

# What do future pharmacists know about, and think of, antimicrobial stewardship?

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## Abstract

**Introduction:** This work aimed to investigate future pharmacists' knowledge of, and attitudes towards, antimicrobial stewardship, a subject area which is embedded in the Queen's University Belfast (QUB) pharmacy undergraduate curriculum.

**Methods:** Following ethical approval and piloting, QUB final year pharmacy students (n=118) were invited to complete a questionnaire on antimicrobial stewardship with questions relating to knowledge of, and opinions on, the concept including whether antimicrobials are advocated for various clinical conditions. Data analysis involved descriptive statistics (% and frequencies) with statistical tests, including the Mann-Whitney U test and *t*-test employed for sub-analysis (of responses and mean scores for male versus female students and United Kingdom & Ireland versus international students), with significance set at  $p < 0.05$ .

**Results:** The response rate was 94.9% (112/118). While no differences of note were evident for gender, United Kingdom & Ireland students were significantly more likely ( $p < 0.001$ ) to be knowledgeable and have appropriate attitudes than international students. Their mean overall score was 73.56 ( $\pm 5.41$ ) versus 68.27 ( $\pm 6.06$ ) for knowledge (maximum score was 91) and 38.07 ( $\pm 4.69$ ) versus 32.94 ( $\pm 5.04$ ) for attitudes (maximum score was 45). Only 61.6% (69/112) of respondents felt confident discussing antimicrobial stewardship with patients or other healthcare professionals.

**Discussion:** While reasonable scores were obtained, further research is needed to ascertain why one in three future pharmacists did not feel confident discussing antimicrobial stewardship. Despite coverage of this subject area throughout the degree programme, it seems that more educational interventions are required (particularly for international students) to ensure graduates can meaningfully contribute to this global health priority in practice.

**Keywords:** *Antimicrobial Stewardship, Attitudes, Knowledge, Pharmacy, Undergraduate Student*

## Introduction

Antimicrobial resistance is a serious threat to global public health; it affects the ability to treat infection effectively and puts patients at risk of prolonged illness, complications and death. It can compromise the success of various surgical procedures and cancer chemotherapy, and the cost of care subsequently increases when additional tests and more expensive drugs or hospitalisation are required (World Health Organisation [WHO], 2018). The National Institute for Health and Care Excellence (NICE) defines it as "the loss of effectiveness of any anti-infective medicine, including antiviral, antifungal, antibacterial and antiparasitic medicines" (NICE, 2015).

A lack of understanding of the consequences of inappropriate antimicrobial use, in tandem with unregulated use of antimicrobials in areas other than primary and secondary healthcare (for example, agriculture) has accelerated the issue (Hwang & Gums, 2016). A multi-faceted approach is required to address this

(NICE, 2017), with the concept of 'antimicrobial stewardship' receiving prominence in recent years. Antimicrobial stewardship strives to preserve future effectiveness and encompasses measures such as educating about appropriate use, developing and following prescribing guidelines, optimising selection, administration, dosing and duration of therapy, encouraging patients to receive recommended vaccines and facilitating an adequate supply of antimicrobials through ongoing research and development (NICE, 2017). Indeed, Governments and health organisations across the globe including the United Kingdom (UK) (GOV.UK, 2014; NICE, 2017) the Australian Government (Australian Government, Department of Health, Department of Agriculture, 2015). Responding to the Threat of Antimicrobial, 2015) Centers for Disease Control and Prevention (CDC) in the United States of America (CDC, 2018), and the WHO (WHO, 2018) have produced strategies, guidelines and public health campaigns about antimicrobial resistance and stewardship.

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It is important that future pharmacists have a sound knowledge and understanding of antimicrobial stewardship, as outlined in pharmacy degree programme syllabuses (General Pharmaceutical Council, 2011; Accreditation Council for Pharmacy Education [ACPE], 2016). Evidence suggests that pharmacists play an important part in antimicrobial stewardship through roles including guideline and policy development, ensuring appropriate prescribing, and advice provision on safe and appropriate use (Gilchrist *et al.*, 2015; Davis *et al.*, 2016; Avent *et al.*, 2018). However, a recent study undertaken in the UK found only 61.5% (8/13) of pharmacy schools taught all the antimicrobial stewardship principles (Castro-Sánchez *et al.*, 2016). A summary of the teaching and

assessment of antimicrobial stewardship within the QUB pharmacy undergraduate degree programme is given in Table I to provide context.

Research has also been conducted to ascertain opinions of undergraduate healthcare students, but these have largely involved medical students (Yang *et al.*, 2016; Wasserman *et al.*, 2017; Weier *et al.*, 2017). Fewer studies have involved pharmacy students (Burger *et al.*, 2016; Rusic *et al.*, 2018) with only one relating to Master of Pharmacy (M.Pharm.) students (Inácio *et al.*, 2017). This current work adds to the wider body of literature from a UK M.Pharm. perspective, with differences between international and non-international undergraduate students and male and female students' responses reported.

**Table I: An outline of the teaching of antimicrobial stewardship on the degree programme**

Year	Degree programme content (and how it is assessed)*
1	<p>Brief overview of medicines: learning from the past and focussing on future priorities, including antimicrobials (written examination)</p> <p>Introduction to the varied roles and responsibilities of a pharmacist and global health priorities including antimicrobial stewardship (written examination)</p> <p>Microbiology, including methods of sterilisation and disinfection, and an introduction to microbial biofilms (laboratory practicals and written examination)</p> <p>Infection control measures training prior to hospital placements (observation by pharmacist tutor on placement and action taken if non-adherence to policy)</p> <p>Function of the body at the molecular, cellular, tissue and system levels to subsequently contextualise pathophysiology of these systems (written examination)</p>
2	<p>Applied clinical pharmacology and therapeutics (Part 1), including evidence-based management of infections, except self-treatable infections, using gold standard resources (written examination)</p> <p>Pharmaceutical technology, including good manufacturing practice, formulation of sterile products and consideration of stability and preservatives (laboratory practicals and written examination)</p> <p>Community pharmacy placement: counselling on appropriate use of an antibiotic (mandatory placement with feedback provided by pharmacist tutor)</p> <p>Exposure to antimicrobial prescribing and infection control measures in a hospital setting whilst on clinical placement</p>
3	<p>Applied clinical pharmacology &amp; therapeutics (Part 2), including evidence-based management of infections, except self-treatable infections, using gold standard resources (written examination)</p> <p>Drug design and development and the prediction of drug properties based on a knowledge of structure-activity relationships, including antimicrobials (laboratory practicals and written examination).</p> <p>Advanced delivery systems for large and small molecules including recombinant drugs (laboratory practicals and written examination)</p> <p>Clinical advice to 'healthcare professionals' to optimise antimicrobial prescribing, including identifying interactions and potential hypersensitivity of antimicrobials, dispensing and counselling 'patients' on their safe and appropriate use (simulation - role-play scenarios in the mock pharmacy)</p> <p>Exposure to antimicrobial prescribing and infection control measures whilst on hospital placement and to over-the-counter antimicrobials whilst on community pharmacy placement</p>
4	<p>Monitoring, audit and feedback, including antimicrobials (clinical audit of prescribing whilst on hospital placement)</p> <p>Over-the-counter medicines and evidence-based management of self-treatable infections. Health promotion advice including ways to limit the spread of infection and the benefits of immunisation. Role of the pharmacist in vaccination administration (simulation - role-play scenarios in the mock pharmacy, case-studies and multiple choice questions)</p> <p>Appropriateness of prescribing and medicines use in care homes, including antimicrobials (written examination)</p> <p>Pharmaceutical care of patients with complex conditions such as human immunodeficiency virus (HIV) and opportunistic infections. Antimicrobial resistance including HIV, gonorrhoea and malaria, and the role of the pharmacist in antimicrobial stewardship (written examination)</p> <p><i>[Not covered by the time of data collection: Role of the pharmacist in antimicrobial stewardship, medicines optimisation, and e-health (conference-style activity i.e. a poster presentation to their year group)]</i></p> <p><i>[Not covered by the time of data collection: development and implementation of guidelines and policies (formulary development workshop encompassing antimicrobials and written examination)]</i></p> <p><i>[Not covered by the time of data collection: medical devices and their link with infection. First aid and wound management including the role of antimicrobials (written examination)]</i></p> <p><i>[Not covered by the time of data collection: role of the pharmacist in industry, including the development of new antimicrobials (written examination)]</i></p>

\*Research-led teaching throughout: reference to work conducted in the School and beyond in relation to antimicrobials and antimicrobial stewardship

## Aims and objectives

The overall aim was to investigate QUB final year M.Pharm. students' understanding and views on antimicrobial stewardship. The objectives were to:

- Ascertain students' knowledge of antimicrobial stewardship, including the requirement of antimicrobials in the treatment of various infections and whether they considered they had received adequate training in the area during the degree programme
- Determine students' attitudes towards antimicrobial stewardship, including their opinions on the role of the pharmacist in this area
- Conduct sub-group analysis (of the responses to individual statements and mean knowledge and attitude scores of international and non-international students' and male and female students) to ascertain whether significant differences existed.

## Methods

All QUB final year M.Pharm. students were invited to participate in the study. Final year students were chosen as they had almost completed the degree programme. Hypothetically, such students should have had a sound level of knowledge and confidence about the subject area so that they could positively contribute to antimicrobial stewardship in the workplace in the incoming months and years.

The paper-based questionnaire was developed with reference to previous published work in the area (Minen *et al.*, 2010; Abbo *et al.*, 2013; Dyer *et al.*, 2014; Justo *et al.*, 2014; Ahmad *et al.*, 2015; Rajiah *et al.*, 2015; Scaioli *et al.*, 2015; Burger *et al.*, 2016; Yang *et al.*, 2016; Inácio *et al.*, 2017; Wasserman *et al.*, 2017; Weier *et al.*, 2017) alongside WHO (WHO, 2018) and GOV.UK resources (GOV.UK, 2014), and NICE Clinical Knowledge Summaries (CKS) relating to the management of various infections (NICE CKS, 2013). The questionnaire had two sections: Section A (five questions encompassing many parts; with all the statements for these questions provided in Tables II and III and Figure 1) focussed on knowledge of, and opinions on, antimicrobial stewardship including satisfaction with training provision, confidence discussing the subject area, and the role of the pharmacist. These were closed-type questions either with a 5-point Likert scale for measuring level of agreement ('Strongly Agree' to 'Strongly Disagree' with a mid-point of 'Neither Agree nor Disagree') or requiring a 'yes' or 'no' answer about whether antimicrobials were advocated for various clinical conditions such as the common cold, impetigo, acute otitis media and urinary tract infections; Section B sought to collect non-identifiable demographic information about gender and the country where they received the majority of their education prior to enrolling on the degree programme. There was a space at the end of the questionnaire for respondents to add additional

comments about antimicrobial stewardship if they so desired. To enhance response rates, the questionnaire was short and the questions were largely closed-format (CDC, 2010). The first sheet outlined the purpose, gave a predicted completion time and explained how the data would be used. It reassured students about the voluntary nature of the study and, from an academic standpoint, that there were no repercussions for not completing the questionnaire, nor any advantages or rewards for completing it. No explanation of antimicrobial stewardship was provided as we sought to ascertain students' understanding of this concept. The questionnaire was piloted with ten pharmacist postgraduate students and as a result, an estimated completion time was ascertained and minor amendments made to the questionnaire ('increase the duration of antimicrobial therapy' statement was reworded to 'increase the duration of antimicrobial therapy beyond that currently advocated' and 'antibacterials' was reworded to 'antimicrobials' in a statement).

Distribution of the questionnaires took place once during Semester 1 (December 2017). One of the authors attended a scheduled mandatory class, briefly outlined the study, and invited students to participate. They were also asked to place completed questionnaires in a designated container prior to leaving the venue.

Data analysis firstly took the form of descriptive statistics, such as the frequency and percentage of respondents who selected a particular option. The responses were coded and entered into Microsoft Excel and R (a language for statistical computing and graphics) was employed for statistical analysis. As the data were largely non-parametric in nature (categorical or ordinal), the Mann Whitney U-Test and *chi*-squared non-parametric statistical tests were used to ascertain differences in responses (*i.e.*, male versus female students' responses to individual statements and international versus non-international student responses to individual statements) with significance set at  $p < 0.05$ . Secondly, overall scores were calculated for students about their knowledge level and attitudes about antimicrobial stewardship. In order to calculate these overall scores correctly, reverse coding of several statements was necessary to ensure students were allocated top marks for selecting the negative options 'disagree' or 'strongly disagree' or 'no' where necessary (for example, that the common cold typically required antimicrobial therapy and that hand-washing as an infection-control measure lacked evidence of effectiveness). When scoring the attitudinal statements, those statements with no predicted answer (of a future healthcare professional), such as students' opinions on training provision and self-confidence with the subject area, were excluded from the analysis. A list outlining the scoring of all statements is available on request from the corresponding author. Comparisons were then undertaken for male versus female students' mean overall scores and international versus non-international student mean overall scores. A *t*-test (Welch's *t*-test) was employed for comparisons if the data were normally

distributed and the Mann-Whitney U if the data were non-normally distributed (with significance set at  $p < 0.05$ ). Normality was ascertained using the Shapiro-Wilk test. Furthermore, Spearman's rank correlation coefficient was used to ascertain how well the relationship between the variables (knowledge and attitude scores) could be described using a monotonic function.

Ethical approval for the study was granted by the QUB School of Pharmacy Ethics Committee on 29th November 2017 (Ref 023PMY2017).

## Results

### Response rate

The response rate was 94.9% (112/118). Out of the 112 completed questionnaires, eight were partially completed (*i.e.*, participants left one or more parts of questions unanswered, therefore both 'n' and '%' is provided throughout). In terms of statistical analysis,  $p$ -values  $< 0.05$  are reported throughout the results section.

### Questionnaire Section B - Demographic information

There were 25 (22.3%) male and 87 (77.7%) female students. In terms of where they received most of their education prior to enrolling on the degree programme, 76 (67.9%) reported the UK or Ireland (referred to as 'UK & Ireland students' or 'non-international students' in this study), 34 (30.4%) reported countries beyond this (mainly Asian countries, and are referred to as

'international students' in this study) and two (1.8%) did not provide an answer.

### Questionnaire Section A - Knowledge of antimicrobial stewardship

The first question related to what antimicrobial stewardship involves and the second focused on what it aims to do. All verbatim statements for these two questions and corresponding responses are provided in Table II. In summary (with comprehensive results presented in Table II), the majority of respondents knew that antimicrobial stewardship related to the selection of appropriate antimicrobials and ensuring an appropriate dosage and duration of therapy. Most also knew it meant reducing their use when not indicated and preserving useful antibiotics for serious illness. Fewer respondents were sure about whether it meant reviewing antimicrobials in the context of human use only. Some also thought (incorrectly) that it aimed to: eliminate sample testing *via* laboratory confirmation of an infection, increase the use of broad spectrum antibiotics, increase the duration of antimicrobial therapy, and manage all infections routinely with two or more antimicrobials.

In terms of the sub-analysis of the individual statements for these two questions, there were no significant differences between male and female responses but several significant differences were noted between UK & Ireland and international student responses. International students were significantly more likely to consider that it involves reviewing antimicrobials in the context of

**Table II: Respondents' knowledge of antimicrobial stewardship**

	SA* (5) n (%)	A* (4) n (%)	NAD* (3) n (%)	D* (2) n (%)	SD* (1) n (%)	Interpolated median
<b>1. Antimicrobial stewardship involves:</b>						
a) the selection of appropriate antimicrobials	74 (66.1)	31 (27.7)	6 (5.4)	1 (0.9)	0 (0.0)	4.74
b) ensuring an appropriate route of administration for the antimicrobial	45 (40.2)	56 (50.0)	8 (7.1)	3 (2.7)	0 (0.0)	4.30
c) ensuring an appropriate dosing regimen for the antimicrobial	65 (58.0)	41 (36.6)	5 (4.5)	1 (0.9)	0 (0.0)	4.64
d) having an appropriate duration of antimicrobial therapy	77 (68.8)	33 (29.5)	1 (0.9)	1 (0.9)	0 (0.0)	4.77
e) reducing the use of antimicrobials where they are not indicated	89 (79.5)	18 (16.1)	3 (2.7)	2 (1.8)	0 (0.0)	4.87
f) ensuring healthcare professionals are educated on the appropriate use of antimicrobials	85 (75.9)	25 (22.3)	2 (1.8)	0 (0.0)	0 (0.0)	4.84
g) reviewing antimicrobials in the context of human use only <sup>†</sup>	35 (31.5)	28 (25.2)	21 (18.9)	21 (18.9)	6 (5.4)	3.77
<b>2. Antimicrobial stewardship aims to:</b>						
a) improve patient outcomes	74 (66.1)	34 (30.4)	4 (3.6)	0 (0.0)	0 (0.0)	4.74
b) preserve useful antibiotics for serious illness <sup>†</sup>	82 (73.9)	27 (24.3)	1 (0.9)	1 (0.9)	0 (0.0)	4.82
c) increase the duration of antimicrobial therapy beyond that currently advocated	13 (11.6)	16 (14.3)	26 (23.2)	41 (36.6)	16 (14.3)	2.48
d) reduce hospital stays <sup>†</sup>	46 (41.4)	44 (39.6)	14 (12.6)	6 (5.4)	1 (0.9)	4.28
e) minimise toxicity and adverse effects in patients	48 (42.9)	46 (41.1)	12 (10.7)	5 (4.5)	1 (0.9)	4.33
f) increase the use of broad spectrum antibiotics <sup>†</sup>	7 (6.4)	14 (12.7)	29 (26.4)	40 (36.4)	20 (18.2)	2.38
g) reduce use of 'single' medicines (managing all infections routinely with $\geq 2$ antimicrobials)	9 (8.0)	25 (22.3)	42 (37.5)	26 (23.2)	10 (8.9)	2.98
h) eliminate sample testing (for confirmation of an infection in a laboratory)	5 (4.5)	21 (18.8)	25 (22.3)	35 (31.3)	26 (23.2)	2.36
i) reduce the amount of time and money spent by the health service on each individual patient	36 (32.1)	38 (33.9)	18 (16.1)	15 (13.4)	5 (4.5)	3.97

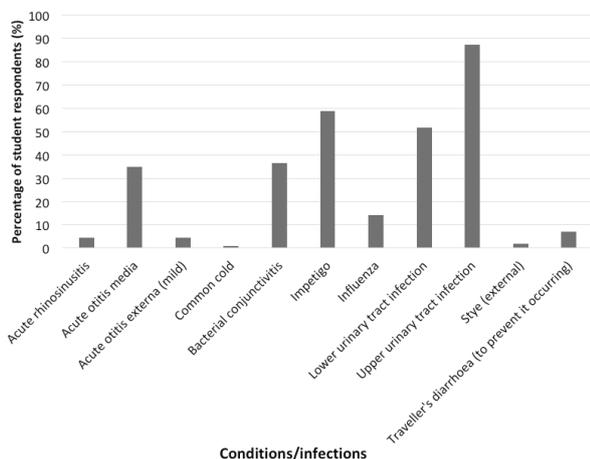
\*SA = Strongly Agree; A = Agree; NAD = Neither Agree nor Disagree; D = Disagree; SD = Strongly Disagree

<sup>†</sup> n=112, except 1(g) n= 111; 2(b) n=111; 2(d) n=111; 2(f) n=110

human use only [76.5% (26/34) versus 46.7% (35/75);  $p=0.034$ ], which is incorrect (Hwang & Gums, 2016). International students were more likely to think that hand-washing (as an infection control measure) lacks evidence of effectiveness [17.6% (6/34) versus 2.7% (2/75);  $p<0.001$ ], which is incorrect (NICE, 2017; CDC, 2018). In comparison to non-international students, and in accordance with NICE (2017), UK & Ireland students were more likely to correctly disagree that it aims to increase the duration of antimicrobial therapy beyond that currently advocated [64.5% (49/76) versus 20.6% (7/34);  $p<0.001$ ]; to increase the use of broad spectrum antibiotics [64.0% (48/75) versus 36.4% (12/33);  $p=0.003$ ] and to eliminate sample testing for confirmation of an infection in a laboratory [63.2% (48/76) versus 35.3% (12/34);  $p=0.001$ ].

The third and final question about knowledge related to first-line management strategies of various infections (and tested students' knowledge on whether an antimicrobial was advocated in normal circumstances as part of this strategy). Figure 1 presents the responses for all the chosen infections. In summary, the majority of student respondents correctly identified that the common cold, acute sinusitis, prevention of travellers' diarrhoea, mild otitis externa and styes did not routinely warrant antimicrobial therapy whereas an upper urinary tract infection did.

**Figure 1: Percentage of respondents who considered an antimicrobial was typically advocated as part of the first-line management strategy, in most patients, for a particular condition (n=112)**



In terms of the sub-analysis of the individual statements for this question, females were more likely than males to (correctly) indicate that impetigo required an antimicrobial as part of the first-line management strategy [66.7% (58/87) versus 32.0% (8/25);  $p=0.004$ ]. UK & Ireland students were more likely than international students to (correctly) indicate that

influenza did not typically require antimicrobial therapy [93.4% (71/76) versus 67.6% (23/34);  $p=0.001$ ] nor did acute otitis media [77.6% (59/76) versus 38.2% (13/34);  $p<0.001$ ] (NICE CKS, 2013).

The overall mean scores for the questions relating to knowledge (maximum available score was 91) are provided below, with students from UK & Ireland significantly more likely to obtain a higher score (to be more knowledgeable) than international students:

All: 71.85 ( $\pm 6.06$ )

Male: 72 ( $\pm 6.59$ ) and female: 71.81 ( $\pm 5.95$ )

UK & Ireland: 73.56 ( $\pm 5.41$ ) and International: 68.27 ( $\pm 6.06$ );  $p<0.001$

**Questionnaire Section A: Attitudes towards antimicrobial stewardship**

The first question about attitudes had various statements including ascertaining the pharmacist's role in antimicrobial stewardship. The second question related to students' confidence and training in relation to antimicrobial stewardship. Table III outlines all verbatim statements for these two questions and the corresponding responses. In summary (with comprehensive results presented in Table III), the majority of respondents considered that antimicrobials were over-used and that no further antimicrobials should be deregulated to non-prescription (over-the-counter) medicines. Most also thought that research and development was a priority and that the pharmacist had an important role to play. A substantial proportion considered they had not received enough training within the degree programme and did not feel confident discussing antimicrobial stewardship with patients or other healthcare professionals.

In terms of the sub-analysis of the individual statements for these two questions, there were no significant differences between male and female responses but several significant differences were noted between UK & Ireland and international student responses. UK & Ireland respondents were more likely to consider that antibiotics are overused nationally and internationally in healthcare [98.7% (75/76) versus 70.6% (24/34);  $p<0.001$ ]. They were also less likely than international respondents to think antimicrobial resistance was mainly a secondary care issue [64.5% (49/76) versus 36.4% (12/33);  $p=0.004$ ]. UK & Ireland respondents were more likely to deem that knowing about antimicrobial stewardship is crucial for their future role as a practising pharmacist [98.7% (75/76) versus 88.2% (30/34);  $p=0.029$ ] and more likely to be in disagreement that, in comparison to doctors and nurses, pharmacists only have a small role to play in antimicrobial stewardship [89.5% (68/76) versus 61.8% (21/34);  $p<0.001$ ]. Similarly, UK & Ireland students were more likely to disagree that 'antimicrobial stewardship is of limited relevance to me' [92.1% (70/76) versus 67.6% (23/34);  $p<0.001$ ].

The overall mean scores for the questions relating to attitude (maximum available score was 45) are provided below, with students from United Kingdom & Ireland

**Table III: Respondents' attitudes towards antimicrobial stewardship, including their views on training provision and confidence about the subject area**

	SA* (5) n (%)	A* (4) n (%)	NAD*(3) n (%)	D* (2) n (%)	SD* (1) n (%)	Interpolated median
a) Inappropriate antimicrobial use in patients is unlikely to cause harm	8 (7.1)	19 (17.0)	11 (9.8)	49 (43.8)	25 (22.3)	2.13
b) Antibiotics are overused nationally and internationally in healthcare	69 (61.6)	31 (27.7)	9 (8.0)	1 (0.9)	2 (1.8)	4.69
c) Antimicrobial resistance is mainly an issue in secondary rather than primary care†	12 (10.8)	17 (15.3)	21 (18.9)	39 (35.1)	22 (19.8)	2.36
d) Conducting further research to develop more antimicrobials is not a priority	4 (3.6)	7 (6.3)	9 (8.0)	61 (54.5)	31 (27.7)	1.91
e) More antimicrobials should be available as over-the-counter medicines	0 (0.0)	8 (7.1)	10 (8.9)	38 (33.9)	56 (50.0)	1.50
f) There is no point developing antimicrobial policies and prescribing guidelines, since this is against the principle of individualised care	1 (0.9)	6 (5.4)	10 (8.9)	47 (42.0)	48 (42.9)	1.67
g) Hand-washing as an infection control measure lacks evidence of effectiveness†	4 (3.6)	4 (3.6)	13 (11.7)	45 (40.5)	45 (40.5)	1.73
h) There is adequate information available for the public about antimicrobial stewardship	6 (5.4)	17 (15.2)	18 (16.1)	56 (50.0)	15 (13.4)	2.23
i) Knowing about antimicrobial stewardship is crucial for my future role as a practising pharmacist	64 (57.1)	43 (38.4)	3 (2.7)	1 (0.9)	1 (0.9)	4.63
j) In comparison to doctors and nurses, pharmacists only have a small role to play in antimicrobial stewardship	1 (0.9)	12 (10.7)	9 (8.0)	42 (37.5)	48 (42.9)	1.69
k) Antimicrobial stewardship is of limited relevance to me	1 (0.9)	5 (4.5)	11 (9.8)	54 (48.2)	41 (36.6)	1.78
l) I would feel confident discussing antimicrobial stewardship with patients or other healthcare professionals	14 (12.5)	55 (49.1)	18 (16.1)	23 (20.5)	2 (1.8)	3.74
m) I have received adequate training on antimicrobial stewardship (including resistance) on the M.Pharm. degree programme	6 (5.4)	50 (44.6)	24 (21.4)	30 (26.8)	2 (1.8)	3.50

\*SA = Strongly Agree; A = Agree; NAD = Neither Agree nor Disagree; D = Disagree; SD = Strongly Disagree

† n=112, except (c) n=111; (g) n=111

significantly more likely to obtain a higher score (to have more appropriate opinions, expected of a future healthcare professional) than international students:

All: 36.50 ( $\pm$ 5.29)

Male: 36.08 ( $\pm$ 7.14) and female: 36.62 ( $\pm$ 4.69)

UK & Ireland: 38.07 ( $\pm$ 4.69) and International: 32.94 ( $\pm$ 5.04);  $p < 0.001$

Lastly, in terms of the monotonic relationship between knowledge and attitude scores,  $p = 0.4836$

## Discussion

Overall, this study has revealed interesting findings in relation to knowledge and attitudes towards antimicrobial stewardship. While many of the future pharmacists' answers were correct (in terms of knowledge and understanding of the subject area) and appropriate (in terms of attitudes towards antimicrobial stewardship and their future role), and overall scores reasonable, there were several concerning results and differences noted between international and UK & Ireland students' responses. International students were significantly less likely to be knowledgeable and have appropriate attitudes than their UK & Ireland counterparts. Furthermore, greater knowledge was associated with more appropriate attitudes. Moreover, it is disappointing that only half of

the future pharmacist respondents believed they had received adequate training on the degree programme (despite it being taught and assessed in each of the four years) and worrying that only about 60% would feel confident discussing antimicrobial stewardship with patients or other healthcare practitioners.

The work has many strengths, particularly since it is only the second study in the UK to investigate M.Pharm. students' knowledge and attitudes towards antimicrobial stewardship and given the current antimicrobial crisis, this research is timely, as healthcare professionals (both current and future) strive to slow the emergence of resistance. Moreover, educators of healthcare disciplines should be cognizant of their students' understanding and views in this important subject area. In addition, the response rate for this study was high (95%) reducing the likelihood of non-response bias. There were also limitations, particularly around the conditions requiring antimicrobial treatment as part of the first-line management strategy (which were presented within Figure 1). In hindsight, some of these were difficult for respondents to answer, although this was not picked up in the pilot. For example, with infective conjunctivitis, NICE CKS advises that this can be treated with hygiene measures alone or with an antimicrobial (such as chloramphenicol) if the patient wants quicker resolution of symptoms (NICE CKS, 2013). Similarly, for lower urinary tract infection, the gender of the patient was not specified yet NICE CKS advises that it can be self-

limiting in women and resolve in a few days without treatment (provided the patient is not pregnant) whereas men usually require an antimicrobial or a delayed prescribing approach may be used (NICE CKS, 2013). Perhaps patient-based scenarios, with further information provided, would have been a more appropriate and contemporary way to test this knowledge. Additionally, uneven sizes of sub-groups and small samples can adversely affect the statistical power and validity of the findings.

The majority of students correctly identified what antimicrobial stewardship involved and aimed to do (such as ensuring an appropriate choice of antimicrobial, and only when required, at the correct dose, duration and route of administration and with the aim of improving patient outcomes) as has been previously reported (Inácio *et al.*, 2017). In this current study, there was a lack of knowledge that it went beyond reviewing antimicrobials for human use only. It could be argued that this is not a pressing concern for future pharmacists but those in community practice should be able to advise veterinary practitioners to regulate the use and supply of antimicrobials for animals in their care and warn farmers against inappropriately using antimicrobials in their animals (Khachatourians, 1998). In addition, only around half of the student respondents knew that antimicrobial stewardship does not aim to eliminate sample testing for confirmation of an infection in a laboratory. A critical factor for resistance arises from empiric antibiotic prescribing without first testing for microbes' sensitivity (NICE, 2017; 2018). It was of some concern that around 20% of respondents believed that antimicrobial stewardship aimed to increase the use of broad spectrum antibiotics. Narrow-spectrum antibiotics are ideal first-choice agents in many circumstances and the use of broad-spectrum antibiotics can leave individuals susceptible to harmful bacterial infections such as *Clostridium difficile* (NICE, 2017; 2018). Many students correctly identified which infections required antimicrobial treatment as part of the first-line management strategy. These were: bacterial conjunctivitis (but only if patient desires quicker symptom resolution as it is typically self-limiting), urinary tract infections (and lower urinary tract infections in men), and impetigo (NICE CKS, 2013). However, around a third of students thought acute otitis media required antimicrobials when, for most patients over three months old, no antibiotic is required or a delayed antibiotic approach is now advocated, as it normally resolves in two-four days (NICE CKS, 2013). International students were more likely to think that influenza typically required antimicrobials; this is just one example revealing how they lacked knowledge (NICE CKS, 2013) and understanding of the subject area in comparison to their non-international peers. Similar findings have been reported previously, with significant differences seen in grades with home students outperforming the non-native English speaking international students in many aspects of the degree programme (Hall *et al.*, 2017). Differences in this current research may also be related to prior education and

culture (in terms of the management of infections, public awareness campaigns and infection control measures) and could be worth exploring further in a subsequent study.

In terms of attitudes towards antimicrobial stewardship, encouragingly, most respondents thought understanding of the subject area was crucial to fulfil their future roles as healthcare professionals. However, they did not think there should be further prescription-only deregulations of antimicrobials. Perhaps this is linked to the criticism that pharmacists received from the medical profession about inappropriate supply of antibacterials when topical chloramphenicol became available over-the-counter about ten years ago (Davis *et al.*, 2009). Only about half of the respondents believed they had received adequate training about antimicrobial stewardship on the degree programme and a third seemed to be unconfident discussing antimicrobial stewardship with patients or other healthcare professionals. From a pharmacy educator's perspective, these results are disheartening given the amount of time devoted to this subject area (outlined in Table I). A similar study in the UK found that students were dissatisfied with the education they received, with less than 50% of the students indicating that their education had prepared them to select appropriate antibiotics and therapeutic regimens (Castro-Sánchez *et al.*, 2016). Guidance from other educators about antimicrobial teaching, as reported in the wider literature (Pulcini *et al.*, 2015; Gallagher *et al.*, 2017; Kufel *et al.*, 2018), could be a useful reference when trying to enhance the antimicrobial teaching provision within QUB School of Pharmacy.

In conclusion, most of the student respondents displayed an adequate level of knowledge and appropriate attitudes towards antimicrobial stewardship although gaps in understanding and learning needs still exist, particularly for international students. In terms of professional responsibilities, it is concerning that only 60% of future pharmacists (who are within months of graduating) felt confident discussing it with patients or other practitioners. This baseline data will now enable academic staff at QUB to re-evaluate the comprehensive teaching provision and reflect on what could be done differently to optimise students' understanding, views and confidence in relation to antimicrobial stewardship.

#### Conflicts of interest

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