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Running title: Assessment of antimicrobial pharmacokinetics curricula

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Abstract:

Introduction

Advances in technology and understanding of pharmacokinetic/pharmacodynamic relationships have prompted guideline updates and advances in precision dosing, but the role of clinical pharmacokinetics (PK) in pharmacy education remains inconsistent. Previous surveys of pharmacy school PK curricula revealed large variations in content, integration, and teaching tools but did not focus on antimicrobials nor details of andragogy used.

Objective

Identify how antimicrobial PK is taught in pharmacy curricula across the United States, as well as instructor perceptions of current practices.

Methods

An online survey was distributed to 118 pharmacy programs across the United States in 2018. This 30-minute questionnaire covered curriculum content, teaching strategies, assessment modalities and perceptions.

Results

Completed surveys were received from 53 programs (45% response rate) via relevant course coordinators. Among 35 traditional progressive curriculum programs (TPC), antimicrobial PK was taught in basic science (33, 94%), clinical PK (15, 43%), pharmacology (8, 23%), therapeutics (28, 80%) and skills lab courses (21, 65%). Among 18 integrated block curriculum programs (IBC), it was taught in foundations/principles (17, 94%), organ systems (12, 67%), and skills lab courses (9, 50%). On average, TPC programs had more courses with antimicrobial PK than IBC programs. Vancomycin and aminoglycosides were the most common antimicrobials taught (100%), while didactic lecturing was the predominant andragogy. Multiple choice was the primary assessment modality, being frequently used in

64% of TPC and 68% of IBC courses, respectively. Among respondents, 72% believed more time was needed to teach PK and 53% believed students were adequately prepared at the start of APPEs.

Conclusion

Antimicrobial PK instructions remains highly inconsistent in U.S. pharmacy schools and colleges. IBC programs may provide less opportunity for antimicrobial PK instruction, which conflicts with the desire for more instruction time. As clinical applications of antimicrobial PK change and expand, it is crucial that pharmacy education prioritizes it appropriately.

Keywords: Pharmacy education, Clinical Pharmacokinetics, Pharmacy Curriculum, Antimicrobial Pharmacokinetics, Therapeutic Drug Monitoring

Introduction

Clinical pharmacokinetics (PK) is both a unique and essential skillset for student pharmacists to learn and apply while providing patient care.[1,2] Not only is it required on the North American Pharmacist Licensure Examination (NAPLEX), but it is also a crucial part of routine clinical practice, especially as PK remains at the core of precision dosing.[3] Compared to other healthcare professionals, the dedicated training in PK is often what sets clinical pharmacists apart. While an understanding of clinical PK is valuable in many patient care settings, it has become increasingly important in the realm of antimicrobials, where therapeutic drug monitoring (TDM) and nuanced dosing can optimize medication use for improved patient outcomes.[4] This is particularly evident in the management of aminoglycosides and vancomycin; antibiotics that are routinely dosed and monitored exclusively by pharmacists in hospitals via institutional protocols.[5,6] The most recent vancomycin guidelines advocate for a shift towards area under the curve (AUC)-guided dosing to improve patient safety, requiring a fundamental change in how vancomycin is both dosed in practice and taught in pharmacy curricula.[7] Additionally,

monitoring beta-lactam levels, particularly in critically ill patients, is becoming increasingly clinically relevant, alongside the already established TDM of several antifungals.[8-10]

Previous surveys of the pharmacy curricula with respect to clinical PK have found a wide variety of content, curricular integration, and teaching modalities.[11,12] The most recent survey reported by Hughes et al. revealed a shift from standalone clinical PK courses towards more longitudinal integration throughout curricula, although fundamental content remained similar.[12] The proportion of programs covering common antimicrobials like vancomycin and aminoglycosides were identified, but antimicrobial PK was not the focus of published survey results. Furthermore, while andragogy used to deliver content was generally described (e.g., lectures, readings, assignments, etc.), the use of active and team-based learning was not identified. Calculation and assessment methods were also not described. These details may be crucial in understanding and improving how antimicrobial PK content is taught.

The purpose of this study was to provide a thorough assessment of antimicrobial PK curricula across US schools and colleges of pharmacy. The goals were to describe antimicrobial PK content as well as quantity and timing, teaching modalities utilized, assessment practices, curricular integration, and faculty perceptions of various aspects of antimicrobial PK content in pharmacy curricula. This information would not only be helpful to pharmacy school faculty/administrators evaluating curricular changes, but also to residency and fellowship directors/preceptors so that they are more aware of the current and changing antimicrobial PK content being taught.

Methods

A cross-sectional, survey-based study of antimicrobial-related PK curricula was disseminated to schools and colleges of pharmacy across the US in September 2018. The study was reviewed and approved by Chapman University and the University of California San Francisco Institutional Review Boards.

An electronic survey was designed using Qualtrics™ (Qualtrics, Inc. Provo, UT) survey software and was electronically distributed to PK and infectious diseases (ID) course coordinators at 118

Accreditation Council for Pharmacy Education (ACPE)-accredited and candidate status US pharmacy schools. Contact information for relevant course coordinators was identified via the Infectious Diseases – Educator Network (ID-EN) database (http://id-en.ucsf.edu) and institutional websites. Alternate faculty identified as the optimal survey respondents were asked to complete the survey instead of the original contacts upon referral. Up to two follow-up emails were sent, if necessary, during the 8 weeks the survey was open. Surveys were completed by a single individual per institution. The survey used a branching-logic format which presented different questions based on participant responses. Those with a traditional progressive curriculum (TPC) were presented with up to 215 questions while those with an integrated block curriculum (IBC) were presented with up to 93 questions; most respondents were presented with fewer than the maximum number of questions. TPC were curricula where students took several classes simultaneously to build from foundational courses to application courses, whereas IBC were curricula where students took just one or two classes simultaneously that integrated foundational and applied topics, organized around organs or systems.

The survey was developed by the authors and externally validated amongst 18 ID-EN members before being sent to designated course coordinators. These 18 members were pharmacy academia faculty interested in infectious diseases/pharmacokinetics education. Feedback from the pilot allowed for minor improvements in survey logic and question clarity. These improvements resulted in a survey that provided quantitative data regarding institutional information, curricular design, course content, instructional strategies, assessment methodologies and surveyor perceptions of antimicrobial PK curriculum. More specifically, questions focused on time dedicated to antimicrobial PK in the curriculum, specific PK concepts, assessment techniques, and andragogical modalities in both didactic and experiential teaching environments. Active learning was defined as students working on problems individually or in informal groups while team-based learning was defined as students working on problems in formal groups. Additionally, perceptions about antimicrobial PK curricula and student preparedness were captured using a 4-point Likert scale.

Descriptive statistics were performed on Microsoft Excel for Microsoft 365(Microsoft, Redmond, WA, USA). Continuous variables were described using medians and interquartile ranges while categorical variables were described using frequencies and percentages.

Results

Out of 118 schools and colleges of pharmacy contacted for the survey, 53 programs across 28 states and territories, of varying size and age, provided a complete response, yielding a survey response rate of 45%. At the time of survey, 50 (94%) were ACPE accredited and 46 (87%) were four-year programs. Among respondent institutions, 35 (66%) were described as having a TPC while 18 (34%) had an IBC. Institutions commonly used letter grading (96%) as well as both team-based learning (TBL) (56%) and problem-based learning (PBL) (56%) andragogy while several planned on significant curricular changes (43%). Other institutional characteristics are described in Table 1.

Among TPC institutions, antimicrobial PK was covered in basic science PK, clinical PK, pharmacology, therapeutics, and skills lab courses, comparatively, it was covered in foundations/principles, organ systems and skills lab courses among IBC institutions (See Table 1). Course duration was identified for basic science and clinical PK courses while in-class time spent in large (entire class present) and small groups was captured for all courses. Andragogy used in large group time varied across courses with didactic lecturing being most common. Across both TPC and IBC courses, a majority covered hand calculations and nomograms in teaching PK. Only one institution taught Bayesian software calculations, which was in a therapeutics course. In TPC courses, textbooks were the most common out of class material used while in IBC courses, recorded lectures were (See Table 2).

Concepts queried in the survey included basic PK principles (absorption, distribution, metabolism, excretion, clearance, half-life), PK modeling, drug-specific PK, TDM, and dosing using PK modeling or Bayesian principles. All concepts except Bayesian modeling were primarily introduced in basic science PK courses in TPC and in foundations/principles in IBC. In TPC, introduction of drug-specific PK and TDM in clinical PK courses also occurred at a number of institutions (47%). There was

minimal concept introduction in pharmacology and skills laboratory courses (<20%), while the only concept introduced in more than 15% of institutions in therapeutics was TDM (25%). Among 35 TPC institutions, only 24 (69%) introduced the concept of Bayesian-guided dosing. Reinforcement of all concepts, except for Bayesian-guided dosing, occurred in clinical PK, pharmacology, and therapeutics courses. In skills laboratory courses, drug-specific PK (57%) and TDM (81%) were the two concepts consistently reinforced. In IBC, introduction of all concepts, except for Bayesian-guided dosing, occurred almost exclusively in foundations/principles courses. Bayesian-guided dosing was introduced in 24% of foundations/principles and 33% of organ systems courses. All concepts except Bayesian-guided dosing were reinforced in both organ systems and skills laboratory courses. (See Figure 2). In TPC therapeutics courses (n=28), vancomycin and aminoglycoside PK were covered in 100% of institutions whereas beta-lactam PK was taught in 68% and antifungal PK in 50%. In IBC organ system courses (n=12), vancomycin and aminoglycoside PK were covered in 100% of institutions while beta-lactam PK was taught in 67% and antifungal PK in 33%.

Across both TPC and IBC courses, similar trends were found in assessment modalities. Multiple choice questions were most commonly utilized, followed by numerical responses only and open-ended responses. For courses with open-ended questions, partial credit was awarded in 84% of TPC courses and 85% of IBC courses (See Table 2).

PK teaching in experiential education was also captured, with 24 (45%), 26 (49%) and 3 (6%) stating PK was rarely, sometimes, or always discussed as some component of the introductory pharmacy practice experiences (IPPE). In the advanced pharmacy practice experiences (APPE), 9 (17%) and 14 (26%) of institutions required a pre-APPE and post-APPE readiness assessment that included clinical PK content. Only 5 (9%) institutions offered a PK elective APPE. Forty respondents reported using additional resources for APPEs, including reference materials (88%), practice questions (68%), simulation curves (20%) and homemade calculators (18%). Teaching modalities included patient calculations (96%), topic discussion (88%), practice cases (38%) and presentations outside of normal patient presentations (19%). Of the 53 respondents, 48 (91%) personally precepted APPE students.

In looking at respondent perceptions about antimicrobial PK curriculum at their own institutions, a large majority agreed that: more time was needed for PK instruction (72%); clinical PK should be assessed on the North American Pharmacist Licensure Examination (NAPLEX) (87%); and it was important to teach how to calculate AUC (85%), as well as peak and trough levels (98%). Over half believed that students were adequately prepared for PK calculations at the start of their APPEs while three quarters believed they were adequately prepared by the end of APPEs (See Figure 3).

Discussion

Pharmacists receive unique training in PK relative to other health professions and this is in the setting of the constantly evolving discussion around patient-specific precision dosing. Given the important clinical and economic benefits of involving pharmacists in TDM, it is crucial to ensure that graduating pharmacy students are equipped with the necessary PK knowledge and skills to meet the challenging demands of individualized patient care.[13,14] This survey evaluated the current landscape of antimicrobial PK curricula to identify similarities, differences, and potential areas for improvement. In a 2016 survey, Hughes et al. reported a decrease in standalone clinical PK courses compared to an earlier survey, which was consistent with our findings.[12] Additionally, our results demonstrated a variety of andragogical modalities, assessment methods and resources used across two different curricular designs.

In looking at the quantity of antimicrobial PK taught across programs, we discovered that programs with an IBC had fewer courses in which antimicrobial PK was taught (foundational, organ systems and skills laboratory courses) whereas programs with TPC taught antimicrobial PK in basic PK, clinical PK, pharmacology, therapeutics, and skills laboratory courses. The increased number of courses with this content in the TPC institutions also allows for more longitudinal reinforcement, which was identified in this survey. With the continued push towards curriculum integration in pharmacy education, these findings suggest that antimicrobial PK may become less prevalent across curricula.[15] This is evidenced by the finding that more programs with TPC are planning to change their clinical PK courses and almost half are planning for a global curriculum change. If antimicrobial PK is deemphasized during

this process, this may lead to a decrease in the expertise of an increasingly relevant clinical skill, as illustrated by the recommendations made in the most recent vancomycin guidelines and shift toward precision medicine which require a more in-depth understanding of both basic and complex PK principles.[7] It is important to reinforce that pharmacists' expertise in clinical PK is not commonly found among other healthcare providers and minimizing its role in pharmacy school curricula may be detrimental to the profession. Although many calculations are now carried out by calculators, both homemade and commercial, a fundamental understanding of the equations and concepts behind them is critical. While early data suggests there may be cost-savings from implementing Bayesian software systems in the hospital setting, these programs are largely still cost-prohibitive and wide-scale adoption is unlikely imminent.[16] The clinical implications of TDM of beta-lactams, while currently not commonly used in clinical practice, is becoming better understood, with data suggesting an emerging role. As TDM becomes more prevalent, the idea of precision dosing having meaningful clinical impact is becoming more real and will require pharmacists to be at the forefront.

To our knowledge, this was the first study to look extensively at teaching and assessment modalities used in delivering antimicrobial PK education. Interestingly, except for skills laboratory courses, didactic lecture was consistently the most common andragogical strategy utilized, particularly in TPC programs. Considering the significant involvement of mathematical calculations, the authors recommend greater adoption of TBL, small group discussions, and other active learning modalities that are more hands-on. With the potential for improved learning outcomes, clinical PK seems like an optimal target for increasing the use of these teaching techniques given the challenging task of correlating hands-on mathematical calculations with more abstract concepts.[17] It is worth noting that in organ systems courses in IBC programs, didactic lecture accounted for less of the large group lecture time when compared to the aggregate of active and TBL. It is possible that shifting from didactic lecture to more active and TBL modalities may be correlated with the overall transformation and updating of curricula from TPC to organ system blocks.

Out of class materials utilized across both TPC and IBC institutions appeared relatively similar and diverse, with textbooks maintaining a significant role. Calculation methods taught were also quite similar, but only one institution used Bayesian software. This is notable given the recent vancomycin guideline recommendations and the belief that practice will shift towards AUC-guided dosing with the use of Bayesian software being commonplace.[7,18] Given the similarities in teaching resources, calculation methods and assessments between TPC and IBC institutions, particularly the use of course readers and practice problems, there may be potential to create universal materials that can be shared across institutions. There is undoubtedly a significant amount of time and effort that goes into creating these materials so the idea of shared resources may be attractive. Practice questions and mock patients were also identified as resources and teaching tools on APPEs, potentially expanding their use beyond the didactic curriculum.

In looking at the perceptions of antimicrobial PK curricula, it was not surprising that a majority of respondents believed more time was needed to teach the subject given these faculty were identified as content experts. It was clear respondents felt that even with practice changes emphasizing AUC calculations, understanding how to calculate peaks and troughs was still relevant. Interestingly, a majority of respondents felt students were not adequately prepared for clinical PK calculations at the start of APPEs but less than 20% of all institutions had readiness assessment. This is likely correlated to the belief that more time is needed to teach clinical PK in curricula, but also may suggest that while students are capable of performing calculations, they may not fully grasp the concepts, nuances behind the numbers, and applications in clinical practice. As PK calculations are revisited across therapeutic/organ system courses, it may be beneficial to ensure integration of relevant clinical concepts to ensure that calculations are not reinforced in isolation. Additionally, 72% agreed that students were adequately prepared by the end of APPEs but only 26% of institutions require a PK assessment during APPEs. This suggests much of this perception may be derived from subjective assessments or less standardized tools, offering the opportunity to create a universal, standardized assessment that could be applied across institutions to ensure consistency in both education, preparedness, and practice. While the NAPLEX

currently includes questions on clinical PK, it is possible that increasing the volume and/or depth of content here would incentivize institutions to expand clinical PK across curricula.[3] Moreover, accrediting bodies such as ACPE could increase specificity of curriculum standards in regard to time and content covered for pharmacokinetics. Lastly, the large number of respondents emphasizing the importance of AUC calculations and the low proportion of courses teaching Bayesian-guided dosing may reflect respondents being content experts who are aware of upcoming changes in clinical practice. While these methodologies are innovative and relatively new in clinical practice, it seems certain that the number of institutions teaching AUC calculations and Bayesian software will increase. If so, the survey results here suggest that additional time and effort may be needed in teaching these concepts to better prepare students for the evolving clinical practices.

There are a number of limitations to this study. Chief among them is risk of nonresponse bias, given a response rate of slightly less than 50%. This could bias the data towards respondents who are more actively engaged in PK curriculum and may be more likely to employ a larger variety of teaching modalities. This would also potentially bias the perceptions of respondents feeling more strongly about the importance of antimicrobial PK in their curriculum. While the respondents did include a representative variety of U.S. programs as demonstrated by the geographical distribution, proportion of 3-year programs, and diversity of size and age across different curricular structures, the findings here may not be generalizable to all schools and colleges of pharmacy. Another limitation of this study is the level of detail asked for in describing time commitments to various teaching methods. Given the variety of teaching modalities available and used, it is possible that responses estimates were not exact, particularly with respect to the numbers of hours devoted to different strategies. Similarly, while the number of distinct classes that included clinical PK content were captured, the number of hours dedicated to different topics and concepts was not captured. Given the fewer amount of IBC courses, it is possible that more hours within those courses were spent teaching clinical PK compared to some TPC courses. Lastly, courses and curricula are constantly changing, making the cross-sectional nature of this survey more important to note. It is likely many of these courses have already changed at the time of this report.

Conclusion

Overall, TPC institutions had more courses with antimicrobial PK and, as a result, more opportunities for concept reinforcement. IBC institutions had less didactic lecture hours utilized in the large group setting, and more small-group, team-based and active learning, specifically in their organ systems courses. Teaching materials and assessment strategies were comparable across all institutions and suggesting potential opportunity for standardization. Additionally, this may present an opportunity for faculty across institutions to collaborate in developing teaching material. Lastly, perceptions of the PK curricula across institutions highlighted the belief that antimicrobial PK may be under taught and that improvements should be made to enhance and modernize material. The data presented here also gives residency directors and preceptors insight into the types of antimicrobial PK concepts currently taught, perhaps allowing them to identify gaps that need reinforcing in postgraduate training. At a time where significant changes to antimicrobial dosing are occurring and TDM is becoming more common, it is crucial that pharmacy students are adequately prepared to provide guidance in the clinical setting as their recommendations are likely to be trusted given the lack of PK expertise among other healthcare professionals.

Transparency declarations

This study was performed as part of routine work. Financial disclosures include: G.F. – Consultant (Critical Innovations, LLC.). E.B.C. – Advisory Board (Theratechnologies), Speaker's Bureau (Paratek). J.J. – Speaker's Bureau (Therapeutic Research Center). Z.J. – Consultant (Bold Insight, inc.). All other authors report no potential conflicts of interest.

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Table 1. Institution Characteristics

Characteristic	Total, n=53 (%)	Traditional progressive curriculum, n=35 (%)	Integrated block curriculum, n=18 (%)
Program length			
6 years	2 (4)	1 (3)	1 (6)
4 years	47 (89)	31 (89)	16 (89)
3 years	4 (8)	3 (9)	1 (6)
Program location			
Northeast	9 (17)	6 (17)	3 (17)
Midwest	13 (25)	9 (26)	4 (22)
South	19 (36)	11 (31)	8 (44)
West	11 (21)	8 (23)	3 (17)
Program class size			
≤100 students	28 (53)	19 (54)	9 (50)
>100 students	25 (47)	16 (46)	9 (50)
Program type			
Public	27 (51)	17 (49)	10 (56)
Private	26 (49)	18 (51)	8 (44)
Program age			
Legacy (≤1995)	27 (51)	19 (54)	8 (44)
New (>1995)	26 (49)	16 (46)	10 (56)
Instructional Strategies Used			
TBL	7 (13)	3 (9)	4 (22)
PBL	7 (13)	4 (11)	3 (17)
Both	23 (43)	15 (43)	8 (44)
Neither	16 (30)	13 (37)	3 (17)
Didactic Grading Strategy			
Letter	51 (96)	34 (97)	17 (94)
Pass/No Pass	1 (2)	0 (0)	1 (6)
Honors/Pass/No Pass	1 (2)	1 (3)	0 (0)
Experiential Grading Strategy			
Letter	33 (62)	24 (69)	9 (50)
Pass/No Pass	13 (25)	8 (23)	5 (28)
Honors/Pass/No Pass	7 (13)	3 (9)	4 (22)
Planning for PK change	18 (34)	14 (40)	4 (22)
Planning for curriculum change	23 (43)	18 (51)	5 (28)
Number of courses with antimicrobial PK content			
1	6 (11)	0 (0)	6 (33)
2	14 (26)	9 (26)	5 (28)
3	19 (36)	12 (34)	7 (39)
4	12 (23)	12 (34)	0 (0)
5	2 (4)	2 (6)	0 (0)
Courses with antimicrobial PK content			
Basic science pharmacokinetics	-	33 (94)	-
Clinical pharmacokinetics	-	15 (43)	-
Pharmacology	-	8 (23)	-
Therapeutics	-	28 (80)	-
Skills lab	30 (57)	21 (60)	9 (50)
Foundations/principles	-	-	17 (94)
Organ systems	-	-	12 (67)

Abbreviations: PK=pharmacokinetics; TBL=team-based learning; PBL=problem-based learning

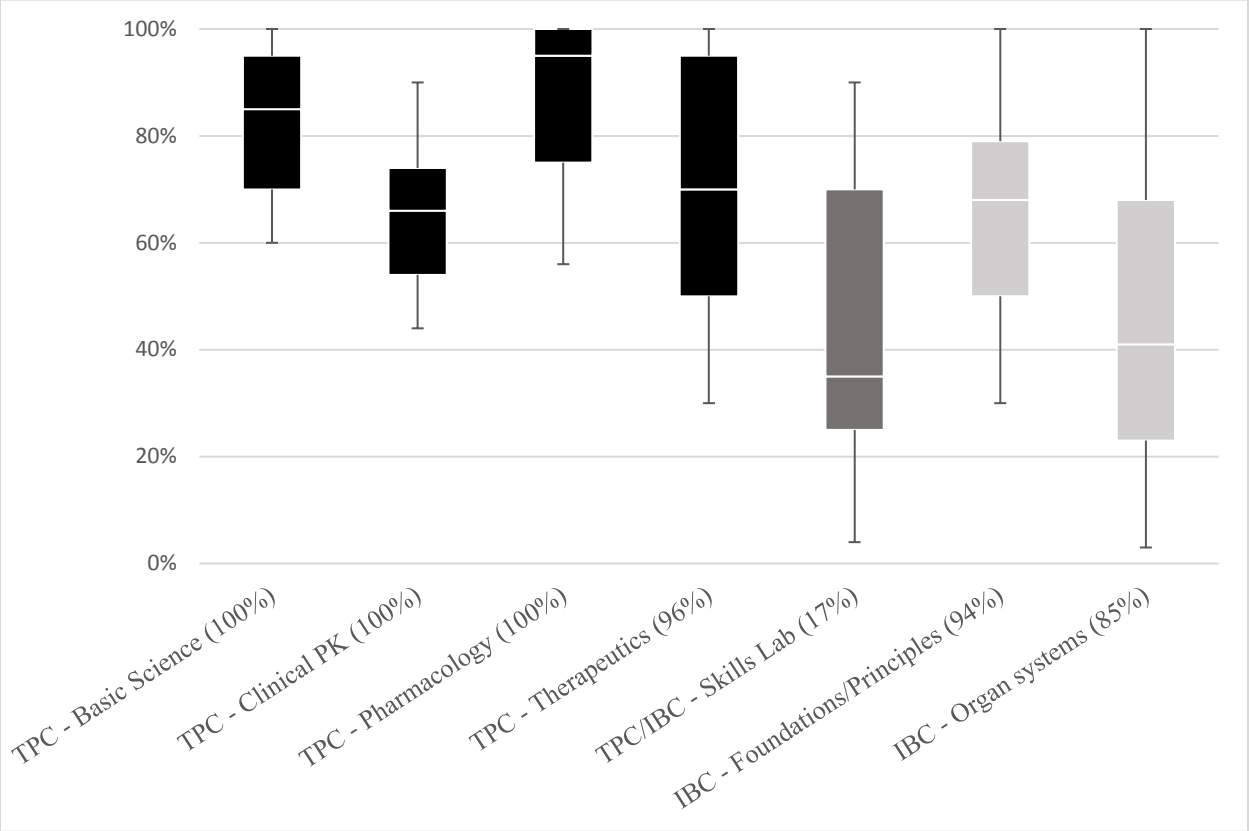
Table 2. Course Materials and Assessment Modalities for Select Courses

	Traditional Progressive Curriculum			Integrated Block Curriculum	
Characteristic	**Basic PK, n=33**	**Clinical PK, n=15**	**Therapeutics, n=28**	**Principles/Foundations, n=17**	**Organ Systems, n=12,**
Course length (weeks)	15 (14-15)	12 (7-15)	-	-	-
Time spent in:					
Large groups (hours/week)	3 (3-3)	3 (2-3)	5 (2-7)	30 (10-30)	8.5 (4.5-19.5)
Small groups (hours/week)	1 (1-1.8)	0.9 (0.5-2)	2 (2-4.5)	7 (2.3-17.5)	8 (1.8-10.5)
Large group pedagogy					
Didactic (%)	85 (70-94.5)	65.5 (53.8-74)	70 (50-95)	68 (50-78.8)	41 (20-70)
Active learning (%)	20 (10-30)	20 (12.5-30)	22 (20-40)	27.5 (16.3-33.8)	45 (28.3-57.3)
TBL (%)	10 (10-35)	25 (10-75)	45 (17-73)	22 (15-34)	20 (12-70)
Antimicrobials					
Vancomycin	18 (55)	15 (100)	28 (100)	13 (77)	12 (100)
Aminoglycosides	18 (55)	15 (100)	28 (100)	12 (71)	12 (100)
Beta-lactams	5 (15)	6 (40)	19 (68)	3 (18)	8 (67)
Antifungals	0 (0)	2 (13)	14 (50)	1 (6)	4 (33)
Calculation methods					
Hand calculations	33 (100)	15 (100)	26 (93)	17 (100)	12 (100)
Nomograms	14 (42)	13 (87)	19 (68)	8 (47)	11 (92)
Course calculators	4 (12)	1 (7)	2 (7)	1 (6)	2 (17)
Commercial calculators	1 (3)	1 (7)	3 (11)	1 (6)	3 (25)
Bayesian software	0 (0)	0 (0)	1 (4)	0 (0)	0 (0)
Course materials					
Textbooks	22 (67)	14 (93)	8 (29)	10 (59)	3 (25)
Course readers	13 (39)	7 (47)	12 (43)	4 (24)	7 (58)
Recorded lectures	12 (36)	7 (47)	9 (32)	9 (47)	9 (75)
Summative assessment modalities, frequently used					
True/False questions	3 (9)	2 (13)	3 (11)	0 (0)	0 (0)
Matching	3 (9)	3 (20)	2 (7)	0 (0)	0 (0)
Multiple choice questions	25 (76)	12 (80)	21 (75)	14 (82)	10 (83)
Multiple selection	7 (21)	4 (27)	8 (29)	1 (6)	2 (17)
Numerical response only	18 (55)	10 (67)	10 (36)	10 (59)	8 (67)
Open-ended response	15 (46)	9 (60)	9 (32)	7 (41)	5 (42)
OSCE	1 (3)	1 (7)	12 (43)	1 (6)	0 (0)
Instructor credentials					
PharmD	8 (24)	14 (88)	27 (96)	5 (29)	12 (100)
PhD	21 (64)	0 (0)	3 (11)	8 (47)	3 (25)
PharmD, PhD	6 (18)	0 (0)	2 (7)	2 (12)	0 (0)

Abbreviations: OSCE=objective structured clinical examinations; PK=pharmacokinetics; TBL=team-based learning

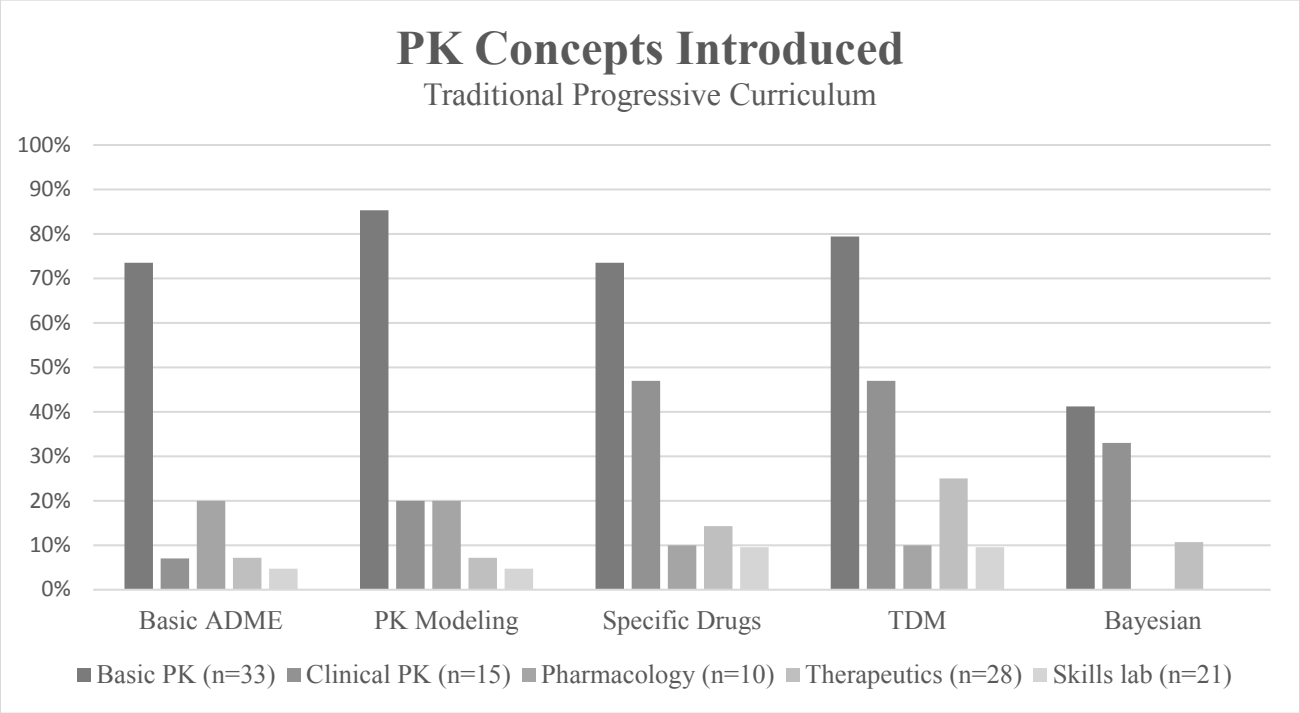
Categorical and continuous variables presented as n (%) and median (IQR), respectively.
Data not shown for pharmacology and skills lab courses in traditional progressive curricula, nor for skills lab courses in integrated block curricula.

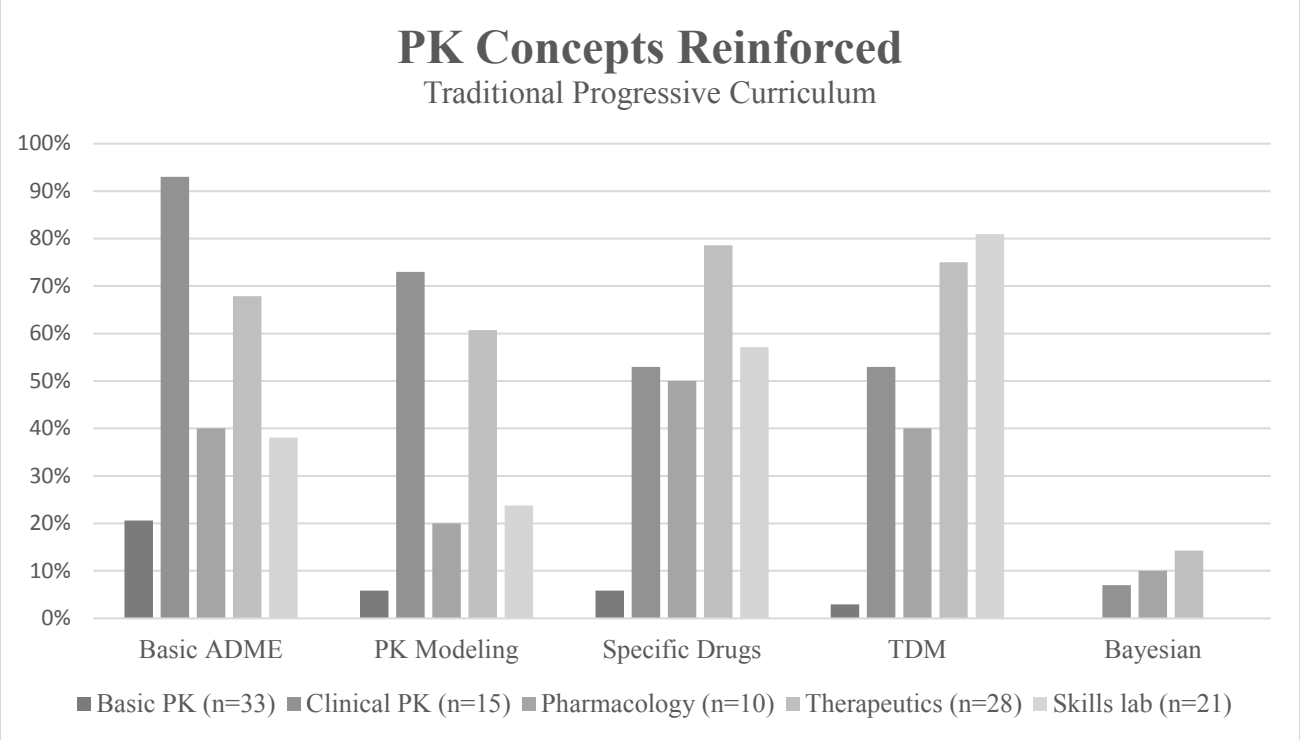
Figure 1. Percentage of Material Delivered via Lecture

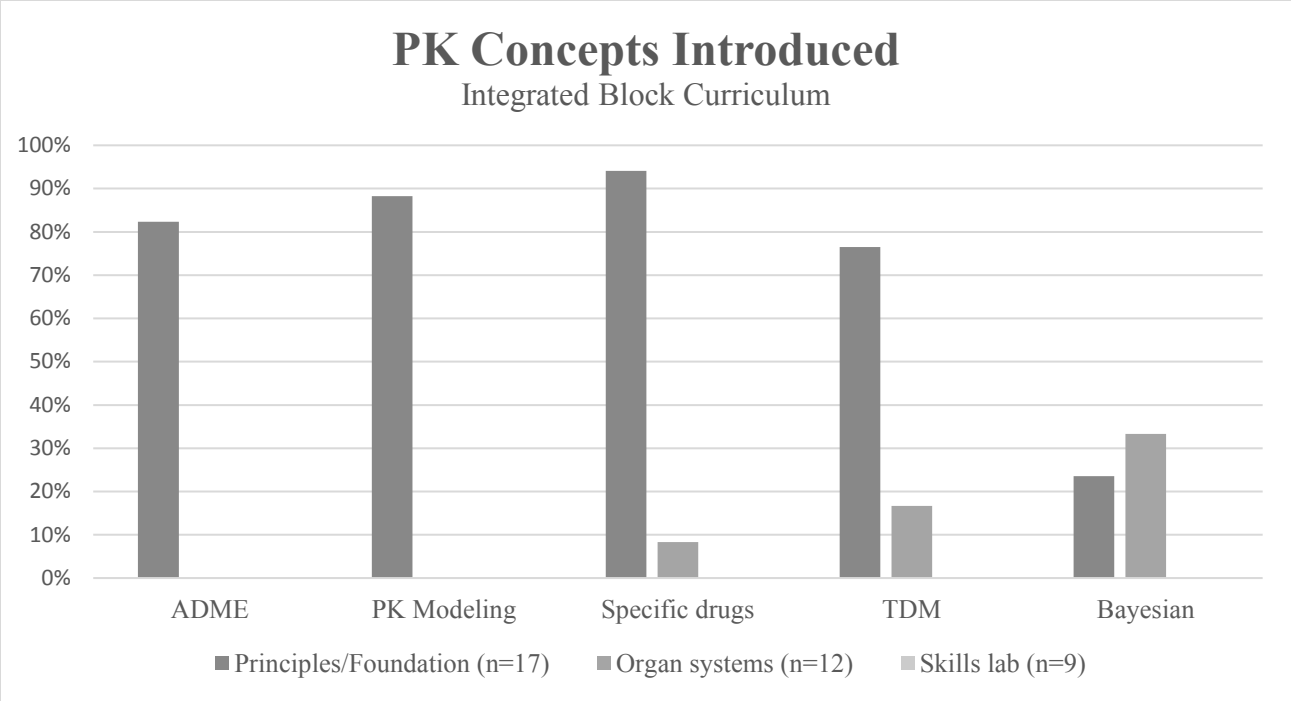


*Percentages in parentheses represent number of courses that included lecture

Figure 2. PK Concepts Covered by Course and Curriculum







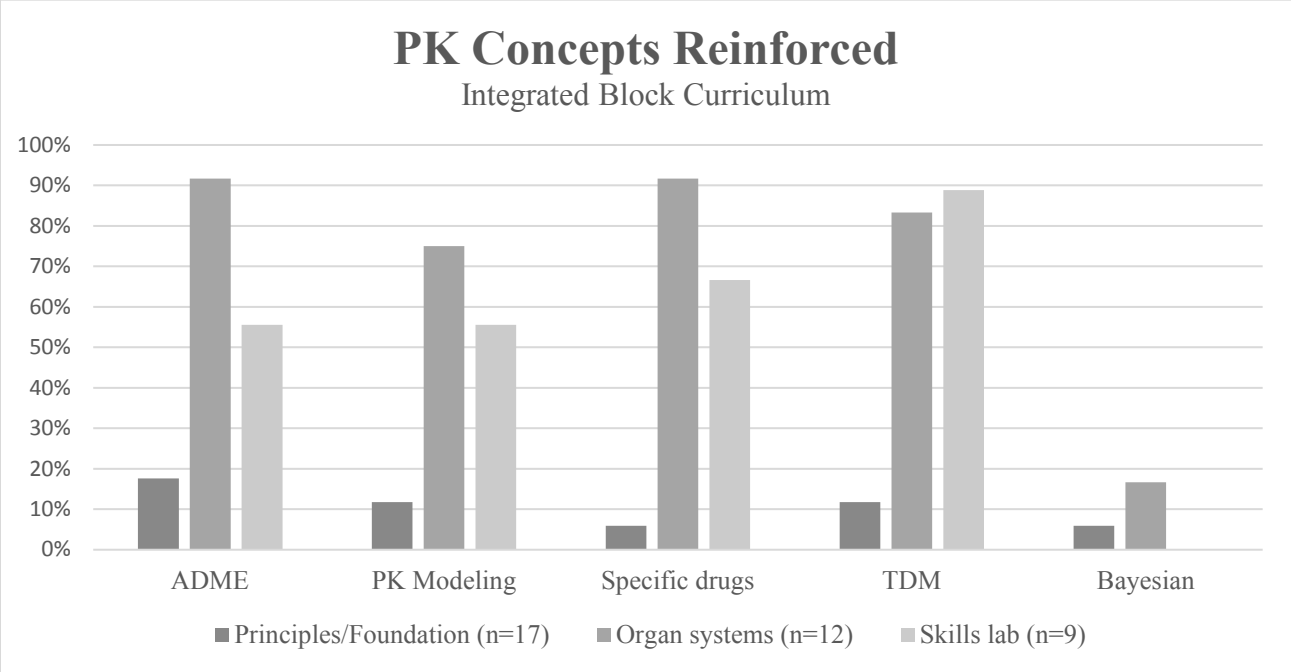


Figure 3. Respondent Perceptions of Antimicrobial PK in Curricula (n=53)