	3	3	1	2	1	3
Sales & Marketing Manager (SCF-PMSM)	0- Pharmaceutical knowledge; 1- Professional communication skills; 2- Organisation and management skills; 3- Professional practice; 4- Personal skills; 5- Upper management skills; 6- Emergency preparedness and response (EPR)	3	4	1	4	3	3	1	2	1	3

*Pharmaceutical care encompasses the safe and rational use of medicines, clinical skills, and patient-centred care

**Includes leadership and working with others

0=No mention; 1=Indirect mention; 2=Direct mention; 3=Special dedicated domain; 4=Field of specialty

SCF-IP=Specialised Competencies Framework - Industry Pharmacists (Lebanon); SCF-PSM=Specialised Competencies Framework – Pharmacists in Sales & Marketing (Lebanon); SCF-PMSM= Specialised Competencies Framework – Pharmacists in Managerial positions in Sales & Marketing (Lebanon)

Discussion

This manuscript maps validated Lebanese pharmacy competency frameworks to global frameworks. The findings underscore the importance of enhancing competencies across four major domains in various curricula and frameworks. These domains include, but are not limited to, digital health, public health, emergency readiness, and pharmaceutical care.

The FIP recognised digital health and digital literacy as vital skills for pharmacists, ensuring the safe and effective use of information and communication technologies in pharmaceutical practice (Anderson *et al.*, 2008, 2009; International Pharmaceutical Federation (FIP), 2021b). A global study by the FIP on digital health in pharmacy education identified knowledge and skill gaps among pharmacy students and the workforce (Mantel-Teeuwisse *et al.*, 2021). The study surveyed 1,060 respondents from 91 countries and underscored the urgent need to integrate basic digital knowledge and skills into pharmacy education programmes. Therefore, integrating digital health

components such as digital literacy, data management, online communication, and other relevant skills into core competency frameworks enables pharmacy students to navigate digital platforms and provide high-quality patient-centred digital care (Aungst & Patel, 2020; Mantel-Teeuwisse *et al.*, 2021).

For instance, including telepharmacy in core competencies acknowledges the importance of providing care at a distance, especially during pandemics, natural disasters, or in remote regions with limited access to traditional pharmacy services. Additionally, integrating digital health concepts into research projects, educational curricula, and training programmes allows students to gain practical experience and familiarity with digital tools and technologies. Hence, using mobile applications for medication management or social media for health communication would enhance patient reach and care.

For core competencies, a comparison of the Lebanese core competency framework (Hajj *et al.*, 2021) with FIP global frameworks for early-career pharmacists (Bajis *et al.*, 2023) and advanced competencies (Meilanti *et*

al., 2023) reveals that the Lebanese framework emphasises fundamental knowledge over specialised practice (including pharmaceutical care) and emergency readiness, and equal emphasis on management, personal, and personal skills. Public health is directly mentioned in the Lebanese and early-career frameworks but not in the advanced framework. Research and education are directly mentioned in the Lebanese framework, with more emphasis on this domain than in the early career framework but less in the global advanced framework. Based on these findings, it is recommended that the Lebanese core competency framework be revised to add the missing domains, mainly focusing on pharmaceutical care, emergency readiness, and digital health. This measure will modernise the Lebanese competency framework, aligning it with the global vision of the pharmacist while maintaining its specificities (Alfaifi *et al.*, 2022).

The present study also highlighted the need for substantial improvements in the frameworks for pharmacists working in hospital, clinical, industrial, and marketing settings by leveraging public health aspects. In contrast, the community pharmacy framework already comprises many public health competencies, so it does not require such improvements. The Global Humanitarian Competency Framework includes domains similar to those in the Lebanese Specialised Competency Framework for Community Pharmacists. However, the latter is not specific to humanitarian settings, emphasising emergency readiness and fundamental knowledge.

The Lebanese framework for hospital pharmacists is comparable to the community pharmacy framework, with a direct managerial aspect (although not a dedicated domain) but no mention of public health. The Lebanese framework for clinical pharmacists is comparable to the hospital pharmacy framework but focuses more on research and personal skills and less on professional aspects. Thus, more emphasis could be placed on managerial and individual skills in hospital pharmacy (Vermeulen *et al.*, 2016) and advanced clinical skills in clinical pharmacy (Engle *et al.*, 2020). Furthermore, adding the public health domain to the hospital and clinical frameworks is highly recommended to better align with global recommendations (Palombi *et al.*, 2013). The public health responsibilities of pharmacists extend beyond the community setting. Pharmacists in all specialities can assume diverse and essential roles in promoting public health. Through their expertise in medication management, antimicrobial stewardship programmes, pharmacovigilance activities, patient care and disease prevention, regulatory compliance, and evidence-based health education, pharmacists from different specialities could significantly improve health

outcomes and community well-being, serving as pillars of health systems in various settings.

The pivotal role of pharmacists in public health services and emergencies has already been showcased for community pharmacists, as evidenced during the COVID-19 pandemic (Ung, 2020; Cadogan & Hughes, 2021; Zeenny *et al.*, 2021) and other disasters and crises (Ford *et al.*, 2013; Bajis *et al.*, 2023). A review assessing the public health impact of community pharmacists during COVID-19 highlighted their crucial contribution, particularly to vaccination efforts (Maidment *et al.*, 2021). Interestingly, the authors discussed recommendations to expand education and training modules in public health and encourage decision-makers to endorse and optimise this advanced role by defining adequate resources, such as reimbursement to cover costs for time, establishing a legal framework, and ensuring logistical support.

In the academic setting, the Lebanese Preceptor Competency Framework displays competencies similar to those suggested by the FIP, except it directly mentions public health (in contrast to “no mention”) and emphasises fundamental knowledge, pharmaceutical care, and emergency readiness. Regarding researchers and instructors, the Lebanese researcher and instructor frameworks emphasise the research and teaching aspects more than the preceptor competencies and indirectly mention pharmaceutical care and public health. These frameworks would benefit from an emphasis on the digital pharmacy aspect by including it in pharmaceutical research, teaching, and learning (Mantel-Teeuwisse *et al.*, 2021). Introducing and reinforcing this aspect is of primary importance to ensure the sustainability of pharmacy practice and provide health for all.

Pharmacists can assume managerial roles beyond sales and marketing, including regulatory affairs, medical affairs, and digital health positions. While this manuscript has focused on sales and marketing frameworks, exploring and addressing the competencies required for these broader managerial roles within pharmaceutical companies is essential.

The three frameworks for pharmacists in industrial and marketing settings indirectly mention pharmaceutical care, public health, and education while emphasising specialised practice and management, particularly for the marketing manager framework. Across all three frameworks, fundamental knowledge, research, personal and professional skills, and emergency readiness are directly mentioned and emphasised. Nevertheless, despite the absence of global frameworks to compare with, these frameworks need strengthening in the domains of pharmaceutical care (Gruber *et al.*, 1995), teaching (Podczek, 2008; EIPG

Advisory Group, 2023), and public health (Saxena *et al.*, 2022).

Lastly, the Lebanese authorities should implement advanced competency frameworks for senior pharmacists, particularly in continuing education and professional development activities (Sacre *et al.*, 2019). At the global level, the FIP should prioritise validating specialised frameworks in different pharmacy specialities based on guiding principles similar to the Basel statement for hospital pharmacy (Vermeulen *et al.*, 2016). Furthermore, the FIP should develop comprehensive guidance for adapting core and advanced competency frameworks to various regions and countries, leveraging differences in practice settings, and promoting modern aspects of the profession.

Limitations and strengths

This study has several limitations that warrant consideration. First, it relies heavily on existing literature and expert consensus for the mapping process, and the number of experts involved may not be sufficient to provide a fully representative view of the field. This limitation could introduce biases in the selection and interpretation of frameworks. Indirect mentions or implied competencies can also lead to subjective interpretations of domain relevance, particularly in digital health and emergency readiness. Nevertheless, the experts in this study have extensive experience in developing and validating core and advanced competency frameworks in Lebanon over several years. Their insights were informed by objective criteria based on the domains and clusters outlined in the four global FIP frameworks.

While this methodological rigour strengthens the study's design, it is essential to acknowledge that expert opinion may still be influenced by personal biases and interpretations, highlighting the need for a broader representation of experts and reviewers to enhance the robustness of our methodology. This study focused primarily on mapping frameworks rather than evaluating their implementation or effectiveness in real-world settings. The absence of data on how these competencies are taught, assessed, and practised within pharmacy curricula limits our ability to make concrete recommendations for curriculum reform or professional development. Furthermore, the existing frameworks do not comprehensively address the competencies needed for pharmacists in diverse managerial roles, such as regulatory and medical affairs. Future research should explore these aspects to ensure that competencies align with evolving industry needs. It should also examine how these frameworks translate into practice and impact patient care and

pharmacy outcomes. Finally, the emphasis on Lebanese frameworks constrains the scope of the study. Although comparisons were made with global frameworks, other countries' unique healthcare and educational contexts may necessitate different competencies or adaptations not fully explored in this work. Hence, a more comprehensive, cross-national analysis is warranted to elucidate how competency frameworks can be universally applicable while respecting regional specificities.

Conclusion

Mapping validated Lebanese core and specialised pharmacy competency frameworks to global standards revealed several opportunities for improvement, highlighting the importance of revising and incorporating new competencies, such as digital health competencies, emergency preparedness, and public health practice, into the Lebanese core competency framework. These competencies would enable pharmacists to adapt to rapidly evolving practices and assume new roles. Policymakers, including the Order of Pharmacists of Lebanon, should collaborate with academic institutions to implement these changes. This collaboration would ensure that pharmacists in Lebanon acquire the skills and knowledge necessary to meet modern healthcare demands and contribute effectively to public health initiatives.

Acknowledgement

None

Conflict of Interests

The authors declare no conflict of interests

Funding

This study received no funding.

References

Alfaifi, S., Arakawa, N., & Bridges, S. (2022). The relevance of the International Pharmaceutical Federation Global Competency Framework in developing a country-level

- competency framework for pharmacists: A cross-sectional study. *Exploratory Research in Clinical and Social Pharmacy*, **5**, 100095. <https://doi.org/10.1016/j.rcsop.2021.100095>
- Alfaifi, S., Bridges, S., & Arakawa, N. (2022). Developing pharmacists' competencies in Saudi Arabia: A proposed national competency framework to support initial education and professional development. *Currents in Pharmacy Teaching and Learning*, **14**(10), 1256–1268. <https://doi.org/10.1016/j.cptl.2022.09.010>
- Al-Haqan, A., Smith, F., Bader, L., & Bates, I. (2021). Competency development for pharmacy: Adopting and adapting the Global Competency Framework. *Research in Social & Administrative Pharmacy: RSAP*, **17**(4), 771–785. <https://doi.org/10.1016/j.sapharm.2020.06.023>
- American College of Clinical Pharmacy. (2023). Standards of practice for clinical pharmacists. *JACCP: Journal of the American College of Clinical Pharmacy*, **6**(10), 1156–1159. <https://doi.org/10.1002/jac5.1873>
- Anderson, C., Bates, I., Beck, D., Brock, T., Futter, B., Mercer, H., Rouse, M., Wuliji, T., & Yonemura, A. (2008). The WHO UNESCO FIP Pharmacy Education Taskforce: Enabling Concerted and Collective Global Action. *American Journal of Pharmaceutical Education*, **72**(6), 127. <https://doi.org/10.5688/aj7206127>
- Anderson, C., Bates, I., Beck, D., Brock, T. P., Futter, B., Mercer, H., Rouse, M., Whitmarsh, S., Wuliji, T., & Yonemura, A. (2009). The WHO UNESCO FIP Pharmacy Education Taskforce. *Human Resources for Health*, **7**(1), 45. <https://doi.org/10.1186/1478-4491-7-45>
- Aruru, M., Truong, H.-A., & Clark, S. (2021). Pharmacy Emergency Preparedness and Response (PEPR): A proposed framework for expanding pharmacy professionals' roles and contributions to emergency preparedness and response during the COVID-19 pandemic and beyond. *Research in Social & Administrative Pharmacy: RSAP*, **17**(1), 1967–1977. <https://doi.org/10.1016/j.sapharm.2020.04.002>
- Aungst, T. D., & Patel, R. (2020). Integrating digital health into the curriculum—Considerations on the current landscape and future developments. *Journal of Medical Education and Curricular Development*, **7**, 2382120519901275. <https://doi.org/10.1177/2382120519901275v>
- Bajis, D., Al-Haqan, A., Mhlaba, S., Bruno, A., Bader, L., & Bates, I. (2023). An evidence-led review of the FIP global competency framework for early career pharmacists training and development. *Research in Social & Administrative Pharmacy: RSAP*, **19**(3), 445–456. <https://doi.org/10.1016/j.sapharm.2022.11.010>
- Bajis, D., Bajis, S., Akel, M., Bizama, A. P., & Chaar, B. (2023). A grounded theory approach to exploring the experiences of community pharmacists in Lebanon on a triple whammy of crises: The Lebanese financial crisis, the COVID-19 pandemic, and the Beirut port explosion. *Exploratory Research in Clinical and Social Pharmacy*, **9**, 100217. <https://doi.org/10.1016/j.rcsop.2022.100217>
- Bruno, A., Bates, I., Brock, T., & Anderson, C. (2010). Towards a global competency framework. *American Journal of Pharmaceutical Education*, **74**(3), Article 3. <https://doi.org/10.5688/aj740356>
- Cadogan, C. A., & Hughes, C. M. (2021). On the frontline against COVID-19: Community pharmacists' contribution during a public health crisis. *Research in Social and Administrative Pharmacy*, **17**(1), 2032–2035. <https://doi.org/10.1016/j.sapharm.2020.03.015>
- Chamoun, N., Ramia, E., Sacre, H., Haddad, M., Haddad, C., Hajj, A., Namnoum, J., Zeenny, R. M., Iskandar, K., Akel, M., & Salameh, P. (2023). Validation of the specialised competency framework for pharmacists in hospital settings (SCF-PHS): A cross-sectional study. *Journal of Pharmaceutical Policy and Practice*, **16**(1), 86. <https://doi.org/10.1186/s40545-023-00592-7>
- Dobrova, V. Ye., Popov, O. S., Shtrimaitis, O. V., Andreeva, O. O., & Proskurnia, O. M. (2022). Joint task force core competency framework adoption process at a national level: A survey of Ukrainian-based clinical research professionals. *Therapeutic Innovation & Regulatory Science*, **56**(5), 814–821. <https://doi.org/10.1007/s43441-022-00428-7>
- EIPG Advisory Group. (2023, September 25). *Insights to the industrial pharmacist role for the future*. European Industrial Pharmacists Group (EIPG). <https://eipg.eu/insights-to-the-industrial-pharmacist-role-for-the-future/>
- Engle, J. P., Burke, J. M., Ashjian, E. J., Avery, L., Borchert, J. S., Faro, S. J. E., Harris, C. S., Herink, M. C., Jain, B., MacLaughlin, E. J., Martello, J. L., Moore, K., Rogers, E., Smith, W. J., & Stranges, P. M. (2020). ACCP clinical pharmacist competencies: Advocating alignment between student, resident, and practitioner competencies. *JACCP: Journal of the American College of Clinical Pharmacy*, **3**(1), 124–132. <https://doi.org/10.1002/jac5.1200v>
- Faruquee, C. F., & Guirguis, L. M. (2015). A scoping review of research on the prescribing practice of Canadian pharmacists. *Canadian Pharmacists Journal / Revue Des Pharmaciens Du Canada*, **148**(6), 325–348. <https://doi.org/10.1177/1715163515608399>
- Ford, H., Dallas, C. E., & Harris, C. (2013). Examining roles pharmacists assume in disasters: A content analytic approach. *Disaster Medicine and Public Health Preparedness*, **7**(6), 563–572. <https://doi.org/10.1017/dmp.2013.99>
- Fries, J. F., Krishnan, E., Rose, M., Lingala, B., & Bruce, B. (2011). Improved responsiveness and reduced sample size requirements of PROMIS physical function scales with item response theory. *Arthritis Research & Therapy*, **13**(5), R147. <https://doi.org/10.1186/ar3461>
- Gruber, W., Llewelyn, J., Arras, C., & Lion, S. (1995). The role of the pharmaceutical industry in promoting patient education. *Patient Education and Counseling*, **26**(1), 245–249. [https://doi.org/10.1016/0738-3991\(95\)00731-E](https://doi.org/10.1016/0738-3991(95)00731-E)
- Hajj, A., Hallit, S., Sacre, H., Akel, M., Zeenny, R. M., & Salameh, P. (2021). Lebanese pharmacy core competencies framework: Tool validation for self-declared assessment. *The International Journal of Pharmacy Practice*, **29**(6), 598–604. <https://doi.org/10.1093/ijpp/riab055>
- Hajj, A., Zeenny, R. M., Akel, M., Sacre, H., & Salameh, P. (2022). The Lebanese experience for early career development: Bridging the gap to reach the International

- Pharmaceutical Federation (FIP) Global Competency Framework. *Pharmacy Education*, **22**(1), Article 1. <https://doi.org/10.46542/pe.2022.221.211220>
- Hogan, T. P., & Agnello, J. (2004). An empirical study of reporting practices concerning measurement validity. *Educational and Psychological Measurement*, **64**(5), 802–812. <https://doi.org/10.1177/0013164404264120>
- Howk, H. (2023). *Online and mail-order pharmacy license compliance* (Wolters Kluwer Expert Insights). Wolters Kluwer. <https://www.wolterskluwer.com/en/expert-insights/online-and-mail-order-pharmacy-license-requirements>
- International Pharmaceutical Federation (FIP). (2016). *Responding to disasters: Guidelines for pharmacy*. International Pharmaceutical Federation (FIP). <https://www.fip.org/files/content/pharmacy-practice/military-emergency-pharmacy/emergency-activities/2016-07-responding-to-disasters-guideline.pdf>
- International Pharmaceutical Federation (FIP). (2017a). *FIP Statement of Policy: Role of the pharmacist in disaster management*. International Pharmaceutical Federation (FIP). <https://www.fip.org/file/1593>
- International Pharmaceutical Federation (FIP). (2017b). *Nanjing statements: Statements on pharmacy and pharmaceutical sciences education*. International Pharmaceutical Federation (FIP). <https://www.fip.org/files/content/pharmacy-education/fip-education/nanjing-statements.pdf>
- International Pharmaceutical Federation (FIP). (2021a). *FIP Global Humanitarian Competency Framework (GbhCF). Supporting pharmacists and the pharmaceutical workforce in a humanitarian arena. Version 1*. International Pharmaceutical Federation (FIP). <https://www.fip.org/file/5130>
- International Pharmaceutical Federation (FIP). (2021b). *FIP Statement of Policy: Digital health*. International Pharmaceutical Federation (FIP). <https://www.fip.org/file/5092>
- International Pharmaceutical Federation (FIP). (2022). *Competency-based education in pharmacy and pharmaceutical sciences: A FIP handbook to support implementation of competency-based education and training*. International Pharmaceutical Federation (FIP). <https://www.fip.org/file/5338>
- Kallio, S., Eskola, T., Airaksinen, M., & Pohjanoksa-Mäntylä, M. (2021). Identifying gaps in community pharmacists' competence in medication risk management in routine Dispensing. *INNOVATIONS in Pharmacy*, **12**(1), Article 1. <https://doi.org/10.24926/iip.v12i1.3510>
- Kehrer, J. P., Eberhart, G., Wing, M., & Horon, K. (2013). Pharmacy's role in a modern health continuum. *Canadian Pharmacists Journal: CPJ*, **146**(6), 321–324. <https://doi.org/10.1177/1715163513506370>
- Kremin, Y., Lesyk, L., Lesyk, R., Levytska, O., & Hromovych, B. (2023). Detailing the ten main professional roles of a pharmacist to provide the scope of professional functions. *Scientia Pharmaceutica*, **91**(1), Article 1. <https://doi.org/10.3390/scipharm91010005>
- Maidment, I., Young, E., MacPhee, M., Booth, A., Zaman, H., Breen, J., Hilton, A., Kelly, T., & Wong, G. (2021). Rapid realist review of the role of community pharmacy in the public health response to COVID-19. *BMJ Open*, **11**(6), e050043. <https://doi.org/10.1136/bmjopen-2021-050043>
- Mantel-Teeuwisse, A. K., Meilanti, S., Khatri, B., Yi, W., Azzopardi, L. M., Acosta Gómez, J., Gülpinar, G., Bennara, K., & Uzman, N. (2021). Digital health in pharmacy education: Preparedness and responsiveness of pharmacy programmes. *Education Sciences*, **11**(6), Article 6. <https://doi.org/10.3390/educsci11060296>
- McMullen, J., Arakawa, N., Anderson, C., Pattison, L., & McGrath, S. (2023). A systematic review of contemporary competency-based education and training for pharmacy practitioners and students. *Research in Social and Administrative Pharmacy*, **19**(2), 192–217. <https://doi.org/10.1016/j.sapharm.2022.09.013v>
- Medina, M. S., Plaza, C. M., Stowe, C. D., Robinson, E. T., DeLander, G., Beck, D. E., Melchert, R. B., Supernaw, R. B., Roche, V. F., Gleason, B. L., Strong, M. N., Bain, A., Meyer, G. E., Dong, B. J., Rochon, J., & Johnston, P. (2013). Centre for the advancement of pharmacy education 2013 educational outcomes. *American Journal of Pharmaceutical Education*, **77**(8). <https://doi.org/10.5688/ajpe778162>
- Meilanti, S., Galbraith, K., Bader, L., Udoh, A., Ernawati, D., & Bates, I. (2023). The development and validation of a global advanced development framework for the pharmacy workforce: A four-stage multi-methods approach. *International Journal of Clinical Pharmacy*, **45**(4), Article 4. <https://doi.org/10.1007/s11096-023-01585-x>
- Meštrović, A., Al-Haqan, A., El-Akel, M., Arakawa, N., Abdulrzaq S. Mukhalati, B., Bader, L., Bates, I., Bruno-Tomé, A., Alves da Costa, F., Eksteen, M., Gallagher, P. J., Hall, K., Henman, M. C., John, D., Mager, D. E., Pieper, J. A., Rouse, M., Kaur Sandhu, A., Schneider, C. R., Tofade, T., & Duggan, C. (2022). Connecting the dots in pharmacy education: The FIP International Pharmaceutical Federation Global Competency Framework for Educators and Trainers in Pharmacy (FIP-GCFE). *Pharmacy Education*, **22**(4), Article 4. <https://doi.org/10.46542/pe.2022.224.100109>
- Namnoum, J., Hajj, A., Iskandar, K., Sacre, H., Akel, M., Zeenny, R. M., Haddad, C., & Salameh, P. (2023). Assessing and validating the specialised competency framework for pharmacists in sales and marketing (SCF-PSM): A cross-sectional analysis in Lebanon. *Journal of Pharmaceutical Policy and Practice*, **16**(1), 128. <https://doi.org/10.1186/s40545-023-00638-w>
- Nash, R. E., Chalmers, L., Brown, N., Jackson, S., & Peterson, G. (2015). An international review of the use of competency standards in undergraduate pharmacy education. *Pharmacy Education*, **15**. <https://pharmacyeducation.fip.org/pharmacyeducation/article/view/324>
- Owczarek, A., Marciniak, D. M., Jezior, R., & Karolewicz, B. (2023). Assessment of the prescribing pharmacist's role in supporting access to prescription-only medicines—Metadata analysis in Poland. *Healthcare*, **11**(24), Article 24. <https://doi.org/10.3390/healthcare11243106>

- Palombi, L., Kading, M., & Hayes, C. J. (2013). The public health pharmacist and the role of the pharmacy curriculum: A call to action. *Currents in Pharmacy Teaching and Learning*, *5*(5), 477–482. <https://doi.org/10.1016/j.cptl.2013.06.011v>
- Penm, J., MacKinnon, N. J., Jorgenson, D., Ying, J., & Smith, J. (2016). Need for formal specialization in pharmacy in Canada: A survey of hospital pharmacists. *Canadian Journal of Hospital Pharmacy*, *69*(5), Article 5. <https://doi.org/10.4212/cjhp.v69i5.1590>
- Podczeck, F. (2008). Pharmaceutics teaching and the pharmaceutical industry. *Pharmaceutical Technology Europe*, *20*(7). <https://www.pharmtech.com/view/pharmaceutics-teaching-and-pharmaceutical-industry>
- Ronquillo, Y., Meyers, A., & Korvek, S. J. (2024). Digital health. In *StatPearls*. StatPearls Publishing. <http://www.ncbi.nlm.nih.gov/books/NBK470260/>
- Sacre, H., Aoun, R., Haddad, C., Abou Selwan, C., Zeenny, R. M., Akel, M., Hajj, A., Hassoun, C., Namnoun, J., Iskandar, K., & Salameh, P. (2023). Specialised competency framework for pharmacists in managerial positions in sales and marketing (SCF-PMSM): Development, validation, and correlates. *Journal of Pharmaceutical Policy and Practice*, *16*(1), Article 1. <https://doi.org/10.1186/s40545-023-00567-8v>
- Sacre, H., Hallit, S., Hajj, A., Zeenny, R. M., Raad, E., Akel, M., Sili, G., & Salameh, P. (2020). Upgrading pharmacy education to produce practice-ready pharmacists in Lebanon. *Pharmacy Education*, *20*(1), 379–394. <https://doi.org/10.46542/pe.2020.201.379394>
- Sacre, H., Saab, M., Haddad, C., Haddad, M., Zeenny, R. M., Akel, M., Hajj, A., Iskandar, K., & Salameh, P. (2023). The specialised competency framework for industry pharmacists (SCF-IP): Validation and pilot assessment. *Journal of Pharmaceutical Policy and Practice*, *16*(1), 96. <https://doi.org/10.1186/s40545-023-00602-8>
- Sacre, H., Tawil, S., Hallit, S., Sili, G., & Salameh, P. (2019). Mandatory continuing education for pharmacists in a developing country: Assessment of a three-year cycle. *Pharmacy Practice*, *17*(3), Article 3. <https://www.pharmacypractice.org>
- Safwan, J., Akel, M., Sacre, H., Haddad, C., Sakr, F., Hajj, A., Zeenny, R. M., Iskandar, K., & Salameh, P. (2023). Academic pharmacist competencies in ordinary and emergency situations: Content validation and pilot description in Lebanese academia. *BMC Medical Education*, *23*(1), 737. <https://doi.org/10.1186/s12909-023-04712-4>
- Sakr, F., Akel, M., Sacre, H., Haddad, C., Tawil, S., Safwan, J., Hajj, A., Zeenny, R. M., Iskandar, K., & Salameh, P. (2023). The specialised competency framework for community pharmacists (SCF-CP) in Lebanon: Validation and evaluation of the revised version. *Journal of Pharmaceutical Policy and Practice*, *16*(1), 77. <https://doi.org/10.1186/s40545-023-00585-6>
- Sam, A. T., & Parasuraman, S. (2015). The nine-star pharmacist: An overview. *Journal of Young Pharmacists*, *7*(4), 281–284. <https://doi.org/10.5530/jyp.2015.4.1>
- Saxena, K., Balani, S., & Srivastava, P. (2022). The role of pharmaceutical industry in building a resilient health system. *Frontiers in Public Health*, *10*. <https://doi.org/10.3389/fpubh.2022.964899>
- Suchanek, D. (2005). The rise and role of specialty pharmacy. *Biotechnology Healthcare*, *2*(5), 31–35. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3571003/>
- Suwannaprom, P., Suttajit, S., Eakanunkul, S., Supapaan, T., Kessomboon, N., Udomaksorn, K., & Sakulbumrungsil, R. (2020). Development of pharmacy competency framework for the changing demands of Thailand's pharmaceutical and health services. *Pharmacy Practice*, *18*(4), 2141–2141. <https://www.pharmacypractice.org>
- Ung, C. O. L. (2020). Community pharmacist in public health emergencies: Quick to action against the coronavirus 2019-nCoV outbreak. *Research in Social and Administrative Pharmacy*, *16*(4), 583–586. <https://doi.org/10.1016/j.sapharm.2020.02.003v>
- Vermeulen, L. C., Moles, R. J., Collins, J. C., Gray, A., Sheikh, A. L., Surugue, J., Moss, R. J., Ivey, M. F., Stevenson, J. G., Takeda, Y., Ranjit, E., Chaar, B., & Penm, J. (2016). Revision of the International Pharmaceutical Federation's Basel Statements on the future of hospital pharmacy: From Basel to Bangkok. *American Journal of Health-System Pharmacy*, *73*(14), 1077–1086. <https://doi.org/10.2146/ajhp150641>
- Zeenny, R. M., Akel, M., Hajj, A., Sacre, H., Hallit, S., & Salameh, P. (2021). Descriptive assessment of graduates' perceptions of pharmacy-related competencies based on the Lebanese pharmacy core competencies framework. *Pharmacy Practice*, *19*(2), 2320. <https://doi.org/10.18549/PharmPract.2021.2.2320>
- Zeenny, R. M., Dimassi, A., Sacre, H., El Khoury, G., Hajj, A., Farah, R., Hajj, H., Lahoud, N., Akel, M., Hallit, S., & Salameh, P. (2021). A cross-sectional survey on community pharmacists' readiness to fight COVID-19 in a developing country: Knowledge, attitude, and practice in Lebanon. *Journal of Pharmaceutical Policy and Practice*, *14*(1), 51. <https://doi.org/10.1186/s40545-021-00327-6>