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Rat Dissection Alternatives in Biology Education: A Systematic Literature Review

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Abstract

Despite the importance of both rat dissection and alternatives for rat dissection, proponents for these alternatives became more apparent during the COVID-19 pandemic and post-pandemically. Incorporating humane education into the Malaysian education system, whereby 3R (reduction, replacement, or refinement) is urged, aligns with the United Nations Sustainable Development Goals (SDGs). Utilising technology is an essential component of any 21st-century learning. Therefore, this study was carried out to explore the need for alternatives in rat dissection that provide both a high learning experience and feasibility using the Systematic Literature Review (SLR). Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) technique is employed. Examining selected literature revealed a substantial positive effect on the student's learning experience regarding perception, task performance, exam performance, and motivation. It is found to be either superior or equivalent to the intended outcomes. This study has also identified the feasibility aspects of the alternatives of rat dissection with respect to the USE model. They were classified into sustainability, affordability, accessibility, and motivation. This study delves into the need for alternatives in rat dissection redesigning in 21st-century learning with high usability that is readily accessible, affordable, and sustainable. Innovation and reform are required to ensure better education through ICT integration, aligning with the Malaysian Digital Education Policy. Thus, it can be concluded that the ideal alternative for rat dissection is Three-Dimensional (3D) models complemented by virtual tools.

Keywords: rat dissection alternatives, humane education, rat dissection, dissection

INTRODUCTION

In the context of biology education, dissection is one of the suggested activities to be carried out in schools. As in Malaysia, frog dissection is indicated for the secondary school/SPM/O-level equivalent syllabus, while rat dissection is in the sixth-form/STPM/A-level equivalent and matriculation/science foundation syllabus.

Thus, many are proponents of hands-on dissection practicals being implemented in schools, especially educators. [1] and [2] are the significant proponents of rat dissection. In addition, [3] and [4] mention that cultivating manipulative skills/dexterity in dissection still applies post-pandemic. However, virtual dissections took off faster during the pandemic. They suggested the return to the whole hands-on experience in learning through dissections [4]. Before the pandemic, most educators and learners were interested in conducting anatomical organ dissections, citing enhanced comprehension, enduring knowledge retention, and increased motivation [5].

In addition, religious views are difficult to separate from the context of Malaysian education. For example, frog dissection in schools. Is it forbidden or permissible? In the debate on Islamic jurisprudence, scholars differ in their opinions about the law of frog dissection, separating into two groups [6]. They agree that if there is a substitute for another animal, such as a rat, then that substitute should be used and not a frog to avoid "khilaf"/error [6]. Hence, educators seek frog dissection alternatives, although the practice is continued in the vernacular schools. Rat dissection practicals are carried out in schools as they are the preferred choice.

However, the proponents for humane education in rat dissection are gaining momentum in Malaysia, especially in sixth-form, matriculation and even A-level education. Rat dissection is compulsory and is to be assessed in practical examinations as part of the nationalised standardised curriculum. Consequently, an alternative to dissection should be proposed to the ministry, with an actual comprehensive study in the Malaysian context. In addition, based on the systematic review by [7], they proposed the steps educational institutions should take to phase out animal dissection.

Lately, studies on rat dissection in the academic setting have been more concerned with humane education in dissection. Some researchers have investigated alternatives to implement dissection. However, the effectiveness of these alternatives is still questionable due to the low acceptance rate of teachers and students. Some believe that other options for rat dissection are less efficient in delivering student education. Indeed, many issues arise regarding these alternatives, such as their usability and motivation. The primary against motivation is the lack of high-quality alternatives that seemingly utilise technology highly [3]. Besides that, a squeamish student might also be reluctant to participate in a rat dissection [8]. Even from the perspective of qualitative studies, little research has examined the effectiveness and impact of visual literacy in rat dissection practicals. Most recently, there has been only one study by [9] on matriculation education in Malaysia. Nonetheless, the effectiveness study is only on the motivation aspect. Therefore, there is a need for an effectiveness study of performance achievement as well. To be more precise, the acquisition of visual literacy is achieved through 1) anatomical organ identification and 2) drawing and labelling skills. The researchers suggested following up with a different target group, such as sixth-form education [9].

Besides that, researchers worldwide have many suggestions for alternatives to implement rat dissection. However, none is in the Malaysian context. A study designed for Malaysia is thus regarded as crucial since many sought to incorporate humane education into the education system. It echoed one of the proponents of humane education in Malaysian schools [10], either by replacing rat dissection in secondary schools with alternatives for dissection or by reducing the usage of actual organisms. Group work in dissection minimises the number of organisms used [11]. Replacement, reduction and refinement (3Rs) are humane education's three core principles. Even the Malaysian Education Ministry emphasised incorporating humane education [12].

METHODOLOGY

This research is founded on a systematic literature evaluation from 1994 to 2023. The latest material has been introduced to advance the ongoing discourse regarding the role of humane education, particularly in rat dissection. The study exclusively concentrates on alternatives to rat dissection. Currently, two recent systematic reviews exist on dissection: [13] and [7]. Nonetheless, both reviews lack precision, focusing on rat dissection while encompassing other taxa, including cats, frogs, and fetal pigs. The articles that were collected were analysed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards. The four stages of PRISMA are a) identification, b) screening, c) eligibility, and d) inclusion. This technique was utilized to assist the researcher in synthesizing pertinent journal articles. Figure 1 delineates the procedures employed in PRISMA, which are modified from [14].

A. Identification

The literature was thoroughly examined using ERIC, ProQuest, and Google Scholar databases, as they encompass a vast array of comprehensive paid databases [15]. It was considered adequate and thorough in the literature [16]. Keywords including "rat dissection alternatives," "humane education," "rat dissection," and "dissection" were employed for identification purposes. The keywords employed must be interconnected using OR, AND, or an appropriate logical operator. A total of 60 journal articles were identified at this stage.

B. Screening

The screening criteria are limited to selecting only research-based papers regarding a) advocates for dissection, b) advocates for alternatives to dissection, and c) humane education related to dissection. Priority is assigned to rat dissection rather than dissection in general and humane education. A review of titles and abstracts eliminated the redundant articles. Following the screening process, 27 journal articles failed to meet the research criteria, and 15 duplicate papers were eliminated, resulting in a total of 18 articles.

C. Eligibility

Eighteen journal articles were meticulously reviewed, concentrating on the title, abstract, methodology, findings, and discussions to confirm their alignment with the study's scope and objectives. Eight journal articles have been excluded due to their failure to address humane and non-humane sampling (six articles) and inadequate discussion of study results (two articles).

D. Inclusion

Ultimately, only 10 journal papers conforming to the specified criteria were selected for this investigation. This qualitative document selection adherence to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) criterion [17] was ensured.

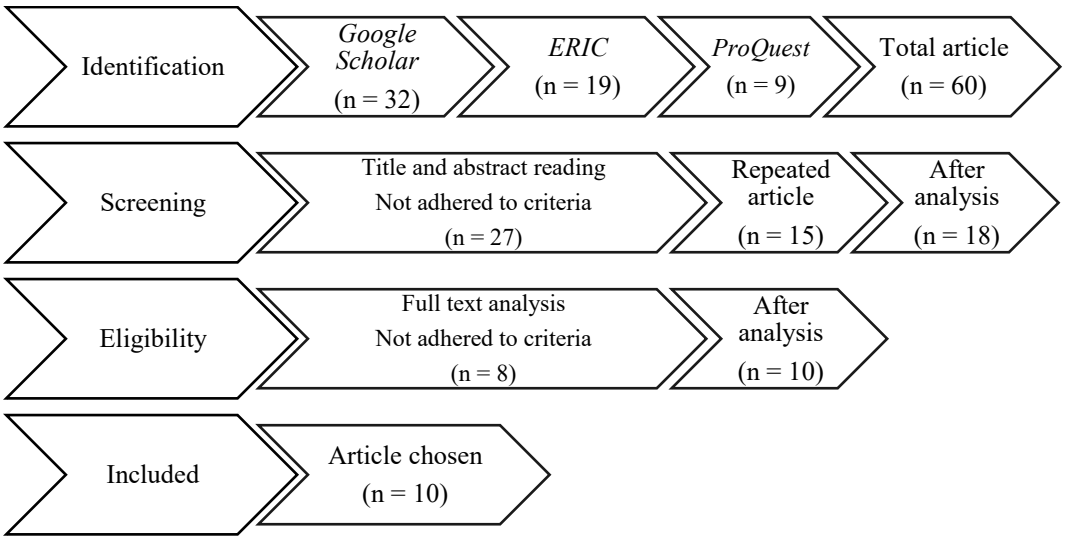

Figure 1: Adapted and altered process of article selection from [14]

RESULTS OF THE STUDY

A. Summary of the Selected Article Journals

The 10 article journals are analysed into various categories: research (year), alternatives employed, sampling (country), humane (total), methodology, general comments, and sources. The results are summarised in Table 1.

Table 1: Summary of the selected article journals on rat dissection alternatives

Research	Alternative Employed	Sampling (Country)	Humane (Total)	Methodology	General Comments	Source
[18]	Computer simulation - virtual	14 tertiary students (USA)	6 (14)	Experimental accompanied by a survey	Resources are only available in universities. However, revision is needed as technology rapidly advances.	Advances in Physiology Education [Q2]
[19]	Model, chart and diagram	2913 tertiary students (UK)	256 (2913)	Experimental accompanied by a survey	Standardisation can be obtained. Six-year study span.	Journal of Biological Education [Q2]
[20]	Video - virtual	350 tertiary students (Brazil)	108 (350)	Experimental accompanied by a survey	Standardisation can be obtained.	Advances in Physiology Education [Q2]
[21]	3D plastic model	59 tertiary students (Slovakia)	14 (59)	Experimental	Standardisation can be obtained.	Journal of Baltic Science Education [Q2]

Research	Alternative Employed	Sampling (Country)	Humane (Total)	Methodology	General Comments	Source
[22]	Plastinated (preserved) specimen	87 secondary students (Brazil)	29 (87)	Experimental accompanied by a survey	The specimen is unique and different, depends on quality, and is not a real-life visual (preservation distortion).	Anatomical Sciences Education [Q1]
[23]	Clay modelling	747 tertiary students (USA)	304 (747)	Experimental accompanied with survey	Standardisation is not possible in clay modelling. Depends on the instructors/educators. Some students found it a distraction from the primary objective.	Anatomical Sciences Education [Q1]
[24]	Computer simulation - virtual	332 adults (Germany)	332 (332)	Survey	Resources are only limited to that university.	Animals [Q1]
[25]	Computer simulation - virtual	105 tertiary students (UK)	53 (105)	Experimental accompanied by a survey	Resources are only available in universities. However, revision is needed as technology rapidly advances.	ALT-J
[9]	Padlet - virtual	120 matriculation students (Malaysia)	80 (120)	Experimental accompanied by a survey	Use Padlet for a motivational study that does not include performance evaluation of learning experiences.	KonPPI-1
[26]	Computer simulation - virtual	391 tertiary students (Australia)	233 (391)	Experimental	Resources are only available in universities. However, revision is needed as technology rapidly advances.	Journal of Biological Education [Q2]

B. Thematic Analysis of the Intended Outcomes from Implementing Alternatives in Rat Dissection

The 10 studies have reported positive effects, either superior or equivalent, when implementing rat dissection alternatives in the context of the learning experience. Learning experience was classified into a) perception, b) task performance, c) exam performance, and d) motivation. The results are summarised in Table 2.

Table 2: Thematic analysis of outcomes from the research

Research	Major Findings	Learning Experience			
		Perception	Task Performance	Exam Performance	Motivation
[18]	Equivalent	*	-	*	-
[19]	Equivalent	*	-	*	-
[20]	Equivalent	*	-	*	-
[21]	Equivalent	-	-	*	-
[22]	Superior	*	-	*	-
[23]	Superior	*	-	*	-
[24]	Superior	-	*	-	-
[25]	Equivalent	*	-	*	-
[9]	Superior	-	-	-	*
[26]	Superior	-	-	*	-

Note: * indicated the specific learning experience; - means none

C. Analysis of the Alternatives Feasibility in the USE Model Context

The 10 studies have suggested alternatives to replace hands-on rat dissection, aligning with humane education 3Rs principles (replacement, reduction and refinement). There is a need to use animal-free alternatives as they allow the achievement of the learning objectives more effectively and have several advantages over animal use. However, many issues arise regarding these alternatives, their usability, feasibility, and the motivation to use them. The primary against motivation is the lack of high-quality alternatives that seemingly utilise technology highly [3]. Before this, educational technology setbacks were often suspected to be due to a lack of cognitive and motivational models [27].

Hence, for all these alternatives, often known as educational technology, it is applicable to incorporate the Usefulness, Satisfaction, and Ease of Use (USE) model by [28] into the modified Technological Pedagogical Content Knowledge (TPACK) by [29]. All educational technology has to be robust educationally and technologically [30] with high usability and feasibility. These factors were categorized as sustainability (usefulness), affordability (ease of use), availability (accessibility/ease of learning), and motivation (satisfaction). The results are summarised in Table 3.

Table 3: Analysis of the alternative's feasibility in the USE model context

Research	Alternatives Feasibility in the USE Model Context			
	Sustainability (Usefulness)	Affordability (Ease of use)	Availability (Ease of learning)	Motivation (Satisfaction)
[18]	↑	↓	↓	↑
[19]	↑	↑	↑	↑
[20]	↑	↑	↑	↑
[21]	↑	↑	↑	↑
[22]	↑	↓	↓	↑
[23]	↑	↑	↑	=
[24]	↑	↓	↓	↑
[25]	↑	↓	↓	↑
[9]	↑	↑	↑	↑
[26]	↑	↓	↓	↑

Note: ↑ indicates high; ↓ indicates low; = indicates moderate

DISCUSSIONS

This section deals with the research results in two main parts: intended outcomes from implementing alternatives in rat dissection, and b) alternatives feasibility in the USE model context.

The ten studies of this Systematic Literature Review (SLR) found that regardless of the reason for seeking alternatives for rat dissection, a common theme emerges: teachers need effective learning tools to illustrate patterns, modelling, and variation [8]. The results show that educational technology alternatives are superior or equivalent in quality and learning experience for students. In addition, [13], in their SLR on all organisms used in dissections, found that 90.0% of the assessed studies found that humane teaching methods provide superior or equivalent learning experiences to harmful animal use. They also mentioned that harmful animals used for teaching and training are not justified [13].

The ten studies of this SLR and from reviews by [7] and [13] revealed a substantial positive effect on the student's learning experience regarding perception, task performance, exam performance, and motivation. Only one of the studies emphasised the motivational aspects, whereas the other nine focused on the cognitive aspects. Besides that, none of these studies encompassed all these four categories of learning experience. Extensive studies in Western contexts have inspired new opportunities to enrich theoretical and practical interpretation within Malaysian contexts. Thus, a study encompassing all four mentioned components of the learning experience is essential in this 21st-century learning. Indeed, it can be achieved through a standardised, useful, easily affordable, accessible and sustainable alternative for all, not just ethical.

However, the against motivation notion for these alternatives is primarily due to a) lacking high-quality alternatives, b) the conviction that alternatives are not as good, c) lacking time to prepare alternative methods, and d) lacking funding [3]. Although dissection manipulative skill/dexterity and ethics are a concern, the alternatives for dissection provide superior or equivalent learning experiences [13], and are based on this SLR. Indeed, some researchers used alternatives to complement hands-on dissection practicals [2], [31]. In addition, alternatives for rat dissection in humane education act as a dissection replacement [7], [8], [22], [32]. However, [30] did mention that all alternatives have their pitfalls and suggested only educational and technologically robust alternatives. Indeed, the ten studies of this SLR also found that regardless of the reason for seeking alternatives for rat dissection, some alternatives, often known as educational technology, are not highly feasible to implement. There is a lack of cognitive and motivational models [27] in the design of these alternatives. Thus, rat dissection needs redesigning in 21st-century learning [1]. There is a need for future alternatives with high sustainability (usefulness) that are easily affordable (ease of use), accessible (ease of learning), and motivating (satisfaction).

The proponents of alternatives for rat dissection all started in early 2001. [26] used virtual rat dissection, a viable alternative to using animals in biology classrooms. The researchers listed many benefits of virtual dissection, including students obtaining higher scores [26]. However, the availability of the alternative is confined to that class only. The research on virtual rat dissection is further explored by [32]. However, the issue of the availability of the software for all has not been addressed, with limited usage of virtual reality [32]. In addition, [33] mentioned that including dissection courses in the content of primary and secondary education science and biology courses is controversial at the international level. Hence, more studies should be conducted on alternatives. The researcher did qualitative research on virtual frog dissection regarding the reflections of hands-on dissection compared to virtual dissection experiences [33]. The researcher also stressed that when necessary, the importance of using these alternatives emerges when

considering the class size, cost, and the implementation of remote education applications. Therefore, it would be helpful to prepare the necessary environments for realising applied, virtual alternatives, or hybrid applications, depending on the circumstances. Besides that, [22] used the plasticine model as an alternative to dissection. Their study provided further evidence to support using plastinated specimens as an effective teaching method in countries where dissection is not feasible as it is banned due to the incorporation of humane education. It is also supported by [8], who suggested using 3D models in American schools.

Moreover, based on the systematic review by [7], they proposed steps that educational institutions should take to phase out animal dissection. Their results provide compelling evidence in support of the 3Rs' principle of replacement in humane education [7]. However, the review is not only confined to rat dissection but also has a broader scope. Based on the review by [7] and suggestions by [8], it can be concluded that the ideal alternative for rat dissection is of virtual tools and Three-Dimensional (3D) models. Building on the robust foundation of previous research, this SLR offers a unique synthesis by suggesting an alternative to rat dissection. These ten studies also employed either a virtual component or a model. Thus, a new alternative to rat dissection is suggested, whereby 3D models are complemented by virtual tools, aligning with the Malaysian Digital Education Policy and the United Nations Sustainable Development Goals (SDGs). A lower-cost alternative, such as a paper model with a virtual tool, offers a new innovative approach, building on established concepts by extending their application into a novel context. This alternative is an easily accessible, sustainable, and standardized alternative throughout the school biology curriculum, which the Ministry of Education will hopefully adopt. The intended outcomes will still be achieved without any policy changes. There is an ethical option for students and teachers to choose from.

CONCLUSION

This study conducted an SLR to explore the need for alternatives in rat dissection that both provide a high learning experience and feasibility. A general conclusion was made based on the analysis of the ten previous studies that had been conducted, confining to rat dissection only. There is a significant positive impact on the student's learning experience regarding perception, task performance, exam performance and motivation. It is found to be either superior or equivalent to the intended outcomes. This study has also identified the feasibility aspects of the alternatives for rat dissection in relation to the USE model by [28]. They were classified into sustainability (usefulness), affordability (ease of use), accessibility (ease of learning), and motivating (satisfaction). This study delves into the need for alternatives in rat dissection redesigning in 21st-century learning [1]. There is a need to select alternatives with high usability that are easily accessible, affordable and sustainable. Innovation and reform are required to ensure better education through ICT integration. Besides that, cognitive and motivational models [27] should be incorporated into these alternative' designs. Based on the review by [7] and suggestions by [8], it can be concluded that the ideal alternative for rat dissection is 3D models complemented by virtual tools.

The research chosen for this systematic review primarily concerns rat dissection learning, whereby school students are the respondents. The researcher's proposed study primarily focuses on Malaysian sixth-form biology students in rat dissection as their laboratory work. The researcher's suggested topic is the development of rat dissection alternatives and their impact on visual literacy skills and motivation in sixth-form dissection. Hopefully, the additional research mentioned in this study will be thoroughly investigated in the context of Malaysian biology education.

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CONFLICT OF INTEREST

We declare no conflict of interest in this article

AUTHOR CONTRIBUTION

Teoh Chern Zhong Conceptualization, Methodology, Software. **Muhamad Ikhwan Mat Saad**: Data collection, Writing original draft. **Rosmilah Misnan**: Visualization, Investigation. **Mohamad Termizi Borhan**: Supervision. **Wong Yoke Seng**: Software, Validation, Writing. **Lee Hoi Yeh**: Reviewing and Editing

DATA AVAILABILITY

All data generated or analyzed during this study are included in this published article.

DECLARATION OF GENERATIVE AI

Not applicable.

ETHICS

Not applicable.

REFERENCES

[1] A. Mager, "Redesigning dissection lessons: Considerations for a meaningful 21st century learning experience," *Learn. to Teach*, vol. 8, no. 1, pp. 124–129, 2019.
[2] S. G. Kalthur, A. K. Pandey, and S. Prabhath, "Benefits and pitfalls of learning anatomy using the dissection module in an Indian medical school: A millennial Learner's perspective," *Transl. Res. Anat.*, vol. 26, pp. 1–6, 2022, doi: 10.1016/j.tria.2021.100159.
[3] M. A. Zemanova, "Attitudes toward animal dissection and animal-free alternatives among high school biology teachers in Switzerland," *Front. Educ.*, vol. 7, no. May, pp. 1–10, 2022, doi: 10.3389/feduc.2022.892713.
[4] S. Z. Y. Ooi and R. Ooi, "Impact of SARS-CoV-2 virus pandemic on the future of cadaveric dissection anatomical teaching," *Med. Educ. Online*, vol. 25, no. 1, pp. 2–4, 2020, doi: 10.1080/10872981.2020.1823089.
[5] Omar Amahmid *et al.*, "Animal use in life sciences education: Current status, teachers' and adolescents' attitudes and alternatives," *Anatol. J. Educ.*, vol. 4, no. 2, pp. 69–80, 2019, doi: 10.29333/aje.2019.428a.
[6] Pejabat Mufti Wilayah Persekutuan, "Al-Kafi #414: Hukum membedah katak bagi tujuan belajar," *Al Kafi li al-Fatawi*. 2016, [Online]. Available: https://muftiwp.gov.my/artikel/al-kafi-li-al-fatawi.
[7] E. Ormandy *et al.*, "Animal dissection vs. non-animal teaching methods: A systematic review of pedagogical value," *Am. Biol. Teach.*, vol. 84, no. 7, pp. 399–404, Sep. 2022, doi: 10.1525/ABT.2022.84.7.399.
[8] J. D. Sack and K. C. Suder, "Getting nerdy with Mel and Gerdy: Scienstructable 3D dissection models, paper & digital," *Am. Biol. Teach.*, vol. 85, no. 3, pp. 178–178, Mar. 2023, doi: 10.1525/ABT.2023.85.3.178.
[9] Muhamad Shakir Saad, Che Jamaliah Abd Manaf, Nor Hayati Samsudin, and Noor Nadhirah Omar, "Keberkesanan penggunaan Padlet dalam proses pembelajaran amali tikus terhadap motivasi bahan pengajaran pelajar," in *Konvensyen Penyelidikan, Professional Learning Communities dan Inovasi Pendidikan Program Matrikulasi KPM Kali Pertama Tahun 2021*, Oct. 2021, pp. 187–201, Accessed: Apr. 03, 2023. [Online]. Available: https://sites.google.com/view/konppi1-2021/home.

[10] K. Y. Chan, "The need for humane education in school curricula," *Free Malaysia Today (FMT)*, Petaling Jaya, Dec. 15, 2022.
[11] F. A. de Oliveira and M. M. Gomes, "School practices in the office of the Natural History/Biology teaching laboratory at Colégio Pedro II (1960-1970)," *Brazilian J. Hist. Educ.*, vol. 23, no. 1, pp. 1–24, Feb. 2023, doi: 10.4025/rbhe.v23.2023.e255.
[12] Malay Mail, "One-year Madani govt: Education ministry prioritises humane education, accessible learning, says minister," 2023. https://www.malaymail.com/news/malaysia/2023/12/04/one-year-madani-govt-education-ministry-prioritises-humane-education-accessible-learning-says-minister/105693 (accessed Sep. 15, 2024).
[13] M. A. Zemanova and A. Knight, "The educational efficacy of humane teaching methods: A systematic review of the evidence," *Animals*, vol. 11, no. 1, pp. 1–17, 2021, doi: 10.3390/ani11010114.
[14] D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman, "Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement," *J. Clin. Epidemiol.*, vol. 62, no. 10, pp. 1006–1012, 2009, doi: 10.1016/j.jclinepi.2009.06.005.
[15] M. Gusenbauer and N. R. Haddaway, "Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources," *Res. Synth. Methods*, vol. 11, no. 2, pp. 181–217, Mar. 2020, doi: 10.1002/jrsm.1378.
[16] M. Gusenbauer, "Google Scholar to overshadow them all? Comparing the sizes of 12 academic search engines and bibliographic databases," *Scientometrics*, vol. 118, no. 1, pp. 177–214, 2019, doi: 10.1007/s11192-018-2958-5.
[17] E. von Elm, D. G. Altman, M. Egger, S. J. Pocock, P. C. Gøtzsche, and J. P. Vandenbroucke, "The strengthening the reporting of observational studies in epidemiology (STROBE) statement: Guidelines for reporting observational studies," *Int. J. Surg.*, vol. 12, no. 12, pp. 1495–1499, 2014, doi: 10.1016/j.ijsu.2014.07.013.
[18] D. G. Dewhurst, J. Hardcastle, P. T. Hardcastle, and E. Stuart, "Comparison of a computer simulation program and a traditional laboratory practical class for teaching the principles of intestinal absorption," *Adv. Physiol. Educ.*, vol. 12, no. 1, pp. 95–104, 1994.
[19] J. R. Downie and J. I. Meadows, "Experience with a dissection opt-out scheme in university level biology," *J. Biol. Educ.*, vol. 29, no. 3, pp. 187–194, 1995, doi: 10.1080/00219266.1995.9655444.
[20] M. de T. Durand, C. B. A. Restini, A. C. D. Wolff, M. Faria Jr., L. B. Couto, and R. B. Bestetti, "Students' perception of animal or virtual laboratory in physiology practical classes in PBL medical hybrid curriculum," *Adv. Physiol. Educ.*, vol. 43, no. 4, pp. 451–457, 2019, doi: 10.1152/advan.00005.2019.
[21] J. Fančovičová and P. Prokop, "The effects of 3D plastic models of animals and cadaveric dissection on students' perceptions of the internal organs of animals," *J. Balt. Sci. Educ.*, vol. 13, no. 6, pp. 767–775, 2014, doi: 10.33225/jbse/14.13.767.
[22] D. M. Guimarães, B. Valério-Gomes, R. L. de Araújo, C. de Oliveira Cudischevitch, and D. Uziel, "Practical anatomy classes: An alternative to improve the learning of middle school students," *Anat. Sci. Educ.*, Jan. 2023, doi: 10.1002/ase.2246.
[23] C. Haspel, H. K. Motoike, and E. Lenchner, "The implementation of clay modeling and rat dissection into the human anatomy and physiology curriculum of a large urban community college," *Anat. Sci. Educ.*, vol. 7, no. 1, pp. 38–46, 2014, doi: 10.1002/ase.1369.
[24] M. Humpenöder *et al.*, "Alternatives in education - evaluation of rat simulators in laboratory animal training courses from participants' perspective," *Animals*, vol. 11, no. 12, pp. 1–26, 2021, doi: 10.3390/ani11123462.
[25] H. L. Leathard and D. G. Dewhurst, "Comparison of the cost-effectiveness of a computer assisted learning program," *ALT-J*, vol. 3, no. 1, pp. 118–125, 1995.
[26] M. Predavec, "Evaluation of E-Rat, a computer-based rat dissection, in terms of student learning outcomes," *J. Biol. Educ.*, vol. 35, no. 2, pp. 75–80, 2001, doi: 10.1080/00219266.2000.9655746.
[27] J. G. Cromley, T. Perez, A. Kaplan, T. Dai, K. Mara, and M. J. Balsai, "Combined cognitive-motivational modules delivered via an LMS increase undergraduate biology grades," *Technol. Mind, Behav.*, vol. 1, no. 2, pp. 1–19, 2020, doi: 10.1037/tmb0000020.supp.
[28] A. M. Lund, "Measuring usability with the USE questionnaire," *Usability interface*, vol. 8, no. 2,

pp. 3–6, 2001.

[29] D. Lai, S. L. Lew, and S. Y. Ooi, "Modified TPACK framework for teachers' efficiency, students' performance and students' engagement," in *Proceedings of Sixth International Congress on Information and Communication Technology*, 2022, vol. 235, pp. 827–835, doi: 10.1007/978-981-16-2377-6_76/COVER.

[30] D. I. Lewis, *The pedagogical benefits and pitfalls of virtual tools for teaching and learning laboratory practices in the Biological Sciences*, 1st ed., vol. 1. York: The Higher Education Academy, 2014.

[31] S. S. Pokale, "Animal dissection: Effective instructional aid than alternative methods," *Int. J. Res. Anal. Rev.*, vol. 6, no. 1, pp. 210–213, 2019, Accessed: Apr. 03, 2023. [Online]. Available: http://ijrar.com/.

[32] T. Sekiguchi and M. Makino, "A virtual reality system for dissecting vertebrates with an observation function," in *International Conference on Electronics, Information, and Communication*, 2021, pp. 13–16, doi: 10.1109/ICEIC51217.2021.9369824.

[33] S. Elmali, "Reflections of hands-on dissection and virtual dissection experiences of pre-service science teachers," *J. Biol. Educ.*, 2022, doi: 10.1080/00219266.2022.2058984.