REVIEWS

Integrating Science and Practice in Pharmacy Curricula

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An integrated curriculum is one where the summation of different academic disciplines forms a coherent whole and, importantly, where the relationships between the different disciplines have been carefully and strategically considered when forming the composite. Within pharmacy curriculum integration is important in order to produce graduates who have the capacity to apply their knowledge to a range of complex problems where available information is often incomplete. This paper discusses the development of an integrated curriculum in which students are presented with an organized, logical sequence of material, but still challenged to make their own integrations and develop as integrative thinkers. An evidence-based model upon which an interdisciplinary undergraduate pharmacy curriculum can be built is presented.

Keywords: integrated curriculum, curriculum, pharmacy education, assessment

INTRODUCTION

The integration of science and practice curricula within pharmacy is of relevance to educators throughout the world in producing graduates who are capable of applying a broad knowledge base to solve complex problems. In the United Kingdom, there is particular interest since the General Pharmaceutical Council's (GPhC's) 2010 education standards specifically state under Standard 5, Criterion 5.1 that the pharmacy curriculum "must be integrated."[1] As all master of pharmacy (MPharm) programs must be accredited by the GPhC, it is essential that schools address this issue. This paper examines some of the background educational and psychological theory underpinning integrated education and proposes an approach to the design of integrated pharmacy curricula.

INTEGRATED CURRICULUM DESIGN

The concept of curriculum integration, where individual disciplines are strategically combined to create a cohesive whole, is not unique to pharmacy education. Some may legitimately ask why curricula should be integrated, particularly in view of the relative lack of empirical evidence that an integrated curriculum produces better graduates and ultimately practitioners. Despite this, the idea has support, and reformers within medical education have attempted to address the following within curriculum design[2]: teaching and learning should promote integration; habits of inquiry and improvement should be encouraged and developed; learning should be individualized, while assessment should be standardized; the development of professional identity should be supported.

The SPICES model of curriculum development outlines a range of criteria to help curriculum planners.[3] The criteria are set within a continuum, one end of which is seen as elements that are desirable in a curriculum and the other end as elements that are negative/undesirable. This model places integrated curriculum at the desirable end of the continuum and discipline-based curriculum at the negative end.

The design of an integrated program is more than the sum of its parts. It is the relationship between those parts and the application of an appropriate academic philosophy and framework that allow for the whole to be of more value than its constituents. It is tempting to think of curriculum design and structure as the most important aspects of integrated delivery, but ultimately integration takes place within the student's mind. Thus, consideration of what makes sense to different people is an essential component of working towards integration.[4] Educators must ensure that the curriculum allows sufficient flexibility for students to become integrative thinkers and not simply accept the integrations made by others.[5] Equally important, in order for students to effectively integrate information, content

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should be delivered in a manner so that there are close spacial and temporal relationships between materials. All of this is challenging as, ultimately, pharmacy is an applied, science-led subject, with separate disciplines at the base, which should be orientated towards professional practice. On this basis, the curriculum is not naturally integrated; the different disciplines tend to separate out, either in terms of teaching or as a function of students attempting to make sense of what they are being taught.

Contemporary pharmacy curriculum discussions[6-10] throughout the world have focused on what "science" and "practice" are and which of these should carry the greatest weight within the modern curriculum, rather than trying to see how to best combine the two, if indeed they are separate entities. This can be unhelpful and may serve to create an either/or type of approach when the vital importance of drawing together fundamental knowledge from the different science disciplines cannot be overstated in terms of developing the kind of pharmacist necessary for modern practice.

Undergraduate pharmacy programs in the United Kingdom are generally designed within a modular structure, and deliver much of the fundamental science at the initial levels of the program. Pharmacy practice is then phased in at different points, but overall has a relatively small footprint within the early years, which gradually increases towards the end of the program, with a corresponding reduction in science content. This model results in students being given the foundation knowledge upfront without consideration of how they will be able to transfer that knowledge to the much more unpredictable professional environment. This "front-loading"[11] of the curriculum is not helpful and leads to a number of challenges. It is common to observe students who cannot make links between theory and practice; they often cannot see the context or the likely application of fundamental science.[12]

Evidence for Integrated Curricula

The integration of curricula is controversial[13]; often there is concern for the identity of the various disciplines taught within the school[3] and concern that integrated curricula are superficial, created at the expense of disciplinary depth.[14] There is a lack of empirical research to suggest that healthcare graduates emerging from integrated curricula become better practitioners[13]; in studies that have found that integrated curricula are superior to traditional curricula, the difference at best can be described as marginal.[15] Much of the focus within studies of integrated curricula is around the perceptions of students or of faculty members[13] and is not specific to pharmacy.[16,17] None of this is to suggest that integrated curricula are ineffective, rather that there is an absence of evidence to prove the benefits of these curricula within healthcare practice. The challenges involved in testing an integrated model with well-designed empirical research projects are significant and require a longitudinal study that includes graduates' early practice years to assess changes in knowledge and competence.

A plausible hypothesis is that the integration of the curriculum creates relevance and meaning for new learning, which in turn allows students to relate facts learned in different settings to practice ie, the transfer of knowledge.[18] There is evidence to support this, with studies showing that students demonstrate improved retention of fundamental information[19] and increased ability to apply what has been learned to real-life situations[20] when they are taught within an integrated framework. There also are arguments that detailed scientific material taught out of context without the opportunity for application leads to poor retention[21] as the material is unlikely to be applied in detail within a reasonable timeframe.[22]

Theoretical Paradigms

The design of an integrated curriculum should be informed by relevant educational and psychological theory, which allows the understanding of how humans process new information and then subsequently transfer that to new situations. Three theoretical constructs, cognitivist theory (and specifically constructivism), andragogy, and meaningfulness in learning can all be used to inform an integrated curriculum.

Cognitivist theory suggests that learning is an active process and something that can be improved upon as learners become more experienced and adopt more sophisticated strategies to improve learning capacity.[23-25] As learners develop, they construct (constructivism) their own understanding of things based on how they view the world.[26] Key to this idea is that new information is rooted in what learners already understand.

The importance of meaningfulness in the context of advanced knowledge acquisition was first highlighted in the 1960s; the learner needs context for new learning, as information provided in isolation is not effective. Knowledge gained in this way can be tested and the ability for the learner to transfer the knowledge to different contexts observed.[27] On this basis, curriculum and teaching and learning strategy should be designed to allow learners to link new information to that already understood and to test that students have developed the ability to transfer knowledge to new situations, as is the challenge within professional practice.[28,29]

Any discussion of teaching in higher education would be incomplete without reference to the concept of andragogy vs pedagogy as postulated by Knowles in 1984 as a way of explaining how adults differ in their learning as compared with children.[30] Knowles suggested that adults display the following specific characteristics as learners: adults are more self-directed in their learning practices; adults have life experience and substantial previous learning, which influences new learning; adults' motivation to learn may be intrinsic rather than extrinsic; adults view learning that can be applied to their everyday lives as more valuable; and adults may be more orientated to problem-centred learning.

These principles have gained wide acceptance as a conceptual framework for curriculum development within the academic community, albeit with limited supporting empirical evidence. Some commentators have suggested that the observed differences in the way that adults and children learn could be attributed to differences in learning environments rather than to any specific cognitive differences in the learning process.[31] It may be more important to consider how the principles of andragogy are supported by the empirically tested ideas within cognitive theories. The relevance of prior learning and experience to new learning is common to both, as is the idea that new information is more effectively learned if it can be applied or categorized as meaningful.

In addition to important theoretical considerations, some parts of the pharmacy curriculum can be considered as more conceptually difficult than others; students often fail to understand the relevance and application to pharmacy. The management of this type of material was defined by Meyer and Land within their theory of threshold concepts.[32] Threshold concepts outline core issues within a subject that are important for understanding; they may lead to a different level of understanding or clarity around a subject area. An example of this within pharmacy is the concept of functional group chemistry and the interpretation of the solubility or reactivity of drugs. By understanding functional groups and how they affect structure activity relationships (SAR), students can gain significant ability to predict the effect of drugs in the body. There are other areas within the curriculum where this concept can be applied, not least in the critical review of prescribing decisions and therapeutics management, where the "shades of grey" or "fuzzy logic" used in clinical decision-making can often be challenging for students.

Threshold concepts[33] are:

- transformative – once understood, a threshold concept can change student learning and behavior with an associated increase in performance;
- probably irreversible – the change resulting from the understanding of threshold concepts is difficult to "unlearn." This is particularly important in terms of the understanding of students' comprehension and skills, as the process of mastering a threshold concept (transformed) may mean that it is very difficult to then understand the position of the student (untransformed);
- integrative – in that the understanding of the threshold concept may lead to links between material that were unclear before the transformation.
- bounded – threshold concepts demonstrate limits in terms of understanding. The limits of a threshold concept may be the point at which conceptual ideas change or different subjects are demarcated.
- inherently troublesome– concepts that sit at odds with what a person would intuitively think. Knowledge of this kind has been referred to as "alien" and "incoherent" with no organizing principle in the eyes of the learner.

These theories should influence the way an integrated curriculum and associated teaching and learning strategy are conceived.

Frameworks for Curriculum Integration

There are several conceptual frameworks that help to identify the extent of integration or ordering the sequence of material within a curriculum. Integration can be conceptualized as a continuum from completely separate discipline teaching at one end to a fully integrated teaching at the other. It is not helpful to view/assess curricula as being either not integrated or fully integrated as, in practice, neither is likely to be the case. Even in a discipline-focused curriculum, there will be aspects of integrated teaching within and between subject disciplines.

Harden[34] outlined the integration ladder as a tool for guiding curriculum design. The 11 steps on the integration ladder are defined:

Isolation. Isolation is completely separate delivery and assessment of subdisciplines without any consideration of the whole. Teaching staff members plan delivery in isolation and are unaware of what goes on elsewhere in the program.

Awareness. Awareness is similar to isolation; however, there is communication between subdisciplines to ensure that the outcomes and content of each area are coordinated. Cross-referencing may occur and duplication is usually avoided.

Harmonization. Sometimes described as "connected," harmonization ocurrs when different disciplines continue to teach separately but make a deliberate attempt to ensure that subdisciplines coordinate and make use of points of commonality. There is deliberate demonstration of links within the curriculum to students.

Nesting. Nesting is when material is still subject-based and is directed by members of the individual discipline.

However, the material is taught using context from another area. This step is sometimes referred to as "infusion."

Temporal coordination. Also known as *parallel teaching*, in temporal coordination, teaching of similar content/subject matter is taught at the same time. Content remains discipline specific and students are left to make their own links as a function of temporal coordination.

Sharing. With sharing, 2 or more disciplines join together to teach, most likely as a result of overlap in curriculum content.

Correlation. With correlation integration, there is separate, discipline-based teaching, but this is brought together by a further integrative session.

Complementary. Complementary integration is an extension of correlation, but the integration sessions play a much larger and pivotal role.

Multidisciplinary. Sometimes referred to as webbed, with multidisciplinary integration, teaching becomes focused around outputs, typically clinical cases where students apply their knowledge and skills to solve practice-based problems. The discipline perspective is maintained but autonomy within the whole may be lost.

Interdisciplinary. In interdisciplinary integration, autonomy and perspective of the individual discipline is lost. There is likely no reference to individual disciplines, with all subjects being reduced to commonalities between disciplines.

Transdisciplinary. In transdisciplinary integration, students typically are immersed in a practice situation and must integrate material from individual subjects in their own mind in order to demonstrate the competencies connected to the tasks.

The choice of which "rung" on the "ladder" to pursue is not as simple as it may seem. An entire course of study probably will not fit into any single area; rather the curriculum will develop in the direction of more extensive integration as the course progresses. Additionally, the realistic challenges faced by some of the levels of integration in terms of a pharmacy context must be considered. In the United Kingdom, to achieve a transdisciplinary level of integration within a pharmacy curriculum is challenging and quite unrealistic as students are not fully immersed in the working environment for sustained periods of time until after they graduate and enter preregistration training. However, the change towards having more extensive placement activities and possible integration of the preregistration year into the MPharm program may well give greater opportunities to this end.

Horizontal and *vertical integration,* terms which appear regularly in curriculum-planning discussions, outline the *direction* of integration as described by Benor.[35] Horizontal integration outlines the relationships between subjects taught at the same level of a program. This is demonstrated by parallel delivery of fundamental chemistry and the concept of quality by design, which then supports understanding of pharmaceutics. The student is learning about the structure of materials and thus the specific chemical characteristics, which ultimately lend the desirable physical characteristics needed to design quality into pharmaceutical products. Although essentially 2 separate disciplines, it is desirable to achieve a level of horizontal integration such that the student is able to view the ideas as a whole in the context of quality by design.

Vertical integration describes the process of taking information used at any one level and extending that through other levels of the program. It can also be used to articulate the relationship between fundamental, discipline-specific knowledge and professional practice. The common issue of students who fail to recall fundamental science material when presented with a more complex, applied problem later in the course can be addressed by extensive vertical integration alongside contextualization and an opportunity to apply information at the point at which it is learned. It is this point where the idea of an integrated *spiral* curriculum becomes useful.

Bruner first described the spiral curriculum model in 1960 to conceptualize and illustrate the way in which education processes appear to form a metaphorical spiral; concepts are introduced at a simple level and then revisited throughout the program at increasing levels of complexity. New learning is related to previous learning with increasing levels of difficulty, and ultimately the student develops improved knowledge and competence.[36] Harden and Stamper[37] extend the spiral curriculum model, outlining its value through 6 features: reinforcement; a move from simple to complex; integration; logical sequence; higher level objectives; and flexibility.

On this basis, the curriculum need not always build up to a point of application providing it is logical and sequential in its approach. Students can benefit from deconstructing more complex, applied problems before necessarily having been guided through basic principles of the specific area. In this way, learners can be encouraged to think around the subjects, while simultaneously checking their own understanding. The benefit of these teaching approaches comes from the opportunity for the learner to expand and elaborate on information as it is learned.

Organizational themes allow learners to make sense of the information provided and should avoid the pitfall of students being expected to accept the integrative views of others. Structures are reflections of how academics, who have a holistic and sophisticated knowledge of their discipline, may view their own area of expertise. Options for organizational themes include discipline themes, organ system themes, chronological themes, and problem-based themes.

Discipline themes is a teaching model based around the separate subjects within the curriculum. This is the traditional model of teaching and need not be completely devoid of integration depending on the method of assessment employed and the degree of horizontal integration between subjects.

Organ system themes is a teaching model based around the organ systems of the body, often seen within medical curricula. In pharmacy terms, this is challenging and requires significant planning and inclusion of some way of addressing some of the fundamental material necessary before students are able to apply pharmaceutical knowledge to body systems.

Chronological themes can apply to both the time course of disease or as related to aging. Some courses examine disease through consideration of the origin of the disease and its time course to resolution or to the ultimate effect it may have on the subject, eg, death. Within this, issues around screening, prevention, treatment, and management of the final stages of the disease can be examined. Alternatively, a course structured around the journey from conception to death is an equally valid approach to examining the changes in susceptibility to disease, response to treatment, and variation in the metabolism and elimination of drugs along the way.

Problem-based themes are a teaching model in which problem solving is used as a central thread for learning and is a model commonly seen in medical education. The idea of students investigating problems and using fundamental scientific information to solve them allows for elaboration on concepts thought to be important within assimilation and recall of knowledge.[38] Problem-based curricula must be carefully designed so that students can see relationships between problems. The role of the academic as facilitator is pivotal in avoiding problems that oversimplify concepts[39] or in guiding students away from imprecise elaborations that fail to address the target concepts for the individual problem.[40]

Organizational threads link material from separate disciplines so as to allow students to be able to navigate the whole of the program. When considering the use of these approaches or attempting to design new ones, curriculum designers should ensure that organizational threads are useful across the specific discipline; allow for change or development; relate previous knowledge and experience to that being presented; are meaningful and relevant to the student (including at the outset of the program); and allow for integration of unrelated experiences and material.[5]

EXAMPLE OF AN INTEGRATED PHARMACY CURRICULUM

The MPharm degree is the only undergraduate route to registration as a pharmacist in the United Kingdom and is designed to produce graduates who are capable of practice within community, hospital, and industrial settings. Students study full-time for 4 years. Graduates must then complete a 12-month period of preregistration training and successfully pass the national registration assessment in order to join the register of the GPhC, the United Kingdom's regulator of the pharmacy profession. The MPharm degree comprises 120 UKCredit Accumulation and Transfer Scheme (UK CATS) points per level. These points are a means of quantifying achievement with 120 credits equated to 1,200 hours of study. In most MPharm programs, the 120 UK CATS points studied at each level are further broken down into separate modules varying from 5 to 60 credits. There are only 2 MPharm programs in the United Kingdom that employ a single, 120-credit integrated module per academic level of study.

The integrated curriculum at Durham University is a novel example of how to provide students with a science-based curriculum while ensuring that the practice of pharmacy is at the core of everything studied. The remainder of this section will outline how we have built this curriculum.

The primary aim in the design of our curriculum was to ensure that it encouraged learners to become integrated thinkers and to actively pursue ways to integrate the knowledge they gain. The curriculum is outlined in Figure 1; the first 3 levels consist of integrated 120 UK CATS point modules, with the final year split in half to allow for completion of a research project.

The modules are not discipline specific; they are organized around the management of patients, using a body systems approach. This is a commonly used structure in the development of integrated, spiral curricula.[41] Modules reflect competency rather than subject material and so progress from understanding of single disease states through to application and management of complex co-morbid presentations.

The organizational thread in our example has a slight difference in that level 1 is used to look at the normal functioning of the human body. The abnormal function or that reflected by disease within specific body systems is explored in subsequent levels. This allows the fundamental science knowledge needed to underpin the rest of the program to be presented in level 1. Again, this sequencing is planned so that when students encounter diabetes, for example, they already have covered the cardiovascular system, the gastrointestinal system, and the urinary system,

Level 1	Fundamentals of pharmacy – the integration of science and practice	
Level 2	Pharmaceutical care – pathology, patients and professionalism	
Level 3	Applied pharmaceutical interventions – design, delivery and decisions	
Level 4	Targeted therapeutics – optimisation, critique and responsibility	Research project

Figure 1. Durham University MPharm program.

and can thus understand the wide-reaching consequences of the disease throughout the body. The sequencing of body systems is outlined in Figure 2.

The design of all modules allows students to start each module with a link to the previous one and to something they inherently understand. Material is repeatedly reintroduced throughout the program to ensure fundamental science is incorporated into all decision-making as the process becomes more complex.

Conceptual Approach

Figure 3 outlines the "conceptual hook" used in our curriculum to link together knowledge and information around a particular case. A simplified example of a level 2 disease state, ie, hypertension, was used to illustrate the concept. By level 2, students have worked through fundamental anatomy and physiology at level 1 and have a solid grounding in functional group chemistry; microbiological taxonomy; biological macromolecule structure; and fundamentals of formulation, including aspects of physical properties of active pharmaceutical ingredients (APIs) and pharmaceutical excipients. These subjects are not presented as separate entities but are brought together using multiple case studies that have been specifically designed to illustrate the relationship between this fundamental science and the eventual professional role. This role is oriented to clinical care, but does not in any way sacrifice industrial context or that of research as a career to achieve this. If the educator accepts that the driving force behind research programs or industrial pharmacy is patient need, then this model can drive learning while still providing important context.

The premise underpinning the use of conceptual hooks was that learning is affected by meaningfulness within material[42] and that teaching should be task-orientated and relevant to the professional role.[43] In general, students of healthcare, or indeed any person, will have an awareness of the context and consequences of common diseases. This may not be detailed knowledge, but the overarching principle that high blood pressure is not a good thing has widespread acceptance. This was therefore used as the cognitive hook or the area of familiarity that tapped into students' existing knowledge. This then allowed the "hook," ie, hypertension, to be applied to several interesting areas of the traditional pharmacy curriculum such as controlled release delivery, therapeutic drug monitoring, and public health. The disease state in this case acts as the anchor for the other information being delivered. This does not mean that those other areas would be delivered superficially; the spiral nature of the curriculum ensures that these other curriculum areas are taught to achieve depth as well as breadth of knowledge. Material learned at this stage is re-examined later in the program, necessitating transfer of knowledge and application to a new, more complex clinical scenario. For example, the area of pain includes use of controlled-release devices so students will be expected to access previous knowledge of this area and

Level 1	'Normal' human physiology	
Level 2	Cardiovascular system Respiratory system Gastrointestinal system Urinary system	
Level 3	Musculoskeletal system Central nervous system Endocrine system Reproductive system	
Level 4	Malignant disease Infectious disease Immune system	Research project

Figure 2. Sequencing of body systems within the MPharm curriculum.

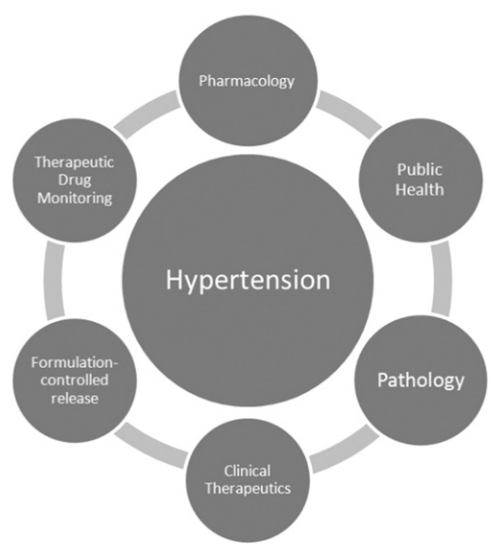

Figure 3. Example of an integrated pathway.

apply it to the clinical and pharmaceutical problems presented within the area of pain.

Assessment

One of the most important aspects of an integrated curriculum is that it encourages students to integrate knowledge for themselves and not just accept the integrations of others.[5] However, the primary driver for students to develop as integrative thinkers is the method by which they are assessed. An integrated curriculum is only as effective as the assessment strategy associated with it; discipline-based assessment will drive students to learn distinct areas of material rather than attempting to integrate.

The assessment strategy in our example was specifically designed to avoid the over assessment often associated with modular programs. The design of the curriculum ensures that repetition exists by design, but any repetition resulting from isolated planning and delivery of module content is minimised or removed. In addition, this approach allows students to measure their own development as learners. This is essential in helping students to develop their own internal metrics as to what the necessary standard is and in becoming self-directed learners.[44]

The main strategy within our assessment is the use of various types of multiple-choice questions (MCQs), extended matching questions (EMQs), and short-answer questions in both formative and summative tests throughout the year. We have chosen these approaches for the reliability and validity they confer to the assessment strategy. The questions are deliberately divided into domain or discipline-based questions and those that have been designed to test the students' ability to integrate information.

Objective structured clinical examinations (OSCE) are used throughout to test application of knowledge and to address the need for students to demonstrate levels of competency. This competency framework is based on the work of Miller[45] and uses the "knows, knows how, shows, shows how, does" hierarchy.

The approach to coursework is focused on students integrating information as well as creating scaffolds to support the next level of the program. Some examples of integrative coursework are:

- Laboratory reports are submitted as a single integrated assessment. Students work though data for each report, but must submit all reports as a single entity with and overarching commentary articulating the way the work fits together.
- A single integrative written essay is included as a final submission at level 1. Students must pick an example and outline the integration of the various subjects they have learned in the context of their chosen example.
- Group-based problem-based learning (PBL) sessions from clinical cases right through to students being given a "sample" containing a compound they must identify and quantify in the context of illicit use of medicines in sport.

The assessment strategy will continue to mature as we attempt to develop reliable and valid methods to assess knowledge and competency specifically within the clinical and pharmaceutical areas that directly supports an improvement in the standard of the final practitioner emerging from our program. Importantly, this strategy must focus on developing graduates who use science and practice as tools to answer complex questions.

CONCLUSION

The integration of the undergraduate pharmacy curriculum is a challenging but important aspect of the education and training of pharmacists. There are many ways to approach curriculum integration and significant amounts of educational and psychological theory to support various curriculum strategies. Our experience supports the view that the curriculum should be considered as a whole and, if necessary, disaggregated into smaller sections rather than being the result of accumulation of separate modules that emanate from subject divisions or institutional regulation.

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