The Analysis of Teaching of Medical Schools (AToMS) survey: an analysis of 47,258 timetabled teaching events in 25 UK medical schools relating to timing, duration, teaching formats, teaching content, and problem-based learning

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Abstract

**Background:** What subjects UK medical schools teach, what ways they teach subjects, and how much they teach those subjects is unclear. Whether teaching differences matter is a separate, important question. This study provides a detailed picture of timetabled undergraduate teaching activity at 25 UK medical schools, particularly in relation to problem-based learning (PBL).

**Method:** The Analysis of Teaching of Medical Schools (AToMS) survey used detailed timetables provided by 25 schools with standard 5-year courses. Timetabled teaching events were coded in terms of course year, duration, teaching format, and teaching content. Ten schools used PBL. Teaching times from timetables were validated against two other studies that had assessed GP teaching and lecture, seminar, and tutorial times.

**Results:** A total of 47,258 timetabled teaching events in the academic year 2014/2015 were analysed, including SSCs (student-selected components) and elective studies. A typical UK medical student receives 3960 timetabled hours of teaching during their 5-year course. There was a clear difference between the initial 2 years which mostly contained basic medical science content and the later 3 years which mostly consisted of clinical teaching, although some clinical teaching occurs in the first 2 years. Medical schools differed in duration, format, and content of teaching. Two main factors underlay most of the variation between schools, Traditional vs PBL teaching and Structured vs Unstructured teaching. A curriculum map comparing medical schools was constructed using those factors. PBL schools differed on a number of measures, having more PBL teaching time, fewer lectures, more GP teaching, less surgery, less formal teaching of basic science, and more sessions with unspecified content.

**Discussion:** UK medical schools differ in both format and content of teaching. PBL and non-PBL schools clearly differ, albeit with substantial variation within groups, and overlap in the middle. The important question of whether differences in teaching matter in terms of outcomes is analysed in a companion study (MedDifs) which examines how teaching differences relate to university infrastructure, entry requirements, student perceptions, and outcomes in Foundation Programme and postgraduate training.

**Keywords:** Medical school differences, Teaching styles, Problem-based learning, Timetables, Lectures, Tutorials, Clinical teaching, Self-regulated learning
Background

Medical schools teach. That much is obvious. But what subjects they teach, what ways they teach subjects, and how much they teach each subject in those different ways is very unclear. Harder still is to know whether medical school differences in teaching actually matter. Does greater or lesser duration of teaching, in different formats, and of different contents, produce doctors who perform and practise differently? In this paper, we report the findings of the AToMs study which provides empirical answers to the questions of what teaching actually occurs in UK medical schools and how schools differ in their teaching. In a companion paper reporting the MedDifs study [1], we describe how differences in teaching format and content relate to a range of different outcome measures. These measures include performance and perceptions during the medical course and afterwards in clinical practice, and how they relate to input measures such as curricular differences, selection processes, and institutional histories.

Recent discourse in medical education, driven particularly by shortages of general practitioners (GPs) and psychiatrists, assumes that differences in teaching result in differences in outcomes. Professor Ian Cumming, the chief executive of Health Education England (HEE), put it straightforwardly when in July 2017 he was quoted as saying:

‘It’s not rocket science. If the curriculum is steeped in teaching of mental health and general practice you get a much higher percentage of graduates who work in that area in future.’ [2]

The UK Royal College of Psychiatrists similarly suggested in October 2017 that:

‘medical schools must do more to put mental health at the heart of the curriculum ... and [thereby] encourage more medical students to consider specialising in psychiatry’ [3], although the President of the College of Psychiatrists did acknowledge that:

‘the data we currently have to show how well a medical school is performing in terms of producing psychiatrists is limited’ [3]

At the heart of that limitation is a lack of detailed quantitative evidence on differences in medical school teaching, and only with such data will a proper analysis be possible of the effects of medical school differences in teaching. The central aim of this study is to provide such evidence.
institutions and courses, are asked to provide detailed information on total contact hours for specific formats of teaching.

The few previous studies have taken as units of analysis either module descriptions and examination papers (as for economics, with a content analysis used on the texts), or individual students and their integrated perceptions (as in the HEPI analyses of contact hours). A different approach uses curriculum maps based primarily on learning objectives, as with the maps produced by the University of Manchester [9], which are not, to our knowledge, available for comparison with other UK medical schools. This study takes a different approach, using medical school timetables as the primary sampling frame, with the basic unit of analysis being timetabled teaching events, defined as the minimal timed units on a timetable.

The historical context of medical school teaching and the rise of problem-based learning

Historically, medical curricula in the UK were remarkably constant in their form from the nineteenth century onwards, and then, as Leinster has put it, despite, ‘medical education [being] a very conservative part of a conservative profession, [ ... ] in the early 1990s change swept through UK medical schools [as] medical school curricula, which had been relatively homogenous, became diverse in terms of teaching methods and contents ... ’ [15][p. 1].

Change was driven by several forces. The GMC had tried unsuccessfully to alter teaching in the Recommendations it published in 1947, 1957, and 1980 [16]. That changed with the GMC’s Tomorrow’s Doctors [17] of 1993 which gave official support to innovation, with proposals that factual overload in traditional curricula should be reduced by a slimmed down core curriculum, supplemented by special study modules (now student-selected components (SSCs)), comprising perhaps one third of teaching, for developing intellectual skills, curiosity, and critical thinking. The major educational innovation for the new and revised courses was mostly the use of problem-based learning (PBL) courses, a method developed half a century ago, at McMaster, Maastricht, and Harvard [18–20]. As with many educational approaches, PBL is not a rigid and fixed approach to a curriculum, but instead, there is ‘great variability’ [21, 22], with many species and subspecies [23]. A recent review suggested that PBL should be regarded as a toolbox of techniques, including, for instance, case-based learning [21]. The newer medical curricula contain a range of different approaches, including ‘end [ing] ... the division between pre-clinical and clinical years, ... earlier contact with patients and greater interactions with teachers’ [24] (p. 19), to which can also be added a greater emphasis on general practice and community involvement. The role of basic sciences in PBL is still controversial, one set of critics saying that, ‘Some medical schools have now largely abandoned formal teaching of basic medical sciences’ [25], to which a reply was that, ‘PBL is not about sacrificing the basic sciences’ [26]. Even proponents of PBL do though recognise some potential disadvantages,

‘PBL sessions may not be structured for optimal decision making as they ask learners to construct meaning independently from data without providing guidance on optimal direction, credible references, nor guides to decision making. As such the PBL learning process is inherently exploratory and therefore inefficient. These inefficiencies highlight the downstream consequences of PBL ... ’ [21](p. 138).

The literature on PBL is voluminous despite a range of reviews and meta-analyses [27–31]. However, these are not definitive on PBL’s strengths and weaknesses. As Neville said in 2009,

‘Problem-based learning (PBL) has swept the world of medical education since its introduction 40 years ago ... [albeit] ... leaving a trail of unanswered or partially answered questions about its benefits’ [32] (p. 1, our emphasis).

Recurrent suggestions are that PBL students ‘find the [ir] learning environment more stimulating and humane’ [33] [p. 564] and that after graduation, there are effects on ‘physician competencies ... in the social and cognitive dimensions ... [but not] in technical and teaching dimensions’ [31] [p. 40]. Much of the problem arises because many studies have considered students in only one or a few schools. Studies of the consequences of PBL have also taken little account of the possible differences between the characteristics of schools which have chosen to introduce PBL, or the students who have themselves chosen to study in PBL schools, either in terms of academic qualifications [34] or in personality or other measures [35].

The present study

The present study uses medical school timetables to define an hour-by-hour analysis of the teaching that takes place in medical schools, allowing a detailed description of differences in UK medical school teaching, particularly considering the role of problem-based learning (PBL). The study can therefore be seen as an exercise in ‘mining the data of the multifaceted curriculum’ [36], to
produce standardised ‘curriculum maps’ [37] for a majority of UK medical schools which are directly comparable between schools. Armed with measures derived from these curriculum maps, we can produce an empirical taxonomy of differences between medical schools in their teaching. The *MedDifs* companion paper [1] then goes on to analyse how differences in content and format of teaching relate to differences in medical school outcomes, including performance in postgraduate examinations, and whether doctors choose to enter general practice or psychiatry.

All courses inevitably have a timetable, so that students know what they should be doing, where and when, and together those timetables summarise student contact hours and the content of those hours, as well as the teaching formats used. The present study used the UK *Freedom of Information Act* 2000 (FoI) to obtain sets of timetables from medical schools. However, timetables themselves are not always readily interpretable to outsiders, requiring local information from those within the medical schools to unpack them properly. The lead researchers therefore recruited students from different years in the various medical schools to classify and code each of the individual timetabled events within medical schools, using the timetables as a basis. The research would not have been possible without this extensive involvement of the local collaborators who were integral to the success of the study, making it appropriate that they are named here as co-authors on this paper, speaking for and validating specific data from their own medical school. We also note that such widespread authorship is now commonplace in the biomedical sciences [40]. A similar exercise in ‘citizen science’ has previously been carried out elsewhere within medicine in the *STARsurg* studies [41, 42].

The present study has the advantage of being able to compare the details of teaching within the single national system of the UK, of which ten schools out of the 25 studied here can broadly be labelled as PBL in approach. The companion study, *MedDifs*, also compares PBL and non-PBL schools in relation to measures of self-directed learning and self-regulated learning

For this study, we consider time for self-directed learning to be that specified (‘directed’) as such in medical school timetables and which has a clear duration; it will later be seen that it is present in all but one medical school. Self-regulated learning, in contrast, is ‘regulated’ by students themselves and can only be quantified by self-report as in two studies [39, 43]. We acknowledge that neither self-directed nor self-regulated are entirely satisfactory terms.

**Names of medical schools**

Research papers often use inconsistent names and abbreviations for medical schools. Here, we have names based on those used by the UK Medical Schools Council (MSC) [44]. More details of all schools can be found in the [World Directory of Medical Schools](https://directory.wmrc.ac.za/).
Medical schools

In 2014–2015, there were 33 medical schools in the UK. Our analysis of teaching considers only schools which have 5-year (standard entry) courses for undergraduates, and therefore, Warwick and Swansea medical schools which are graduate entry only are not included. Where schools have both 5-year and graduate entry or other courses, we only consider the 5-year course. Standard entry courses were provided by 31 schools, of which data were available for 25 schools (Aberdeen, Barts, Birmingham, Brighton and Sussex, Cambridge, Cardiff, Dundee, Edinburgh, Glasgow, Hull York, Imperial, Keele, King’s, Leeds, Leicester, Liverpool, Manchester, Newcastle, Norwich, Nottingham, Oxford, Queen’s, Sheffield, St George’s, and UCL). Six schools were omitted from the study: Exeter and Plymouth as they were reorganising after Peninsula Medical School was split, St Andrews as it does not have a clinical course, Lancaster as it has only recently produced graduates, and Bristol and Southampton for logistical reasons.

Problem-based learning schools

A useful distinction is between schools that are or are not regarded as PBL. There is no hard classification, and for convenience, we use the classification provided on the BMA website for the eleven UK schools described as either PBL or CBL. (case-based learning)2, i.e. Barts, Cardiff, Exeter, Glasgow, Hull York, Keele, Liverpool, Manchester, Norwich, Plymouth, and Sheffield [47], with the addition of St George’s whose students and website described the school as PBL. Ten of these PBL schools are in the 25 schools studied here.

Medical school year numbering

Medical school year numbering is not always consistent, some medical schools having compulsory intercalated/integrated BSc or other degrees. For present purposes, intercalated years were omitted, and other years labelled as years 1 to 5. Many schools refer to years 1 and 2 as basic medical sciences (BMS) and years 3, 4, and 5 as clinical (Clin). It is recognised that this is not always an accurate description of course content for some medical schools which have more integrated courses. We therefore simply refer to years 1, 2, 3, 4, and 5.

2PBL and CBL are similar but conceptually distinct with an important distinction between them: problem-based learning uses an ‘open enquiry’-based learning method whilst CBL uses a guided enquiry-based learning method [46]. Too few schools in the UK used CBL to make it possible to compare it with PBL and non-PBL, and therefore, it has been included within the PBL group.

Other datasets

We have used three external datasets to validate aspects of the current data or to contribute to the analyses. In particular, we are grateful for having been given access to the following: the HEPI datasets which annually ask a representative set of students at UK universities to complete a questionnaire about their teaching, data from a study which asked UK medical students about self-regulated teaching time [39], and a study of teaching of general practice which collected data from heads of Departments of General Practice in UK medical schools [48].

The level of analysis

It must be emphasised that throughout this study, all measures are at the level of medical schools and are not based on raw data at the student level. It is likely that students vary in the extent to which they attend provided teaching, and we have no direct data on that.

Statistical analysis

The majority of conventional descriptive and inferential statistics were calculated using IBM SPSS v24. Factor analysis was used to explore the inter-relations of the various measures and to reduce them to a smaller set of more informative measures. R v3.4.2 [49] was used to carry out the factor analysis, in particular using Velicer’s parallel analysis in the fa.parallel() function in the psych package for deciding on the number of factors, and calculation of normal (van der Waerden) scores with score() in the jmOutlier package to convert non-normal distributions to normal scores. Some plotting used ggplot2() in R.

Ethical permission

None of the data in this study are personal data, the data only relating to administrative data on medical school timetables, and therefore, ethical permission was not required.

Results

A total of 47,258 timetabled events were recorded at 25 different UK medical schools for the 2014–2015 academic year, with a mean of 1890 events per school (SD = 342, range = 1302 to 2616). Overall, the numbers of events classified for each year were 8996 (year 1, 19.0%), 8402 (year 2, 17.8%), 11,253 (year 3, 23.8%), 10,176 (year 4, 21.5%), and 8381 (year 5, 17.7%). Elective and SSC (student-selected component) hours were not classified by year.

Teaching format and duration

Teaching events differ in their format and are broadly classified as formal teaching (n = 43,317), timetabled self-directed learning (n = 3341), student-selected components (SSCs; n = 25), electives (n = 25), and unspecified (n =
SSCs and electives were recorded as a single teaching event per school, so that the mean length is long (SSCs—408 h, SD = 202 h, range = 70 to 735 h; electives—259 h, SD = 42 h, range = 175 to 350 h). Excluding SSCs and electives, timetabled teaching events had a mean duration of 2 h 6 min, a median duration of 1 h 30 min, and a modal duration of 1 h 0 min, with a standard deviation of 1 h 23 min and 95% range of 30 min to 4 h 30 min, skewed to the right (skewness = 1.51) with a minimum of 5 min and a maximum of 25 h 15 min which was a clinic session in the Emergency Department.

### Start and end times

Timetabled events typically have a modal length of 1 h and start during normal working hours (mean = 11:33, median = 11:10, mode = 09:00, with a 95% range from 08:30 to 16:00; there are visible modes at 09:00 and 13:00–14:00). However, as Fig. 1a–c shows, a small proportion of events occur outside of normal working hours. The scattergram of end time in relation to start time shows that some teaching occurs during the evening, night, and early morning, and can be of long duration, as would be expected with clinical teaching.

### Durations of timetabled teaching events

Although the basic unit of analysis is the timetabled teaching event, some events are much longer than others. A simple count of number of events does not take event length into account, therefore making results difficult to interpret. To express the data in a clearer way, we have therefore weighted teaching event data by the length of the event. In Figs. 2 and 3, the times have also been divided by 25, the number of medical schools in the study, and the tables can therefore be read directly as the total number of timetabled teaching hours experienced by a typical medical student at a typical medical school for each teaching format or content, either within a year or within the entire course. Teaching times in year 1 and year 2 average 518.9 h, which for a notional teaching year of 30 weeks is 17.3 h/week, whereas the mean time for years 3, 4, and 5 is 974.7 h, which for a typical year of 48 weeks is 20.3 h/week. The overall total teaching time is 3962 h, which excludes SSCs and electives, which had estimated mean total times of 408 and 259 h, so that the total of all teaching time for an average medical student is 3962 + 408 + 259 = 4629 h.

### Teaching formats

Timetabled events were classified into twenty different teaching formats. Figure 2 shows the number of hours of each format of teaching experienced by a typical medical student for each of the five course years, sorted by the mean year of the course in which the format is used. There is a cluster of teaching formats used mainly in the first 2 years, typical of BMS teaching, and then a second cluster of teaching formats in years 3, 4, and 5, mainly consisting of clinical teaching methods. Lectures predominate across the course as a whole with a mean of 714 h, 18% of all teaching. Timetabled self-directed study has 351 h and occurs in all years, but particularly years 1 and 2. Within years 3, 4, and 5, unsupervised ward sessions account for 572 h, followed by supervised ward sessions—other (373 h), GP sessions (272 h), and clinic sessions (271 h).

### Teaching content

Classifying teaching content was difficult, not least because some medical schools teach more integrated courses than others, and also the same topic can often be named in different and overlapping ways (e.g. biochemistry or molecular biology). Overall, there were over 70 specific terms used, with some restricted to one or two medical schools. After several exploratory attempts, the different terms for teaching content were agglomerated into 18 conceptually distinct categories, which are shown in Fig. 3. The figure is sorted by the mean year in which teaching typically occurs. A broad separation occurs between teaching content typically taught within years 1 and 2 and teaching content taught more within years 3, 4, and 5. Within years 1 and 2, pathological sciences (171 h), neurosciences/behavioural sciences/physiology (163 h), anatomy/histology (118 h), and pharmacology/clinical pharmacology (55 h) are the classic ‘pre-clinical’ or basic medical sciences. Other topics typically taught in years 1 and 2 include reflection (31 h), ethics and law (41 h), and epidemiology (44 h). Years 3, 4, and 5 are dominated broadly by clinical topics, by internal medicine (696 h), followed by surgery (401 h) and general practice (342 h). Psychiatry (178 h), paediatrics (190 h), obstetrics and gynaecology (203 h), and oncology/palliative care (54 h) are characterised by occurring mainly in year 4, while anaesthetics/perioperative care/critical/emergency care (202 h) is the only topic occurring mainly in year 5. Some ‘clinical’ topics do occur in years 1 and 2, notably internal medicine (30 h in year 1) and general practice (16 h in year 1). Administrative/pastoral/organisation/practical topics (137 h) occur across the entire course. Finally, the inevitable arbitrariness and difficulty of any classification is shown by the 887 h, 22% of all teaching, for which coders were unable to make specific attributions to any one dominant content area. As will be shown later, these hours are much more likely to occur in PBL courses, and in part reflect the nature and flexibility of PBL teaching itself.
Differences between medical schools

Figures 2 and 3 have given an overall view of the pattern of teaching in UK medical schools for a typical student, but a primary interest of the survey is in differences between medical schools. Figure 4 summarises the total hours of teaching in each school, broken down by year, with a range of 3593 to 6213 h for formal teaching, excluding SSCs and electives which are shown separately. For details of estimates of self-regulated learning, see the end of the “Results” section.

Fig. 1 Start and end times of teaching events: a start time on logarithmic scale (red) (inset: start time on linear scale (green)), b duration in hours (grey), and c start and end time (blue). In c, note that some events start on 1 day and finish on the next.

Differences in the details of teaching at each school are summarised in Fig. 5, with PBL and non-PBL courses separated. Teaching format and teaching content are shown together, as often these might be expected to be interlinked (e.g. anatomy/dissection in teaching format with anatomy-histology in teaching content). The data for Fig. 6 are available as a spreadsheet in Supplementary File 1.

Figure 5 is complicated, but emphasises the variation in how different medical schools organise and describe...
their teaching, and that itself belies any simplistic, unitary description of ‘UK Medical Education’. In navigating through Fig. 5, some comments may be helpful:

1. **PBL schools.** Medical schools can be broadly divided into those which do or do not principally use PBL, and ten schools were classified as PBL schools (see the “Method” section). The PBL schools are shown to the right in Fig. 5 with a blue, italic font. Figure 6 compares the numbers of hours for each of the teaching formats and contents of the PBL and non-PBL schools. Some measures have wide variation, and differences in variance are taken into account in the \(t\) tests. Fifteen of 45 differences (33%) are significant with \(p < 0.05\), and four are significant with a Bonferroni-corrected significance of \(0.05/45 = 0.0011\). PBL schools have more hours of PBL teaching, early clinical experience, sessions in general practice, GP teaching, and unspecified content. PBL schools also had fewer hours in lectures, biochem-molecular biology, anat-histology, neuro-behav-physiology, pathology etc., oncology-palliative care, and surgery. The five main BMS subjects (biochemistry etc., anatomy etc., neuroscience etc., pathology etc., and pharmacology etc.) accounted for fewer hours overall in PBL schools, but there were no differences in total teaching in the eight clinical topics.

2. **Measures with greater variability.** Occasional rows in Fig. 5 have a large variability, a good example being laboratory practicals for Nottingham, which
with a value of 482 is much larger than most other medical schools. Variability was assessed systematically as the percentage coefficient of variation (CV) across medical schools, calculated as $100 \times (SD \text{ scores})/(\text{mean of scores})$. The mean (median) CV across all measures is 73% (58%). CVs are shown in Fig. 5, with red shading indicating CVs greater than 80%. Overall, there is much more variation across medical schools in formats of teaching rather than content of teaching, although a major exception is ‘reflection,’ which receives 436 h at Liverpool, but the second highest value anywhere else is 65 h, at Nottingham, the CV being 274%. Amongst formats of teaching, laboratory practicals showed the most variability (166%), followed by self-directed study (123%) and supervised ward session—other (121%). Noteworthy is that total teaching times showed least variability (17% and 14%) suggesting that variation between schools was because schools mostly chose to allocate time differently, not because they had different overall teaching times.

3. **Factor structure of medical school teaching.** The complexities of Fig. 5 have been reduced by using a principal component analysis of the 42 measures (the totals having been excluded since they are redundant). The correlation matrix is necessarily singular, there being 42 measures but only 25 schools, but a principal component analysis can still be carried out. A concern is that a number of the measures in Fig. 5 are skewed, and therefore, all measures were converted to normal (van der Waerden) scores. Velicer’s parallel analysis suggested there were three significant factors, but reification of all the factors was not straightforward, and therefore, for simplicity, only the first two factors were extracted, without rotation, which accounted for 31% of the total variance. Factor scores for the individual schools were extracted using the regression method. Factor 1 is labelled

| Year1 | Year2 | Year3 | Year4 | Year5 | Total | Percent | Mean |
|-------|-------|-------|-------|-------|-------|---------|------|
| Biochem-MolBiol | 37.8 | 8.8 | 1.7 | 0.7 | 0.2 | 49.2 | 1.2% | 1.3 |
| Anat-Histology | 61.4 | 45.7 | 9.3 | 0.9 | 0.8 | 118.1 | 3.0% | 1.6 |
| Neuro-Behav-Physiology | 80.7 | 62.5 | 11.4 | 7.1 | 1.0 | 162.7 | 4.1% | 1.7 |
| Ethics&Law | 18.5 | 8.6 | 7.3 | 4.0 | 2.8 | 41.2 | 1.0% | 2.1 |
| Reflection | 5.5 | 19.7 | 3.6 | 1.1 | 1.3 | 31.2 | 0.8% | 2.1 |
| Path-Immun-Hist-Haem-Biochem-Microb | 47.1 | 60.5 | 42.4 | 15.5 | 6.4 | 171.9 | 4.3% | 2.3 |
| Epidemiology | 17.2 | 10.6 | 6.0 | 7.7 | 2.6 | 44.1 | 1.1% | 2.3 |
| Pharm-ClinPharm | 11.9 | 19.5 | 13.1 | 3.9 | 6.5 | 55.0 | 1.4% | 2.5 |
| Admin-Pastoral-Organisational-Practical | 35.3 | 19.9 | 31.9 | 15.7 | 34.4 | 137.1 | 3.5% | 3.0 |
| Internal Medicine | 29.8 | 50.7 | 252.2 | 212.5 | 151.3 | 696.5 | 17.6% | 3.6 |
| Psychiatry | 1.3 | 3.7 | 40.1 | 113.9 | 19.3 | 178.3 | 4.5% | 3.8 |
| Oncol-Palliative | 0.8 | 2.3 | 8.3 | 33.9 | 8.6 | 53.9 | 1.4% | 3.9 |
| Surgery | 2.4 | 5.8 | 125.2 | 144.1 | 123.4 | 400.9 | 10.1% | 3.9 |
| GP | 15.5 | 19.1 | 66.4 | 96.7 | 140.6 | 338.2 | 8.5% | 4.0 |
| Paediatrics | 0.7 | 2.2 | 25.3 | 129.5 | 31.8 | 189.5 | 4.8% | 4.0 |
| O&G | 0.6 | 2.7 | 22.2 | 145.5 | 31.7 | 202.7 | 5.1% | 4.0 |
| Anaes-Periop-CritCare | 4.0 | 2.2 | 32.0 | 45.8 | 117.9 | 202.0 | 5.1% | 4.3 |
| Other: not coded | 162.3 | 160.3 | 216.6 | 107.73 | 240.4 | 887.31 | 22.4% | 3.1 |
| **Total** | **532.8** | **504.9** | **915.0** | **1086.2** | **920.8** | **3959.7** | **100.0%** | **3.3** |
Traditional vs PBL teaching, and factor 2 is labelled Structured vs Unstructured teaching. Figure 7a shows the loadings of the teaching format and teaching content measures on the first two factors. The first factor, Traditional vs PBL teaching, has loadings to the left-hand side on PBL teaching time, as well as GP sessions, and loadings to the right-hand side on lectures, biochemistry etc., neuroscience etc., anatomy-histology, surgery, and internal medicine. This factor is clearly distinguishing PBL courses from traditional courses. That is strongly supported by Fig. 7b which shows the factor scores for each medical school on the two dimensions, with PBL and non-PBL courses plotted separately. The ten PBL schools in blue are distinct as a group from the non-PBL courses (in black), although there is an area of overlap in the middle.

The major predictor of Traditional vs PBL teaching is hours of PBL teaching, and Fig. 8 shows the close relationship. Nevertheless, in both Figs. 7a and 8, it is clear that within both PBL schools and non-PBL schools, there is variation on PBL hours and Traditional vs PBL teaching scores, suggesting a continuum of the extent to which schools use a PBL approach. In Fig. 7b, it is apparent that Edinburgh is clustering with PBL schools, albeit at the lower of PBL hours, and we note that its current website does refer to its PBL teaching [50], showing the inevitable arbitrariness of any hard classification. The second factor in Fig. 7a, b, Structured vs Unstructured teaching, is clearly separate from Traditional vs PBL teaching, and it is noteworthy in Fig. 7b that Structured vs Unstructured teaching is independent of being a PBL course, there being clear variation within both PBL and non-PBL courses. Structured vs Unstructured teaching is mostly but not entirely associated with teaching formats, the formats at the top of Structured vs
Unstructured teaching in Fig. 7a including tutorials, anatomy dissection, theatre sessions, laboratory practicals, simulation, bedside teaching, observation of procedures, and clinic sessions, whereas loadings at the bottom of the figure are mainly associated with GP sessions, unsupervised ward sessions, ethics and law, small groups, reflection, and self-directed study. This factor probably relates to the extent to which teaching is organised or self-directed (although lectures do not fit well in that classification).

Content areas also vary on the Structured vs Unstructured teaching factor, with anatomy being highly structured and ethics and law highly unstructured.

Validation of estimated teaching hours against external data

The data in Figs. 2, 3, and 5 show the estimated hours of various teaching formats in different medical schools based on teaching events derived from timetables. Despite their seeming face validity, it is important to validate the measures against other data on differences in medical school teaching. Unfortunately, such data are rare, but here, we describe validation against two other estimates of teaching time.

1. The HEPI Student Academic Experience Surveys. Although differences have been shown in teaching hours across different schools, that does not...
necessarily mean that students themselves perceive those differences. A useful comparison therefore is with the estimates of perceived contact hours in the HEPI Student Academic Experience Surveys. Medical students in the HEPI surveys were asked about timetabled sessions per week, both overall, and also in teaching groups of size 0–5, 6–15, 16–50, 51–100, and 100+ other students. Figure 9 shows correlations between the HEPI estimates and those for lectures, seminars, small groups, and total teaching hours for the medical schools in the current survey, with larger positive correlations in

|                           | non-PBL (n=15) | PBL (n=10) | t-test* |
|---------------------------|----------------|------------|---------|
|                           | Mean       | SD        | Median  | Mean       | SD        | Median  | P       |
| Anatomy/Dissection        | 74.4       | 27.7      | 70      | 81.7       | 23.0      | 80      | 0.483   |
| Early Clinical Experience | 39.8       | 24.3      | 38      | 98.8       | 71.5      | 92      | 0.035   |
| Laboratory Practical      | 70.8       | 124.3     | 27      | 46.2       | 54.5      | 34      | 0.506   |
| PBL                       | 30.5       | 41.5      | 13      | 190.0      | 78.9      | 160     | <0.001  |
| Self-directed study       | 282.0      | 323.9     | 156     | 454.6      | 563.5     | 228     | 0.396   |
| Lecture                   | 820.3      | 104.6     | 789     | 554.0      | 230.1     | 572     | 0.005   |
| Small Group               | 138.5      | 156.5     | 100     | 101.2      | 87.8      | 82      | 0.455   |
| Communication skills      | 42.7       | 32.0      | 39      | 52.1       | 22.4      | 41      | 0.393   |
| Practical skills          | 87.1       | 25.7      | 83      | 92.7       | 34.5      | 104     | 0.668   |
| Seminar                   | 153.4      | 90.5      | 123     | 131.5      | 219.9     | 59      | 0.771   |
| Tutorial                  | 230.3      | 121.4     | 227     | 177.8      | 118.7     | 181     | 0.296   |
| Supervised ward session - bedside teaching | 71.8 | 56.8 | 61 | 82.6 | 69.5 | 60 | 0.686 |
| Procedures (observation e.g. endoscopy list) | 38.2 | 36.4 | 31 | 27.7 | 29.1 | 26 | 0.436 |
| Clinic session            | 294.2      | 163.1     | 293     | 235.3      | 145.7     | 242     | 0.356   |
| Simulation                | 20.1       | 19.2      | 15      | 8.4        | 10.3      | 5      | 0.081   |
| Supervised ward session - ward round | 213.6  | 195.6  | 123 | 142.8 | 146.8 | 83 | 0.313 |
| Theatre session           | 131.6      | 76.4      | 127     | 117.2      | 81.5      | 90      | 0.760   |
| Supervised ward session - other | 384.4  | 482.1  | 284 | 357.1 | 429.8 | 185 | 0.883 |
| GP sessions               | 212.6      | 116.8     | 206     | 362.2      | 163.3     | 334     | 0.024   |
| Unsupervised ward session | 508.4      | 684.3     | 333     | 667.5      | 545.1     | 525     | 0.526   |
| SSCs                      | 351.7      | 181.7     | 335     | 482.0      | 217.5     | 530     | 0.157   |
| Elective                  | 266.0      | 42.1      | 280     | 248.4      | 42.0      | 264     | 0.316   |
| Unspecified Type          | 53.7       | 86.2      | 24      | 77.1       | 223.2     | 2      | 0.758   |
| Total including SSCs and Elective | 4522.8 | 576.6 | 4603 | 4788.1 | 717.1 | 4861 | 0.342 |

Biochem-Mollibol 65.2 28.6 55 25.2 12.3 24 <.001
Anat-Histology 137.2 31.7 140 89.5 35.1 96 0.03
Neuro-Behev-Physiology 195.7 50.7 200 113.2 43.9 113 <.001
Ethics&Law 48.0 46.6 33 30.4 12.0 26 0.18
Reflection 16.3 16.2 14 53.6 135.0 4 0.406
Path-Immum-Hist-Haem-Biochem-Microb 203.0 79.5 191 124.1 82.0 102 0.038
Epidemiology 41.4 22.1 41 48.2 26.1 37 0.505
Pharm-ClinPharm 63.6 28.3 68 42.0 11.5 43 0.019
Admin-Pastoral-Organisational-Practical 145.9 100.0 127 123.6 56.1 112 0.484
Internal Medicine 762.6 233.1 703 596.3 280.9 665 0.135
Psychiatry 191.2 82.9 185 157.5 67.0 171 0.263
Oncol-Palliative 66.5 31.5 72 34.9 31.7 28 0.024
Surgery 458.8 160.2 424 313.8 158.3 299 0.037
GP 278.9 104.0 254 437.5 181.1 447 0.026
Paediatrics 202.5 52.7 209 170.0 56.9 185 0.166
O&G 219.5 85.7 192 177.6 46.4 165 0.134
Anaes-Periop-CritCare 203.0 84.2 226 200.6 79.9 180 0.943
Unspecified content 598.4 392.3 563 1319.9 736.8 1102 0.014
BMS teaching** 664.2 118.4 673 394.0 117.6 401 <.001
Clinical teaching*** 2384.0 447.4 2397 2088.1 430.2 2127 0.113
Total Content (excluding SSCs and Elective) 3898.1 522.3 4002 4057.8 874.9 3972 0.612

* t-test corrects for different variances
** Anat-Histology + Neuro-Behev-Physiology + Path-Immum-Hist-Haem-Biochem-Microb + Pharm-ClinPharm + Admin-Pastoral-Organisational-Practical
*** Internal Medicine + Psychiatry + Oncol-Palliative + Surgery + GP + Paediatrics + O&G + Anaes-Periop-CritCare

Fig. 6 Teaching formats and contents at PBL and non-PBL schools. Average (SD; median) hours of teaching for the different teaching format and content areas for an average student at the ten PBL schools and the fifteen non-PBL schools. Differences significant on the t test (p < .05) are shown in colour, red indicating the group with the greater amount of teaching and green the lesser amount of teaching. t tests take account of differing variances, and significant results are shown in bold.
green and larger negative correlations in red. Although the total estimates in the two sets of data (HEPI_Q1A and total hours) show only a weak and negative correlation ($r = -0.202$), much clearer is that student estimates of time in large groups (100+) show a strong positive correlation with timetabled lecture times ($r = 0.622$), timetabled seminars correlate positively with time in groups of 16–50 students ($r = 0.561$), and timetabled small groups correlate positively with time in groups both of size 6–15 ($r = 0.317$) and 16–50 ($r = 0.352$). The overall HEPI estimate of ‘timetabled sessions’ is perhaps too broad a measure, confounding different formats of teaching making it hard for students to answer. However, the estimates for the HEPI groups of size 6–15, 16–50, and 100+ differentiate clearly between
**Fig. 8** Hours of PBL teaching for individual medical schools. Scores of PBL (blue) and non-PBL schools (black) on the first factor (PBL vs traditional) in relation to timetabled hours of PBL teaching (vertical). The fitted line is a Loess curve.

**Fig. 9** Validation of hours of teaching in the Teaching Survey with hours of teaching in the HEPI Student Academic Experience Survey. Pearson correlations based on 24 medical schools. *p < .05; **p < .001. Correlations greater than an arbitrary level of 0.3 shown in green and correlations less than an arbitrary level of −0.3 shown in red.
timetabled small groups, seminars, and lectures in the AToMS data. These data therefore provide mutually supporting evidence for the validity of both the AToMS timetabled teaching event data and the perceptions of teaching load by the HEPI student respondents.

2. Estimates of GP teaching time. A recent study of GP teaching by Alberti et al. [48] estimated time for what it called ‘authentic GP teaching’, defined as ‘teaching in a practice with patient contact, in contrast to non-clinical sessions such as group tutorials in the medical school’. Information was provided by the current heads of GP teaching at UK medical schools for students entering in 2007 and 2008 (for which no differences were described). Schools in the Alberti et al. paper were not named, but we are grateful to the authors for providing us with raw data on total GP teaching time and authentic GP teaching time. For our own data, we calculated an equivalent to the authentic teaching score by considering only teaching described as clinically based within GP. For the 25 schools in our study, total GP teaching correlated 0.692 ($p < 0.001, n = 25$) with the total teaching time estimates for the same schools in the Alberti et al. study, and estimates of authentic teaching in our study correlated 0.709 ($p < 0.001, n = 25$) with the estimates from the Alberti et al. study. Authentic teaching represented about 77% of all GP teaching in our data and about 82% in the Alberti et al. data. The total duration and the proportion of authentic teaching are similar in our study and that of Alberti et al. The data from the two studies are therefore reassuringly similar, despite being estimated in different ways.

Together, the HEPI and the Alberti et al. data provide a good validation of the teaching times estimated using our own methodology and provide reassurance of the other estimates of teaching time.

Estimating hours of self-regulated learning

The AToMS study only includes time for self-directed learning where it is explicitly directed in medical school timetables (which itself may be somewhat oxymoronic). Medical students are also, however, expected to study in their own time, which we distinguish from self-directed learning by calling it self-regulated learning, as it is regulated by students themselves. We know of two UK studies which have estimated self-regulated learning, the study of Lumley et al. [39] which had data from 20 UK medical schools and the HEPI study which included all UK medical schools. For the 20 medical schools with data in both studies, the correlation was 0.515 ($p = 0.020$; alpha reliability = 0.67). It should be noted that ‘time-logging’ data suggest that in general, student estimates of time spent on academic activities correlate well with actual time spent [51], suggesting that the data from the two studies are likely to be valid estimates of actual time. Data from the two studies were merged by converting mean time at each of the 29 medical schools to a $z$-score, averaging the $z$-scores if there were two estimates, converting the final values to $z$-scores, and then back-estimating actual hours based on the mean and SD in the Lumley et al. study, which had explicitly surveyed medical students. For the 25 schools in the current study, the estimated means of self-regulated learning by medical school varied from 5.7 to 18.2 h per week (mean = 11.2, SD = 3.02; $N = 25$ medical schools). On the basis of two pre-clinical years of 30 weeks, and three clinical years of 48 weeks, these times are multiplied by 204 and included in the stacked bar chart of Fig. 4 as red bars. It is worth noting that the average self-regulated learning across the course (11.2 × 204 = 2284 h) is equivalent to about 49% of the average formal timetabled teaching (4629 h, including SSCs and electives), as can be seen in Fig. 4, confirming that much student study and learning take place outside of formal teaching.

Discussion

The AToMS study provides what is perhaps the first comprehensive timetable-based analysis of variation in teaching formats and contents in the majority of UK medical schools, with possible predecessors in the 1975 and 1988 surveys of UK medical schools by the General Medical Council [52, 53], which though are discursive and more limited quantitatively. In contrast, our data are quantitatively rich and raise a number of issues which we consider in turn.

The role of the GMC

In 1957, the GMC, which had been created 99 years earlier,

‘abandoned the principle of recommending a prescribed minimal curriculum to the medical schools ... Instead it issued ‘Recommendations’ which were most permissive, reminded the schools that they were responsible for designing their own curricula, and exhorted them to experiment’ [54].

In the years that followed, how and what teaching was actually taking place in each medical school became far less clear, despite many undoubted changes in medical school curricula [55]. Liberalisation mainly followed on from Tomorrow's Doctors in 1993, but it is far from clear what the effects were. That problem mattered relatively little until the past decade when pressure from the NHS
and HEE forced questions to be asked about the effects of different formats of medical training, with answers in short supply. The research solution required data from medical schools, but historically, medical schools have been reluctant to publish data which might allow differences between them to be inferred, as notionally all are equivalent via GMC accreditation. However, indirect evidence has slowly emerged over the years suggesting that any idea of equivalence was incorrect [56–58]. The time has come, as the GMC itself realises [59], for proper comparative data from medical schools to be made available.

The GMC, in the context of a report on the extent to which medical students are prepared for foundation practice, has overviewed medical school differences quite generally [60]. It began by saying that:

‘Variation between medical schools in the interests, abilities and career progression of their graduates is inevitable and not in itself a cause for concern …’

Inevitably a statement such as that is followed by caveats, and the overall tenor of the report is that medical school differences do matter, or at least might matter. We consider the relationship between medical school teaching differences and a range of other measures such as the qualifications of entrants, the resources available, the perceptions of teaching, and the outcomes in foundation training and post-graduate examinations in the MedDifs study [1]. The purpose of the present study is to provide a conceptual map of medical school teaching and the differences that occur, with the impact of those differences considered later [1].

Obtaining information from medical schools

The majority of medical schools collaborated with our study, and we thank them very much for their assistance. We hope that the details described in the comparative data presented here will justify their time and effort in contributing to an unusual and important study. That a minority of medical schools refused to provide information on a topic as basic as the teaching that they provide was disappointing.

Limitations of the data available in the present study

Medical school curricula are complex, and different people may well describe the same events in different ways. We have attempted to describe the teaching formats and teaching content of timetables, and no doubt that could have been done differently. Despite standardisation of our coding definitions across our team of coders, precise distinctions between tutorials, seminars, and group work are not always possible, and different schools may use the same terms in different ways. Teaching on subjects such as ‘molecular biology’ or ‘paediatrics’ may be ostensibly of the same length but contain very different material. Indeed, different students at a single medical school will inevitably have different content in their teaching, particularly in clinical subjects, and of course, even if students attend the same teaching, it does not mean that they equally are interested by, attend to, or retain that content. There is no doubt our study could have been done differently and in much greater depth. We are nonetheless gratified that our two validation tests—with the HEPI data and with data on GP teaching in medical schools—find that our results are corroborated by other studies. We therefore believe that this study is a starting point for future studies which can look in further detail both at individual teaching contents, and the broader picture of medical school teaching, perhaps carried out on an official basis.

Total teaching time at UK medical schools and the European Directive

Although the primary interest of our study was not in total teaching time, our study nevertheless provides useful information. The Medical Act 1983 does not specify a specific duration for a medical course, but European Directive 93/16/EEC specified that 5500 h of ‘theoretical or practical instruction’ should take place ‘under the supervision of a university’ before the completion of undergraduate medical training. The Directive also specified a minimum of 6 years for the course, which resulted in what has been called a ‘legal fiction’ that the first foundation (pre-registration) year was a part of the course. The requirement of 6 years was subsequently removed by Directive 2013/55/EU.

Figure 4 shows the total volume of timetabled teaching events at each school, with a range of 3543 to 6205 h from the least to the greatest, giving a coefficient of variation of 14.4% (mean = 4569, SD = 657). It should be noted that intercalated/integrated BSc/BMedSci/BA degrees are not included in these totals, although such degrees are compulsory at Oxford, Cambridge, Imperial College, UCL, and Nottingham.

We are also aware that even when self-directed study is not timetabled in some medical schools, there is nevertheless an expectation of additional work which would come under the heading of self-regulated learning, and should be added to the total hours that can be regarded as education in a broader sense.

Self-regulated learning, in one study of UK medical students, averaged 10.6 h per week during term time...
referred to and discussed later during clinical studies in years 3, 4, and 5, as it had been previously, as in the GMC’s 1977 survey [52]. Early clinical experience, clinic, and GP sessions are now timetabled within the first 2 years, although they still form only a minor part of the early curriculum. The major thrust of clinical teaching is in clinics, wards, and theatres, with only relatively little dedicated learning of practical skills and little use of simulation. Student-selected components are present in all medical schools, although they are far from the one third of the medical course that Tomorrow’s Doctors had originally suggested.

Medical school differences and problem-based learning
Medical schools vary in the durations of different teaching formats and different teaching contents. That variation is clearly shown in the matrix of Fig. 5. Making sense of Fig. 5 is not easy, but Fig. 7a, b helps, with Fig. 7b being particularly useful as it maps the 25 UK medical schools; the closer the schools are together, the more similar their teaching approach. The first dimension is clearly related to PBL teaching, and the second seems to reflect variation in how structured or unstructured the medical courses are, although these two factors seem to correlate with many other features of the courses (see Fig. 7a).

PBL has been the most controversial and one of the most interesting changes in UK medical education [55]. Understanding this change and the implications remains difficult. Figure 6 shows that PBL schools differ from non-PBL schools on several measures of teaching time. Unsurprisingly, PBL schools have more PBL teaching. PBL schools also have more GP teaching and GP sessions, as well as more ‘unspecified content’. PBL schools have fewer lectures, less specific time on basic medical sciences, and less specified time on the teaching of surgery. Although PBL schools have less timetabled basic medical science teaching, it does not necessarily imply students are exposed to fewer hours of such teaching, as it may occur within specifically timetabled PBL sessions, or in the much larger duration of ‘unspecified content’ which characterises PBL schools. Answers to critical questions about ‘the detailed basic science content of PBL sciences’ [25, 26] will require a different form of data collection involving analysis of specific content within teaching. Figure 7b also demonstrates the uniqueness in the philosophy and approach of PBL schools, with the 10 PBL schools clustered to the left of the plot. It must be noted, though, that there is a clear continuum of PBL [21–23] and non-PBL schools, with variation within the PBL schools as well as variation within the non-PBL schools on the traditional-PBL dimension.
The key questions for PBL (and indeed for any variations in medical school teaching) concern professional outcomes during training and practice. Cavenagh, in comparing traditional and ‘new’ (i.e. mostly problem-based learning) curricula, put it forcefully:

“The big question ... is how successful has the new curriculum been [ ... ]. [O] ur first concern must be that doctors are clinically competent, practise evidence-based medicine and are safe practitioners. ... If this can be delivered within the context of a supportive educational and clinical environment, where medical students are nurtured in a way that feeds their own humanity and encourages their thirst for learning and knowledge, then with effective recruitment strategies a revised curriculum should achieve the aspirations outlined for Tomorrow’s Doctors’ [24](p. 21).

Assessing the extent to which those latter aims have been met is far from straightforward, not least because of the range of the outcome measures required. A ‘rigorous comparison’ [25] of PBL and non-PBL courses will require a wide range of outcome measures, and a start on that will be provided in the MedDifs study [1].

**Timetables and actual student behaviour**

This study is about timetables, and timetables should, of course, apply to all students in equal ways. Timetables though are an idealisation of an intended curriculum in the minds of those planning and running a medical school. Timetables are also for an idealised student, actual teaching provided varying due to particular placements at different hospitals or GP practices, etc. How timetables relate to what students actually do is a different matter. In a very rare study using detailed diaries of clinical students on rotations, Worley et al. [61] showed that although timetabled hours of lecture teaching were 3–4 h per week, actual student-recorded hours averaged 3 h 12 min a week, with a range from 1 h 11 min to 8 h 24 min. Other forms of teaching showed similar variation across students, with tutorials having a mean of 7 h 54 min with a range of 4 h 12 min to 14 h 7 min and individual study having a mean of 26 h 33 min and a range of 10 h 25 min to 49 h 23 min. Timetables can therefore only say so much about what students are actually doing, and mainly are describing what they should be doing. Nevertheless, if little actual time is timetabled for an activity, then it is probably a reasonable assumption that little is actually being done on that activity. A corollary is that only a small proportion of notional clinical teaching time on wards may actually be spent on teaching itself [62]. There is also the probability that much real teaching is informal, particularly between student and student, while in hospitals, but also while socialising outside of formal medical education, or anywhere where students chat about the cases they have seen and their interpretation. Such teaching and learning may well be mediated via the social networks that inevitably are developed during medical school [63]. The present study does show different approaches in different medical schools to what should be taught, reflecting the different educational philosophies and priorities of the schools. Further studies are needed to address the question of how students within medical schools differ in the actual teaching that they receive (and ‘time-logging’ may help [51]). A yet further problem is to assess what of that actual received teaching is influential and effective (rather than being perceived as boring, uninteresting, or irrelevant), and perhaps influences subsequent clinical practice or career choices.

**Clarification**

We have been asked to make clear, to avoid any possible doubt, that neither this nor the MedDifs paper is stating or implying that any of the schools detailed are providing a sub-standard education or are otherwise badly run.

**Conclusions**

UK medical schools differ in the format and the content of their teaching, which can be assessed from timetables. Inclusion of the data from Fig. 5 in the UK Medical Education Database (UKMED [64]) will allow other researchers to investigate medical school differences more deeply. Two main patterns underlie the differences, with schools varying in the extent to which they are traditional or PBL-oriented, and the extent to which teaching is structured or unstructured. PBL schools differ in a number of different ways from non-PBL schools, although there are also many broad similarities. The present approach provides a basis both for assessing how teaching changes within UK medical education and also for determining the extent to which teaching differences result in outcome differences later in medical careers.

**Supplementary information**

Supplementary information accompanies this paper at https://doi.org/10.1186/s12916-020-01571-4.

**Additional file 1: Supplementary file 1.** Data for Fig. 5 as Excel file.

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This study are available within the article (Fig. 5). Other raw data that support the findings of this study are available from the corresponding author on reasonable request.

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Authors' contributions
OPD and ACH originated the idea of the study and discussed it with ICM.

Ethics approval and consent to participate
None of the data in this study are personal data, but instead are based on aggregated data supporting the detailed analyses at each site. Statistical analyses were developed by ICM in discussion with OPD and ACH, and an early draft written by ICM was commented on by OPD, ACH, HLH, and TJ. All authors have seen the submitted manuscript, commented on it, and have approved it.

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Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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