ORIGINAL ARTICLE

A Scoping Review of Worldwide Patent Applications in Anatomical Education (2018-2022)

Rowena F. Genuino, MD, MSc,[1] Rafael C. Bundoc, MD,[1] Florida F. Taladtad, MD,[1] Kevin L. Ocampo,[2] Gere Ganixon T. Ang, MD,[3] Joseph Daniel S. Timbol[4] and Christopher S. Constantino, MD[1]

[1]Department of Anatomy, College of Medicine, University of the Philippines Manila
[2]Technology Transfer and Business Development Office, University of the Philippines Manila
[3]Clinical Simulation Laboratory, College of Medicine, University of the Philippines Manila
[4]College of Medicine, University of the Philippines Manila

ABSTRACT

Background and Objective. Anatomical education utilizes mainly cadaver dissection, but it also depends on innovations such as novel preservation techniques, simulation models, and virtual dissection apps. There is no review on anatomical patents. This study aimed to review the worldwide landscape of existing patents on anatomical education to identify gaps and opportunities for utilization and further innovations.

Methods. We conducted a scoping review for inventions, utility models, and industrial design applications on anatomical education. We searched the following databases as of December 31, 2022 (WIPO Patentscope, Espacenet, and Derwent). We deduplicated the records, screened them for eligibility, and extracted information on characteristics of the patent application and applicant. We computed frequency and percentage according to country, type of applicant, number of inventors, type of patent, scope of patent, purpose of patent, organ system, status of patent, and time to patent granting.

Results. Out of 667 merged records from the initial search, we removed 312 duplicates, excluded 97 records, and included 258 reports in the review. The median number of patent applications per year was 58 (range, 32, 61). Majority of the applications were from China and USA (36.0 and 34.9%, respectively), national in scope (62.8%), industry as applicant (49.6%), inventions (77.5%), usable beyond anatomy (70.9%), physical models (53.1%) and with pending status (63.6%). The median time to granting for 65 patents was 316 days (range, 40 to 1568).

Conclusion. For the period 2018-2022, there were 258 patent applications related to anatomical education, both as a basic science and in clinical applications, were mostly inventions, applied for by industry, contributed by US and China, only national in scope, physical 3D models (mostly musculoskeletal, head/neck and sensory organs, and whole body), and usable beyond basic anatomy. The majority of patent applications are still pending with only 65 granted patents. Plastinated specimens, and the urinary, reproductive, and pulmonary organ system models were least represented.

Keywords: intellectual property, patent, invention, review, anatomy, education, training

eISSN 2094-9278 (Online)
Published: May 30, 2025
https://doi.org/10.47895/amp.v59i6.7687

Corresponding author: Rowena F. Genuino, MD, MSc
Department of Anatomy, College of Medicine
University of the Philippines Manila
547 Pedro Gil Street, Ermita, Manila 1000, Philippines
Email: rfgenuino@post.upm.edu.ph
ORCiD: https://orcid.org/0000-0003-2395-2322

INTRODUCTION

Intellectual property (IP) is broadly defined by the World Intellectual Property Organization (WIPO) as "creations of the mind".[1] These are protected by intellectual property rights which are given to the creator for them to have an exclusive right over the use of that creation for a given time. Patents, utility models, and industrial designs are all forms of intellectual property rights that play a crucial role in safeguarding innovations and fostering creativity in various industries, including the medical education field (Table 1).[2]

Because an IP can be considered as a financial resource, doctors, paramedical professionals, and medical students should be aware of its benefits.[3] Additionally, the development

Table 1. Types of Intellectual Property (IP) Rights[2]

Term	Definition
Patent	Government-issued grant, bestowing an exclusive right to an inventor over a product or process that provides any technical solution to a problem in any field of human activity which is new, inventive, and industrially applicable
Utility model	Also a right to an invention that offers a new technical solution to a problem and is also industrially applicable, but it does not require invention to have an inventive step
Industrial design	Concerned with the aesthetic (e.g., three-dimensional, two-dimensional features) aspects of an article

of a previously intangible idea to a useable technology that benefits society may act as an intrinsic motivator for researchers to engage in its development.

Sharing of intellectual properties in anatomical education have been used to produce state-of-the-art facilities and equipment for teaching anatomy in Bristol, UK with the help of third-party companies.[4] However, it was highlighted that not all intellectual property ventures guarantee success and that monitoring and evaluation of learning outcomes should still continue throughout their implementation.[5] Technology in the form of virtual and augmented reality, holograms, mixed reality, virtual dissection tables, social media, mobile applications, mobile devices, 3D printing, online video sharing, simulation, educational games, e-learning, and other software can be integrated into clinical education and training.[6] Recent developments in computer technology and software have the potential to enhance learning and identification of anatomical structures and their relationships to each other.[7] Furthermore, intellectual property development can also be used as metrics for promotion and incentives in the field of academics.[8,9] However, knowledge on intellectual property was adequate only in ⅓ of surveyed faculty in six health-care professional institutions in Belagavi, Karnataka, India.[10] Intellectual property is a relatively new discipline in research whose applications have not yet been fully maximized by any discipline up to this point in time.[11]

A preliminary search in PubMed and CINAHL, and local Philippine science database, HerdinPlus yielded 13 relevant reviews on intellectual property in general, or in the medical field, but not necessarily related specifically to anatomical education (See https://github.com/users/RFGenuino/projects/1/views/1?pane=issue&itemId=41323831 for search details). Reviews on intellectual property include performance in patent applications of universities in Chile,[12] trends and transitions of intellectual properties for 87 US-based universities from 1981 to 1995,[13] the culture of academic patenting and type of technology transfer office models of universities in the United States and China in the context of existing national systems and policies,[14] and nurse-authored patents in the USA.[15] Medical innovation patent reviews were mostly on biotechnology, and included digital pathology (USPTO; prior to 2014; 876 patents),[16] genetics (WIPO, EPO; 1990 to 2009;150,000 patents,[17,18] lipase immobilization (WIPO; 1976-2019; 3066 patents),[19] biocatalysis,[20] essential medicines in developing countries,[21] drug development in the Massachusetts Institute of Technology,[22] cardiothoracic and cardiovascular surgery (international; 1976 to 2000),[23] and dentistry in India using the Intellectual Property Office website of India (2005 to 2009)[24].

OBJECTIVES

This study aimed to fill in the knowledge gap on the patent landscape in the field of anatomical education. The specific objectives of this study were to: 1) describe the characteristics of anatomical patent applications, 2) evaluate their relevance and potential impact in anatomical education and patient care. By identifying useful and relevant applications as well as lacking or underrepresented areas, we can highlight those that can already be adopted and recommend areas that provide opportunities for future innovations.

METHODS

We conducted a scoping review of IP applications for anatomical education worldwide for the past five years. This study was registered with University of the Philippines Manila-Research Grants and Administration Office (UPM RGAO-2022-1451) and a study protocol was submitted and exempted from review by the UPM-Research Ethics Board (UPM REB 2023-0023-EX) and can be provided upon request. No protocol amendments were applied.

Eligibility Criteria

We included patents for inventions, utility models, and industrial design applications that were related to gross anatomical education as a basic science or applied science (for training of clinical skills) (e.g., dissection tools, models, simulation, apps), any country, any applicant, and any type of inventor. We excluded those that were for the anatomical education of non-humans, those that were for the purposes of processing of human remains NOT related to its use as an educational tool, those that were exclusively for patient care or patient safety in healthcare, and those related to histological or cytological education. We also excluded non-English patents that could not be translated into English.

Information Sources

On January 12, 2023, we searched the following patent databases for patents that had priority/application dates between January 1, 2018, to December 31, 2022.

1. **WIPO Patentscope** (https://patentscope.wipo.int/search/en/search.jsf).[25] The WIPO PatentScope database is a global patent database maintained by the WIPO and as of 2022 contains more than 109 million patent documents. It contains millions of patent documents from around the world, including international Patent

Cooperation Treaty (PCT) applications and other patent documents from over 100 national and regional patent offices worldwide.

2. **Espacenet** (https://worldwide.espacenet.com/).[26,27] Espacenet is a free publicly available database maintained by the European Patent Office (EPO) from 1782 to the present, but also contains data from the WIPO, and many other national and regional patent offices. It is updated daily and contains data on more than 140 million patent documents from around the world.
3. **Derwent** (https://www.derwentinnovation.com/login/).[28] The Derwent patent database is a global patent database maintained by Clarivate Analytics that requires a paid subscription. It originally started as the Derwent World Patents Index (DWPI) in 1991. It provides comprehensive coverage of patents and patent applications from 75 jurisdictions around the world, including the United States, Europe, Asia, and other regions. The database includes over 58 million patent documents.

Search Strategy

We used pretested search strategies for each database (https://github.com/users/RFGenuino/projects/1/views/1?pane=issue&itemId=41323831).

Data Charting Process

A set of two reviewers independently screened, assessed, and extracted data from the included studies. For disagreements, the pair of reviewers discussed or if a consensus was not reached, a third reviewer was consulted.

Data Variables

For the outcome of patent characteristics, we extracted the following data items: patent code (priority/application/publication), country, type of applicant (academic, industry, individual, government), inventors, number of inventors, type of patent (Invention or utility model or industrial design), scope of patent (international or national), date of application, date of publication, date granted, status of patent (pending, abandoned, granted, rejected), purpose of patent (specific to anatomy vs usable beyond anatomy), organ system, category of patent (e.g., cadaver dissection, computer-implemented technologies, models per organ systems).

We did not search for funding source or any missing data beyond the patent information provided in the respective databases. We resolved unclear information by discussing the best interpretation among pairs of reviewers. Data extraction templates and detailed summary data tables can be provided upon request.

Data Synthesis

We used Microsoft Excel to compute for frequency and percentage of categorical variables and generate tables and graphs showing variable trends and distributions. We described and summarized characteristics of IP applications for each category of educational or training tool (models, CITs, cadaver dissection, and miscellaneous).

RESULTS

Search Flow

The search strategy yielded 667 patent applications and 312 duplicates were removed. Among the remaining 355, we excluded 97, leaving 258 patent applications for inclusion in the review (Figure 1).

Characteristics of Anatomical Patent Applications

Majority of the IP applications were from China (36%, 93/258) and United States (34.9%, 90/258), each contributing a third of the total patents; followed by Russia (5.8%, 15/258) (Figure 2).

There was a slowly rising number of applications between 2018-2021, with a median of 58 per year, noting a sharp drop by 48% from 2021 (n =61) to 2022 (n = 32) (Figure 3).

Models were the most numerous category (53.1%, 137/258) followed by computer-implemented technologies (CITs) (20.9%, 54/258) (Figure 4).

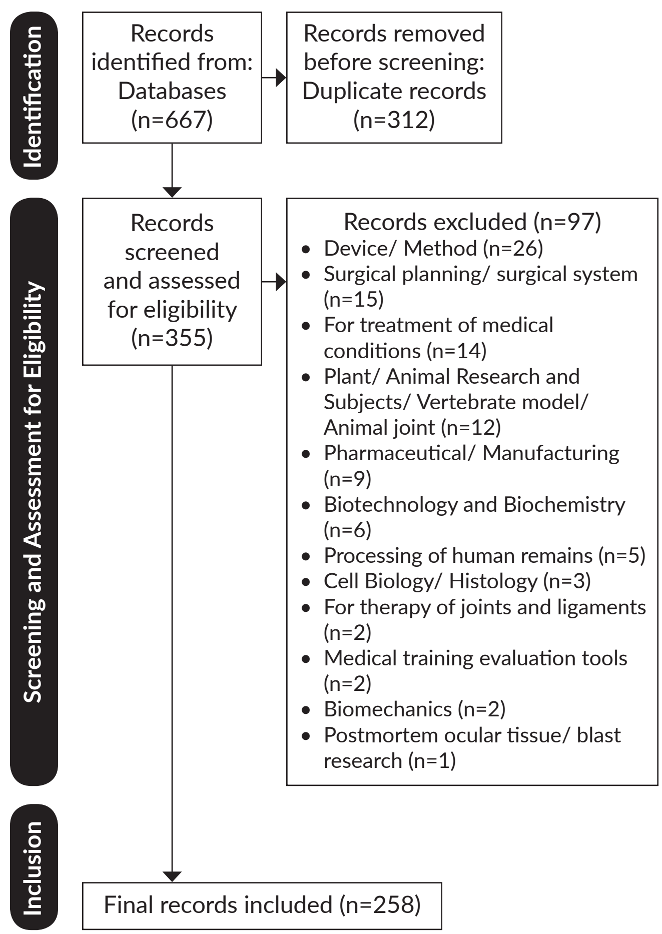

Figure 1. Search flow diagram.

Note: List of excluded patents may be provided upon request.

Majority of the 258 patent applications were limited to national in scope (162, 62.8%), with industry as applicant in half (128, 49.6%). More than three quarters were inventions (200, 77.5%) and were usable beyond anatomy (183, 70.9%). More than half were still pending (164, 63.6%) and only a fourth were granted (65, 25.1%), with median time to granting of 316 days (range, 40 days) for a teaching aid for learning the musculoskeletal structure of the human body (KR20210082018A) in 2021 to 1568 days, for a fixture tool for securing a bio-textured organ model (EP3806068A1). The median number of inventors was three (range, 1 to 22) with a single inventor (62, 24.0%) being the most common number, followed by two inventors (50, 19.4%), and four inventors (43, 16.7%). The patent with 22 inventors (Brazil; university and a foundation) was a simulator for orogastric surgery and gastroesophageal atresia for clinical and surgical training, with both diagnostic and therapeutic purposes (Table 2). The applicants with the highest number of patent applications were Intuitive Surgical Operations Inc. (US) (n = 23), followed by Tornier, Inc (n = 10), and Edwards Lifesciences (n = 5).

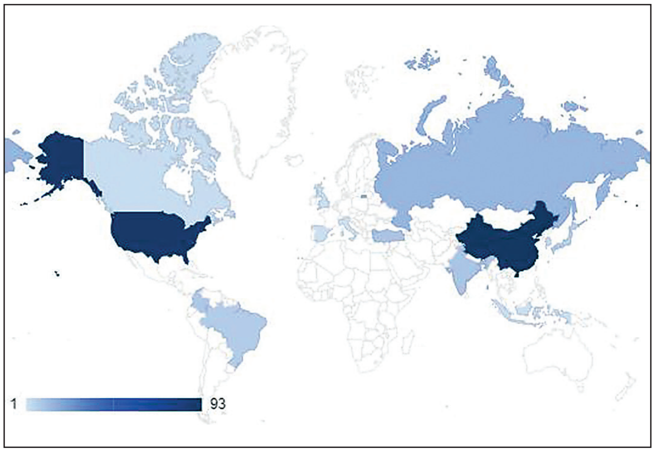

Figure 2. Geographical distribution of patent applications.

The darker blue color in the map corresponds to a higher number of patent applications.

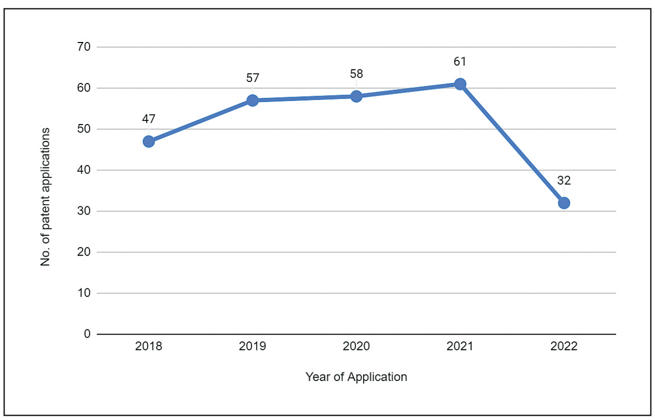

Figure 3. Number of patent applications per year: 2018-2022.

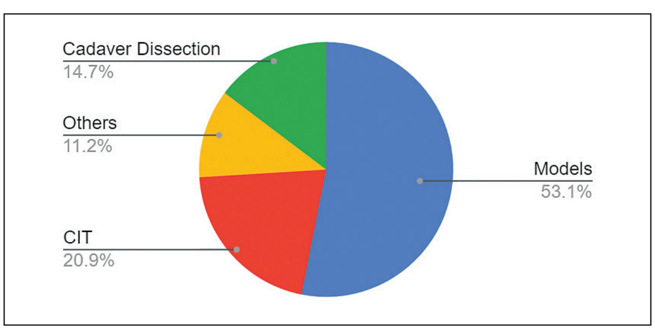

Figure 4. Frequency distribution based on type of patent (%).

CIT – Computer-implemented technology

Of the models, the musculoskeletal system (37/137, 27.0%) were the most numerous, of which there were 11 granted patents (Table 3). The least represented were the urinary system (6/137, 4.4%) and pulmonary system (1/137, 0.7%), with only one patent granted for each. The most common CIT patent applications (n=54) were artificial intelligence plus extended reality (n = 15), artificial intelligence only (n = 12), and mixed reality (n = 11), of which there were nine granted patents. Cadaveric dissection patents (n=38) include dissecting implements (n=16), dissecting tables (n=10), embalming fluids and processes (n=12), of which there were two granted patents for dissecting implements, and six for dissecting tables.

Relevance and Potential Impact in Anatomical Education and Patient Care

Among the 11 granted patents for musculoskeletal models, there are two that can be potentially useful for medical students studying basic anatomy; musculoskeletal structure of human body [KR102287632B1] and whole-body muscle model of human body [CN214475931U]. The 1st patent introduces an innovative teaching material that allows medical students to gain better understanding of the musculoskeletal structure by directly installing stretchable elastic muscle models onto a human skeleton model. The patent also aims to enhance medical students' comprehension of muscle attachment points using 3-D multi-joint movements. The rest would be more fit for students or trainees in higher levels or medical practitioners. The 2nd patent features detachable components, magnetic connections, and exchangeable genitals, offering medical students a versatile and interactive learning tool.

The lone patent for each of the least represented organ systems were directed mostly for higher levels of medical education and not basic anatomy. The endotracheal intubation simulator [CN112587233A] can be used as a safe and realistic way to practice this critical procedure for those rotating in Emergency Medicine or Anesthesiology departments. Similarly, the urological simulator [RU208258U1] would be more useful for surgeons since it is designed to practice percutaneous bladder puncture under ultrasound guidance.

Table 2. Summary of Characteristics of Included Patent Applications (n=258)

Characteristic	No.	%
Country		
China	93	36.0
USA	90	34.9
Russia	15	5.8
India	10	3.9
Turkey	10	3.9
Colombia	9	3.5
Brazil	8	3.1
Japan	6	2.3
South Korea	3	1.2
Canada	3	1.2
Indonesia	2	0.8
United Kingdom	2	0.8
Spain	2	0.8
European Patent Office (EP)	1	0.4
Hong Kong	1	0.4
International Bureau (IB)	1	0.4
Italy	1	0.4
Singapore	1	0.4
Scope		
National	162	62.8
International	96	37.2
Type of applicant		
Industry	128	49.6
Academic/University	88	34.1
Individual	33	12.8
Government	9	3.4
Number of inventors		
1	62	24.0
2	50	19.4
3	38	14.7
4	43	16.7
5	17	6.6
6	19	7.4
7	8	3.1
8	7	2.7
9	3	1.2
10	3	1.2
11 to 22	8	3.1
Type of patent		
Invention	200	77.5
Utility model	57	22.1
Industrial design	1	0.4
Purpose of patent		
Usable beyond Anatomy (Broad applicability)	183	70.9
Specific to Anatomy	75	29.1
Category of patents		
Models	137	53.1
Computer-implemented technology (CIT)	54	20.9
Cadaver dissection	38	14.7
Miscellaneous	29	11.2
Status of patents		
Pending	164	63.6
Granted	65	25.1
Abandoned/ Withdrawn	17	6.6
Rejected	11	4.3
Expired	1	0.4

Table 3. Summary of Patents per Category

Category	No. of Approved/ Granted Patents	Total No. of Patents
Models*	**42**	**137**
Musculoskeletal	11	37
Head and Neck/Ear	10	24
Neurologic	5	10
Whole body	3	16
Circulatory	4	16
Digestive	3	9
Reproductive	3	8
Eye	1	10
Pulmonary	1	1
Urinary	1	6
CIT**	**9**	**54**
AI	1	12
Virtual Reality	1	7
Augmented Reality	1	3
Mixed Reality	3	11
XR	1	2
AI plus XR	1	15
Other CIT	1	4
Cadaver dissection†	**10**	**38**
Dissecting tables	6	10
Dissecting implements	2	16
Embalming fluids and processes	2	12
Miscellaneous‡	4	29

* *Supplementary Table S3.1*

** *Supplementary Table S3.2*

† *Supplementary Table S3.3*

‡ *Supplementary Table S3.4*

Supplementary Tables for list of granted patents for each category may be found at: http://doi.org/10.17605/OSF.IO/Z2UHA

Note: List of pending, abandoned/withdrawn, and rejected patents may be provided upon request

AI – Artificial intelligence, CIT – Computer-implemented technology, XR – Extended reality

Of nine granted patents for CITs, two of these are university-based patents: a virtual human body model [CN111429569A] and a transanal endoscopic surgery simulator [CN209297597U]. The first invention offers a cutting-edge approach to anatomical education through immersive technology, potentially impacting patient care by producing well-prepared healthcare professionals. The second invention provides realistic surgical simulation, with a high potential to improve patient care by enhancing the skills of healthcare professionals.

Cadaveric dissection patents (n=38) include dissecting implements (n=16), dissecting tables (n=10), embalming fluids (n=7), and processes (n=5), of which there were 2 granted patents for dissecting implements, and 6 for dissecting tables. Among the embalming fluids and processes, two were granted. Two of these dissecting table patents are university-based patents: a teaching demonstration frame that can also collect blood, body cavity effusions, or tissue fluids generated during dissection [CN211264779U], and a multi-directional dissecting table whose angles can be adjusted [CN211264642U]. The innovative designs may enhance anatomical teaching through safe and sanitary dissection classes as well as easy access to different parts of the cadaver.

Notably, both plastination patents were rejected, that of a liver specimen casting model and method [CN109049460A] and an in-situ embedding method and model for foot bone [CN108877446A].

DISCUSSION

Summary of Main Findings and Interpretation

Scientific productivity is conventionally measured by the number of patents or publications.[29] This study noted that two countries (China and USA) had the greatest number of IP applications on anatomical education, mirroring their respective scientific productivity trends. This trend can be traced back to significant landmark legislations, namely the improved IP rights law in the US in 1981, with China following suit in 2002. An overview on patenting trends and technology commercialization in the technology transfer offices in US and China showed a steady rise in university patents from the period 1981 to 2020.[14] This trend was attributed to substantial resources, government support, emphasis on academic entrepreneurship, and skilled technology transfer staff in the US and Chinese universities. Among 3.4 million patent applications filed worldwide, China took the lead with 1.59 million patent applications, followed by the United States (591,473), Japan (289, 200), Republic of Korea (237,998), and Europe (188,778) with the highest growth rate also taken by China (+5.5%), India (+5.5%), and the Republic of Korea (+2.5%).[30] It may be easier and more practical for the Philippines, being in closer proximity to China and with a more similar Asian body type, to utilize marketed Chinese patents, while considering quality and longevity of products.

The trend for industry to lead in patent applications is similar to a review of 110 dental patents in India from 2005-2009 wherein 70% of applicants were private companies and 27.3% were individuals.[24] In our worldwide review, however, unlike the Indian review where universities were the least contributor at 2.7%, universities were the 2nd leading patent applicants. Universities as patent applicants ensure that the patents eventually become adopted into the educational curricula. In a review article, they aimed to raise IP awareness among clinical and translational researchers in universities and academic hospitals by providing a concise overview of patent protection and important implications of IP for research and the researcher.[8] A recent development that heralds university-based patent activity is the recent collaboration between the University of the Philippines Manila-Technology Transfer and Business Development Office (TTBDO) with the UPCM Anatomy Department in applying for patents for a dissection table and an interactive computer application by two co-authors in this study.

Physical models being the most common IP application in our review reinforce the solid role of 3D traditional anatomical models as the cornerstone of teaching gross anatomy. This can address the problem of shortage in cadavers in recent years, which was aggravated by the COVID-19 pandemic. Being low-cost compared to digital counterparts, physical models have been around since the 1700s with its origin traced to Europe.[31] The educational value of 11 3D low-fidelity models published between 2000-2010 in three leading Anatomy journals lies in its use as a memory aid, reduction in cognitive overload, facilitating problem-solving, arousing student enthusiasm and participation, and requiring minimal resources to produce.[32] In a systematic review of eight studies (7 RCTs, 1 quasiRCT), physical models showed a significantly higher overall knowledge outcome ($p < 0.001$), spatial knowledge acquisition ($p < 0.001$), and long-retention knowledge outcome ($p < 0.01$) compared to all other educational methods.[33] The use of 3D printing may be utilized to create accurate models based on scan data of high-resolution computed tomography images, plastinated upper limb prosection,[34] and radiologic images[35].

The most common organ system modelled was the musculoskeletal system and may be due to its superficial location as the first layer (after skinning the cadaver) to be dissected among all organ systems. The complex spatial organization, underlying neurovascular structures and musculotendinous insertions into the bones can be better appreciated using physical 3D models. Based on the Global Burden of Disease Surgery, among the noncommunicable diseases, after neoplasms (61.4%), musculoskeletal disorders (84%) were the most frequent surgical procedures among admitted patients followed by digestive diseases (36.2%), cardiovascular and circulatory disorders (32%); diabetes, urogenital, blood, and endocrine (33.3%), neurologic (10.2%) and respiratory (4.3%).[36] A review on patents for musculoskeletal disorders showed preponderance of ergonomic applications that can address preventing such injuries.[37] However, majority of the musculoskeletal model patents were simulations specific to certain joints that are more useable for higher levels of medical training (e.g., surgery or rehabilitation medicine training). This highlights the gap in musculoskeletal patents that emphasize basic anatomical knowledge rather than proficiency in clinical procedural or surgical skills.

The head and neck, and the sensory organs (ear) were the 2nd most common body part models that had anatomical education IP applications. Although they only account for 10% of the total body surface area, the intricate structure of the sensory organs and their relatively very compact and small size, making it difficult to study them in-situ, may explain why they have a large representation. These patented models may potentially benefit our medical students in understanding minute anatomical details of these structures. The least represented organ systems being the pulmonary system, with only an endotracheal intubation simulator, and the urinary system, with only a urological simulator, point to fields that are underrepresented and may be further developed by potential patent applicants.

Whole body models were the 3rd most common patent application for models. Since an overall study of entire human body is the key to an integrated holistic approach to anatomical education, whole body models are essential and form the staple of any anatomy department. The importance of anatomical models, whether physical or digital, as an option to the unavailability, discomfort and inconvenience of cadaveric dissection has been recognized.[38] Whole body models are increasingly being sought after because of the perennial scarcity of bequeathed bodies (cadavers) that would serve as silent mentors in the dissection laboratories of medical schools worldwide.

CITs being the 2nd most represented patent applications reflect the newest rising trend of information technology to enhance learning in medical education.[6] In the EPO database, computer technology was the fastest growing field with a growth of +9.7%; notably, medical technology had a positive but lower growth at +0.8%.[39] In a review of simulation training studies,[40] virtual patients, settings, or environments were employed in teaching laparoscopic surgery, gastrointestinal endoscopy, suturing skills, emergency resuscitation, anatomical examinations, among others. In another systematic review (51 trials in both high- and low-middle-income countries),[41] virtual patient simulations were more effective in improving skills and equally effective in improving knowledge compared to traditional education. It also reduced anxiety among 39 undergraduate medical students in the operating room attending a coronary bypass surgery.[42] Game-based virtual simulations have also been shown to improve test score and learner motivation.[43] Another advantage of virtual simulations is the reduction of risk to patients from untrained students, and the risk of transmission of infectious diseases, especially during the COVID-19 pandemic lockdowns.[44] As our medical students form part of the "digital native" generation, the use of computer technology may reduce the cognitive load and benefit those who are visual learners.

Patents related to cadaveric dissection such as dissecting tables, implements, embalming fluids and processes, were less common than the models and CITs. This could be attributed to the longstanding tradition of cadaveric dissection in anatomy education. The Japanese Guidelines (2012) underscored the role of cadaveric surgical training for acquiring essential medical skills and fostering innovations in surgical or interventional skills.[45] Ergonomically constructed dissection tables and implements, and reduction of hazards associated with chemicals used in cadaveric preservation has been emphasized,[46] as shown in the 10 dissecting table IP applications in our study that features self-cleaning, automation, and improved chemical preservation techniques. This would redound to an enhanced cadaveric dissection experience.

Plastinated specimens had only two patent applications and this may be due to its high cost of production and difficulty in obtaining human cadavers. Patents for plastination processes and models might have significantly tapered in current times since the process was invented in the 1970s. Most patents for plastination would have been awarded decades ago. Nonetheless, its pivotal role in anatomical education is shown by an overall perception among 39 students in India that plastinated specimens are more real and authentic, and required more respect and care than 3D-printed models, which were perceived to be easier to use for learning basic anatomy.[35] However, both patent applications were rejected. The authors are not privy to reasons for the rejection, but it can be hypothesized that because plastination as a process has already existed since the 1970s, the two patent applications could not have added any novelty, inventive steps, or industrial applicability, which are criteria that need to be fulfilled by patent applications.[47]

The knowledge gained from this review can help anatomy departments to check on which applicable recently patented technologies or educational tools are suited for their context, especially in the light of hybrid learning highlighted during the COVID-19 pandemic.[48] Gaps in the anatomical education field that are not yet filled with the current patent applications, notably in the pulmonary and urinary organ systems, may be further explored and innovations jumpstarted to keep up with the times.[49]

Strengths and Limitations

This is the first scoping review on anatomical patents to our knowledge. A rigorous methodology was used to comprehensively search for patents on this topic. A limitation of the evidence was that some patent descriptions were machine-translated from non-English languages and were difficult to comprehend; each pair of reviewers discussed and came up with the best interpretation of the data.

Limitations of the review process is that we may have missed patents that did not use the search terms in our search strategy; possible future search terms could be based on the international patent classification (IPC) system.

CONCLUSION

For the period 2018-2022, patent applications related to anatomical education, both as a basic science and in clinical applications, were mostly inventions, applied for by industry, contributed by US and China (out of 17 countries and two international patent offices), only national in scope, physical 3D models (mostly musculoskeletal, head/neck and sensory organs, and whole body) and computer implemented technologies, and usable beyond basic anatomy. Majority are still pending with only 65 granted patents. Among the models, the urinary and pulmonary organ system models were the least represented. The existing patented anatomical education technologies may be relevant in both basic anatomical education and medical specialty training. To supplement the teaching of anatomy using traditional methods, the existing technologies based on patent information may be tapped. In addition, the underrepresented organ systems, topics, or categories can be prioritized by inventors seeking to apply for patents in anatomical education. The acceptability, usability, cost-effectiveness, and impact of these technologies on actual learning outcomes among students of anatomy, especially in lower-income countries such as the Philippines, may be further explored. A further study comparing the patent applications between the different basic sciences, aside from anatomy, would be beneficial to optimize the use of technology and innovations across the medical curriculum.

Supplementary Material

Search strategies are available at https://github.com/users/RFGenuino/projects/1/views/1?pane=issue&itemId=41323831

Supplementary tables for Table 3 are available at https://github.com/users/RFGenuino/projects/1/views/1?pane=issue&itemId=41196616

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

All authors declared no conflicts of interest.

Funding Source

None.

REFERENCES

1. World Intellectual Property Office. What is Intellectual Property? [Internet]. WIPO. 2023 [cited 2023 Sep 11]. Available from: https://www.wipo.int/about-ip/en/#
2. Beneito P. The innovative performance of in-house and contracted R&D in terms of patents and utility models. Res Policy. 2006 May 1;35(4):502–17. doi: 10.1016/j.respol.2006.01.007.
3. Kumar V, Aranha V, Bhanushali N, Jain R, Atre S, Singh S. Assessment of knowledge, attitude and practice regarding intellectual property rights among dental task force attending private dental colleges in Navi Mumbai: a cross-sectional study. J Med Life. 2021 Jan 1;14(1):93–9. doi: 10.25122/jml-2020-0003.
4. Greene JRT. Design and development of a new facility for teaching and research in clinical anatomy. Anat Sci Educ. 2009;2(1):34–40. doi: 10.1002/ase.57. PMID: 19217068.
5. Roberts AM. Anatomical education: A team effort. Anat Sci Educ. 2009;2(4):195. doi: 10.1002/ase.98. PMID: 19598205.
6. Moro C, Stromberga Z, Birt J. Technology Considerations in Health Professions and Clinical Education. In: Clinical Education for the Health Professions. Springer Singapore; 2020. p. 1–22. doi: 10.1007/978-981-13-6106-7_67-1.
7. Moro C, Birt J, Stromberga Z, Phelps C, Clark J, Glasziou P, et al. Virtual and augmented reality enhancements to medical and science student physiology and anatomy test performance: a systematic review and meta-analysis. Anat Sci Educ. 2021;14(3):368–76. doi: 10.1002/ase.2019. PMID: 33378557.
8. Heus JJ, de Pauw ES, Lambooij M, Manca M, Rijkers H, Heineman M. Importance of intellectual property generated by biomedical research at universities and academic hospitals. J Clin Transl Res. 2017 May 5;3(2):250. PMID: 30873476; PMCID: PMC5881943.
9. Lewensohn D, Dahlborg C, Kowalski J, Lundin P. Applying patent survival analysis in the academic context. Res Eval. 2015 Apr 1;24(2):197–212. doi: 10.1093/reseval/rvu040.
10. Deshpande AP, Ankola AV, Sankeshwari R, Jalihal S, Kabra L, Bhat DV, et al. Assessment of knowledge and awareness regarding intellectual property rights among the health-care professionals in Belagavi city: A cross-sectional study. J Educ Health Promot. 2022 May 1;11(1):211.
11. Rout SK. A brief review on intellectual property rights with special attention on patent. J Appl Adv Res. 2018 May 15;73–7. doi: 10.4103/jehp.jehp_967_21. PMID: 36003255; PMCID: PMC9393961.
12. Schmal G, Zárate R, Vargas S. The way towards the patents in the universities. Ingeniare. Revista Chilena de Ingeniería. 2006;14(3):172–86.
13. Owen-Smith J. Trends and transitions in the institutional environment for public and private science. High Educ (Dordr). 2005;49:91–117. doi: 10.1007/s10734-004-2917-5.
14. Fasi MA. An Overview on patenting trends and technology commercialization practices in the university technology transfer offices in USA and China. World Patent Inf. 2022 Mar 1;68. doi: 10.1016/j.wpi.2021.102091.
15. Davis CR, Glasgow MES. An examination of nurse-authored patents: Implications for nursing practice. Nurs Forum (Auckl). 2020 Nov 1;55(4):772–81. doi: 10.1111/nuf.12480. PMID: 32851679.
16. Cucoranu IC, Parwani AV, Vepa S, Weinstein RS, Pantanowitz L. Digital pathology: A systematic evaluation of the patent landscape. J Pathol Inform. 2014 Jan;5(1):16. doi: 10.4103/2153-3539.137729. PMID: 25057430; PMCID: PMC4060404.
17. Kers JG, van Burg E, Stoop T, Cornel MC. Trends in genetic patent applications: the commercialization of academic intellectual property. Eur J Hum Genet. 2014 Oct 1;22(10):1155–9. doi: 10.1038/ejhg.2014.12.
18. Palazzoli F, Bire S, Bigot Y, Bonnin-Rouleux F. Landscape of chromatin control element patents: Positioning effects in pharmaceutical bioproduction. Nat Biotechnol. 2011 Jul;29(7):593–7. doi: 10.1038/nbt.1918. PMID: 21747382.
19. Almeida FLC, Castro MPJ, Travália BM, Forte MBS. Trends in lipase immobilization: Bibliometric review and patent analysis. Process Biochem. 2021;110:37–51. doi: 10.1016/j.procbio.2021.07.002.
20. de María PD, de Gonzalo G, Alcántara AR. Biocatalysis as useful tool in asymmetric synthesis: an assessment of recently granted patents (2014-2019). Catalysts. 2019;9(10):858. doi: 10.3390/catal9100858.
21. Beall RF, Blanchet R, Attaran A. In which developing countries are patents on essential medicines being filed? Global Health. 2017 Jun 26;13(1). doi: 10.1186/s12992-017-0256-1. PMID: 28651631; PMCID: PMC5485610.
22. Huang S, Siah KW, Vasileva D, Chen S, Nelsen L, Lo AW. Life sciences intellectual property licensing at the Massachusetts Institute of Technology. Nat Biotechnol. 2021 Mar;39(3):293–301. doi: 10.1038/s41587-020-00793-3. PMID: 33692518.
23. Vecht JA, Athanasiou T, Ashrafian H, Mayer E, Darzi A, von Segesser LK. Surgeons produce innovative ideas which are frequently lost in the labyrinth of patents. Eur J Cardiothorac Surg. 2009 Apr;35(4):480–8. doi: 10.1016/j.ejcts.2008.11.042. PMID: 19168370.
24. Bijle MNA, Patil S. Filed and granted Indian patents in dentistry from 2005-2009: a critical analysis and review. Indian J Dent Res. 2013;24(5):646. doi: 10.4103/0970-9290.123363. PMID: 24355974.
25. World Intellectual Property Organization – Intellectual Property Portal [Internet]. [cited 2023 Mar 12]. Available from: https://ipportal.wipo.int/
26. European Patent Office. Espacenet: patent database with over 120 million documents [Internet]. [cited 2023 Mar 12]. Available from: https://clarivate.com/products/ip-intelligence/patent-intelligence-software/derwent-innovation/

27. Espacenet: 20 years of free access to patent information in Europe | Epo.org [Internet]. [cited 2023 Oct 12]. Available from: https://www.epo.org/en/news-events/press-centre/press-release/2018/452125
28. Derwent Innovation - Patent search for IP professionals [Internet]. Clarivate. [cited 2023 Oct 12]. Available from: https://clarivate.com/products/ip-intelligence/patent-intelligence-software/derwent-innovation/
29. Kumar A, Srivastava A, Kumar RPJ, Tiwari RK. Recent patents on biotechnology measurement of scientific productivity in R&D sector: Changing paradigm. Recent Pat Biotechnol. 2017;11:20–31. doi: 10.2174/1872208310666161223123523. PMID: 28017124.
30. Worldwide IP Filings Reached New All-Time Highs in 2021, Asia Drives Growth [Internet]. [cited 2023 Mar 7]. Available from: https://www.wipo.int/pressroom/en/articles/2022/article_0013.html?utm_source=google&utm_medium=cpc&utm_campaign=Search%3A+WIPI+2022+%28EN%29&utm_term=Patent+Statistics&utm_content=search+ads&gclid=EAIaIQobChMIgu3fneSg_AIVd9pMAh08pwwUEAAYASAAEgLW7_D_BwE
31. Maerker A. Anatomizing the Trade: Designing and Marketing Anatomical Models as Medical Technologies, ca.1700–1900 [Internet]. [cited 2023 Oct 15]. Available from: https://about.jstor.org/terms
32. Chan LK, Cheng MMW. An analysis of the educational value of low-fidelity anatomy models as external representations. Anat Sci Educ. 2011;4(5):256–63. doi: 10.1002/ase.238. PMID: 21744512.
33. Yammine K, Violato C. The effectiveness of physical models in teaching anatomy: a meta-analysis of comparative studies. Adv Health Sci Educ Theory Pract. 2016 Oct 1;21(4):883–95. doi: 10.1007/s10459-015-9644-7. PMID: 26459329.
34. Radzi S, Chandrasekaran R, Peh ZK, Rajalingam P, Yeong WY, Mogali SR. Students' learning experiences of three-dimensional printed models and plastinated specimens: a qualitative analysis. BMC Med Educ. 2022 Dec 1;22(1). doi: 10.1186/s12909-022-03756-2. PMID: 36171608; PMCID: PMC9520930.
35. Asghar A, Naaz S, Patra A, Ravi K, Khanal L. Effectiveness of 3D-printed models prepared from radiological data for anatomy education: A meta-analysis and trial sequential analysis of 22 randomized, controlled, crossover trials. J Educ Health Promot. 2022;11(1):353. doi: 10.4103/jehp.jehp_199_22. PMID: 36567994; PMCID: PMC9768753.
36. Rose J, Chang DC, Weiser TG, Kassebaum NJ, Bickler SW. The role of surgery in global health: Analysis of United States inpatient procedure frequency by condition using the global burden of disease 2010 framework. PLoS One. 2014 Feb 26;9(2). doi: 10.1371/journal.pone.0089603. PMID: 24586967; PMCID: PMC3935922.
37. Yoon SY, Jung MC. Trends of intellectual property on musculoskeletal disorder, motion capture technology and ergonomics. J Ergon Soc Korea. 2015;34(5):437–45. doi: 10.5143/JESK.2015.34.5.437.
38. Fredieu JR, Kerbo J, Herron M, Klatte R, Cooke M. Anatomical models: a digital revolution. Med Sci Educ. 2015;25(2):183–94. doi: 10.1007/s40670-015-0119-6. PMID: 34363996.
39. European Patent Office. The EPO at a glance | Epo.org [Internet]. [cited 2023 Oct 12]. Available from: https://www.epo.org/en/about-us/at-a-glance
40. Cook DA, Hatala R, Brydges R, Zendejas B, Szostek JH, Wang AT, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. JAMA. 2011 Sep 7; 306(9):978–88. doi: 10.1001/jama.2011.1234. PMID: 21900138.
41. Kononowicz AA, Woodham LA, Edelbring S, Stathakarou N, Davies D, Saxena N, et al. Virtual patient simulations in health professions education: systematic review and meta-analysis by the Digital Health Education Collaboration. J Med Internet Res. 2019 Jul 1;21(7). PMID: 31267981; PMCID: PMC6632099.
42. Sargolzaei F, Omid A, Mirmohammad-Sadeghi M, Ghadami A. The effects of virtual-augmented reality training on anxiety among operating room students attending coronary artery bypass graft surgery. Nurs Midwifery Stud. 2021 Oct 1;10(4):229–35. doi: 10.4103/nms.nms_62_21.
43. Jenson CE, Forsyth DM. Virtual reality simulation: using three-dimensional technology to teach nursing students. Comput Inform Nurs. 2012 Jun;30(6):312-8; quiz 319-20. doi: 10.1097/NXN.0b013e31824af6ae. PMID: 22411409.
44. Sinou N, Sinou N, Filippou D. Virtual reality and augmented reality in anatomy education during COVID-19 pandemic. Cureus. 2023 Feb 19; 15(2):e35170. doi: 10.7759/cureus.35170. PMID: 36949987; PMCID: PMC10029107.
45. Shichinohe T, Kondo T, Date H, Hiramatsu M, Hirano S, Ide C, et al. Guidelines for cadaver dissection in education and research of clinical medicine (The Japan Surgical Society and The Japanese Association of Anatomists). Anat Sci Int. 2022 Jul;97(3):235–40. doi: 10.1007/s12565-022-00645-y. PMID: 35606673; PMCID: PMC9167807.
46. Owolabi JO, Tijani AA, Ihunwo AO. A need to protect the health and rights of anatomists working in dissection laboratories. Risk Manag Healthc Policy. 2022;15:889–93. doi: 10.2147/RMHP.S353385. PMID: 35547644; PMCID: PMC9081885.
47. Riederer BM. Plastination and its importance in teaching anatomy. Critical points for long-term preservation of human tissue. J Anat. 2014 Mar;224(3):309. doi: 10.1111/joa.12117. PMC3931543. PMID: 23621482; PMCID: PMC3931543.
48. Cheng H, Esmonde-White C, Kassay AD, Wunder ML, Martin C. Developing a hybrid four-prong approach to anatomical education during the COVID-19 pandemic. Med Sci Educ. 2021 Aug 1;31(4): 1529. doi: 10.1007/s40670-021-01306-y. PMID: 34026305; PMCID: PMC8131080.
49. Majumder MAA, Haque M, Razzaque MS. Editorial: Trends and challenges of medical education in the changing academic and public health environment of the 21st century. Front Commun (Lausanne). 2023 Mar 24;8:1153764. doi: 10.3389/fcomm.2023.1153764.