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ORIGINAL

Medical students' perceptions of anatomy teaching using technology and cadavers

Percepciones de estudiantes de medicina sobre la enseñanza de anatomía con tecnología y cadáveres

Artur Danieli do Amaral[1] ✉, Facundo Juan Manuel Correa[1] ✉

[1]Universidad Abierta Interamericana, Facultad de Medicina y Ciencias de la Salud. Buenos Aires, Argentina

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Corresponding Author
Artur Danieli do Amaral ✉

ABSTRACT

Introduction: anatomy is a fundamental subject in medical education and, in recent years, traditional cadav-eric dissection has increasingly been complemented by digital tools such as virtual and three-dimensional resources.
Method: a descriptive cross-sectional online survey was administered to 135 medical students from first to sixth year enrolled in different schools in Buenos Aires City, gathering information on how they had taken Anatomy, their use of technology, perceived advantages and disadvantages, and preferences regarding cadav-ers and digital resources.
Results: most students rated both cadaveric practice and technological tools positively but clearly favored a blended approach; more than half would still choose dissection if they had to select a single method, whereas many reported that technology improved understanding and supported out-of-class review, particularly among those who studied during the COVID-19 pandemic using virtual formats.
Conclusions: students do not view the issue as choosing between cadavers or technology, but rather express a desire to learn with both, suggesting that the most appropriate educational strategy is to deliberately combine traditional cadaver-based teaching with digital tools.

Keywords: Anatomy; Undergraduate Medical Education; Cadaver; Virtual Reality; Medical Students.

RESUMEN

Introducción: la anatomía es un componente esencial en la formación médica y, en los últimos años, se ha visto atravesada por la incorporación progresiva de recursos digitales que conviven con la disección tradicio-nal de cadáveres.
Método: se llevó a cabo un estudio observacional, descriptivo y transversal mediante una encuesta en línea aplicada a 135 estudiantes de primero a sexto año de Medicina de distintas facultades de la Ciudad Autónoma de Buenos Aires, relevando modalidad de cursada de Anatomía, uso de tecnología, ventajas, desventajas y preferencias respecto de cadáveres y recursos digitales.
Resultados: los encuestados otorgaron una valoración favorable tanto a la práctica con material cadavérico como al empleo de herramientas tecnológicas, aunque la mayoría se inclinó por un modelo combinado; más de la mitad optaría por la disección si debiera elegir un único recurso, mientras que una proporción conside-rable indicó que la tecnología facilita la comprensión de los contenidos y el repaso, especialmente en el con-texto de cursadas virtuales durante la pandemia de COVID-19.
Conclusiones: los estudiantes no plantean una oposición entre cadáveres y tecnología, sino que expresan el interés en aprender con ambos recursos, lo que sugiere que la estrategia pedagógica más adecuada es integrar de manera planificada las prácticas tradicionales y las herramientas digitales.

Palabras clave: Anatomía; Educación Médica de Pregrado; Cadáver; Realidad Virtual; Estudiantes de Medi-cina.

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INTRODUCTION

Anatomy represents a fundamental pillar of medical education, as it provides detailed knowledge of the structure of the human body, which is indispensable for clinical reasoning, surgical practice, and the interpretation of diagnostic images.[1,2,3] Traditionally, cadaver dissection is considered the "gold standard" in anatomical teaching, not only because it offers direct hands-on experience and realistic spatial perception but also because it allows students to encounter anatomical variability and fosters essential ethical and human values in professional training.[4,5,6]

In recent decades, the incorporation of educational technologies such as three-dimensional simulators, virtual reality, augmented reality, and interactive digital platforms has opened up new pedagogical possibilities. These tools are particularly valuable in contexts where access to cadaveric material is limited, complementing and enriching traditional teaching.[7,8,9]

Recent studies have explored the effectiveness of virtual reality (VR) in anatomy education. A systematic review with meta-analysis revealed that compared with traditional methods, immersive technologies, such as virtual and augmented reality (VR/AR), yield moderate improvements in the acquisition of anatomical knowledge.[1,10,11]

Another review focused exclusively on VR showed a moderate improvement in exam scores compared with other approaches, with an SMD of 0,53 (95 % CI 0,09–0,97).[2,12]

In Latin America, a survey of anatomists revealed that approximately 34 % report that their undergraduate students perform cadaver dissection in their courses. Although this practice is not included in all the curricula, most participants agree that dissection remains a fundamental tool for developing professional competencies and for adequately addressing the emotional dimensions associated with working with the human body.[3,13]

However, controversy persists regarding which of these approaches—the use of digital technologies or cadaver dissection—is more effective and better valued by medical students.

This study is based on the hypothesis that medical students view the complementary use of digital technologies in anatomy education positively, although they continue to regard cadaver dissection as a fundamental tool for their practical training. The objective is to survey future physicians' perceptions of anatomy education and compare the use of digital technologies with the use of cadavers.

METHOD

Study Design

An observational, descriptive, cross-sectional study was conducted based on an online survey. The main objective was to survey medical students' perceptions of the different modalities of anatomy teaching and compare the use of digital technologies with that of cadaver dissection.

Population and Sample

The population consisted of medical students in their first through sixth years. Most responses came from students at the Inter-American Open University (UAI), although students from other medical schools in the city of Buenos Aires also participated.

The sample was nonprobabilistic, selected for convenience, and consisted of 135 students who voluntarily completed the questionnaire. All first- through sixth-year students who agreed to participate and completed the form were included.

Setting

Data collection was conducted virtually using a questionnaire designed specifically for this study and distributed via WhatsApp groups, with the collaboration of doctors and peers who helped share it among different student groups. The form was available for three months, during which time responses were collected.

Instrument and variables

A self-administered questionnaire created on the Google Forms platform was used. The form included closed-ended and mixed-format questions organized into sections. The first section addressed general information (age, year of study, and sex), while the following sections explored the format in which anatomy was studied (in person, blended, or online), the frequency of technology use, and perceptions regarding the usefulness of each method. Some questions used a five-point Likert scale to assess the degree of agreement with various statements regarding learning, practice, and satisfaction. The perceived advantages and disadvantages of using cadavers and technology, as well as students' personal preferences regarding both methods, were also investigated.

The main variables considered were as follows:

- Teaching modality (in person, blended, or virtual).
- Perception of learning (assessed using a Likert scale).
- Preference for teaching methods (cadavers, technology, or both).

The complete questionnaire used is attached in appendix 1.

Statistical analysis

A descriptive statistical analysis of the data collected via the questionnaire was performed. Quantitative variables were summarized using measures of central tendency and dispersion, whereas categorical variables were described as absolute and relative frequencies, expressed as X.X% (n=Y). Data processing and tabulation were carried out using a spreadsheet (Microsoft Excel).

Ethical considerations

Participation was voluntary and anonymous and did not involve the collection of sensitive personally identifiable information. By accessing and completing the form, students provided their informed consent for the use of their responses for academic and research purposes.

RESULTS

Sample characteristics

A total of 135 completed questionnaires were analyzed, corresponding to 100,0 % (n=135) of the sample. The basic demographic characteristics of the participants (distribution by year of study and sex) are presented in table 1.

Table 1. General characteristics of the sample

Variable	Category	n	%
Year of study (n=135)	1st	48	35,6
	2nd	16	11,9
	3rd	20	14,8
	4th	16	11,9
	5th	13	9,6
	6th	22	16,3
Gender (n=135)	Female	87	64,4
	Male	48	35,6

Anatomy course history

Most students had previously taken Anatomy, representing 76,3 % (n=103) of the sample, while 23,7 % (n=32) reported being currently enrolled in the course at the time of response to the survey.

With respect to the calendar year in which Anatomy was taken, 5,2 % (n=7) of the participants were in person in 2018 or earlier, 6,7 % (n=9) were in person in 2019, 13,3 % (n=18) were online in 2020 due to the pandemic, 5,2 % (n=7) were online in 2021 due to the pandemic, 11,1 % (n=15) were in person in 2022, 13,3 % (n=18) were in person in 2023, 10,4 % (n=14) were in person in 2024, and 34,8 % (n=47) were currently being enrolled in 2025.

Regarding the format of the anatomy course, 76,3 % (n=103) reported having taken it entirely in person with access to cadavers, 17,0 % (n=23) took it entirely online using only digital resources during the pandemic, and 6,7 % (n=9) took it in a partially in-person or blended format. During the course, 84,4 % (n=114) indicated that they had access to cadaver lab sessions, whereas 15,6 % (n=21) reported not having such access.

Use of Technological Tools

With respect to the use of technological tools for learning anatomy (virtual reality, 3D models, interactive software), 27,4 % (n=37) used them frequently (1–2 times per week), and 15,6 % (n=21) used them very frequently (several times per week).

On the other hand, 25,9 % (n=35) used them sometimes (1–3 times a month), 17,0 % (n=23) rarely (less than once a month), and 14,1 % (n=19) reported not having used these types of resources

Perceptions of cadaver practice and technology

Perceptions were assessed using a five-point Likert scale (1 = strongly disagree, 5 = strongly agree); the complete distribution of responses for each statement is presented in Table 3.

With respect to the statement “Practicing with cadavers helped me better understand anatomy,” 70,4 % (n=95) agreed or strongly agreed, while only a minority disagreed, and 6,7 % (n=9) remained neutral.

In contrast, regarding “Technological tools improved my learning in anatomy,” 68,1 % (n=92) agreed or strongly agreed, and nearly one-fifth (19,3 %, n=26) remained neutral.

The statement “The combined use of cadavers and technology is the best teaching strategy” garnered the highest consensus, with 74,8 % (n=101) agreeing or strongly agreeing and only 14,8 % (n=20) disagreeing.

With respect to “Technological tools allow me to review outside the practical classroom,” 78,5 % (n=106) agreed or strongly agreed, and less than 12,0 % disagreed, indicating a high regard for technology as a review resource.

With respect to “The clinical rotation provided me with practical skills that technology cannot replicate,” 59,3 % (n=80) agreed or strongly agreed, while 21,5 % (n=29) remained neutral.

The statement “I feel better prepared for clinical practice because of technology” elicited more varied responses, with 37,0 % (n=50) agreeing or strongly agreeing, 38,5 % (n=52) remaining neutral, and 24,4 % (n=33) disagreeing.

Finally, “I am satisfied with the way anatomy is taught at my school” received 65,2 % (n=88) of the responses agree or strongly agree, whereas 18,5 % (n=25) disagreed and 16,3 % (n=22) remained neutral.

Perceived advantages and disadvantages of using cadavers

Among the advantages of using cadavers, the most frequently cited option was "more realistic knowledge of the human body," reported by 91,1 % (n=123), followed by "better spatial understanding of the organs" with 61,5 % (n=83), "greater knowledge retention" at 31,1 % (n=42), and "development of clinical skills" at 25,2 % (n=34), while only 1,5 % (n=2) chose "none of the above."

With respect to the disadvantages of using cadavers, 65,2 % (n=88) mentioned "deterioration over time," 60,7 % (n=82) cited "difficult access/limited availability," 30,4 % (n=41) "requires special facilities," 8,1 % (n=11) "emotional impact," and 8,9 % (n=12) indicated "none of the above."

Perceived advantages and disadvantages of using technology

Regarding the advantages of technology, 85,2 % (n=115) of the students selected "Greater accessibility and availability," 65,2 % (n=88) "Unlimited repetition of content," 42,2 % (n=57) "Interactivity and dynamism," and 28,1 % (n=38) "Lower cost and greater hygiene," while 3,0 % (n=4) selected "None of the above."

With respect to the disadvantages of technology, 51,1 % (n=69) identified "lack of realism," 48,9 % (n=66) "high cost of some resources," 34,8 % (n=47) "requires access to devices or the internet," 28,9 % (n=39) "may distract from the main content," and 8,1 % (n=11) selected "none of the above."

Barriers to the implementation of cadavers and technology

With respect to barriers to the use of cadavers in medical schools, the most frequently cited were "lack of donated bodies," which was mentioned by 66,7 % (n=90), followed by "high costs" at 28,9 % (n=39), "lack of physical space" at 27,4 % (n=37), "health/legal requirements" at 24,4 % (n=33), "ethical/cultural resistance" at 8,9 % (n=12), and "none of the above" at 20,7 % (n=28).

With respect to technology implementation, 52,6 % (n=71) cited "acquisition/licensing costs" as a barrier, 43,0 % (n=58) cited "lack of IT infrastructure," 28,9 % (n=39) cited "lack of teacher training," and another 28,9 % (n=39) cited "resistance to change," whereas 5,9 % (n=8) mentioned "little local evidence of effectiveness," and 20,0 % (n=27) cited "none of the above."

Overall preferences and perceptions regarding teaching methods

Table 2. Statement with which they most identify, by year of study (n=135)

Year of study	Both methods helped me equally	I learned better using cadavers	I learned better using technology	I didn't learn well with either	Total row
1st	45,8 % (n=22)	45,8 % (n=22)	6,2 % (n=3)	2,1 % (n=1)	48 (100 %)
2nd	43,8 % (n=7)	43,8 % (n=7)	12,5 % (n=2)	0,0 % (n=0)	16 (100 %)
3rd	65,0 % (n=13)	5,0 % (n=1)	25,0 % (n=5)	5,0 % (n=1)	20 (100 %)
4th	62,5 % (n=10)	6,2 % (n=1)	31,2 % (n=5)	0,0 % (n=0)	16 (100 %)
5th	61,5 % (n=8)	15,4 % (n=2)	23,1 % (n=3)	0,0 % (n=0)	13 (100 %)
6th	27,3 % (n=6)	36,4 % (n=8)	22,7 % (n=5)	13,6 % (n=3)	22 (100 %)

Table 3. Distribution of responses on the Likert scale regarding cadavers and technology (n=135)

Item	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Practicing on cadavers helped me better understand anatomy	10	21	9	33	62
Technological tools improved my learning in anatomy	5	12	26	52	40
The combined use of cadavers and technology is the best teaching strategy	10	10	14	38	63
Technological tools allow me to review outside the classroom	9	7	13	35	71
The internship gave me practical skills that technology cannot replicate	7	19	29	24	56
I feel better prepared for clinical practice thanks to the dissection	14	26	34	23	38
I feel better prepared for clinical practice thanks to technology	6	27	52	35	15
I am satisfied with the way anatomy is taught at my school	15	10	22	41	47

When the statements with which they most identified were analyzed, 48,9 % (n=66) indicated that "Both methods helped me equally," 30,4 % (n=41) reported having learned better using cadavers, 17,0 % (n=23) stated having learned better with technology, and 3,7 % (n=5) noted that they did not learn well with either method. With respect to the preferred method, 58,5 % (n=79) chose cadavers, 31,1 % (n=42) preferred technology, and 10,4 % (n=14) stated that they had no preference.

When asked whether the combined use of cadavers and technology should be mandatory in anatomy education, 71,1 % (n=96) answered "Yes," 14,8 % (n=20) answered "No," and 14,1 % (n=19) indicated "I'm not sure." Finally, regarding the possibility that technology might completely replace the use of cadavers in the future, 41,5 % (n=56) believed this would not be possible, 34,1 % (n=46) answered "Yes," and 24,4 % (n=33) estimated that the replacement could be only partial.

DISCUSSION

In this study, which was conducted among 135 medical students from different years, it was observed that most students value both cadaver-based practices and the use of technological tools but prefer an approach that combines both resources rather than the complete replacement of one by the other. Nearly half reported that both methods were equally useful to them; more than one-third would choose cadaver dissection as the sole resource, and only a portion of the sample believed that technology could fully or partially replace cadavers.[14,15,16]

A significant proportion of the participants took the Anatomy course in 2020–2021 in an online format because of the pandemic, and this group reported using technological tools more frequently to study and review; this context helps explain the high level of agreement regarding the usefulness of technology, without altering the overall preference for continuing with cadaver-based practices. Even among those who took the course in a virtual format, reservations are observed when the complete replacement of cadaveric material with digital resources is proposed, suggesting that the pandemic experience reinforced the value of technology as a support but not as a substitute for in-person dissection.[17,18]

This profile is consistent with recent studies describing similar perceptions: students continue to view cadaveric dissection as a central experience for understanding anatomy and developing clinical skills, although they support the incorporation of virtual resources as a complement rather than a replacement.[4,5] In fact, other authors report that students tend to view virtual dissection as a complement rather than a replacement for traditional dissection,[5] in line with the preference for the blended model observed in this study.[19,20,21]

Various studies that integrate virtual components into courses primarily based on cadaveric dissection have shown that students view digital platforms positively, highlighting improved anatomical visualization and the ability to review material outside the laboratory.[6] This is also reflected in our data, where a significant proportion of respondents indicate that technological tools enhance their learning and facilitate independent review.[22,23]

Interpretation of the findings

The fact that cadaveric dissection remains the preferred method when students must choose a single resource suggests that they perceive it as the most comprehensive means of integrating theory, practice, and professional experience.[4,5] According to recent studies, working with cadavers not only promotes a more accurate three-dimensional understanding but also allows for the development of manual skills and ethical experiences associated with the donated human body—aspects that technology has not yet fully replicated.[4,24]

Moreover, the widespread acceptance of combined use and the high level of agreement regarding the value of digital tools for review indicate that students view anatomy education as a hybrid process. Virtual resources facilitate exploring sections in different planes, repeating procedures, and adapting the pace of study, which explains why they are perceived as powerful complements to in-person learning.[6]

The more varied distribution of responses to the statement "I feel better prepared for clinical practice because of technology" suggests that while these resources help organize and understand content, they are not yet considered equivalent to experience with real human material in terms of clinical preparation.[5,6] Other studies have reached similar conclusions: after virtual components are incorporated into dissection-based courses, they describe improvements in visualization and theoretical performance but emphasize that the digital experience should be understood as a complement and not as a substitute for traditional dissection.[4,5,6]

Furthermore, when differences were analyzed by year of study, it was observed that in the early years, the prevailing perception was that both methods were equally helpful, whereas in more advanced courses, the proportion of students reporting having learned better through cadaveric dissection increased, which could be linked to a more clinical perspective on anatomy (table 2). Notably, despite the perceived difficulties in accessing cadavers and technological infrastructure, most participants are satisfied with how anatomy is taught at their faculty, suggesting that students value the institutional effort to combine different strategies.[25,26]

Implications, limitations, and future directions

Overall, the results support the advisability of maintaining access to cadaver-based practices whenever possible, integrating them with digital resources that serve as structured learning support.[4,5,6] The combination of dissection and virtual tools allows leveraging both the realism and tactile experience of the cadaver and the flexibility, repetition, and improved visualization offered by technologies.

Students' own perceptions also point to specific areas for improvement: with respect to cadavers, they frequently mention the lack of donated bodies, costs, and health requirements, which reinforces the need for donation policies, ethical handling, and resource optimization.[4] With respect to technologies, they highlight the lack of realism and the costs of licenses and equipment,

which necessitate considering economic feasibility and available infrastructure before implementing advanced solutions.[6]

Among the main limitations of this study are the cross-sectional design and the nonprobabilistic convenience sample, which restrict the generalizability of the findings, as well as the absence of inferential analyses, which limits the interpretation of differences between subgroups to a descriptive level only.[5,6] Future research could evaluate interventions that more systematically integrate virtual resources into cadaveric courses, measuring not only perceptions but also objective learning outcomes and the evolution of students' attitudes throughout their academic careers.[4,5,6]

CONCLUSIONS

The present study sought to understand how medical students experience anatomy education when they use cadaver-based practices, technological tools, or a combination of both.

The responses from 135 students across different years revealed that most valued both resources but felt more comfortable with a blended model, where cadaveric dissection remained central and technology served as support.

In this sample, many students chose dissection as their sole method if they had to choose because they associate it with more realistic learning and skills that technology cannot yet fully replicate, while digital tools stand out for facilitating understanding and review—a point particularly evident among those who took courses virtually during the pandemic.

Ultimately, the participants noted that each modality has its strengths and limitations, which presents medical schools with the challenge of designing proposals that systematically integrate cadaver-based practices with virtual resources, taking into account the barriers to access, costs, and infrastructure they describe.

This study is descriptive and was conducted at a single university with a nonprobabilistic sample; therefore, its results should be interpreted with caution and cannot be automatically generalized to all contexts. However, the internal consistency of the data and its alignment with the available literature suggest that it offers a useful perspective for further reflection on anatomy education in hybrid settings.

FINANCING

None.

CONFLICT OF INTEREST

None.

AUTHORSHIP CONTRIBUTION

Conceptualization: Artur Danieli do Amaral, Facundo Juan Manuel Correa.
Data curation: Artur Danieli do Amaral, Facundo Juan Manuel Correa.
Formal analysis: Artur Danieli do Amaral, Facundo Juan Manuel Correa.
Drafting - original draft: Artur Danieli do Amaral, Facundo Juan Manuel Correa.
Writing - proofreading and editing: Artur Danieli do Amaral, Facundo Juan Manuel Correa.

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ANNEXES

Appendix 1. Questionnaire administered to medical students—the Google Forms platform

1. What year of medical school are you in? *
    - 1st
    - 2nd
    - 3rd
    - 4th
    - 5th
    - 6th

2. Age:* (Open-ended response)
3. Gender (optional):
    - Female
    - Male
    - Other/Nonbinary
    - I prefer not to answer

4. Have you taken the Anatomy course? *
    - Yes
    - No
    - I am currently taking it

5. In which calendar year did you take the Anatomy course? *
    - 2018 or earlier (in person)
    - 2019 (in person)
    - 2020 (online due to the pandemic)
    - 2021 (online due to the pandemic)
    - 2022 (in person)
    - 2023 (in person)
    - 2024 (in person)
    - 2025 (currently enrolled)

6. How was your anatomy course? *
    - Entirely in person with access to cadavers
    - Partially in person (hybrid: cadavers + digital resources)
    - Fully online (digital resources only/pandemic)
    - I haven't taken Anatomy yet

7. If you took Anatomy online (during the pandemic), compared to in-person classes, do you consider that the learning experience was: (Check all that apply)
    - Much worse than in person
    - Worse than in person
    - Similar
    - Better than in-person
    - Much better than in-person

Experience with teaching methods

8. Did you have access to cadaver lab sessions during the Anatomy course?
    - Yes
    - No

9. How often did you use technological tools (virtual reality, 3D models, interactive software) to learn anatomy?
    - Never
    - Rarely (less than once a month)
    - Sometimes (1–3 times a month)
    - Frequently (1–2 times/week)
    - Very frequently (several times a week)

Perception (Likert scale)

10. Indicate your level of agreement with the following statements:* (Scale from 1-Strongly Disagree to 5-Strongly Agree)
    - Practicing on cadavers helped me better understand anatomy.
    - Technological tools improved my learning in anatomy.
    - The combined use of cadavers and technology is the best teaching strategy.
    - Technological tools allow me to review outside the practical classroom.
    - Practical training gave me hands-on skills that technology cannot replicate.
    - I feel more prepared for clinical practice because of dissection.
    - I feel more prepared for clinical practice because of technology.
    - I am satisfied with the way anatomy is taught at my school.

Advantages and disadvantages

11. Advantages of using cadavers:* (Check all that apply)
    - More realistic understanding of the human body
    - A better spatial understanding of the organs
    - Development of clinical skills
    - Improved retention of knowledge
    - None of the above

12. Disadvantages of using cadavers:* (Check all that apply)
    - Difficult access/limited availability
    - Emotional impact
    - Requires special facilities
    - Deterioration over time
    - None of the above

13. Advantages of using technology:* (Check all that apply)
    - Greater accessibility and availability
    - Unlimited content playback
    - Interactivity and dynamism
    - Lower cost and better hygiene
    - None of the above

14. Disadvantages of using technology:* (Check all that apply)
    - Lack of realism
    - High cost of some resources
    - Requires access to devices or the internet
    - May distract from the main content
    - None of the above

Preferences and the future

15. Which of the following statements do you identify with most? *
    - I learned better using cadavers
    - I learned better using technology
    - Both methods helped me equally
    - I didn’t learn well with either

16. If you had to choose just one method, which would you prefer for learning anatomy?
    - Cadavers
    - Technology
    - I have no preference

17. Do you think that the combined use of cadavers and technology should be mandatory in anatomy education?
    - Yes
    - No
    - I’m not sure

18. Do you think that in the future, technology will be able to completely replace the use of cadavers?
    - Yes

- No
- Partially

19. Main barriers to implementing cadavers at your school:* (Check all that apply)
    - Shortage of donated bodies
    - High costs
    - Health and legal requirements
    - Lack of physical space
    - Ethical/cultural resistance
    - None of the above

20. Main barriers to implementing technology in your department:* (Check all that apply)
    - Acquisition/licensing costs
    - Lack of faculty training
    - Lack of IT infrastructure
    - Little local evidence of effectiveness
    - Resistance to change
    - None of the above

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