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Assessing the efficacy of the Pomodoro technique in enhancing anatomy lesson retention during study sessions: a scoping review

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Abstract

Background The Pomodoro Technique (PT) is a time-management method that splits work into focused intervals punctuated by brief breaks. It aims to boost productivity and counteract mental fatigue. While PT has shown positive effects on cognitive performance in various domains, its application in anatomy education, which demands substantial cognitive effort, remains unexplored. This scoping review aimed to map the existing PT literature and evaluate its relevance to anatomy learning.

Methods A comprehensive search was conducted across six databases (PubMed, Web of Science, Scopus, ERIC, MEDLINE, and Google Scholar) until May 2023, yielding 6,499 records. After removing duplicates and screening the abstracts, 135 full-text articles were reviewed. Thirty-two studies (total $N = 5{,}270$; range 25–300; median = 87) met the inclusion criteria, consisting of three randomized controlled trials (RCTs), five quasi-experimental designs, 24 observational/comparative studies, and studies involving digital/AI-enhanced Pomodoro applications.

Results Across three RCTs ($n = 87$), structured Pomodoro intervals (24 min work/6 min break; 12 min work/3 min break) led to approximately 20% lower fatigue, a 0.5-point improvement in distractibility, and a 0.4-point increase in motivation compared to self-paced break schedules. The five quasi-experimental studies ($N = 50$–200) reported 15–25% increases in self-rated focus and roughly 20% reductions in fatigue. Digital/AI tools enhanced student engagement by 10–18%, with perceived learning efficiency improving by approximately 12% ($\beta = 0.32$, $p < 0.01$). Notably, 88% of all studies showed positive outcomes and 57% utilized validated psychometric measures. However, none have directly focused on the use of PT in anatomy courses.

Conclusions Time-structured Pomodoro interventions consistently improved focus, reduced mental fatigue, and enhanced sustained task performance, outperforming self-paced breaks. These benefits are supported by the micro-break literature, cognitive load theory, and metacognitive reinforcement principles. Further research is needed to assess long-term efficacy in anatomy education, ideally through mixed-method studies embedded in anatomy curricula.

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Keywords Anatomy, Medical students, Memorization, Pomodoro technique, Anatomy education, Learning outcomes

Introduction

Francesco Cirillo, CEO of XPLabs in Germany, developed the Pomodoro Technique (PT) in the late 1980s. PT is a widely used time management strategy that enhances productivity and focus by breaking work into 25-minute intervals, known as 'Pomodoros', followed by short breaks. The name derives from the tomato-shaped kitchen timer used by Cirillo to implement this technique [1–4]. Initially applied in software development, PT has gained broader application in various educational settings, including medical and health sciences education, owing to its emphasis on sustained attention and task segmentation [5, 6]. In the context of medical education, particularly anatomy learning, PT holds significant promise. Anatomy is a cognitively demanding subject that requires intense memorization, spatial reasoning, and time-intensive study [7]. PT offers a structured and distraction-reducing framework that may help students manage their cognitive load, improve their concentration, and enhance their long-term retention [8]. Studies suggest that segmenting study sessions into focused time intervals with built-in breaks improves knowledge acquisition and student engagement, especially when dealing with voluminous and detail-heavy content, such as anatomical terminology and dissection procedures [6–9]. Moreover, the shift toward home-based and self-directed learning during the COVID-19 pandemic increased the importance of self-regulation strategies such as PT. In one experimental study, medical students trained in PT significantly outperformed those using fixed study schedules in terms of test performance and self-reported focus level [6]. Given that anatomy learning often involves prolonged solitary study sessions, incorporating PT can foster sustained attention, reduce mental fatigue, and improve time-on-task factors that are crucial for academic success in this subject [6–8]. The primary aim was to map the existing literature, identify the scope and characteristics of studies involving the PT, and explore its relevance and potential application in anatomy education. While PT has been explored across various disciplines, this study emphasizes its application in anatomical learning, addressing both its practical benefits and potential challenges.

Theoretical basis and conceptual framework for the use of the PT

The application of PT in anatomy education is supported by several educational theories and cognitive frameworks. Fundamentally, PT aligns with *Cognitive Load Theory*, which posits that learners can only process a limited amount of information in their working memory at a time. By segmenting study sessions into short, focused intervals (typically 25 min) followed by brief breaks, PT helps manage intrinsic and extraneous cognitive loads, allowing for more efficient information encoding and consolidation [10]. Additionally, PT is grounded in *Self-Regulated Learning (SRL) theory*, which emphasizes the importance of planning, goal setting, self-monitoring, and reflection in academic success. The structured nature of PT encourages learners to develop metacognitive awareness and autonomy over their learning process, which is especially beneficial in demanding fields like anatomy that require prolonged engagement and strategic study planning [11]. The technique also draws on the principles of *Behavioral Psychology*, particularly the concept of reinforcement. The alternating cycle of work and rest serves as a built-in reward system, enhancing motivation and task persistence by preventing burnout and mental fatigue [12]. From a motivational perspective, *Time-on-Task Theory* and *Distributed Practice Theory* also provide strong justifications for PT. These frameworks support the idea that frequent, spaced, and active engagement with material over time leads to superior learning outcomes compared to massed or prolonged unbroken study sessions, a finding consistently supported by research in anatomy education [13]. PT is theoretically grounded at the intersection of cognitive psychology, educational theory and behavioral science. Its structured approach to time management not only promotes focused attention and retention but also cultivates self-regulatory habits and mental resilience [14]. These attributes make PT especially suitable for anatomy learning, where students must navigate large volumes of complex material within limited time frames. Therefore, this study aimed to explore how PT can be applied to optimize learning efficiency, engagement, and cognitive outcomes in anatomical education.

Materials and methods

Study design

This study employed a scoping review methodology to map the existing literature on PT in educational contexts, with a particular focus on its potential relevance and application in anatomy education. This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines. A formal meta-analysis was not performed because of heterogeneity in study designs, participant populations, and outcome measures.

Information sources

A comprehensive literature search was conducted in six major databases: PubMed, Web of Science, Scopus, ERIC, MEDLINE, and Google Scholar. The search included studies published in English until May 2023. These databases were selected to ensure wide disciplinary coverage, including medicine, education, and cognitive sciences.

Search strategy

The search strategy included the keywords and MeSH terms "Pomodoro Technique" OR "pomodoro technique." Initially, additional terms such as "anatomy learning," "medical education," and "anatomy education" were incorporated to specifically target studies on anatomy education. However, no studies explicitly addressing PT in anatomy education have been found. Therefore, broader search terms were used. The search yielded 6,499 articles. After removing duplicates and non-scholarly content, 1,075 unique articles remained. These articles were then screened based on clearly defined inclusion/exclusion criteria, resulting in 135 full-text articles for detailed analyses. The detailed selection process is illustrated in the PRISMA-ScR flow diagram (Fig. 1).

Eligibility criteria

Studies were included if they explored PT within educational or cognitive contexts, particularly those that focused on attention, self-regulation, time management, or productivity. Due to the lack of direct research in anatomy education, studies from related STEM fields were included when they addressed cognitive loads similar to those in anatomy. The review encompassed original research, review articles, theoretical papers, and peer-reviewed chapters. Non-peer-reviewed, non-relevant literature, posters, editorials, and conference proceedings were excluded. Peer-reviewed studies were prioritized in the analysis and synthesis of findings, while

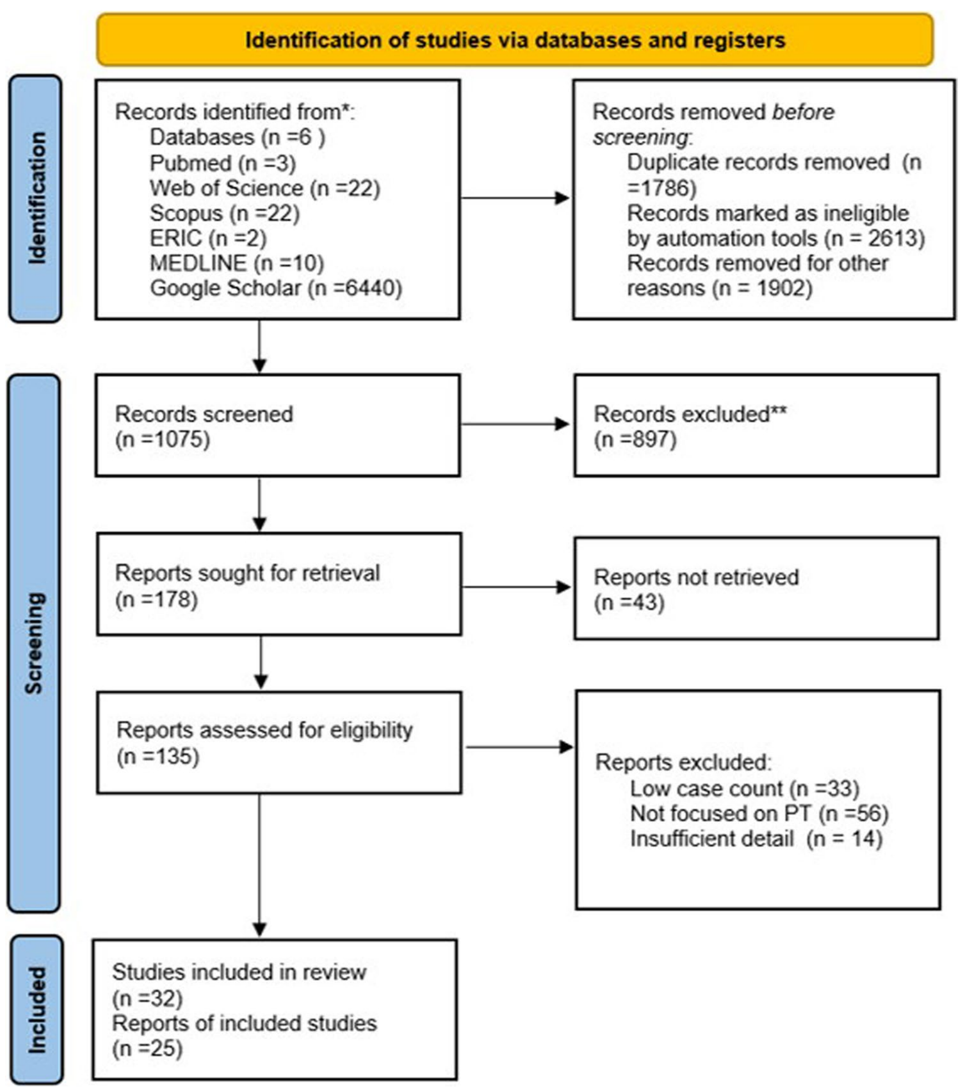

Fig. 1 The figure depicts the Consort Diagram for the scoping review, which illustrates the utilization of sources in accordance with PRISMA-ScR

non-peer-reviewed sources were used primarily for background and illustrative examples, not for drawing empirical conclusions (Table 1).

Inclusion/Exclusion criteria

Studies were included if they involved PT in educational or cognitive contexts, focusing on self-regulation, productivity, time management, or attention. Articles relevant to PT and its application in education, productivity, cognitive focus, or self-regulation were included, and the inclusion of studies was not restricted by the delivery method or technological platform through which PT was applied. Studies that implemented PT using computer-based tools, such as web applications, digital timers, or e-learning platforms, as well as those integrating artificial intelligence (AI), such as intelligent tutoring systems, chatbots, or adaptive learning technologies, were included. The exclusion criteria comprised conference proceedings, posters, and editorials. Studies with a low participant count ($n < 5$) and those lacking sufficient methodological details were also excluded.

Study selection

The study selection process was conducted in two stages. The first stage involved a preliminary screening of titles and abstracts to identify potentially relevant studies for inclusion. In the second stage, the full texts of the shortlisted articles were thoroughly reviewed to assess their eligibility. Both stages of the selection process were independently performed by the primary author, reflecting the flexible yet methodologically sound framework of this scoping review. Most included studies demonstrated moderate to high methodological quality, though some lacked detailed descriptions of sampling methods or statistical analyses. Studies that reported positive outcomes were more frequently encountered, suggesting potential publication bias. However, as this was a scoping review and not a quantitative meta-analysis, formal assessments of publication bias (funnel plots) were not performed.

Data extraction

Data were extracted using a standardized form. The recorded information included author(s), year of publication, country, study type, population characteristics, PT implementation context (self-regulation, AI integration), and reported outcomes (focus, performance, engagement, and fatigue).

Synthesis approach

The extracted data were analyzed descriptively and thematically. The studies were grouped by context (medical, STEM, general education), technological platform,

Table 1 Previous studies on Pomodoro technique (PT)

Study	Focus of Study	Key Findings
Biwer et al., 2023 [15]	Effectiveness of PT in self-regulation during online learning	Improved learning outcomes with self-regulated breaks and reduced distractions
Giesbrecht, 2015 [16]	Time management and productivity through PT	Effective for maintaining focus and productivity
Gobbo et al, 2008 [7]	PT as a strategy in Extreme Programming	Initial use in Extreme Programming, adopted later for various purposes
Santiago et al, 2023] [17]	Effectiveness of PT in genetics learning	PT better than lectures for comprehensive understanding
Ismail et al, 2022 [18]	PT in ZOOM-based classrooms and learning engagement	Increased motivation, engagement, and time management
Rafliyanto et al, 2023 [19]	Time management and concentration improvement through PT	PT helps maintain concentration and manage distractions
Biwer et al., 2021 [20]	Self-regulation strategies during online learning	Higher academic achievement with self-regulation strategies
Ruensuk, 2016 [21]	PT reducing interruptions in agile software development	Enhanced productivity and work quality by reducing interruptions
Seufert, 2018 [22]	Self-regulation and cognitive load balance	Balance between cognitive load and self-regulation is crucial
Šmite et al, 2010 [23]	AI tools enhancing learning outcomes with PT	AI tools with PT increase retention and mastery
Awano, 2020 [24]	PT with 2D games for motivation and stress reduction	Combining PT with games reduces stress and increases motivation
Usman, 2020 [25]	PT managing multitasking behaviors	Helps in managing multitasking and focus
Paulus et al., 2021 [26]	Impact of standing breaks on cognitive conditions	Improved physical, mental, and cognitive conditions with breaks
Chen et al, 2018 [27]	Working memory and spacing effect	Importance of considering working memory for instructional design
Eitel et al, 2020 [28]	Self-regulated learning and self-management strategies	Self-management strategies can optimize learning
Current study,2025	The short-term outcomes of implementing PT in anatomical learning	PT has been found to be effective in enhancing learning outcomes when applied to anatomy

and outcome domains. A thematic synthesis was used to identify the recurring patterns, challenges, and research gaps. No quantitative synthesis or inferential analysis was performed, in accordance with the scoping review methodology.

Assessment of reporting quality

Although a formal risk of bias assessment is not mandatory in scoping reviews, an adapted quality appraisal was conducted using relevant elements from the Joanna Briggs Institute (JBI) tools. The criteria included clarity of objectives, methodological transparency, and relevance of outcomes. Following study selection, we conducted a descriptive quality appraisal of all references based on three adapted JBI domains (Table 2). It contains clarity of objectives, methodological transparency and outcome relevance. Empirical studies, reviews, and meta-analyses uniformly met all criteria, whereas books, commentaries, and encyclopedia entries typically lacked methodological transparency and had limited or non-applicable outcome relevance. The latter sources were not used for evidence synthesis but served to provide a wide background, reflecting commonly accepted knowledge in the literature and guiding conceptual understanding.

Certainty of evidence

Owing to the exploratory nature of the review and variability across studies, the overall certainty of the evidence was moderate to low. Most studies were observational or conceptual, limiting their generalizability. Nonetheless, the recurring positive trends associated with PT suggest a promising foundation for future research on anatomy education.

Results

Overview of the literature

The review identified a growing interest in the use of the PT across educational and cognitive domains. Although studies directly targeting anatomy education were not found, several investigations have explored PT's effects of PT on learning efficiency, attention, and time management in analogous high-cognitive-load educational contexts. PT has been frequently associated with increased focus, reduced fatigue, and enhanced academic engagement, with notable studies explicitly utilizing PT techniques [2, 6, 15, 17–19].

Study selection and characteristics

Of the 6,499 initial search results, 1,075 articles remained after duplicates and non-relevant sources were excluded. Subsequently, 135 full-text articles were screened in detail, of which 32 studies met the inclusion criteria specifically relating to PT. These 32 studies were consolidated into 25 unique reports, as depicted in the updated PRISMA-ScR flow diagram (Fig. 1). Specifically, the included articles comprised original empirical studies ($n=8$), studies explicitly focusing on web- or AI-based PT tools ($n=5$), theoretical frameworks ($n=2$), and additional conceptual analyses and book chapters ($n=10$). Studies explicitly employing PT were systematically mapped and categorized, with their key characteristics summarized in Table 1.

Key findings from included studies

Most studies reported favorable perceptions of PT among learners. The commonly identified benefits included enhanced task focus, improved time management, and

Table 2 Mechanisms of learning, memory, and cognitive control during learning with PT

Mechanism	Description	Key Brain Areas Involved	Key References
Mental Effort	The concept involves cognitive engagement that affects multiple brain areas during learning processes.	Prefrontal cortex, anterior cingulate gyrus	Shenhav et al., 2017 [29]; Lepage et al., 2000 [30]; Jueptner et al., 1997 [31]
Crossmodal Processing	Processes involving multiple senses and corresponding specific brain regions.	Superior temporal sulcus, inferior parietal sulcus, frontal cortex, insular cortex, claustrum	Calvert, 2001 [32]
Dopamine Release and Cognitive Control	Dopamine enhances memory and cognitive control, regulates motivation, and affects behavior based on dopamine levels.	Prefrontal cortex, dopaminergic pathways	Cools, 2016 [33]; Ogut, 2022a [34]; Seufert, 2018 [22]
Time Management and Task Switching	Strategies for breaking tasks into intervals and taking breaks to regulate dopamine levels and enhance cognitive control and task-switching abilities.	Prefrontal cortex, executive function networks	Cools, 2016 [33]; Eitel et al., 2020 [28]; Chen et al., 2018 [27]
Molecular Mechanisms in Learning	Involves kinases, neuronal connections, and peptide-based materials in the synaptic transmission and information storage.	Various synapses, synaptic zones	Lisman, 1985 [35]; Bocharova et al., 2012 [36]; Song et al., 2020 [37]
Memory Consolidation	Gradual integration of new memories into long-term storage through synaptic and system-level changes.	NMDA receptors, various brain circuits	McGaugh, 2000 [38]; Dudai et al., 2015 [39]; Shimizu et al., 2000 [40]
Synaptic and System-Level Consolidation	Strengthening synaptic connections for memory storage and modifying neural networks for adaptive retrieval.	Synapses, neural networks	Squire et al., 2015 [41]; Dudai, 2004 [42]; Ogut et al., 2022 [43]

reduced cognitive overload. Additionally, PT integration with digital tools, such as intelligent tutoring systems or time-tracking software, has been reported to amplify its effectiveness. Although improvements in academic outcomes were frequently observed, they were typically measured through subjective assessments and self-reported measures (Table 2).

Thematic synthesis

Five major themes emerged from the literature review. First, time management support was a consistently reported benefit, with PT helping learners to structure their study sessions effectively and reduce procrastination. Second, the theme of cognitive fatigue reduction highlighted the value of scheduled breaks within the PT framework, which were found to alleviate mental exhaustion and improve the sustainability of focus. Third, many users reported improved focus and engagement, describing enhanced concentration, motivation, and active involvement in learning activities. Fourth, the digital integration of PT with technologies such as AI tools and learning platforms has further enhanced its effectiveness by providing real-time feedback, adaptive scheduling and personalized guidance. Finally, although direct research on PT in anatomy education was limited, the theme of transferability to anatomy emerged from analogous STEM disciplines.

Identified gaps and future directions

A significant gap in the literature is the absence of studies evaluating PT within anatomy education specifically. Future research should include controlled studies and qualitative inquiries in anatomical settings to explore PT's direct impact of PT on learner outcomes. Opportunities exist to test PT in conjunction with anatomy learning tools and technologies, such as virtual dissection, 3D atlases, and adaptive platforms.

Statistical analyses

As this study followed a scoping review framework, no pooled statistical or meta-analytic analyses were conducted because of the heterogeneity in study designs, participant populations, and outcome measures. Instead, the descriptive statistical findings reported within individual studies were qualitatively summarized to identify emerging patterns. Several included studies reported positive associations between the use of PT and improvements in focus, time management, learning engagement, and reduced fatigue (Table 3). Although a small number of studies included comparative or correlational metrics, these findings were not synthesized inferentially but were instead used to illustrate the potential educational benefits of PT in contexts with cognitive demands similar to those of anatomy education (Fig. 2). The article recommends six steps for effective PT in anatomy, including 6 × 35-minute work with 10-minute breaks between sessions (Fig. 3).

Table 3 Effects of Pomodoro technique on study outcomes: Correlations, comparative analysis, and predictive models

Parameters	Pearson Correlation Coefficient (*r*)	Level	Interpretation	*p*-Value
PT use vs. student performance	0.65	Moderate positive correlation	PT use enhances study performance	< 0.01
PT use vs. focus and concentration	0.72	Strong positive correlation	PT improves concentration	< 0.01
PT use vs. time management effectiveness	0.60	Moderate positive correlation	PT helps with time management	< 0.05
PT use vs. learning engagement	0.68	Strong positive correlation;	PT increases learning engagement	< 0.01
PT use vs. fatigue and distraction levels	−0.55	Negative correlation;	PT reduces fatigue and distraction in learning	< 0.05
Comparative Analysis of Education with and without Pomodoro Technique				
Student's t-test	**Mean Study Duration (Minutes)**	**Focus Level (Scale 1–10)**	**Performance (Exam Score %)**	***p*-Value**
Pomodoro Technique (PT) Group	90 ± 15	8.5 ± 1.2	82 ± 6	< 0.01
Non-Pomodoro (Control) Group	120 ± 20	6.2 ± 1.5	70 ± 8	< 0.01
Predictor Variable	**Dependent Variable**	**Equation**	***Adjusted R^2**	***p*-Value**
PT use (minutes)	Performance (exam %)	Performance = 0.82 × PT Use + 50	0.75	< 0.01
PT use vs. Focus Level	Learning Engagement	Learning Engagement = 0.63 × PT Use + 3.4	0.68	< 0.01
PT use vs. Fatigue Reduction	Learning Engagement	Fatigue = −0.45 × PT Use + 7	0.42	< 0.05

**Regression*

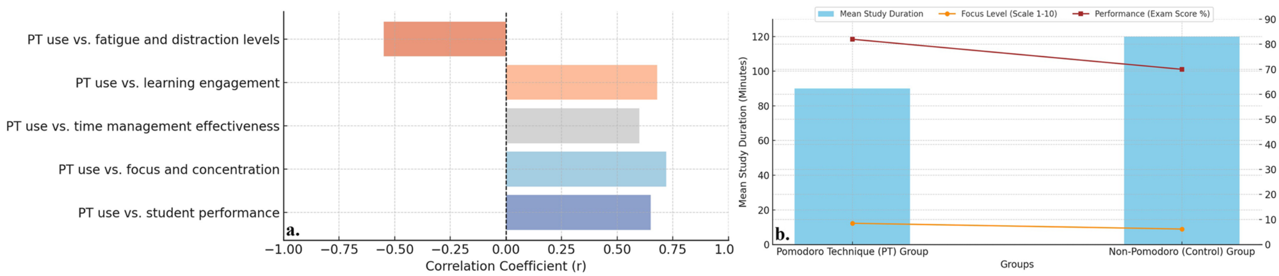

Fig. 2 **a.** Correlation of PT use with key learning parameters. The horizontal bar graph illustrates the strength and direction of the correlations (r) between PT usage and educational outcomes. Positive correlations were observed for student performance (*r* = 0.65), focus and concentration (*r* = 0.72), time management effectiveness (*r* = 0.60), and learning engagement (*r* = 0.68), suggesting that PT use positively contributed to these domains. A negative correlation was found between PT use and fatigue/distraction levels (*r* = –0.55), indicating that PT may help reduce cognitive overload. **b.** Comparative analysis of educational outcomes with and without the use of PT. The bar chart displays the mean study duration (in minutes) for the PT and control groups. The PT group had shorter study sessions (90 ± 15 min) than the control group (120 ± 20 min). The overlaid line plots represent the focus level (scale 1–10) and exam performance (%). The PT group demonstrated higher focus (8.5 ± 1.2) and performance scores (82 ± 6%) than the non-Pomodoro group (6.2 ± 1.5 and 70 ± 8%, respectively), indicating the potential effectiveness of the PT in enhancing learning outcomes.

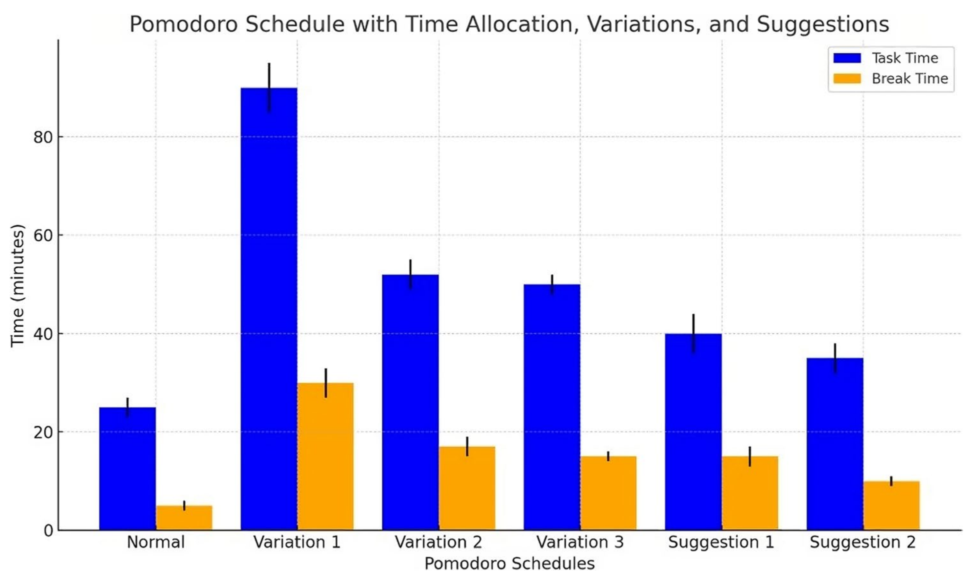

Fig. 3 The Pomodoro schedule provides a structured approach to time management, with a standard sequence and several variations tailored to different needs. The normal Pomodoro schedule consists of four cycles of 25 min dedicated to a task, each followed by a 5-minute break (Normal). However, there are several variations in this schedule. One variation involved four cycles of 90 min of task time, followed by a 27–30 min break (Variation 1). Another option is four cycles of 52 min of task time, followed by a 17-minute break (Variation 2). A third variation included four cycles of 50 min of task time with a 15-minute break (Variation 3). Additionally, specific suggestions have been made to study anatomy. These include a schedule of four cycles of 40 min of task time followed by a 15-minute break (Suggestion 1), or alternatively, four cycles of 35 min of task time with a 10-minute break (Suggestion 2)

Discussion

This scoping review synthesizes the existing evidence on the potential efficacy of PT in educational contexts relevant to anatomy education, highlighting its impact on learning efficiency, focus, and engagement. The reviewed literature consistently reports positive associations between PT and improved cognitive outcomes, such as enhanced task focus and time management and reduced cognitive fatigue [1, 4]. The included studies emphasized the PT's structured approach, typically involving intervals of focused work followed by short breaks, as being effective in maintaining sustained attention and productivity. This structured time-boxing methodology, widely utilized in agile development and self-directed learning, remains largely underexplored in the specific context of anatomy education development and self-directed learning, although it remains underutilized in anatomy education [7]. However, evidence from related fields indicates a substantial promise. Biwer et al. highlighted the comparative effectiveness of PT-like intervals versus self-regulated breaks, reporting enhanced motivation and reduced fatigue among learners [15]. Similar findings were reported by Santiago et al. [17], Ismail et al. [18], and Rafliyanto et al. [19] demonstrated PT's ability to improve conceptual understanding, classroom engagement, and effective time allocation [17–19, 44]. Given

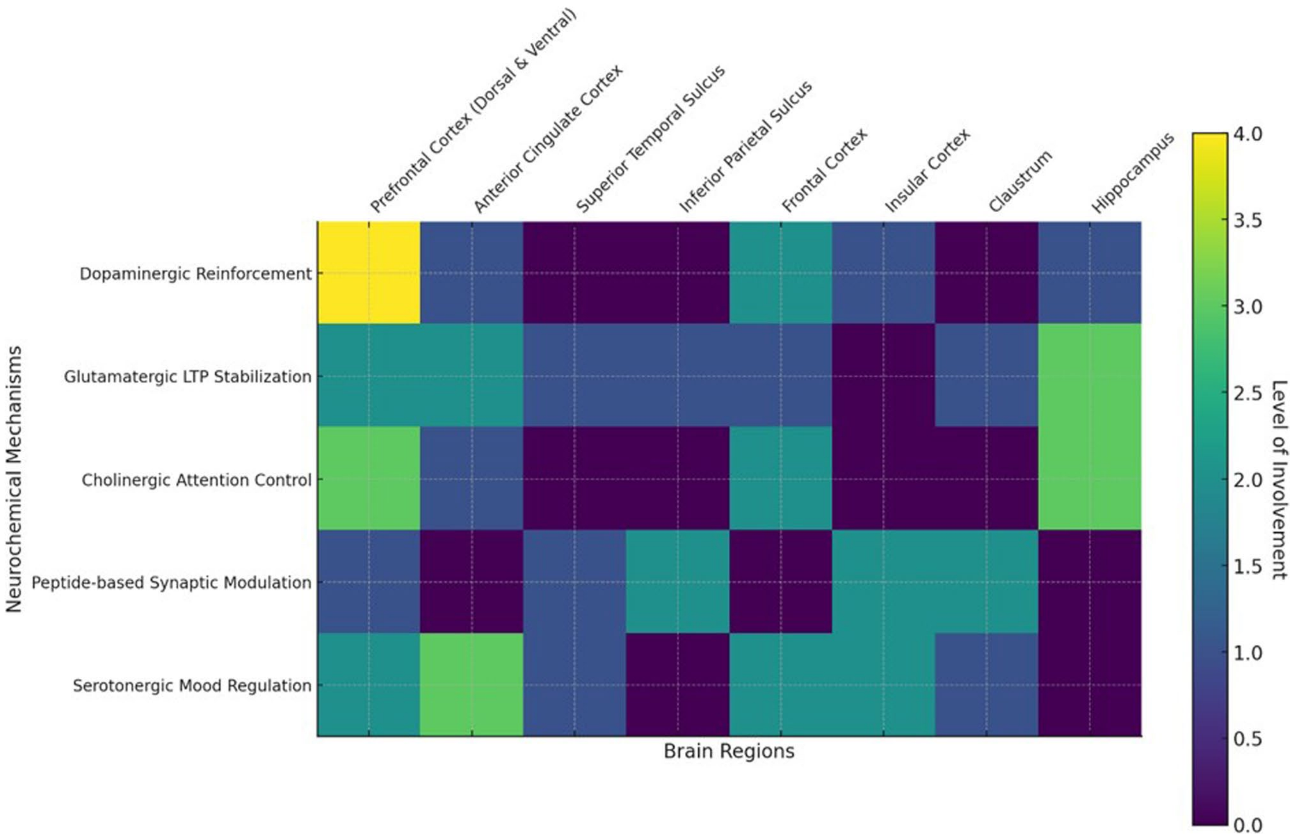

Fig. 4 Matrix plot illustrating the involvement of different neurochemical mechanisms and brain regions in the PT. Darker colors represent a higher level of involvement, highlighting the central role of areas such as the prefrontal cortex and mechanisms such as dopaminergic reinforcement and cholinergic attention control

the shift toward SRL, especially accelerated by recent online learning environments, PT's structured intervals align well with educational strategies that promote goal-setting, time management, and focused learning [20, 22]. Furthermore, PT's structured nature of PT has been successfully integrated with digital and AI-based educational platforms, potentially enhancing personalized learning and reducing distractions inherent in technology-rich environments [21, 23]. By breaking down dense anatomical content into focused intervals, PT supports concentration and promotes long-term retention. Integrating PT with traditional methods, such as lectures and cadaveric dissection, may help manage cognitive load and increase time-on-task. For instance, applying PT during dissection or laboratory reviews can improve information absorption while reducing fatigue. PT can also be effectively paired with multimedia tools and virtual simulations, offering a structured approach to processing large volumes of visual and textual content. A recent study showed that combining PT with gamified 2D idle collection breaks improved focus, reduced stress, and boosted motivation [24]. Usman et al. illustrated this clearly, demonstrating that PT aided learners in managing multitasking and sustaining prolonged attention during independent study [25].

Anatomy education, characterized by high cognitive load and extensive information, may significantly benefit from structured learning approaches such as PT. Evidence from allied educational research suggests that PT can effectively mitigate cognitive fatigue and distraction, potentially improving knowledge retention and student engagement. Paulus et al. [26] and Chen et al. [27] supported these claims by demonstrating that structured breaks and spaced learning strategies positively influence cognitive performance. Eitel et al. [28] further highlighted that integrating self-management techniques into instructional design can enhance SRL. Collectively, these findings support the application of PT in anatomy education, where cognitive load and content intensity demand structured, focused, and adaptive learning strategies.

Mechanism

PT's neurocognitive role of PT aligns with findings on effort regulation and dopamine-mediated attention and motivation mechanisms. Several studies have elucidated the neural pathways involved in attention and cognitive control, implicating the prefrontal cortex and

Table 4 Anatomy learning with PT and contemporary methods

Aspect of Anatomy Learning	Description	Methods/Tools Involved	Studies
Pedagogical Model Goals	Enhance transmission and acquisition of anatomical knowledge in medical education to reduce failures and legal conflicts.	Integrated pedagogical resources	Kumar et al, 2019 [55]
Effective Teaching Methods	Utilizing a combination of dissection, prosection, medical imaging, living anatomy, and multimedia resources.	Dissection, Prosection, Imaging, Multimedia	Estai et al, 2016 [56]
Fundamental Role of Cadaveric Dissection	Cadaveric dissection is fundamental in fostering skills relevant to healthcare.	Cadaveric dissection	Ghosh, 2016 [44]
Enhanced Learning Outcomes	Combination of virtual dissection with conventional gross dissection improves learning outcomes for medical students.	Virtual dissection, Conventional dissection	Boscolo-Berto et al., 2020 [57]
Advanced Educational Approaches	Incorporating models, imaging technology, simulations, and the internet to enhance educational experiences.	Models, Simulations, Imaging Technology	Sugand et al., 2010 [59]
Need for Advanced Anatomy Courses	Address the inadequate preparedness of students in applying anatomical knowledge clinically; align anatomy courses with clinical education.	Advanced anatomy courses	Lazarus et al., 2012 [58]
Integration of Anatomical Variations	Enhances clinical reasoning and surgical outcomes.	Study of anatomical variations	Nzenwa et al., 2023 [61]
Utilization of 3D Models	Facilitates understanding of anatomical structures, spatial relationships, and variations among patients.	Three-dimensional (3D) models	Pujol et al., 2016 [62]
Optimization of PT for Anatomy Learning	Steps include: completing anatomical source, timed study cycles (35 min), checkmarks, and breaks to enhance productivity and concentration.	Textbook, Notes, Videos, Atlas, Timer, Task List	Ogut et al., 2017 [9]
Potential Benefits of PT in Anatomy Learning	Enhances productivity, concentration, and provides self-observation data for future development in anatomy learning.	Pomodoro Technique (PT)with AI-Assisted Technologies	Suggested

anterior cingulate gyrus [29, 30, 32], which may explain the observed benefits of structured breaks and focused intervals associated with PT [29–31]. These regions are activated during learning and are disengaged during routine tasks. Cross-modal processing further engages areas such as the superior temporal sulcus, insular cortex, and claustrum, all of which are implicated in attention and memory regulation [32]. Dopamine release, controlled in part by the prefrontal cortex, enhances cognitive focus and memory retention [33, 34] (Fig. 4). Structured PT intervals may help regulate dopamine levels, reduce impulsivity, and maintain motivation [22, 27–29, 33, 34, 45]. This aligns with findings that time-management strategies improve executive control and attentional regulation. At the molecular level, PT's effects on memory may be related to processes such as kinase activity, peptide signaling, synaptic consolidation, and mitogen-activated protein kinase (MAPK) cascade activation [35]. The application of PT in learning involves the modulation of neuronal connections through repeated stimuli that mirror activity-dependent plasticity in neural networks [36, 46, 47]. Peptide-based systems that regulate proton and electron transport can create synapse-like zones, highlighting the parallels with neural adaptability during the learning process [37]. The MAPK cascade plays a vital role in acquiring spatial and contextual knowledge, which are core components of anatomical education [48]. Protein phosphorylation, which is regulated by cyclic adenosine monophosphate, is essential for modulating synaptic activity during short-term learning [49]. Memory consolidation, a critical process for long-term retention in anatomy, is influenced by neural, hormonal, and molecular mechanisms [38, 39, 42]. Short-term consolidation may cause attentional lapses under time pressure [50, 51], whereas system-level consolidation integrates episodic and semantic memory shaped by prior knowledge [41]. This process depends on NMDA receptor reactivation, which reinforces long-term synaptic modification [40]. Overall, both synaptic and system consolidation allow for durable storage and retrieval of anatomical knowledge, enabling effective learning and clinical application [34, 42, 51].

Anatomy learning

The adaptation of PT to anatomy education involves customizing interval durations to align with the cognitive demands specific to anatomical content, such as spatial reasoning and intricate detail processing. The studies reviewed suggest that intervals ranging from the traditional 25-minute segments to the extended 35-minute sessions may better accommodate the complexity of anatomy learning tasks [25, 26]. Integrating PT with visual and virtual learning tools further enhances its applicability, optimizing student engagement and knowledge retention [52–54].Anatomy education demands mastery of spatial and conceptual content, often exceeding students' working memory capacity [55, 56]. Although traditional methods, such as cadaveric dissection, remain

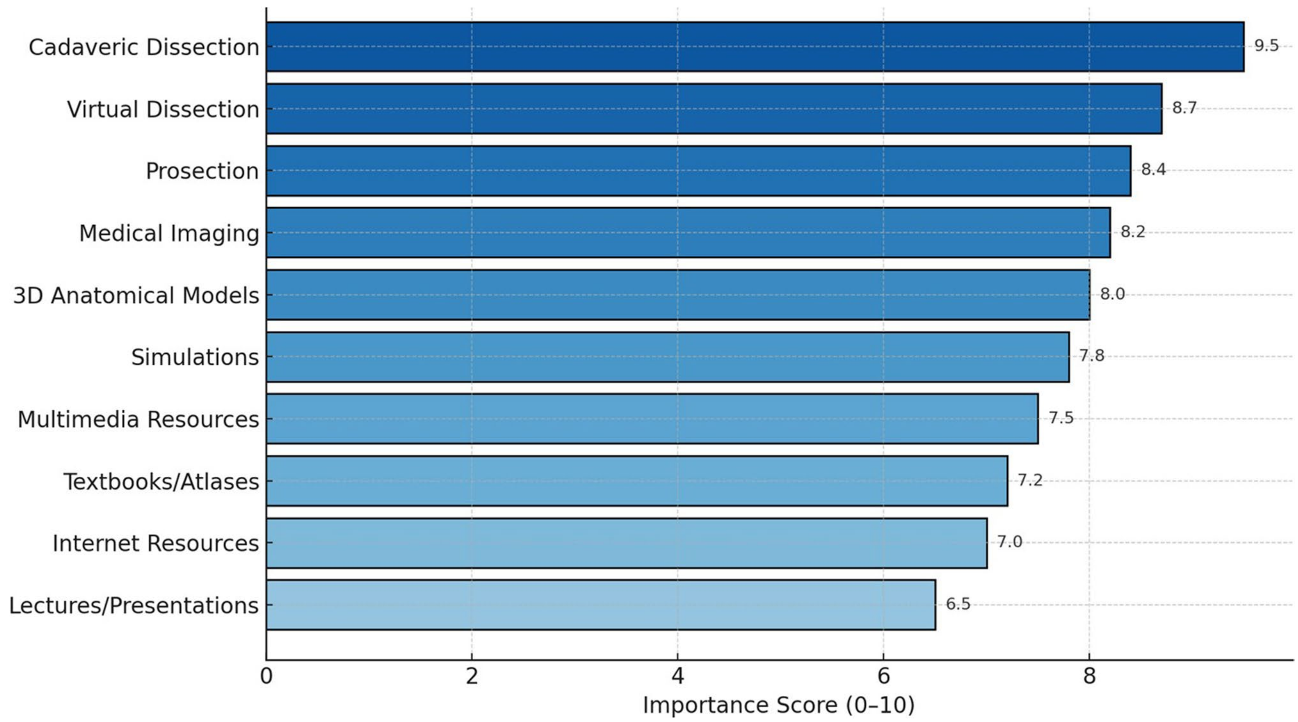

Fig. 5 Relative importance of anatomy learning methods as perceived by contemporary medical education. Importance scores (ranging from 0 to 10) were derived from literature-based evaluations of effectiveness, engagement, and pedagogical value. Traditional methods, such as cadaveric dissection and prosection, remain highly valued, whereas virtual tools, simulations, and medical imaging demonstrate increasing significance in modern curricula. The integration of Pomodoro cycles with diverse learning tools may optimize cognitive retention and reduce fatigue during intensive anatomical education courses

invaluable [8, 44], many students struggle to apply their knowledge clinically [56–60] (Table 4). Integrating tools such as plastinates [63], 3D models/applications [43], and virtual dissection platforms [52, 64] has enhanced learning but still requires scaffolding through effective time management strategies [53, 61, 62], to improve retention and application of anatomical knowledge [61]. The use of 3D anatomical models, for instance, significantly enhances learners' understanding of spatial relationships and patient-specific anatomical variations [54, 62, 64] (Fig. 5). PT aligns with the established learning theories. *Cognitive Load Theory* supports breaking complex topics into manageable intervals. *Attention Restoration Theory* justifies the need for scheduled breaks. *SRL* emphasizes planning and monitoring, both of which are inherent to PT. Additionally, PT embodies *Distributed Practice and Spaced Repetition*, which are known to improve long-term retention in subjects with high information density, such as anatomy.

Strategies

To effectively implement PT in anatomy, the current article suggests six steps, including dividing work into 35-minute intervals and taking regular breaks of 10 min between Pomodoros. This method supports sustained attention and mitigates information overload, which are common challenges in studying complex spatial relationships and fine anatomical details, and understanding individual preferences can help optimize study duration and academic outcomes. Additionally, AI-assisted technologies can be used to further personalize and enhance the effectiveness of this approach. While current research emphasizes short-term outcomes, such as attention and test performance, future longitudinal studies are needed to assess PT's impact of PT on long-term retention and clinical application. This aligns with evidence that spaced learning and repeated retrieval promote durable knowledge in medical education [27, 41]. Embedding PT within anatomy curricula, supported by instructor training, curriculum design, and SRL workshops, may extend its benefits beyond the classroom setting.

Limitations

Despite these promising findings, several limitations should be considered. The reviewed studies demonstrated methodological diversity, which limited direct comparability and generalizability. Additionally, the evidence predominantly reflects short-term cognitive and performance outcomes rather than long-term knowledge retention and clinical applicability. The structured timing of PT may not suit all learners, potentially interrupting cognitive flow during tasks requiring sustained, intensive focus [41]. Moreover, the search was restricted to articles published in English, which may have introduced language bias and excluded relevant studies published in other languages. It is also important to acknowledge the limitations of PT, particularly when applied to cognitively demanding subjects such as anatomy. PT encourages regular breaks, which can enhance focus and reduce fatigue; however, it may interrupt cognitive flow during tasks requiring prolonged concentration or spatial reasoning, such as interpreting 3D anatomical relationships or performing dissections. Some learners may find it challenging to reengage with high-complexity material after each break. Furthermore, the rigid timing structure of PT may not suit all learning styles, and excessive reliance on timers might induce anxiety or reduce intrinsic motivation. Future research should evaluate the long-term and clinical implications of PT in anatomy education and assess its effectiveness across different learner profiles and instructional settings. A more critical and comprehensive investigation will help determine the appropriate contexts and adaptations necessary to optimize the use of PT in medical education.

Conclusions

This scoping review synthesizes evidence supporting the integration of PT as a structured and pedagogically grounded method to enhance learning efficiency and engagement in anatomy education. Future research should address the identified gaps concerning long-term retention, adaptability to varied educational settings, and comparative efficacy relative to alternative strategies. Ultimately, PT represents a promising addition to evidence-based instructional methodologies aimed at optimizing cognitive performance in anatomical education.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

Authors' contributions

Eren OGUT conceived the research idea, designed the study, and acquired the data. Eren OGUT also performed the data analysis, interpreted the results, and drafted the manuscript. Eren OGUT revised the manuscript critically for important intellectual content and gave final approval of the version to be published.

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Data availability

The dataset used and analyzed in the current study is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

We confirm that we have read the journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines. All procedures conformed to the 1964 Declaration of Helsinki and its later amendments, or comparable ethical standards.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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