Ir J Med Sci (2016) 185:195–201
DOI 10.1007/s11845-015-1268-7

ORIGINAL ARTICLE

The relevance of basic sciences in undergraduate medical education

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Received: 14 November 2014 / Accepted: 31 January 2015 / Published online: 14 February 2015

Abstract
Background Evolving and changing undergraduate medical curricula raise concerns that there will no longer be a place for basic sciences. National and international trends show that 5-year programmes with a pre-requisite for school chemistry are growing more prevalent. National reports in Ireland show a decline in the availability of school chemistry and physics.
Aim This observational cohort study considers if the basic sciences of physics, chemistry and biology should be a prerequisite to entering medical school, be part of the core medical curriculum or if they have a place in the practice of medicine.
Methods Comparisons of means, correlation and linear regression analysis assessed the degree of association between predictors (school and university basic sciences) and outcomes (year and degree GPA) for entrants to a 6-year Irish medical programme between 2006 and 2009 ($n = 352$).
Results We found no statistically significant difference in medical programme performance between students with/without prior basic science knowledge. The Irish school exit exam and its components were mainly weak predictors of performance ($-0.043 \geq r \leq 0.396$). Success in year one of medicine, which includes a basic science curriculum, was indicative of later success ($0.194 \geq r^2 \leq 0.534$).
Conclusions University basic sciences were found to be more predictive than school sciences in undergraduate medical performance in our institution. The increasing emphasis of basic sciences in medical practice and the declining availability of school sciences should mandate medical schools in Ireland to consider how removing basic sciences from the curriculum might impact on future applicants.

Keywords Undergraduate · Medical · Admission · Science · Student · Predictive · Assessment · Education

Introduction

As medical programmes shorten and topics jostle for space in newly evolved curricula, there is a concern that there will no longer be a place for basic sciences. The Flexner Report in 1910 [1] placed a strong emphasis on the scientific basis for medical practice and, a century later, the Association of American Medical Colleges (AAMC) and the Howard Hughes Medical Institute (HHMI) [2] expressed a concern that the basic science content in medical school curricula was not reflective of the expanding scientific knowledge base of medicine.

This paper examines the academic entry requirements of a 6-year undergraduate medicine programme and considers whether the basic sciences of physics, chemistry and biology hold any predictive value in success on an undergraduate medical programme and if those basic sciences should be a prerequisite to entering medical school or if instead they should form part of the core medical curriculum.

Medical programme duration and entry requirements: international practice

Undergraduate medical education is categorised into 4-, 5- and 6-year programmes. Four-year programme places are

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Table 1 Undergraduate programme offerings and entry requirements in Ireland, UK and Australia

		Ireland	United Kingdom incl. Northern Ireland	Australia
Number of medical schools		6	33	18
Number of undergraduate programmes		7	36	9
Duration	Science prerequisites for entry	Ireland	United Kingdom incl. Northern Ireland	Australia
Five-year programmes	Chemistry only	–	2	2
	Chemistry + min 1 Science/Math	3	23	1
	Any Science(s)	1	1	–
	No prerequisite	–	–	2
Six-year programmes	Chemistry only	–	–	–
	Chemistry + min 1 Science/Math	–	5[a]	1
	Another Science (not chemistry)	–	–	–
	Any Science(s)	3	–	1
	No prerequisite	–	5[b]	2[a]
	ACCESS[β] only	–	7	–

[a] Programmes include an integrated BA/BSc

[b] Programmes include a traditional pre-medical programme

[β] In the UK, Access courses bridge the gap between the qualifications of an applicant and those qualifications needed to enter onto an undergraduate degree course. Applicants may also need to satisfy a number of socio-economic criteria

reserved for graduates whilst 5- and 6-year programmes, normally differentiated by the inclusion of a year of basic science studies or an integrated bachelor's degree, admit students on the basis of secondary school results.

We reviewed undergraduate medical programme offerings and school entry requirements for non-degree holders in Ireland, the UK and Australia where English is the primary spoken language. The school examinations of the Irish Leaving Certificate (LC) and Australian Tertiary Admission Rank (ATAR) both require a student to undertake a minimum of six and ten subjects, respectively. By contrast, the most common school qualification in the UK, the A-Levels, have a constricted but deep focus on three/four subjects only. In addition to an overall score in one's school exit examination, presentation of school basic sciences is also a typical prerequisite to medical education. Our review found that 72 % of undergraduate offerings in the UK were 5-year programmes of which 96 % stipulated school chemistry as a prerequisite (Table 1). The remaining 28 % of offerings were 6-year programmes, half of which contained intercalated BA/BSc programmes which required school chemistry for entry. Therefore, only 14 % of UK undergraduate programmes included a pre-medical year which had no prerequisites. By comparison, 43 % of programmes in Ireland and 56 % in Australia offered programmes of 6-year duration. A key shift towards graduate programmes is evident in Australia resulting in an overall declining availability of undergraduate options [3, 4]. European initiatives such as the Bologna Declaration [5] and Directive 2005/36/EC [6] contain recommendations which have the potential to impact upon the future duration and structure of basic medical degree programmes in Ireland.

This institution, UCD School of Medicine and Medical Science, offers a 4-year graduate entry programme and a 6-year undergraduate programme. Approximately, 67 % of the first year curriculum in the 6-year programme consists of basic physical and applied sciences relevant to medicine and the remaining 5 years comprise two and a half years of systems-based pre-clinical learning with vertically integrated clinical subject matter followed by two and a half years of clinical learning. For the period of time included in this study, the academic requirements for admission to the six-year programme at UCD were an overall LC score and any one laboratory science subject.[1]

Access to science in Irish Secondary Schools

At least one science subject is required for entry to every undergraduate programme in Ireland (Table 1). However, in 2012, a survey of secondary schools found that 47 % had removed one or more subjects from their LC offerings since 2009 with 32 % of those schools dropping chemistry and/or physics [7]. In 2013, a further 19 % of schools dropped Physics and 15 % dropped chemistry from their LC offering [8]. In 2012/13, 75 % of state-funded secondary schools outside of the country's capital Dublin offered physics as a LC subject and 79 % offered chemistry [9]. This creates a challenge for those who wish to study medicine but may not fulfil the entry criteria for several Irish medical schools.

Methods

The objective of this study was to consider the relationship between basic sciences and performance within a

[1] The following subjects in the Irish LC are recognised laboratory science subjects: agricultural science, biology, chemistry, physics and chemistry (Joint), physics.

medical programme. We examined the relationship firstly between school basic sciences and medical programme performance and secondly between the basic sciences in year one of our medical curriculum and subsequent programme performance. Students admitted to our 6-year medical programme on the basis of the Irish LC between 2006 and 2009 inclusive were included in the analysis. All students had undertaken their studies in a modularised programme and performance was measured by year Grade Point Average (GPA) to a maximum of 4.20. Degree GPA is calculated on the penultimate and final year of study; therefore, GPA's for Year one, two, three and four along with final degree GPA were included for analysis.

School basic sciences included the grades achieved in the subjects of physics, chemistry and biology. The competitive nature of applications to medicine can result in a proliferation of high grades in school subjects; therefore for comparative purposes, we included overall LC points and the subjects of English and mathematics, which are required by all students for matriculation purposes and thus tend to yield a wider spread of grades. For mathematics, students were categorised based on the level of exit examination paper taken; honours or ordinary level. Overall LC points were to a maximum of 600 and all individual subjects to a maximum of 100 points.

Independent sample *t*-tests and one-way analysis of variance tests were used to consider differences in the medical programme performance between students who presented with and without school basic sciences as part of their admission criteria. Post hoc tests by Tukey correction were applied to all analyses where multiple comparisons were made. Pearson's correlation coefficients then measured the effect of both school and university basic science performance on later medical programme performance. Multiple linear regression further allowed us to show the predictive value of several entry criteria models.

For correlation and regression analysis, all raw GPA scores, LC points and module GP's were standardised to *z*-scores allowing for comparison of GPA's, points or GP's from different distributions. Normal distribution was checked for all study variables and statistical significance was taken as $P \leq 0.05$; significant and $P \leq 0.01$; extremely significant. While a correlation coefficient of ± 1 indicated perfect correlation, values above 0.8 were considered strong correlations, 0.3–0.8 were moderate correlations and less than 0.3 were weak correlations. Exemption from full ethical review was granted by the Human Research Ethics Committee at University College Dublin as the study data was anonymised.

Results

Descriptive statistics

Summary statistics for the sample ($n = 352$) showed that the mean age of a student at the time of programme commencement was 18.45 years [standard deviation (SD) = 1.14 years] and 201 students (57.1 %) in the sample were female and 151 (42.9 %) were male.

Relationship between school basic sciences and medical programme performance

There was largely no difference in the medical programme performance of students who presented with or without school chemistry, physics and/or biology, although those presenting with honours mathematics were found to have a statistically significant GPA of, on average, 7 % higher than those with ordinary level mathematics across all years of the medical programme (Table 2).

Moderate correlations were found between year one of medicine and the predictors of total LC points, school physics and school mathematics ($r = 0.300$, $r = 0.268$ and $r = 0.210$, respectively) although the relationship diminished in some subsequent years (Table 3). Biology was the most correlate school science with degree GPA and school English was most correlate overall ($r = 0.396$). Linear regression revealed that English, mathematics and a science subject were collectively a moderate predictor of success (Table 4) with the subjects of English, mathematics and biology together accounting for up to 37.9 % of variance in the final degree GPA. School English became increasingly significant from year one to final year whereas the predictive trend for school science varied. Biology, for example, was shown to have little or no effect in the mid years of the programme, yet beta values were highest for degree GPA ($\beta = 0.278$) (Table 4).

Relationship between university basic sciences and medical programme performance

Correlations found between year one GPA and latter year GPA's indicated that first-year success was highly indicative of success in subsequent years, particularly in the relationship between first- and second-year performance ($r = 0.732$) (Table 3). The subjects of chemistry, physics and zoology in year one were correlated with later programme performance, particularly in the case of chemistry and degree GPA ($r = 0.407$). Although we found no evidence of any predictive relationship between school biology and medical programme performance, the year one zoology content was moderately predictive in later programme success (r values ranging from 0.400 to 0.538). Year one

Table 2 Significance values for the presence of school predictor variables versus year and programme GPA

	Year 1 GPA		Year 2 GPA		Year 3 GPA		Year 4 GPA		Degree GPA	
	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o
Honours mathematics										
Sample (*n*)	300	51	296	50	288	48	206	38	65	8
Year GPA	3.38**	3.10	3.10**	2.91	3.27**	3.05	3.34*	3.17	3.20*	2.96
Chemistry										
Sample (*n*)	306	45	301	45	294	42	217	27	68	5
Year GPA	3.34	3.38	3.06	3.11	3.23	3.27	3.32	3.31	3.17	3.33
Physics										
Sample (*n*)	169	182	167	179	162	174	118	126	39	34
Year GPA	3.40*	3.29	3.07	3.07	3.24	3.24	3.28	3.35	3.18	3.17
Biology										
Sample (*n*)	249	102	245	101	237	99	175	69	53	20
Year GPA	3.33	3.38	3.07	3.06	3.23	3.27	3.32	3.31	3.17	3.21

w presence of school subject, *w/o* absence of school subject

* $P \leq 0.05$, ** $P \leq 0.01$

Table 3 Pearson coefficients for each predictor variable versus year and programme GPA

		Year 1 GPA	Year 2 GPA	Year 3 GPA	Year 4 GPA	Degree GPA
Programme entry variables						
Total LC points	Pearson correlation (*r*)	0.300**	0.343**	0.312**	0.257**	0.331**
	N	351	346	336	244	73
LC Biology points	Pearson correlation (*r*)	0.169**	0.129*	0.099	−0.043	0.250
	N	249	245	237	175	53
LC Chemistry points	Pearson correlation (*r*)	0.175**	0.167**	0.214**	0.146*	0.113
	N	306	301	294	217	68
LC Physics points	Pearson correlation (*r*)	0.268**	0.261**	0.297**	0.326**	−0.026
	N	169	167	162	118	39
LC Mathematics points (honours)	Pearson correlation (*r*)	0.210**	0.133*	0.177**	0.035	0.215
	N	300	296	288	206	65
LC English points	Pearson correlation (*r*)	0.190**	0.232**	0.220**	0.290**	0.396**
	N	351	346	336	244	73
HPAT	Pearson correlation (*r*)	0.116	0.001	0.073	–	–
	N	94	94	86	0	0
Programme performance variables						
Year 1 GPA	Pearson correlation (*r*)	–	0.732**	0.704**	0.615**	0.505**
	N	–	345	336	244	73
Year 1 Chemistry (accumulated GPA)	Pearson correlation (*r*)	–	0.545**	0.508**	0.428**	0.407**
	N	–	344	335	243	73
Year 1 Physics (accumulated GPA)	Pearson correlation (*r*)	–	0.483**	0.460**	0.316**	0.377**
	N	–	345	335	243	73
Year 1 Zoology	Pearson correlation (*r*)	–	0.538**	0.442**	0.407**	0.400**
	N	–	343	333	241	73

* $P \leq 0.05$, ** $P \leq 0.01$

accounted for 24.5 % of the variance in degree GPA and the basic science curriculum was found to account for 41.3 % of GPA variance in year two and 19.4 % of final year GPA variance (Table 4). In both cases, chemistry and zoology were the strongest independent contributing variables.

Discussion

We considered the relationship between school and university basic sciences and subsequent medical programme performance. Our findings were then used as a catalyst to

Table 4 Regression models of the relationship between predictor variables and year and programme GPA

	Year 1		Year 2		Year 3		Year 4		Degree GPA	
	Beta (β)	r^2 (%)	Beta (β)	r^2 (%)	Beta (β)	r^2 (%)	Beta (β)	r^2 (%)	Beta (β)	r^2 (%)
Model 1										
Total LC points	0.300**	8.70	0.343**	11.50	0.312**	9.50	0.257**	6.20	0.331**	9.70
Model 2										
LC English points	0.235**	9.30	0.270**	8.40	0.269**	9.70	0.332**	10.20	0.453**	22.50
LC Mathematics points	0.229**		0.158**		0.201**		0.055		0.258*	
Model 3										
LC English points	0.256**	13.10	0.296**	10.00	0.297**	10.30	0.324**	9.10	0.531**	37.90
LC Biology points	0.182**		0.13		0.083		−0.025		0.278*	
LC Mathematics points	0.243**		0.145*		0.185**		0.092		0.244*	
Model 4										
LC English points	0.220**	10.50	0.249**	10.30	0.259**	11.10	0.319**	11.50	0.471*	20.90
LC Chemistry points	0.128*		0.158*		0.171**		0.182*		0.042	
LC Mathematics points	0.201**		0.111		0.141*		0.009		0.224	
Model 5										
LC English points	0.241**	11.20	0.226**	8.90	0.285**	15.60	0.413**	26.30	0.348*	4.10
LC Physics points	0.155		0.204*		0.258**		0.366**		0.042	
LC Mathematics points	0.172*		0.066		0.091		−0.024		0.137	
Model 6										
Year 1 Chemistry			0.321**	41.30	0.329**	34.40	0.344**	26.30	0.193	19.40
Year 1 Physics			0.145**		0.169**		0.03		0.164	
Year 1 Zoology			0.314**		0.220**		0.251**		0.218	
Model 7										
Year 1 GPA			0.732**	53.40	0.704**	49.40	0.615**	37.60	0.505**	24.50

* $P \leq 0.05$, ** $P \leq 0.01$

enter a discussion as to whether basic sciences are still relevant to undergraduate medical education.

Basic sciences and medical programme performance

Research regarding the predictive power of pre-admission academic criteria is broad and conflicting, which is unsurprising given the variations in both school curricula, school qualifications and medical school entry requirements. Consistent with research in the UK [10–13], we found that academic or cognitive ability held some predictive value in later programme success. One of the largest systematic reviews conducted found that prior academic performance, measured by A Level grades, medical admission tests and GPA's, accounted for up to 23 % of variances in undergraduate medical performance [10]. We found that the Irish LC accounted for no more than 11.5 % of the variance in any year. This differential in findings could, however, be explained by the fact that the A-level curriculum is to a considerably greater depth than the LC curriculum.

Our research confirmed expectations with respect to previous academic achievement, whilst making a distinction between cognitive ability and substantive content. Although there was generally no statistically significant difference in the performance between students with and without prior basic science knowledge, we found that, as suggested in other research [14, 15], the grades achieved in those sciences were statistically significant in programme performance. This might confirm the existence of a relationship between overall cognitive ability and medical programme performance [16, 17].

Although, the predictive value of school mathematics has not been clear in previous research [14, 18, 19], we found that students who presented honours mathematics performed statistically better than their colleagues with ordinary mathematics. Consistent with other research [16] we found that the predictive value of English was greatest in the final 2 years, which is somewhat unsurprising as it has been previously suggested that there is an increased emphasis on communication skills, understanding of individual and unique patient cases and sensitivity to complex situations in those years [20]. It should be noted that high correlation coefficients between mathematics and English and programme performance could also be attributed to broader grade ranges in those two school subjects.

Consistent with previous findings [21], overall performance in the first year of medicine was indicative of later performance. Contrary to our discoveries for school science, the accumulated GP's for the university subjects of chemistry, physics and zoology were moderately predictive of later performance. As previously mentioned, the spread of grades in school sciences is exceptionally narrow compared to that of university sciences and this may have contributed to higher coefficient values between the grades achieved in the year one collated science subjects GP's and subsequent medical programme performance.

Basic sciences and future-proofing our graduates

Medical education plays a key role in preparing future doctors with the skills needed to respond to changes in our health care system. Flexner outlined an academic training model linking those scientific principles which are the foundations of human health and disease to clinical decision-making [1]. It has been postulated previously that students' early exposure to the basic sciences may help to provide them with a lifelong critical approach to medical advances and their applications [22] in addition to supporting clinical reasoning skills, a critical analysis of medical and surgical interventions and the analysis of processes to improve health care [23, 24]. Although difficult to anticipate where the future of medical practice lies, a review of the predicted changes to health systems and medical practice points to increasingly complex and therapeutic interventions where areas such as interventional radiology, nano medicine, robotic surgery and personalised health all require a scientific literacy that mandates a basic understanding of physics and chemistry.

Basic sciences and access to undergraduate Medicine

Our review of 57 medical programmes in Ireland, the UK and Australia found that 35 (of which 26 were in the UK) offered 5-year programmes which, amongst other subjects, had a pre-requisite for school chemistry. It is evident, therefore, that majority of international medical programmes value chemistry and/or other school sciences as part of their entry criteria. Only 14 % of UK medical schools offered a traditional pre-medical year indicating that the depth of study in A-Level sciences obviates the need for the inclusion of those sciences in the medical programme. By comparison, 50 % of programmes in Ireland contain a pre-medical year of study. Alignment to this international rubric and removal of the basic science curricula in a medical programme mandates careful consideration of both the depth of study and the availability of science subjects in secondary schools. It would be possible to construct a more utilitarian curriculum with a truncated programme, but the evidence would suggest that this route would be most appropriate for those who study school science to a great depth. Our institution equally has a strategic objective to broaden the range of opportunities for students with diverse backgrounds to participate in our educational programmes [25]. Protecting the accessibility of our medical programme is imperative.

Conclusion

In the 100 years since the publication of the Flexner Report, there has been much debate regarding the role and value of basic sciences in medical education. It is clear from our research and global review of medical schools that basic sciences are valued but whether basic science teaching belongs in a secondary or tertiary curriculum is highly dependent on the secondary education qualification. Qualifications which require a student to study six or more subjects, such as Ireland's Leaving Certificate or Australia's ATAR offer a reduced depth of study in comparison to A-Levels where only three to four subjects are undertaken.

Reformation of undergraduate medical education must also acknowledge the changes in both the practice of medicine and the health care systems within which our physicians practice. Developments in medical practice are increasingly based on a foundation in physics and chemistry with nano biology, advanced therapeutics and radiographic imaging all exponentially expanding. There is little chance that a curriculum devoid of these fundamentals will be capable of nurturing graduates with enough scientific agility to lead the development of the diagnostic and therapeutic tools of the future.

Conflict of interest None.

Ethical standard The Human Research Ethics Committee at University College Dublin confirmed that this study was exempt from full ethical review.

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