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Review

A conceptual basis and key components for pharmacy core curriculum in the age of artificial intelligence

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ABSTRACT

The present article addresses education curriculum for pharmacy practice in the community and hospital setting. A conceptual basis for a change in pharmacy education in the age of artificial intelligence (AI) is first provided and discussed. Then a new core curriculum is proposed to include the following components: (1) broad outcome domains (modified from the American Association of Colleges of Pharmacy with addition of research skill); (2) competencies relating to healthcare improvements; and (3) key pharmacy course work. The outcome domains can be easily mapped together with the other 2 components to show an interactive relationship of the outcomes-based curriculum. This conceptual basis and key components can offer an initial step in developing a common but relevant core curriculum pertinent to pharmacy education in the age of artificial intelligence. Such core curriculum should be applicable not only to Asia but also other parts of the world.

Key words: artificial intelligence, curriculum, education, pharmacy

1. Introduction

The present article is based on an initial invited presentation at the 5th Asian Association of Schools of Pharmacy (AASP) Deans Forum, held in Macau, China on July 10–11, 2018. The theme of the Forum was "Framework for a Core Curriculum for Asian Schools of Pharmacy". This Forum was hosted by Dean Y.Z. Zhu of the School of Pharmacy of the Macau University of Science and Technology and attended by 215 participants from 142 different institutions/schools (including 36 participants from institutions outside Asia).

This article is written primarily as a conceptual idea of pharmacy education in the age of artificial intelligence in Asia. Thus, the authors are greatly appreciative of the input and feedback from AASP members and those at the Forum, specifically the Chairs and Co-Chairs of all 4 sessions including: Paul WS Heng, Ph.D and Eun-Seok Park, Ph.D. (Pharmaceutics/Pharmacokinetics session), Ji Wang Chern, Ph.D. and Daryono Hadi Tjahjono, Ph.D. (Drug Discovery/ Biology session), Fe-Lin Lin Wu, Ph.D. and Motoko Kanke, Ph.D. (Pharmacy Practice/ Clinical Pharmacy session), and Shu-Chuen Li, Ph.D. and Tetsumi Irie, Ph.D. (Pharmaco-epidemiology/Pharmacoeconomics session). In addition, other attendees at the Forum who provided valuable input are also incorporated. Since the 2 initial presenters (M. Chow and S. Chow) are primarily in clinical pharmacy and translational research in USA, (although one of the co-authors, M. Chow, had 9 years of academic teaching and research in Hong Kong and had served as the Founding President of AASP), further input in the preparation of this manuscript was provided by David Kember, Ph.D, an expert in education research with many years of experience in Hong Kong and Australia. Thus, we hope the thoughts expressed in this article—which combines both American and Asian concepts—would be useful not only to many Asian educators/students but also others outside Asia.

2. Pharmacy curriculum change—an integral part of human life change

"There is nothing permanent except change"- Heraclitus, 554BC-483BC

"It is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change"- Charles Darwin 1809-1882

"Education is the most powerful weapon which you can use to change the world" -Nelson Mandela 1918-2013

The 3 quotations above represent the important concept of "change" in human life and the tremendous role of education that can play within the "change" process of human life. The fact that human race has been able to continuously adapt and make revolutionary changes qualifies the human race as the superior specie among the animal kingdom. This is evident from the tremendous progress made in short human history (less than 200,000 years since our ancestor Homosapien) (Harari, 2018) as compared to that of the dinosaurs which became extinct despite 60 million years of existence. The history of Homosapien is an excellent example of "survival of the fittest" principle observed by Darwin.

As human beings progressed over time and made major changes, such as that occurred within the agricultural revolution, scientific revolution, industrial revolution, and the latest technological revolution (artificial intelligence with computers, internet and robotics), the quality of human life also changes in giant steps. Pharmacy practice, as part of the health care system for human society, is expected to change and adapt accordingly, otherwise the present services provided by the pharmacists will become obsolete in the future. Changes in pharmacy education are necessary to educate the pharmacists to become viable member of the health care team in the 22nd century.

How has pharmacy practice changed in the recent past and what role has education played? Pharmacy has been historically defined as "the practice of preparation and dispensing of medicinal drugs". Such practice is viewed as the traditional practice and has existed for more than 500 years. However, with advances from the scientific revolution (about 500 years ago) and industrial revolution (about 200 years ago), the task of preparation of drugs (tablets, capsules, injections etc.) has been primarily taken over by the pharmaceutical industry in the last century. Thus, a new role of pharmacy practice has evolved within the last 50 years to provide drug information and clinical services in combination with dispensing of drugs (see Table 1). The transition of the traditional to new role of practice stems largely from implementation of the Pharm.D. curriculum by the schools of pharmacy as well as support from multiple pharmacy professional organizations. In North America, the Pharm.D. degree is the sole degree required as of 2000 in USA and 2022 in Canada. In many Asian countries, similar education has also been initiated and implemented (Chen et al., 2018). While not every Asian country has adopted a Pharm.D. curriculum like that of US/Canada, majority have already incorporated clinical pharmacy in the Asian pharmacy curriculum.

Table 1. Modern Pharmacy Practice.

1. Clinical pharmacy services
a. Admission medication reconciliation
b. Medication profile daily review, including TDM
c. Multidisciplinary patient care rounds
d. Medication Use Process Performance Enhancement Team
e. Specialized patient care teams, e.g. Antimicrobial Stewardship Program, TPN etc
f. Collaborative or independent practice, e.g. CMM, MTM
g. Vaccination
2. Dispensing, compounding and distribution of medication

Abbreviations:
TDM - therapeutic drug monitoring; CMM - comprehensive medication management (a pharmacist-physician collaborative practice that is reimbursed by payor for reviewing/recommending patient's drug therapy in USA); MTM - medication therapy management (a pharmacy independent service reimbursed by Medicare in USA for reviewing and recommending drug therapy of a given designated patient, usually on an annual basis); TPN - total parenteral nutrition

3. Expected change in pharmacy practice in the age of artificial intelligence

We are now at the dawn of artificial intelligence (AI). Although the new role of clinical pharmacy practice has evolved 50 years ago, will this be adequate in the next 50 years? What will be the greatest need in health care at that time and how can the pharmacist play an important role? Answering these questions will provide a new direction as well as a strategy for improving pharmacy practice to meet the health care needs in the age of AI in the years ahead. Obviously, future changes in pharmacy practice will depend on the capabilities of AI. As AI becomes more mature, it is likely to immensely impact the provision of drug information and dispensing function by the pharmacist. The World Economic Forum has predicted a "robot pharmacist" will be available in 2025 (World Economic Forum, 2015). With continued technological advancement in subsequent years, such robot pharmacist will be expected to provide not only basic drug information but also dispending functions, the predominant tasks of the present day pharmacists. In reality, some form of robotic dispensing have already been operating today in the hospital and community settings (Zaleski, 2016). Thus, in the near future, the current traditional tasks by the pharmacist will no longer need to be performed by the pharmacists. Thus, the profession will need to continue to evolve to stay relevant and useful.

There will be no doubt that the "robot pharmacist" using AI can easily outperform human being in speed and accuracy, especially pertaining to dispending of drug product and information. It has been predicted that the expansion of knowledge which is currently doubling every 13 months, is predicted to double every 12 hours in the near future (Schilling, 2013). With such rapid expansion of knowledge, the pharmacist not only will need to rely on AI but must also evolve to achieve a new, useful role in healthcare, which is most likely managed by a new interdisciplinary health care team. According to Drs. Steven A. Wartman and C. Donald Combs, 2 well known medical academicians, medical practice in the age of AI is predicted to be (1) provided in many locations, (2) provided by newly-constituted health care teams, and (3) based on growing array of data, and (4)

the interface between medicine and machines which will need to be skillfully managed (Wartman & Combs, 2018). Thus, the pharmacist should concentrate on becoming a valuable member of the team by contributing to health care improvement. This is the fundamental goal of the collaborative team-based approach because patients, insurers and regulators all want improved healthcare outcomes (Wartman & Combs, 2018).

In 2008, Berwick, Nolan and Whittington from the Institute for Healthcare Improvement (IHI, a non-profit organization whose mission is to improve health and health care world wide), introduced the concept of "triple aim" for health care improvement (Berwick, Nolan & Whittington, 2008). According to IHI, the original "triple aim" was conceived and pilot tested in over 100 organizations around the world and has reported good successes (IHI, n.d (a); IHI, n.d (b)). Although this "triple aim" was originally conceived to aim for delivery of high value care in the USA, such concept has been now adopted as a set of principles for health system reform within many organizations around the world (Sikka, Morath & Leape, 2015). In subsequent publications an expansion of an additional aim to constitute the "quadruple aim" was proposed (Bodenheimer & Sinsky, 2014; Sikka, Morath, Leape, 2015). This expansion has received wide support including IHI (Keefe, & Katz, 2015; Feeley, 2017). The current "quadruple aim" which includes the original 'triple aim' consists of: (a) improving patient experience of care (including quality and satisfaction), (b) improving health of populations, (c) reducing per capita costs of health care, and (d) improving the care and experience of the health care provider.

Since the "quadruple aim" really make sense and the initial "triple aim" has been tested and accepted by many managed care organizations, we strongly believe the future health care team members should focus on these improvements. We propose that the "quadruple aim" can become the performance objectives of the pharmacists. If they are competent in performing such objectives, they will no doubt be valuable members of the new healthcare team in the age of AI.

4. Wider curriculum changes in higher education

Changes in pharmacy practice are a mirror of technological and societal changes to all professions. The pace of technological innovation, the knowledge explosion and the shortening of knowledge doubling time make an uncertain future for all healthcare professions.

These rapid changes and the uncertain future are leading to a major rethink on curricula in higher education (Blackmore & Kandiko, 2012). The acquisition of a knowledge base is of little value if much of that knowledge becomes outdated soon after graduation—or even before graduation. More important is the development of skills, competencies, attributes and values which would enable graduates to cope with the technological change in an uncertain future. It is also important that these graduates are trained to be creative, innovative and entrepreneurial to shape future directions in healthcare.

Universities have, therefore, begun to define their curricula, not just in terms of content to be learnt, but as a set of graduate attributes to be acquired. Most commonly these are specified as an outcomes-based curriculum.

5. Core pharmacy education outcomes in the age of artificial intelligence

If the essential performance objectives of the pharmacist are related to the competencies of achieving the 4 health care improvements as described above, what pharmacy curriculum changes are needed to provide the proper education to achieve these competencies? In constructing curriculum design, the first step is to define the learning outcomes (Morcke, Dornan & Eika, 2013; Stupans, 2017). An outcome defines "what skills and qualities the pharmacist should have" whereas a competency is a "determination of what skills and qualities the pharmacist should have to care for patients". These 2 terms can be used interchangeably without any essential difference (Morcke, Dornan & Eika, 2013; Stupans, 2017). Once we have the attribution for each, we can link/map the education outcomes (as proposed below) to the competencies (see Figure 1). We believe an outcomes-based curriculum design is a desirable approach for effective education/training of future pharmacists. Such approach has been considered a gold standard based on Carnegie Foundation's Flexner centenary report, although a recent critical review found the research documenting its effects to be fairly rare (Morcke, Dornan & Eika, 2013). However, Chow and his colleagues had provided strong indication of improvement of learning outcomes that can be achieved from such an approach (Ho et al., 2009). Thus, we are advocating the use of this approach in the present article.

We strongly believe in achieving the "quadruple aim" of healthcare improvement described above which can be the new role for the pharmacist in the age of AI. Recently, the American College of Clinical Pharmacy (ACCP) proposed six essential competency domains. They are: direct patient care, pharmacotherapy knowledge, system based care and population health, community health, professionalism, and

- Domain l - Possess foundational knowledge
- Domain 2- Possess essentials for practice and care
- Domain 3- Possess effective approaches to practice and care
- Domain 4 - Possess the ability to develop personally and professionally
- Domain 5 - Possess research skills

Fig. 1. Educational Outcome Domains. Adapted from Saseen et al., 2017.

continuing professional development (Saseen et al., 2017). The overall content and intent are not too different from the competencies in achieving "quadruple aim" improvement. However, the "quadruple aim" is more patient oriented and self- improvement oriented, and thus can be easily used as the expected competencies. We also examine the current education domains as originally published in 2013 by the American Association of College of Pharmacy (AACP) (Medina et al., 2013). We found the 4 broad outcome domains to be desirable and should still be appropriate in the age of AI (see Figure 1). However, we believe there is a strong need for the pharmacist to innovate (e.g. develop new programs or treatments) to achieve healthcare improvements. Thus, the future pharmacist must also possess research skills to be competent in achieving the 4 healthcare improvements. In other words, possessing research skills should be the fifth education outcome domain. The research can include laboratory, clinical or pharmacoeconomic/epidemiologic outcomes research skills. These five educational outcome domains corresponding to the four performance competencies can be cohesively mapped together as shown in Figure 2. The emphasis and details can be further expanded depending on the requirements of the individual teaching institutions.

6. Development of attributes

Adoption of an outcomes-based curriculum has implications for how contents are taught as well as what is taught. Teaching graduate attributes independently of content has proved to be ineffective. Instead it is necessary to teach elements of the curriculum in ways which provide practice in the use of the attribute (Kember, 2008; Kember & Leung, 2005; Kember, Leung & Ma, 2007).

Examples will be given in respect of the outcome domains in Figure 3. Outcome 3.1 requires students to be able to identify and solve therapeutic problems. This calls for students to be given practice in dealing with the type of ill-defined problems encountered in practice. The importance of achieving this outcome has led to some health professional education programs adopting problem-based learning approaches.

Outcome 3.2 calls for graduates to be active in professional collaboration. This means that, during their degree, students need to develop the ability to work as part of a team. They need to heighten their interpersonal communication skills. This implies that a portion of their assessment activities should be designated as small-group tasks; most commonly in the form of group projects.

Adopting forms of teaching and learning conducive to developing attributes is likely to require staff development. Many academics habitually teach didactically as they are accustomed to knowledge-based curricula. Changing to a teaching and learning approach more conducive to nurturing graduate attributes can be a difficult process. Kember (2009) describes a multiple-aspect process for staff development to reorient teaching in a university to a more outcomes-based approach. The article contains a case study relating to pharmacy.

Competency Outcomes	Foundational knowledge	Essentials for practice and care	Effective approaches to practice & care	Develop personally & professionally	research skills
Improve the health of individual and populations	x	x	x		x
Reduce the per capita cost of health care	x	x	x		x
Improve the patient experience of care (including quality and satisfaction)	x	x	x		x
Self improvement				x	x

Fig. 2. Competency grid with outcome mapping.

7. Relevance of the core pharmacy education outcomes to pharmacy practice in Asia

At present, pharmacy education curricula among Asian pharmacy schools are diverse. Some pharmacy schools like that in the People's Republic of China and India, the bachelor, masters, and doctoral degrees in pharmacy are primarily suited for work in the drug industry. In China, pharmacy practice is primarily hospital based. After students complete a 4 year Bachelor of Science in Pharmacy, those interested in being a licensed pharmacists must work in a related field for 3 years before being qualified to take a test to come a licensed pharmacists. The time requirement will be only one more year for those with masters degree and no prior work experience is required for those with a doctoral degree (Fang et al., 2013). In India, the majority of the pharmacists work in community and hospital pharmacies. The Indian education programs offer Diploma in Pharmacy (D.Pharm.), Bachelor of Pharmacy (B.Pharm.), Master of Pharmacy (M.Pharm.), Doctor of Pharmacy (Pharm.D.) and Doctor of Philosophy (Ph.D.). However, the graduates with D. Pharm (2 years and 3 months of study/practice) are the main man power source of pharmacy practice (dispensing function) in India (Sahu et al., 2016). Except for the D.Pharm., graduates from the majority of the other degree programs are educated for work mostly suitable for drug industry.

In other Asian countries, pharmacy education curricula that are exclusively devoted to pharmacy practice include Bachelor, Masters or Pharm.D. degrees. In Thailand and Korea, a 6 year Pharm.D. degree curriculum is the main program. In contrast, Japan has a 6-year Bachelor degree curriculum for pharmacy practice. In Australia, Hong Kong, Taiwan, Singapore, and Malaysia a 4 year Bachelor degree plus practice training are required for pharmacy license. Majority of the schools also offer Masters or Pharm.D. degrees as an option.

	Courses/Subjects						
Outcome domains & Subdomain	Pharmaceutical sciences (pharmacology/immunology/pharmaceutics/pharmacokinetics courses)	Social/behavioral/administrative sciences (Healthy policy/Pharmacovigilence/ quality of life courses)	Pharmacy practice and self care therapeutics	Interprofessional Education	Introductory pharmacy practice experience	Advanced pharmacy practice experience	Evaluative & Investigative Research (research methods & biostatistics for practice and translational research and independent study project)
1. Foundational knowledge							
1.1. Learn to develop, integrate, & apply fundamental knowledge to improve patient drug therapy	X	X	X	X			X
2. Essentials for practice & care							
2.1. Provide patient-centered care	X	X	X	X	X	X	X
2.2. Promote health and wellness for individuals/population	X	X	X	X	X	X	X
2.3. Provide and develop practice guidelines/evidenced based best practices	X	X	X	X	X	X	X
3. Effective approaches to practice/care							
3.1. Identify and solve therapeutic problem	X		X	X	X	X	X
3.2. Active in interprofessional collaboration	X		X	X		X	X
4. Ability to develop personally/professionally							
4.1. Self-awareness of the potential in enhancing and limiting personal and professional growth		X	X	X	X	X	
4.2. Demonstrate leadership		X					
4.3. Engage in innovative activities		X	X	X	X	X	
4.4. Demonstrate professionalism		X	X	X	X	X	
5. Pharmaceutical/Clinical research skills							
5.1. Generate a relevant research hypothesis	X						X
5.2. Design and implement appropriate experiments to address the hypothesis or research question	X			X			X
5.3. Apply fundamental principles of statistical analysis	X						X

Fig. 3. Outcome domains and course mapping.

In view of the diversity of pharmacy education curricula as well as diversity in economic, culture, social and political environments, proposal of a uniformed pharmacy practice education curriculum would not be possible for Asia at present. Furthermore, implementation of an outcomes-based curriculum, as described and proposed in the present article, may not be realistic for some of the Asian school, although some schools have already adopted such an approach, e.g. those in Hong Kong and Australia. However, a core pharmacy curriculum framework as described above is likely to be relevant in the age of AI, especially at the maturing state. At that time, robot pharmacists are expected to replace the human function of dispensing drugs and information. Thus, to educate the pharmacist of the future, the core curriculum domains mapped with competencies (see Figure 3) should be strongly encouraged as a common initial step for pharmacy curriculum development in Asia. Individual schools of pharmacy can further incorporate additional subdomains (like that published by AACP (Medina et al., 2013)) together with specific course titles and credit hours to develop the whole curriculum uniquely for the individual school.

8. Conclusion

The proposed core curriculum (see Figure 3) is based on the widely accepted health care improvement needs as well as our view on how pharmacists can play a vital role to contribute to health care improvement, as a member of such health care team in the age of AI. We believe the education

outcomes domains for the core curriculum (see Figure 3) proposed should be applicable to all Asia as well as other parts of the world. The proposed core curriculum can be the initial step of developing an outcomes based curriculum. Additional steps such as detailed course content, learning activities and assessments will all need to follow and be included in the curriculum planning. How individual schools construct and implement these steps is beyond the scope of this paper and we encourage AASP to provide further guidance in the future.

We believe the proposed core curriculum can be an initial common step in new curriculum development for all Asian pharmacy schools in the age of AI. This can be an important future step toward harmonization of pharmacy education in Asia in the age of AI. Although the American College of Clinical Pharmacy (ACCP) has recently issued a white paper with the following view: "Revising the goals, content, and process of pharmacy education will not and of itself change practice…. any sustainable change in pharmacy practice ultimately must be driven and maintained by the practice community" (Saseen et al., 2017). We believe a good education curriculum can initiate practice change, but sustainable change must be maintained by the practice community. Thus, we strongly endorse the formation of a pharmacist Practice Research Network (PRN) in Asia. Such PRNs have played an important role in American clinical pharmacy practice by supporting the advancement of clinical research, practice, and networking of pharmacist specialists (ACCP 2018).

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