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Why don't they know enough about anatomy? A narrative review

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Abstract

Background: Publications in a variety of journals have described the problem of medical students' decreasing anatomical knowledge. Interestingly, the number of people making this assertion is growing, despite a lack of empirical evidence that today's medical graduates actually know less about anatomy than medical students in the past. Nevertheless, many people are claiming that students' anatomical knowledge is impaired due to negative effects from several factors, including teaching by non-medically qualified teachers, diminished use of cadaver dissection as a teaching tool and neglect of vertical integration of anatomy teaching.

Aim: To find empirical evidence for the factors claimed to have an influence on anatomical knowledge of students.

Method: A literature search.

Results: There is a lack of sufficient quantity and quality of information within the existing literature to support any of the claims, but the gathered literature did reveal some fascinating insights which are discussed.

Conclusion: Anatomy education should be made as effective as possible, as nobody will deny that medical students cannot do without anatomical knowledge. Because of promising findings in the areas of teaching in context, vertical integration and assessment strategies, it is recommended that future research into anatomy education should focus on these factors.

Introduction

'For doctors, the human body is the focus of investigation and intervention on a daily basis' (Turney 2007, p. 104). Both anatomists and clinicians agree that accurate knowledge of anatomy and individual variations is vital to ensure safe and efficient clinical practice. It also underpins the development and retention of clinical knowledge and skills (Dangerfield et al. 2000; Fasel et al. 2005; Raftery 2006). It is therefore worrying that publications in diverse journals have highlighted the problem of decreased anatomical knowledge of today's medical students, which, in a worst case scenario, might lead to medical errors. Despite the absence of empirical evidence for the existence of this problem, it is persistently emphasised by authors who lay the blame for it on one or more of the following factors:

(1) *Anatomy is taught by non-medically qualified teachers*
Anatomy is increasingly taught by staff with non-medical backgrounds, who may lack insight into the reasons why a subject is taught or why it is relevant from a clinical perspective.

(2) *The absence of a core anatomy curriculum*
In order to fit the anatomy curriculum into the available time, in some cases, all aspects of anatomy were pruned, irrespective of vocational relevance. This included deleting specific body regions, embryology and/or histology from the educational programme.

Practice points

- In some institutions, the number of students per anatomy teacher has more than doubled whereas the mean total teaching time for anatomy has reduced by more than 50%.
- Future research should concentrate on what and how students learn from dissection and other teaching tools before drawing conclusions in favour of the either method.
- Teaching anatomy in context may not only increase anatomical knowledge but also improve its application in problem solving.
- The sole use of multiple choice questions and/or the lack of a minimal requirement for each tested discipline have a negative effect on students' study behaviour and retention of knowledge.
- Further research on vertical integration of anatomy education is strongly recommended because it may help solve several issues by, among others, promoting repetition and increasing opportunities for teaching in context.

(3) *Decreased use of dissection as a teaching tool*
Anatomy teaching by the time-honoured method of cadaveric dissection is decreasing, mostly due to time and/or money constraints.

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(4) *Anatomy is not taught in context*
Anatomy should be taught within relevant contexts, such as clinical skills, pathology or radiology.

(5) *Integrated curricula (problem-based learning or systems-based curricula)*
In integrated curricula, basic and clinical sciences are taught simultaneously (horizontal integration), with clinical sciences being introduced in the early years while continued attention is being paid to basic sciences in the later years of the curriculum (vertical integration). Additionally, many medical schools with integrated curricula have abandoned formal basic science teaching and instead stimulate students to explore these areas through 'self-directed learning', supervised by (non-medical) facilitators. Within these curricula, anatomy is likely to be taught piecemeal, and it is claimed that students no longer gain a coherent, overall picture of the anatomy of the whole body.

(6) *The way anatomical knowledge is assessed*
For practical reasons, anatomical knowledge is increasingly assessed by multiple choice type questions, wherein good 'power-test takers' often do well through their ingenuity in eliminating distracter items (Cahill & Leonard 1999). What is also considered alarming is elimination of the requirement of minimal competence in each of the disciplines tested.

(7) *Decrease in anatomy teaching time*
The multitude of subjects and competencies to be taught in the undergraduate medical curriculum has diminished the amount of time available for anatomy education.

(8) *Neglect of vertical integration of anatomy teaching*
Vertical integration within curricula is often unidirectional. Whilst clinical topics are integrated in the early years of the medical curriculum (traditionally the time slot for basic science teaching like anatomy), it is perceived to be far less common for basic sciences to be taught in the later years of the curriculum.

The above factors were extracted from 32 articles (Table 1) published after 1990 (29 different first authors, nine of which held their primary posts in an anatomy department). The articles were published in educational, anatomical, surgical or radiological journals, but also in general medical journals such as the British Medical Journal and The Lancet. Most articles were retrieved by a search for keywords in the title, others by scrutinising references of relevant articles; they were mostly published as an editorial, letter/correspondence, commentary, essay or matter for debate and generally contained very little information to underpin the statements that were made. Considering the serious implications of the claim that anatomical knowledge is being eroded as well as the current lack of firm evidence to support it, we investigated whether the claim holds some truth and, if so, which factors influence it. The eight factors listed above served as the starting point for a review aimed at identifying empirical evidence to support, and help deal with, their negative effects. After describing the methods of our systematic literature search, we discuss what the review revealed in relation to each factor. Finally, we discuss the findings and present conclusions with recommendations for further research.

Methods

Keywords were selected for each factor and used to search Pubmed and Medline. All searches were limited by language (English, Dutch and German) and publication date (1950–2007). The titles and abstracts of the retrieved articles were screened, after which the full text of potentially relevant articles was printed and read. Next, a reference search of these relevant articles was performed (Figure 1 shows a search flow profile). Studies conducted among students of disciplines other than medicine (e.g. physiotherapy, radiology, dentistry, veterinary medicine, occupational therapy or nursing) were excluded.

The influence of teaching of anatomy by non-medically qualified teachers

The argument that anatomical knowledge is negatively influenced when it is taught by non-medically qualified staff raises two questions: (1) is it true that anatomy is increasingly taught by non-medically qualified staff and (2) if so, does this affect students' anatomical knowledge? There does seem to be a trend throughout the world for anatomy to be increasingly taught by non-medically qualified teaching staff (Table 2). The most convincing data to support this were published by Pryde & Black (2005), who revealed that between 1983/1984 and 2003/2004, the percentage of medically qualified anatomy teachers in the five medical faculties of Scotland decreased from 56% to 41%. Furthermore, some studies reported that medically qualified anatomy teachers were generally older than their non-medically qualified colleagues. Van Mameren (2004) showed for example that *only 38%* of anatomy teachers in the eight medical faculties of The Netherlands were medically qualified and that of this percentage *more than three quarters* were aged 50 years or older. This suggests replacement of older, medically qualified, by younger, non-medically qualified, teachers, who may be appointed for other qualities than their medical knowledge. Unfortunately, none of the studies we reviewed examined if there was a connection between the qualifications of teaching staff and students' knowledge of anatomy; so, question two remains unanswered.

An argument that is frequently put forward in discussions on the qualifications of anatomy teaching staff is that researchers and clinicians are only interested in teaching (at the frontier of knowledge) in their particular areas of expertise, which does not help students to build a solid knowledge base. Halasz (1999) proposed the following interesting solution: 'What are the alternatives? For one, we can get the competent non-specialist to teach. A person who knows what is broadly important and applicable is much better able to instruct a student than the super-specialist who, in his or her very expertise, often lacks perspective' (p. 6). *Competent* is the operative word in this citation. For, based on the assumption that students' knowledge is strongly influenced by 'who teaches', qualifications may be relevant but not necessarily decisive for the quality of teaching. For example, individual

teachers' enthusiasm for teaching and didactic abilities may carry much more weight than their professional background.

Another interesting, but very different, aspect is student–staff ratios, which were reported in some articles on anatomy teaching staff. Pryde & Black (2005) found that between 1983/1984 and 2003/2004, student–staff ratios in the five medical faculties in Scotland increased from 20:1 to 58:1. In other words, by 2004, the number of students per teacher had more than doubled! One may wonder whether decreasing (or at best stable) staff numbers and increasing student numbers (resulting in for example less time to assist individual students with difficult subjects) may have had a negative impact on students' knowledge of anatomy. It seems worthwhile to conduct further research to establish the severity of this problem and look for ways to deal with it, such as the use of peer-to-peer teaching methods.

The influence of the absence of a (national) core anatomy curriculum

In some countries, medical schools are subject to inspection by external regulators (for example the General Medical Council in the UK) to ensure a high quality of education. Guidelines from these regulators are unfortunately 'fairly non-specific concerning the factual knowledge expected of graduates but are fairly comprehensive with regard to the requirements for clinical, generic and attitudinal skills' (Bradley 2001, p. 231). In order to overcome this problem, some authors have created a list of anatomical structures that students should know, in an attempt to define a core anatomy curriculum (Leonard et al. 1996; Griffioen et al. 1999; McHanwell et al. 2007). However, there is little agreement among authors on the content of such lists and authors do not define the depth of the required knowledge (e.g. for a muscle: to be able to recognize the muscle in the human body, know attachment sites, innervations, function, variations, etc.). Some researchers have asked students in different stages of the undergraduate curriculum (Moxham & Plaisant 2007) or after finishing their studies (Richardson 1983; Cottam 1999) whether they thought the contents of their anatomy course were of sufficient clinical relevance. While concurring to a certain degree, students also showed considerable differences of opinion on and between specific subjects.

Unfortunately, none of the articles we reviewed reported a study investigating (the absence of) a core curriculum and its effect on anatomical knowledge. Most articles in which reference was made to a core anatomy curriculum reported that the content of an anatomy course/curriculum was debated (Evans & Watt 2005: '[. . .] the anatomy staff have used their collective experience in conjunction with discussion and input from clinical colleagues across a range of disciplines' [p. 23]) but did not describe the outcome of this debate (e.g. a list of structures), let alone any effect on students' knowledge. Extensive descriptions of anatomy course content are limited to articles dealing with postgraduate specialist training (MacLean et al. 1996; Kilroy & Driscoll 2006).

If a national core anatomy curriculum were in place, teachers (basic science and clinical) would know what students were expected to learn and it would help students to attain that knowledge. Although getting anatomists and clinicians to agree upon a core curriculum may seem a daunting task (see studies of Koens et al. 2005b, 2006), it is probably not an unattainable goal. An important contribution to this discussion is the recent publication of 'AMEE Guide no 41. The place of anatomy in medical education' (Louw et al. 2009), which describes an ideal course which is 'principle based and problem oriented'. The authors focus on the definition of and distinction between 'general' and 'specific' anatomies, and how these can be taught by using different teaching methods, learning materials and assessment programmes.

The influence of not using dissection as a teaching tool in anatomy education

The teaching tools used in anatomy education can roughly be divided into five categories: (1) cadaver related, (2) clinically related, (3) computer/internet related, (4) other material related (e.g. models or books) and (5) other (e.g. lectures, practical classes or problem-based learning; PBL tutorials). Winkelmann (2007) conducted an extensive review study, comparing how dissection of a cadaver by students and the use of prosections (cadavers previously dissected by others) affected students' anatomical knowledge. Although comparison was hindered by the fact that the studies included in the review differed in more than one variable, traditional dissection appeared to offer a slight added benefit compared to prosections. In this review, we included only articles in which dissection by students was compared to teaching tool other than prosections. Although not straightforward, the results again seem to be slightly in favour of dissection. More importantly, however, a combination of teaching tools appeared to yield the best performances (Table 3). Biasutto et al. (2006), for example, found better results for students who only dissected cadavers compared to students who only used computer resources, but reported that the best scores were found in the group of students who learnt by both dissection and the use of computer resources.

The inconclusive findings concerning the influence of different anatomy teaching tools on student knowledge may be related to the fact that tools like computer models are more helpful in learning complex anatomical structures (e.g. the inner ear, bones of the skull or the brain). Students may get a better understanding of complex structures from 3D computer models, which enable zooming and rotation, whereas less complex structures (e.g. abdominal organs) can easily be studied from a textbook or cadaveric material. An interesting finding in this respect is that medical staff (both anatomists and clinicians) seem to want to keep dissection as a teaching tool (Patel & Moxham 2006), whereas students do not always rate dissection as the most useful tool for learning anatomy (Nnodim 1988; Dinsmore et al. 1999; Azer & Eizenberg 2007). Furthermore, recent research has shown that a dissection course is not a uniform learning experience (Winkelmann et al. 2007). Different students may very well have different approaches in dealing with a dissection course (or other teaching methods for that matter), therefore undergoing divergent learning experiences, which may result in difference

in amount and form of knowledge between individual students.

While human cadaver dissection may seem to be on the way out in undergraduate medical education (substituted by other teaching tools), it is definitely gaining popularity in postgraduate training (Wong & Stewart 2004). Authors advocating the use of dissection in *undergraduate* education frequently mention its benefits for other learning objectives besides anatomical knowledge, such as professionalism, manual dexterity, teamwork, self- and peer-evaluation, ethics, etc. (Aziz et al. 2002; Rizzolo 2002; Gregory et al. 2009).

Last but not least, results from Erkonen et al. (1992) and Stanford et al. (1994) could indicate that different teaching tools aid students in learning different knowledge, as the studies showed that whether learning anatomy from computed tomography (CT) images or cadaver had different effects on test questions using CT images or cadavers ($p < 0.0001$). This is in agreement with results of Biasutto et al. (2006) mentioned above. Based on these considerations, we would recommend that future research should concentrate on *what* and *how* students learn from dissection and other teaching tools before drawing conclusions in favour of the either method.

The influence of not teaching anatomy in context

Interestingly, teaching in context is not a new argument; in fact, it was advocated more than a century ago: 'One lecture [. . .] by a good anatomist [. . .] who is neither ignorant nor careless of the work of a surgeon, or the duties of a physician, on a good well-developed living subject, would do more real good than six months' lectures on minute anatomy [. . .]' (Prosser 1868, p. 545). The contexts that are commonly used in anatomy teaching can be roughly divided into four categories: (1) clinical skills (physical examination), (2) pathology (e.g. cancer, neurological diseases, musculoskeletal problems), (3) radiology (e.g. interpreting X-rays, CT, ultrasound) and (4) surgical procedures (e.g. appendectomy or endoscopic/laparoscopic procedures). In many studies, students reported more positive attitudes/perceptions in relation to a course teaching anatomy in context than in relation to traditional course formats (Fitzpatrick et al. 2001). A few studies have compared students' anatomical knowledge before and after a course in which anatomy was taught in context (Table 4). Unsurprisingly, students knew more after the course than they did before it, but the study methods used preclude any firm conclusions as to whether this was due to teaching in context or to course attendance irrespective of teaching method (more time spent learning leads to more knowledge). Our literature search yielded *not one* study comparing the results of teaching anatomy within and out of context.

Studies by Koens et al. (2003, 2005a) showed that creating a context that actually facilitates learning, retention and transfer of knowledge is not as straightforward as is often thought. To reach those goals, creating a context may have to go much further than, for example, introducing a CT scan to facilitate the learning of the anatomy of the abdomen. Currently, we do not yet fully understand all the (im)possibilities of teaching (anatomy) in context.

The influence of integrated curricula (problem-based learning or systems-based curriculum)

A meta-analysis examining the effectiveness of problem-based learning (PBL), conducted in 1993 by Vernon & Blake (1993), reported that: 'PBL was found to be significantly superior with respect to students' programme evaluations (i.e. students' attitudes and opinions about their programmes) [. . .] and measures of students' clinical performance [. . .]. PBL and traditional methods *did not* differ on miscellaneous tests of factual knowledge [. . .] and tests of clinical knowledge [. . .]' (p. 550). Two more recent meta-analysis show similar results (Colliver 2000; Newman 2003).

Studies that specifically address the influence of PBL and systems-based curricula on *anatomical* knowledge are few (Table 5). Their results show no clear benefits or drawbacks of integrated curricula compared to traditional ones. Studies examining the difference in *basic science* knowledge (including anatomy) between students in different curricula (Alleyne et al. 2002; Woloschuk et al. 2004) were also inconclusive.

The available evidence, or lack of it, shows that the effect of innovative curricula on anatomical knowledge remains to be ascertained, although it is doubtful whether this will ever be done conclusively. On a slightly differing note, the authors of a curriculum comparison study (Prince et al. 2003) suggested that the educational approach underpinning a curriculum may not be the strongest determinant of students' anatomical knowledge. This observation was prompted by results showing that better scores in anatomical knowledge appeared to be related to whether anatomical aspects were revisited during the course of the undergraduate curriculum. The amount of time devoted to anatomy teaching, repetition and teaching in context may have a much stronger impact than whether or not a school has an integrated or a traditional curriculum. However, further research will have to provide evidence to underpin this notion.

The influence of the way anatomical knowledge is assessed

Many articles describe different ways to assess students' anatomical knowledge. Frequently used methods are: (1) multiple choice questions (MCQs), (2) short answer questions, (3) essay questions, (4) identifying structures in a picture or cadaver (either MCQ or short answer) and (5) drawing structures. Tests can be of the pen and paper type, computer based or oral. Research has shown that MCQs and open questions are equally effective in assessing students' knowledge at the time of the test, in other words, both types of question discriminate between the 'good' and the 'bad' students, despite some exceptions relating to individual students (Barnett 1960).

When we searched the literature for this review, we were surprised to note that most of the articles on assessment methods in *anatomy education* dated from the period 1960–1980. Furthermore, our search revealed only three articles comparing different methods for assessing anatomical

knowledge (Table 6). The results seem to indicate that the sole use of MCQs and/or the lack of a minimal requirement for each tested discipline have indeed a negative effect on students' study behaviour and retention of knowledge. This seems consistent with other research outside health-related education (Sax & Collett 1968; Gill et al. 1978; Gay 1980).

The influence of decreased time for anatomy education

As with the influence of non-medically qualified teachers, the supposed negative effects of reduced teaching time raise two questions: (1) has teaching time for anatomy actually decreased and (2) if so, has this affected students' anatomical knowledge? The review offers an answer to the first question only (Table 7). Designated teaching time for anatomy did, in fact, decrease during the past decades. For example, mean total teaching time (including lectures, practical sessions and tutorials) for gross anatomy at five medical schools in Scotland decreased from 382 h in 1983/1984 to 151 h in 2003/2004, a reduction by more than 50%! This is all the more interesting in light of findings in the same institutions during the same period, showing a more than 50% rise in student–staff ratios (Pryde & Black 2005).

In the absence of studies linking teaching time to knowledge results, question two again has to remain unanswered. Those undertaking further research on this subject are advised to consider the following possibility. When decreases in teaching time are calculated, time is usually measured as the number of hours (either lecture or laboratory time) of teacher–student contact. What is generally ignored is the possibility that a decrease of contact hours does not automatically imply that students spend less time learning anatomy. The decrease in contact hours may be counterbalanced by more self-study time. So, in order to gain a realistic insight into how much time students devote to learning anatomy, it is important to also look at time for self-study, especially in curricula with a self-directed learning approach.

The influence of neglect of vertical integration of anatomy education

We found only one article investigating anatomy education in the later, traditionally clinical, years of the undergraduate curriculum and its effects on students' anatomical knowledge (Table 8). Again, the methods used preclude conclusions regarding the attribution of reported improved knowledge to vertical integration or to the mere fact that a course was offered.

There is a scarcity of articles on vertical integration of anatomy (only 42 articles in the systematic literature search, less than one-third of the number of articles on the other factors). Few researchers have investigated how anatomy was vertically integrated in a curriculum (Evans & Watt 2005), how this was achieved, why vertical integration is important, or how it affects the *perceptions/attitudes* of medical students concerning anatomy education (Brynhildsen et al. 2002). This paucity of studies is surprising, since vertical integration of anatomy is greatly desired (Waterston & Stewart 2005) and considered helpful in solving several issues: (1) it increases teaching time, (2) teaching can be a collaborative effort of basic science experts and clinicians (increasing the clinical relevance of what is taught), (3) it promotes repetition in teaching and learning and (4) it offers increased opportunities for teaching in context (e.g. teaching the anatomy that is relevant to a specific clinical rotation). Further research on vertical integration of anatomy education is therefore strongly recommended.

Discussion and conclusion

The results of this narrative review reveal a scarcity of studies dealing with the factors identified as potentially influencing anatomical knowledge. In addition, the studies we did find were lacking in methodological quality. Consequently, the review offers no basis for firm conclusions, and only conflicting conclusions at best. In other words, there appears to be a lack of empirical evidence to support the claimed influence of *any* of the proposed factors. One may wonder why this should be so.

A first explanation might be that the assumed deterioration of anatomical knowledge levels is a perception arising from generation conflict. This interpretation is supported by the fact that complaints of declining anatomical knowledge were also heard in decades preceding the period we studied (Taylor & Wilson 1975). It is not uncommon for a generation to complain that younger generations are less capable of many things, whether it be driving a car, saving money, maintaining relationships, doing arithmetic or reproducing anatomical knowledge. Although this may seem a plausible explanation at first sight, things are probably far more complex. All the studies we found examined only one factor, but it may well be the case that, in practice, a combination of factors is at stake in the actual or perceived decline of students' anatomical knowledge. And, it is equally likely that the crucial factors are others than the ones we examined. It may, for instance, be fruitful to explore the influence of different student–staff ratios.

Whether or not students' anatomical knowledge is decreasing, and whether or not this will endanger doctors' professional performance, it remains highly relevant to identify factors that play a role in the acquisition of anatomical knowledge. There is a general consensus that medical students *definitely cannot do without* anatomical knowledge, and consequently without anatomy education, although opinions may differ as to its scope. However, in medical education today, the key question regarding anatomy education increasingly focuses on how education can be made as effective as possible. Following are some considerations which may give direction in the search of an answer to this question.

An interesting theme within educational research on teaching in context is the notion of 'transfer': using a concept learnt in one context to solve a problem in a different context. 'Stories of medical students who have learnt the basic science, passed the examinations, but were then unable to apply this knowledge to solve or explain problems, are commonplace. Typically, this dissociation is viewed as an issue of learning out of context, and proposed solutions attempt to integrate the basic science better with the clinical problems' (Norman 2009, p. 808). Creating an adequate context to teach in

(as described earlier), but also retrieving a learnt concept to solve a new problem are more difficult than one might think (Norman 2009). However, results reported by Woods et al. (2005, 2007a, 2007b) indicate that teaching in context aids retention of basic science and clinical knowledge, diagnostic reasoning and correct clinical diagnosis ('transfer'). Thus, teaching in context may not only increase anatomical knowledge but also improve its application in problem solving.

An issue concerning assessment of basic science knowledge that every teacher should be aware of is dealt with by Swanson & Case (1997): 'The amount of material to be learned in a typical basic science course is overwhelming, and students must make choices of what to study. Because medical students are highly motivated and academically strong, they want to perform well on tests, and they look to tests for guidance on what material is worth studying. To the extent that tests are congruent with major course goals, the tests will appropriately communicate what should be learnt. To the extent that there is a mismatch between course goals and tests, assessment may well focus student preparation and learning in unfortunate directions' (p. 74). In a recently published overview of cognitive psychology research on the relationship between learning and assessment, Larsen et al. (2008) suggest that choosing a method of assessment should depend on the goal of the assessment, although further research is needed to confirm this. If the goal is to measure factual knowledge at the moment the test is taken and to distinguish the 'good' from the 'bad' students, there are no limitations to the use of MCQs. If there are other goals as well, such as to stimulate study behaviour, improve retention of knowledge and/or measure ability to apply knowledge in problem-solving, other assessment methods are probably preferable. Swanson & Case (1997) seem to agree with this when they write: 'Clearly, in order to encourage learning for understanding, assessments need to test more than recall of isolated facts. Instead, assessments should focus on application of basic science knowledge, often to clinical situations, and on integration of knowledge across topics and courses to achieve a coordinated, cross-disciplinary understanding of those situations. [. . .] Research on assessment must directly consider the likely impact that alternate assessment plans (including content and frequency as well as method) will have on student learning activities and outcomes' (p. 74).

Last but not least, one might want to know what *students* think of their anatomical knowledge. As the perceptions of anatomists and clinicians about their knowledge might be inaccurate, there are indications that students are even more severe in their judgement of their anatomical knowledge (Prince et al. 2005), although it is not clear why students should place such high demands on anatomical knowledge. However, since students clearly feel strongly about anatomical knowledge, they are also likely to have strong opinions concerning factors influencing that knowledge and may well be able to tell us how they would like to go about in learning their anatomy. A nice example in the direction of the latter is the study of Wilhelmsson et al. (2009), in which the approach to learning anatomy of second year medical students is explored by means of individual, semi-structured interviews. More extensive research in the aforementioned areas may shed a different light on, and add pieces to the puzzle of, how to increase the effectiveness of anatomy education.

Based on promising research findings so far, or on prospects of a contribution to more than one area of concern, we propose that research should focus on the following factors: the possibilities of teaching in context, the implementation of vertical integration and the implementation of assessment strategies. Interestingly, anatomy education is probably only a special case of the general effects of these factors. Findings in these areas may well have wider application than anatomy education and extend to all basic and maybe other sciences as well.

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Supplementary material available online

Figure 1

Tables 1–8

References of all articles mentioned in Tables 1–8