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Comprehensive evaluation of the educational impact and effectiveness of specialized study modules in cross-sectional anatomy: a study on student engagement and learning outcomes

Eren Ogut[1*], Fatos Belgin Yildirim[2], Yesim Senol[3] and A. Utku Senol[4]

Abstract

Background This study aimed to evaluate the effectiveness of Special Study Modules (SSMs) in Cross-Sectional Anatomy. These modules offer students the opportunity to develop their learning skills and foster specific academic interests. This study aimed to assess the satisfaction levels and learning outcomes of students who participated in the Cross-Sectional Anatomy SSMs, as determined by their feedback.

Methods Data for this descriptive study were collected from student feedback at the beginning and end of the SSMs. A total of 100 undergraduate medical students provided feedback on the modules between 2018 and 2022. The student survey consisted of 11 questions, and feedback was obtained using an open-ended questionnaire.

Results 74% of students emphasized the importance of these classes ($p=0.004$).Teamwork was also significantly valued by 9% of students ($p=0.025$). While 52% of students appreciated the module for presentation skills and clinical learning, the difference was not statistically significant. The module's impact on career choice and communication with faculty was noted by 13% of the students ($p=0.057$).

Conclusions Cross-sectional anatomy SSMs were found to be valuable by students, enhancing their ability to identify anatomical structures in cross-sectional images and distinguish sections from different levels and regions. SSMs also promote greater proficiency in imaging techniques. Overall, these modules were effective in key educational domains, particularly in facilitating the integration of knowledge and fostering teamwork among participants.

Keywords Student selected component (SSC), Special study module (SSM), Medical school curriculum, Medical education, Undergraduate medical student, Anatomy education

*Correspondence:
Eren Ogut
erenogut@yahoo.com.tr; eren.ogut@medeniyet.edu.tr
[1]Department of Anatomy, Faculty of Medicine, Istanbul Medeniyet University, Istanbul, Türkiye
[2]Department of Anatomy, Faculty of Medicine, Akdeniz University, Antalya, Türkiye
[3]Department of Medical Education, Faculty of Medicine, Akdeniz University, Antalya, Türkiye
[4]Department of Radiology, Faculty of Medicine, Akdeniz University, Antalya, Türkiye

Introduction

The importance of creating comprehensive curricula for medical students is emphasized by the necessity of learning, structured knowledge, and practical skills. This requirement is increased by an expanding knowledge base, evolving educational content, continuous societal changes, responsibility to respond to these changes, and the crucial need for medical students to possess the clinical competencies necessary for their profession [1]. Today, society expects healthcare systems to deliver safe, evidence-based, patient-centered care through well-coordinated interprofessional teams operating within frameworks that minimize errors, ensure quality, and optimize outcomes. This has created a pressing need to reform medical education by incorporating inter-professional learning experiences that teach health professionals to work collaboratively with each other. Consequently, there is a need to integrate basic science and medical knowledge with clinical practice [2]. Special study modules (SSMs) are programs that provide students with opportunities to study subjects beyond the core curriculum. SSMs provide students with opportunities to enhance their learning skills, styles, and interests [3, 4]. In pregraduate medical education, SSMs play a crucial role in achieving objectives related to knowledge, skills, attitudes, and behavior [3]. This has also been referred to as the 'student-selected component (SSC)' [3, 5]. SSCs are a recent innovation in medical education. First introduced in the United Kingdom (UK) in the 1990s, following recommendations from the General Medical Council's Tomorrow's Doctors, SSCs offer students considerable flexibility and depth in their studies. These components have since become a core feature of medical curricula across the UK and have been adopted, to a lesser extent, in other countries [6]. SSCs offer students a range of opportunities to enhance their learning experiences. As there is a growing emphasis on student assessment to evaluate a broad spectrum of professional skills and standards in both foundational and specialized training, SSCs are increasingly recognized as critical for personal, professional, and academic development. It is essential that these programs are implemented with clear objectives to fully capitalize on their potential [5]. SSMs facilitate in-depth exploration and the development of advanced competencies such as critical thinking [7]. Students who are encouraged to take greater responsibility for their learning can select topics of personal interest. SSMs can either focus on specific areas of the core curriculum where students already possess foundational knowledge or skills or cover topics unrelated to the core, including foreign languages or sports medicine. These modules can be integrated into the core curriculum or arranged in time blocks. The sequential approach, in which SSMs follow core blocks, offers several advantages, including protected time for SSMs and the ability to assess students against set standards, ensuring mastery of the core curriculum at varying paces. Despite some potential drawbacks, the core and options framework represents a significant advancement in medical education [7]. The rationale for this study emphasizes the significant role that SSMs play in achieving the knowledge, skills, attitudes, and behavioral objectives in medical education. SSMs offer several advantages, including the opportunity for in-depth study, integration into educational programs, a multidisciplinary approach, and the ability to address various student interests [3, 4, 8–10].

Traditional anatomy education, which relied on didactic lectures and comprehensive body dissections with personal instruction, has been replaced by a diverse array of educational tools. These include SSMs, problem-based workshops, computer simulations, plastinates, 3D imaging methods/applications, ultrasound, VR techniques, and other teaching aids [4, 11–15]. In previous years, SSMs offered by the Akdeniz University Faculty of Medicine encompassed a wide range of topics, excluding Cross-Sectional Anatomy. These include skin adornments such as tattoos and piercings, pharmacovigilance (drug side effects), methods for detecting protein levels in cells and tissues, and the investigation of cancer pathogenesis in experimental models, particularly focusing on the role of the nervous system. Other topics addressed the impact of nutrients on health, evidence-based medicine applications, healthy living and exercise, gait analysis, laser-tissue interaction, anatomy of snoring, history and future of organ transplantation, philosophy of science and medicine, opioid use in pain management, clinical gene therapy applications, use of photography in medicine, and correction of incorrect anatomical terms [9]. Cross-sectional anatomical SSM was not included in the aforementioned programs. Therefore, this program was established to bridge the gap between clinical and basic sciences and to enable students to identify the structures they observe in atlases, not only in a sectional view but also through plain radiography, CT, and MRI. The necessity of integrating basic sciences with clinical practice arises from the evolving landscape of medical education, which now emphasizes interprofessional learning experiences to prepare students for collaborative healthcare environments. This approach aligns with the expectations of modern healthcare systems that demand patient-centered, evidence-based care delivered by well-coordinated interdisciplinary teams [16, 17]. Consequently, integrating basic science and medical knowledge with clinical practice is essential for fostering meaningful learning, structured knowledge acquisition, and the development of clinical competencies. SSMs provide students with opportunities to explore subjects beyond the core curriculum, develop independent learning

strategies, and enhance their critical thinking skills [18, 19]. Despite its widespread adoption in medical curricula, cross-sectional anatomy has not yet been incorporated as an SSM, highlighting a gap in the curriculum that this study aims to address.

The research questions were as follows:

(1) How does participation in a cross-sectional anatomy SSM influence students' understanding of radiological imaging techniques?
(2) To what extent does this module contribute to the integration of anatomical knowledge into clinical practice?
(3) What are the benefits of this module in relation to students' professional decision-making and future specialty choices?

Our study aimed to assess the educational value of a cross-sectional anatomy SSM in enhancing students' clinical reasoning, radiological interpretation skills, and spatial visualization skills.

Methods

Number of participants

This study was conducted at the Akdeniz University, Faculty of Medicine. Ethical approval was granted by the Ethics Committee of Akdeniz University, Faculty of Medicine, under protocol ID TBAEK-251 (approval date: 25/04/2024), in accordance with the principles outlined in the Declaration of Helsinki. For this study, 100 participants who attended the cross-sectional anatomical SSM were selected. Participant selection took place between 2018 and 2022, ensuring that all the included students had completed or were actively engaged in the modules by the end of the selection period. Written informed consent was obtained from all participants. Data analysis was conducted using IBM SPSS version 25.0 to calculate frequencies, percentages, and standard deviations. The sample size was determined to be $n = 100$ using the G*Power test (version 3.1.9.7, Germany) [20, 21]. The calculation was based on a power of 0.80, effect size of 0.5, and alpha level of 0.05.

Inclusion criteria

Participation in this study was voluntary, and all students provided written, informed consent. To be eligible, students were required to be enrolled in the Akdeniz University Faculty of Medicine and attend at least one Cross-Sectional Anatomy SSM session. As feedback was collected at the end of each session, only those who had already participated in the modules were included in the study.

Exclusion criteria

Students were excluded from the study if they chose to withdraw from voluntary participation or declined to participate. Additionally, students who had not attended any Cross-Sectional Anatomy SSM sessions were excluded, as the study focused on feedback from individuals with firsthand experience. As none of the students met the exclusion criteria, no participants were excluded from the study.

Duration of the study

The SSMs were conducted for 2 h per week and held biweekly. The start date of the study marked the implementation of SSMs in Cross-Sectional Anatomy and the commencement of the data collection process. Student selection and data collection involved obtaining feedback from participants in cross-sectional anatomical SSMs between 2018 and 2022. A total of 100 students participated, and their feedback was gathered using a survey comprising 11 questions. The analysis of this feedback and the derivation of results began immediately after data collection and continued until completion. The evaluation of the study results commenced after the data analysis was finalized and extended through the preparation of a report. The validity of the survey was established through content and construct validity assessments. Content validity was ensured by a panel of experts in anatomy and medical education who reviewed the questionnaire to confirm its relevance, clarity, and comprehensiveness in evaluating students' experiences with the Cross-Sectional Anatomy SSMs. Construct validity was assessed by examining the alignment of the survey items with the study's underlying theoretical framework. To evaluate reliability, internal consistency was measured using Cronbach's alpha values. Cronbach's alpha was 0.85, indicating an acceptable level of reliability for the survey. Qualitative data obtained from open-ended responses were analyzed using coding and thematic analyses.

Student participation in cross-sectional anatomy SSMS

During this process, the students were informed of the purpose, content, and participation procedures of the SSMs. The objectives and content of the cross-sectional anatomy module were clearly defined. The course objectives were to provide a comprehensive understanding of human anatomy through cross-sectional images, enhance the ability to identify anatomical structures via anatomical landmarks in various planes, integrate anatomical knowledge with clinical applications, and improve spatial visualization skills for interpreting radiological images. The course content includes an introduction to cross-sectional anatomy and imaging techniques (Fig. 1), a detailed study of the cross-sectional anatomy of the head and neck, thorax, abdomen, pelvis, and limbs,

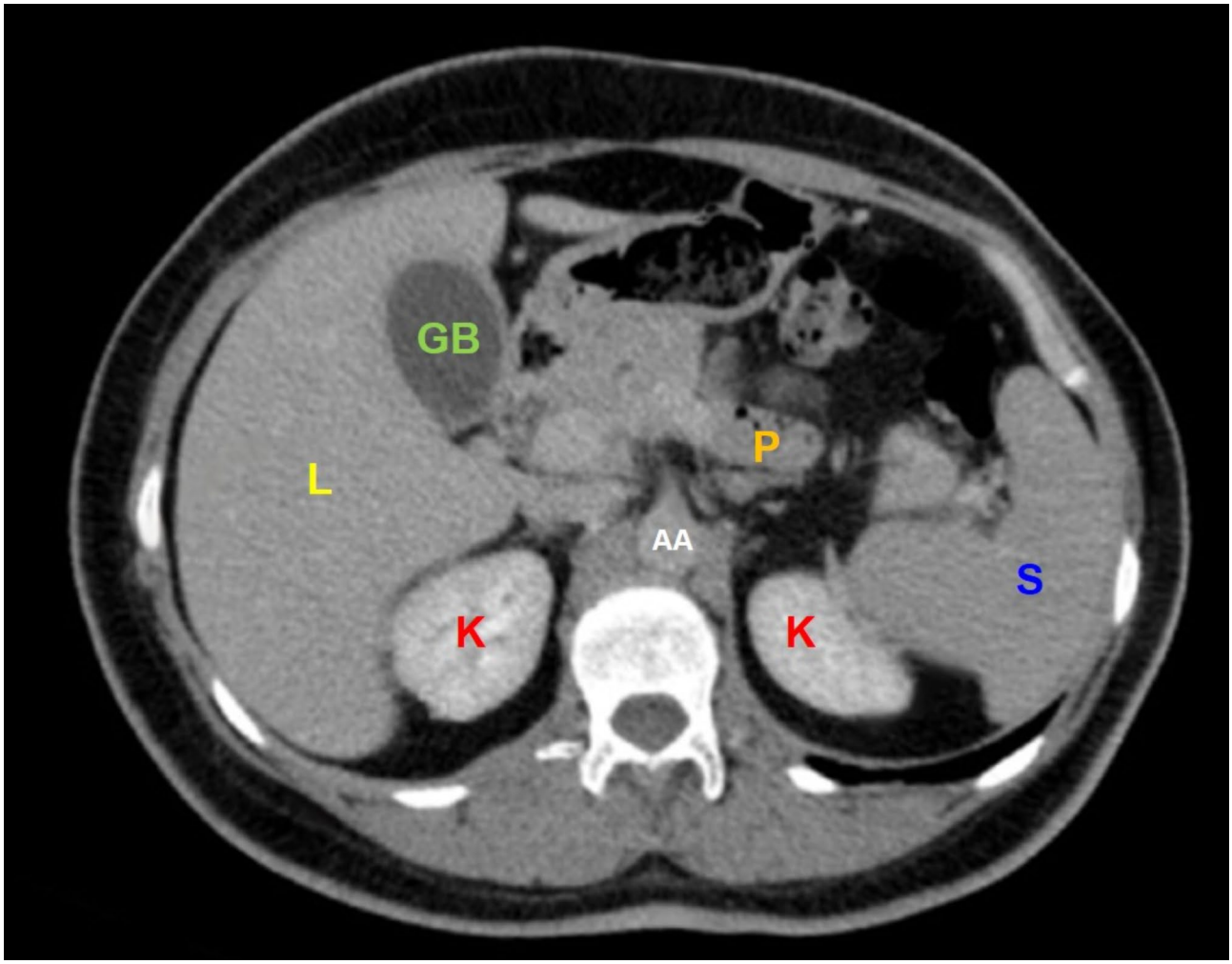

Fig. 1 In the Cross-Sectional Anatomy Special Study Module (SSM), radiological cross-sectional images are used to delineate organs and anatomical structures at various levels and to discuss potential imaging findings associated with pathologies. The figure illustrates the use of Computed Tomography (CT) of the upper abdomen as employed in modules **L**:Liver, **GB**: Gallbladder, **P**:Pancreas, **S**:Spleen, and **K**:Kidney

and the correlation of anatomical structures with clinical cases and imaging modalities such as Computed Tomography (CT) (Fig. 2). Additionally, the course offers hands-on sessions with cross-sectional images to reinforce the learning and discussion of common anatomical variations and their clinical significance [22]. Cross-Sectional Anatomy SSMs were conducted in conjunction with radiology, where students were tasked with identifying anatomical structures they had learned from anatomical sections using radiological images [23] and attempted to diagnose diseases affecting the relevant organs. Table 1 summarizes the contents of the cross-sectional anatomical SSM.

SSM evaluation process

At the end of each session, students were asked to provide open-ended feedback on how the module could be improved and their feelings about it. Data regarding students' expectations of the SSMs were collected using the same 11-item questionnaire used for gathering feedback after the module. The questionnaire used in this study, which was developed specifically for this research, is shown in Table 2. The survey questionnaire was designed with a comprehensive approach to assess several key aspects of the Cross-Sectional Anatomy SSM, including student satisfaction, the effectiveness of teaching methods, and the acquisition of skills, particularly in interpreting cross-sectional images and integrating anatomical knowledge with clinical practice [24, 25]. The questionnaire included both closed-ended questions to collect quantitative data and open-ended questions to capture qualitative insights into students' experiences [26]. The questionnaire was designed to evaluate constructs related to learning effectiveness, and engagement. These constructs align with the established frameworks for assessing educational interventions in medical

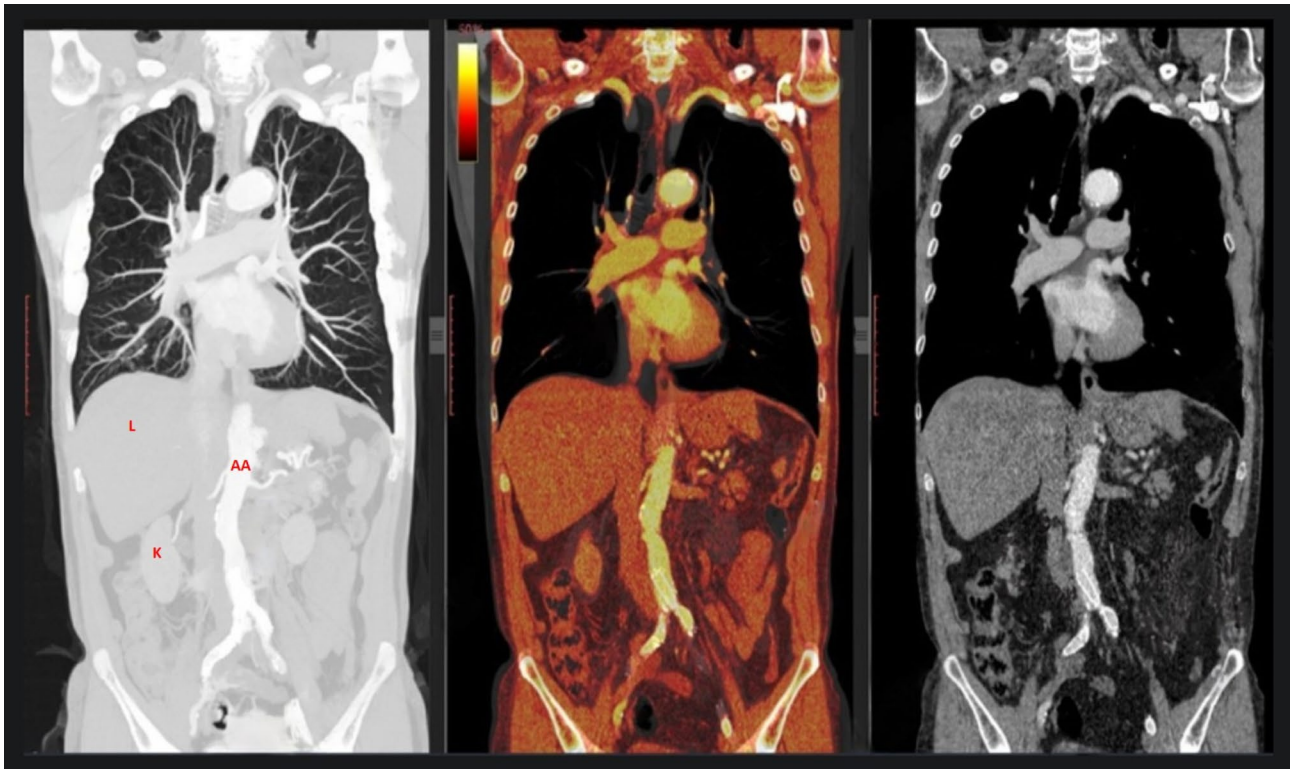

Fig. 2 This figure illustrates the integration of Artificial Intelligence in medical imaging and Computed Tomography Angiography (CTA). It also provides a detailed description of anatomical organs, structures, and vessels as depicted through these imaging modalities. In the Cross-Sectional Anatomy Special Study Module (SSM), these imaging modalities are employed in various planes to delineate normal anatomical structures and identify pathological signs of diseases. **AA**: abdominal aorta; **L**: liver; **K**: kidney

education [27, 28]. The questionnaire underwent a content validity assessment by a panel of experts in anatomy and medical education. Internal consistency reliability was measured using Cronbach's alpha, which ensured the reliability of the scale used in the questionnaire [29, 30].

Data analysis

Feedback was analyzed using descriptive and comparative statistical methods to evaluate satisfaction, acquired skills, and module effectiveness. We used thematic analysis to analyze open-ended feedback, a widely recognized method in qualitative research [31]. The steps included data familiarization (reading and reviewing student responses), generating initial codes (identifying key phrases and recurring themes), searching for themes (grouping similar codes into overarching themes), reviewing themes (refining and categorizing the themes to ensure that they accurately represented the data), and defining and naming themes (assigning clear definitions to the themes extracted). The findings were assessed to identify the key areas for improvement.

Follow-up

Based on the study results, recommendations for improving SSMs and their future applications were developed. The steps for implementing these recommendations were planned and monitored. These steps encompassed periods when the study method was and was not applied. After completing the study, the results were evaluated, and future steps were determined.

Methods and tools used in the study

*Surveys were u*sed to collect students' opinions and feedback on the SSMs. The open-ended questions in the surveys allowed the students to freely express their thoughts and provide feedback. *Monitoring forms were u*sed to track and evaluate the SSM process (Table 3). This study used cross-sectional anatomical information.

Statistical analyses

Statistical analyses were performed using IBM SPSS (version 25.0; IBM Corp., Armonk, NY, USA). Variables following a normal distribution are presented as mean ± standard deviation, while variables not following a normal distribution are presented as medians. Categorical variables are presented as frequencies (percentages). Gender-based comparisons of satisfaction and learning outcomes were conducted using independent t-tests for normally distributed continuous variables and Mann-Whitney U tests for non-normally distributed variables,

Table 1 Contents of the cross-sectional anatomy special study module

Module Section	Topics
Introduction to Cross-Sectional Anatomy	- Overview of cross-sectional imaging modalities - Importance and applications in clinical practice
Basic Concepts of Cross-Sectional Imaging	- Principles of CT (Computed Tomography) - Principles of MRI (Magnetic Resonance Imaging) - Image acquisition and interpretation basics
Anatomical Terminology and Planes	- Anatomical planes (sagittal, coronal, transverse) - Anatomical directional terms - Spatial relationships in cross-sectional images
Head and Neck Anatomy	- Cross-sectional anatomy of the skull and brain - Detailed anatomy of the head and neck structures - Pathological findings in head and neck imaging
Thoracic Anatomy	- Cross-sectional anatomy of the thorax, including lungs, heart, and major vessels - Pathological findings in thoracic imaging
Abdominal and Pelvic Anatomy	- Cross-sectional anatomy of abdominal organs - Pelvic anatomy and reproductive organs - Imaging of common abdominal and pelvic pathologies
Musculoskeletal Anatomy	- Cross-sectional anatomy of bones, joints, and muscles - Common musculoskeletal pathologies and their imaging characteristics
Vascular Anatomy	- Cross-sectional anatomy of major arteries and veins - Imaging of vascular structures and common vascular disorders
Integration of Anatomy with Clinical Applications	- Case studies demonstrating the application of cross-sectional anatomy in clinical settings - Correlation of imaging findings with clinical symptoms
Advanced Imaging Techniques	- Introduction to advanced imaging techniques (functional MRI, Positron Emission Tomography(PET)-CT) - Applications and interpretation in complex clinical scenarios
Presentations	- Hands-on practice with cross-sectional imaging software - Interpretation of cross-sectional images from clinical cases
Evaluation and Review	- Assessment of students' understanding of cross-sectional anatomy - Review of key concepts and common challenges
Current Trends and Future Directions	- Emerging technologies and advancements in cross-sectional imaging - Future trends and their potential impact on clinical practice

with a significance level set at $p<0.05$. A linear regression analysis was conducted to analyze the relationship between the number of students and their expectations. The correlation coefficient (r) was calculated to assess the strength of the linear relationship between the number of students and the percentage of responses. Furthermore, the coefficient of determination (R^2) was computed (0.99), meaning that 99% of the variance in students' expectations (Table 4) could be explained by the number of students responding. A chi-square test was performed to assess the statistical significance of the differences in the proportion of students' expectations (Table 5).

Table 2 Survey questions for the cross-sectional anatomy special study module (SSM) administered to students

Numbers	Questions
Q1.	What were your expectations for the Cross-Sectional Anatomy Special Study Module (SSM) before it began?
Q2.	How did the module help you understand how anatomical knowledge is applied in clinical practice?
Q3.	How did the module contribute to your knowledge of human anatomy?
Q4.	To what extent did the module enhance your understanding of radiological imaging techniques?
Q5.	In what ways did the module support your decision-making in choosing a specialty?
Q6.	How did the module help you reinforce the topics covered?
Q7.	Did the module help you develop presentation skills? If so, how?
Q8.	What were the most significant benefits you gained from the module?
Q9.	How effective was the module in integrating basic and clinical sciences?
Q10.	How did the module contribute to your clinical learning and ability to perform clinical analysis?
Q11.	How did your interaction with faculty members and participation in their research enhance your learning experience?

Qualitative data analysis was conducted using thematic analysis to identify the recurring themes in the student feedback. A coding framework was developed to categorize the responses, and the data were systematically coded by two independent researchers to ensure the consistency of the coding. Any discrepancies in coding were resolved through discussion. Qualitative analysis was performed using NVivo (QSR International, Melbourne, Australia). Thematic analysis focused on key areas such as integration with clinical practice, knowledge reinforcement, skill acquisition, student satisfaction, and the educational impact of the SSM.

Results

A total of 100 students participated in the study, including 40 females (40%) and 60 males (60%). The students were asked about their expectations and perceived benefits of the elective cross-sectional anatomy SSM, which covered aspects such as the application of anatomical knowledge in clinical practice, understanding human anatomy, radiological imaging techniques, and the development of presentation skills. The results indicated that the integration of basic anatomical knowledge with clinical practice was the most emphasized area among students. On the first day, the students were asked about their expectations

Table 3 Cross-Sectional anatomy special study module (SSM) monitoring forms

Participant Information

Student ID: _____

Date: _____

Gender: _____

Module Expectations & Learning Outcomes

1. What were your expectations for the Cross-Sectional Anatomy Special Study Module (SSM) before it began?

[Open-ended response]

2. How did the module help you understand how anatomical knowledge is applied in clinical practice?

[Open-ended response]

3. How did the module contribute to your knowledge of human anatomy?

[Open-ended response]

4. To what extent did the module enhance your understanding of radiological imaging techniques?

[Open-ended response]

5. In what ways did the module support your decision-making in choosing a specialty?

[Open-ended response]

Module Effectiveness and Learning Focus Areas

Integration of Knowledge

6. To what extent did the module help integrate basic and clinical sciences?

☐ Very ineffective

☐ Somewhat ineffective

☐ Neutral

☐ Somewhat effective

☐ Very effective

7. Did the module help you understand how anatomical knowledge is applied in clinical settings? Please provide examples

[Open-ended response]

Presentation Skills

8. Did the module help you develop your presentation skills?

☐ Not at all

☐ A little

☐ Moderately

☐ Significantly

☐ Exceptionally

9. If yes, how did the module help you develop presentation skills?

[Open-ended response]

10. How did preparing and delivering presentations during the module impact your confidence and approach to public speaking?

[Open-ended response]

Clinical Learning and Analytical Skills

11. How did the module enhance your clinical learning and analytical skills, especially in relation to radiological imaging techniques?

[Open-ended response]

12. Were there any specific imaging techniques or clinical analysis methods that you found particularly valuable?

[Open-ended response]

Faculty Interaction and Research Engagement

13. How did your interaction with faculty members during the module enhance your learning experience?

[Open-ended response]

14. Did participating in faculty-led research activities contribute to your understanding of the subject matter? If so, how?

[Open-ended response]

15. How did faculty involvement in your learning process impact your overall experience with the module?

[Open-ended response]

Overall Module Feedback

16. What were the most significant benefits you gained from this module?

[Open-ended response]

17. To what extent do you feel the module met your initial expectations?

☐ Did not meet expectations

☐ Partially met expectations

Table 3 (continued)

Participant Information
☐ Met expectations
☐ Exceeded expectations
18. How likely would you recommend this module to other students?
☐ Not likely
☐ Somewhat likely
☐ Likely
☐ Very likely
19. Any suggestions for improvement or additional comments?
[Open-ended response]

Table 4 Students expectations from the selected cross-sectional anatomy SSM

Expectation	Description
Learning how to apply anatomical knowledge in clinical practice	Understanding the clinical applications of anatomy
Gaining more knowledge of human anatomy	Enhancing overall knowledge of human anatomy
Understanding radiological imaging techniques	Learning about radiological imaging methods
Benefiting in the choice of specialization	Gaining insights that aid in specialization decisions
Reinforcing topics covered	Consolidating knowledge of the subjects
Developing presentation skills	Acquiring skills for effective presentations

SSM: (Special Study Module)

Table 5 Evaluation of participant feedbacks

Category	*n*	%	χ2	*p*
Gaining very useful and important knowledge	48	48.0	0.688	0.407
Acquiring presentation skills	52	52.0	1.371	0.242
Integration	74	74.0	8.288	0.004*
Clinical learning and clinical analysis	52	52.0	1.371	0.242
Beneficial for career choice	13	13.0	3.621	0.057
Increased communication with faculty members	13	13.0	3.621	0.057
Teamwork	9	9.0	5.038	0.025*

from the elective cross-sectional anatomy SSM course. Students expressed their expectation to learn how anatomical knowledge applies in clinical practice, gain a better understanding of human anatomy, learn radiological imaging techniques, benefit from choosing a specialty, reinforce covered topics, and develop presentation skills (Q1). Integration with clinical practice was emphasized by 73.9% of the students (Q2), while 52.2% reported that the module significantly enhanced their understanding of anatomy (Q3). Feedback regarding the understanding of imaging techniques was generally positive, although not quantified (Q4). Approximately 13% found the module helpful for specialty decision-making (Q5), and the reinforcement of topics was implied through feedback (Q6). Additionally, 52.2% of the students reported that they gained presentation skills (Q7). The most significant benefits identified were knowledge gain (47.8%), presentation skills (52.2%), science integration (73.9%), clinical learning (52.2%), and improved communication with faculty (13%) (Q8). The effectiveness of integration was noted by 74% of the students (Q9), and 52.2% felt that the module contributed to their clinical learning and analytical skills (Q10). Finally, 13% mentioned an enhanced learning experience through faculty interactions and research observations (Q11). The most emphasized theme was integration, as reflected by most students. Additionally, 13 students noted that the special study module was beneficial to their careers.

The regression equation was $Y = 4.35X - 0.03$, where Y represents the percentage (%) of responses, and X represents the number of students (n). The correlation coefficient was approximately 0.99, indicating a strong positive correlation. Moreover, the coefficient of determination (R^2) was 0.99, indicating that nearly 99% of the variance in the percentage of responses could be explained by the number of respondents. This demonstrates a linear relationship, suggesting that students' expectations were highly consistent and predictable based on the number of responses received (Fig. 3). The chi-square value was 9.01, with a p-value of 0.173, indicating that the differences were not statistically significant, as the p-value was greater than 0.05.

Student feedback and comments

The students provided additional qualitative feedback regarding their experiences with the elective SSM. Most students expressed satisfaction with the integration of basic and clinical sciences. Specific comments included:"One of my main expectations was to learn how the anatomy knowledge we acquired would be related to the clinical setting. The SSM was beneficial in this regard, helping us relate it to clinical contexts."

> *The SSM serves as a common ground between basic and clinical sciences. I learned a lot.*

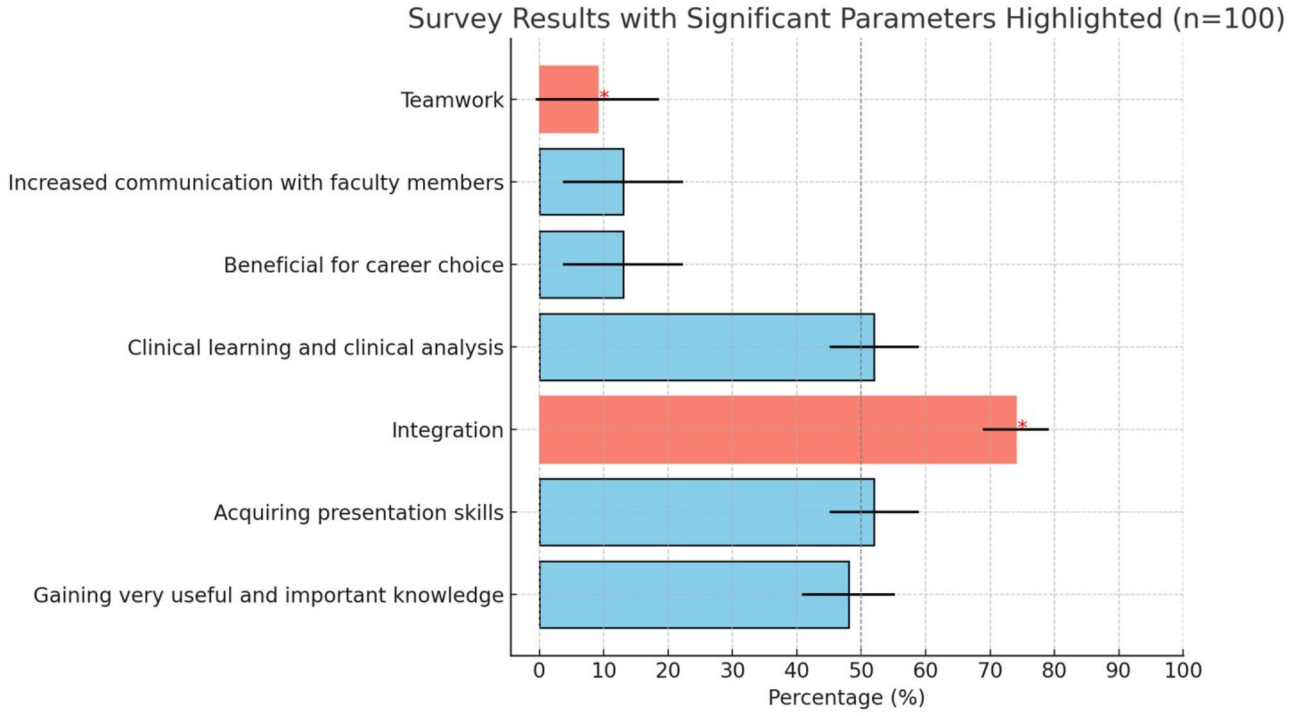

Fig. 3 The figure presents the survey results for the Cross-Sectional Anatomy Special Study Module (SSM) and reflects students' feedback on various aspects of the module. Integration with Clinical Practice emerged as the most significant benefit, with approximately 74% of students emphasizing its importance. Over half of the students reported both an understanding of anatomy and presentation skills, with each category receiving 52.2% of the responses, respectively. Support in choosing a specialty and improved communication with faculty were less frequently highlighted, each being noted by 13% of the students. Additionally, 52.2% of the students valued clinical learning and analysis equally. The percentages of respondents in each category are shown, with error bars representing the standard errors. Categories with statistically significant differences ($p < 0.05$) are highlighted in salmon color with a red asterisk next to them

In problem-based learning, some imaging techniques were mentioned, and I had the opportunity to examine them more closely.
I was initially apprehensive about presenting, but it turned out to be enjoyable, and I found that starting early was beneficial.

Additionally, 13 students highlighted that the module was beneficial to their careers, emphasizing the impact of the course on their future professional development. Table 6 summarizes students' feedback based on the focus area and individual comments.

Discussion

This study demonstrated the effectiveness of cross-sectional anatomical SSMs in enhancing students' learning, clinical integration, and professional development. The key findings indicated that students highly valued clinical integration, with 73.9% of them identifying it as the most beneficial aspect of the module. Additionally, 95% of the students reported that their initial expectations were met, reinforcing the perceived educational utility of the SSMs. However, these results align with those of previous studies that emphasized the importance of integrating anatomy education with clinical applications [32, 33]. Additionally, the number of participants in the integration and teamwork categories was significantly different from the expected frequency. Career benefits and increased communication with faculty members were of borderline significance. In the other categories, the number of participants did not significantly differ from the expected frequency. These results indicate that participants placed greater importance on education and development in areas such as integration and team work. The primary factor influencing students' module choices was the topic itself, cited by 38.9% of respondents. The influence of educators was also significant, affecting 23.3% of students. Peer influence, perceived foundational value for future studies, and perceived module ease were less influential, with 11.6%, 11.1%, and 9.9% of students, respectively. Only 5.2% of participants did not choose their modules [9].

Studies have shown that faculty members and students hold positive views regarding the implementation of SSMs and support innovative strategies [3]. The significant differences observed in the integration and teamwork categories highlight the role of SSMs in fostering collaborative learning. Prior research has demonstrated that small-group learning enhances teamwork,

Table 6 Student feedback categorized by focus area and learning outcomes

Focus Area	Student Feedback	Learning Outcomes
Integration of Knowledge	"One of my fundamental expectations was to understand how the anatomical knowledge we have learned could be related to clinical practice. This SSM was very beneficial in this regard; we learned how to apply it in clinical settings". "This SSM demonstrated the intersection of basic and clinical sciences. I learned a lot".	-Most students found the module effective in bridging the gap between anatomical theory and clinical practice. -They appreciated the practical application of learned knowledge in real-world settings.
Presentation Skills	"Initially, the idea of giving a presentation was intimidating and discouraging, but starting early seems beneficial for the future. I even found that preparing and delivering presentations was enjoyable rather than burdensome"	-Twelve students reported significant improvement in their presentation skills. -They noted that the early practice and preparation helped them overcome initial apprehensions and find enjoyment in presenting.
Clinical Learning and Analytical Skills	"In problem-based learning, some imaging techniques were mentioned, and I had the opportunity to study them in greater depth"	-Students highlighted that the SSM provided a deeper understanding of imaging techniques and clinical analysis. -This focus helped them enhance their analytical skills and clinical knowledge.
Experience with Faculty	Thirteen students reported having an enjoyable experience with faculty members and observing their involvement in various research activities.	-Students valued the engaging interactions with faculty and the opportunity to observe their research, which enriched their learning experience and provided insights into practical applications of their studies.

Special Study Modules (SSMs)

communication skills, and problem-solving abilities, which are essential in clinical practice [10]. However, the borderline significance of career benefits and increased faculty interaction suggests that while these aspects are acknowledged, their impact may require further investigation. The study also identified the primary factors influencing module selection, with the topic being the most significant factor (38.9%). This finding is consistent with previous research, indicating that students prioritize personal interests and relevance to future careers when selecting SSCs/SSMs [34, 35]. One study reported that SSC, SSMs, and independent projects aid students in learning specific aspects of neurosurgery and increase their interest in the field. Most participants either presented their work at conferences or published their findings [36]. Both students and faculty members have indicated that SSMs contribute not only to benefits such as providing opportunities for research, reading articles, in-depth learning, developing presentation skills, and working in small groups, but also to social activities and personal development [9]. For instance, some students reported that participation in SSMs led them to start exercising, adopt healthier eating habits, and quit smoking [37]. Students placed the greatest value on the insights gained from patients' experiences of illness, including aspects of understanding, knowledge, and empathy. They also felt that they had enhanced clinically relevant skills, such as communication, analysis, presentation, writing, and ethical reasoning. Other benefits include personal growth, development and overall satisfaction [37]. Similar findings were reported in studies conducted by Yates et al. Students have suggested including an SSM on a topic not directly related to medicine in the educational curriculum [38]. Enthusiasm and collaboration increased following the implementation of the core curriculum and SSMs at the Faculty of Medicine and Health Sciences, Universiti Malaysia Sarawak [8]. SSMs were incorporated into the undergraduate medical curriculum based on General Medical Council (GMC) recommendations. The most common themes were health and prevention, followed by communication skills (64.4% and 62.7%, respectively). Transferable skills were well represented across specialties, with information gathering and organizational skills being notably emphasized. Student feedback was positive, indicating the development of a broad range of transferable skills and alignment with the GMC-recommended themes [39]. One study found positive trends in students' knowledge, confidence, and experience with SSM across three survey time points. The mean scores for satisfaction with guidance, enjoyment of the SSM process, and perceived value of active learning over passive methods were consistently above 8.0. Students have indicated that involvement in research increases the likelihood of future research engagement and improves their research experiences [40]. The results of our study align with the existing literature, highlighting the significance of integration of anatomical knowledge into clinical practice within the Cross-Sectional Anatomy SSM. These findings reinforce the educational benefits reported in previous studies, particularly in terms of enhancing core competencies and promoting collaborative learning.

SSC reportedly positively influences cognitive, personal, and professional development. By providing students with choices, the SSC fosters self-direction and proactive behavior. Students gain research experience and develop independent thinking and analytical skills [41]. A previous study reported that SSM had varying degrees of success in developing different skills among the participants. The majority reported improvement

in utilizing the Internet (68.7%) and giving verbal presentations (61.7%), while a smaller percentage reported improvement in accessing library articles (29.0%) and preparing posters (30.9%) [9]. In line with these findings, our study also demonstrated the significant educational benefits of Cross-Sectional Anatomy SSM. Notably, 74% of the students emphasized the importance of integration within the SSM ($p = 0.004$), and 52% reported acquiring the presentation skills. Additionally, 9% of the students highlighted teamwork, which was statistically significant ($p = 0.025$). Although the influence on career choice and increased communication with faculty members were acknowledged by 13% of students, these categories approached but did not reach statistical significance. These results align with the literature, confirming the effectiveness of SSMs in fostering key skills, particularly in integration, teamwork, and presentation.

One study investigated the changing patterns of SSC selection among medical students and the motivational factors behind it. The following primary motivations were identified: knowledge gaps, genuine interest, career strategy, exam preparation, and opportunism. The findings highlight a complex relationship between these motivations and SSC choices, with research-skills SSCs being particularly associated with career strategies [42]. Cross-sectional imaging and 3D printing are cutting-edge methods for enhancing anatomy education compared to traditional approaches; however, their implementation in medical schools remains limited [43]. Previous studies have reported that student satisfaction and learning outcomes can be influenced by both the academic year and the field of study [44, 45]. Additionally, changes in course content, teaching methods, and assessment strategies may affect students' satisfaction and learning outcomes. As noted by Komarek et al., continuous improvements to educational programs are often made in response to feedback, which can lead to variations in student perceptions across cohorts [46].

From a methodological perspective, this study employed a structured, survey-based approach to assess student perceptions. Although this methodology effectively captures students' subjective experiences, it has inherent limitations. Self-selection bias may have influenced the results, as students who actively chose the module may have had a predisposition to find it beneficial. Furthermore, the absence of a control group limits the ability to compare the effectiveness of cross-sectional anatomy SSMs with that of traditional anatomy education methods [43]. Early innovative efforts have been made to integrate cross-sectional anatomy into medical curricula. For instance, Oh et al. employed clay models of internal organs using their cross-sections to teach students the interpretation of cross-sectional diagnostic imaging [47]. This study highlights the potential of innovative teaching methodologies, such as the integration of cross-sectional imaging and 3D printing, in anatomy education. The existing literature supports the advantages of these approaches in improving spatial understanding and radiological interpretation skills [43]. However, despite their proven benefits, the implementation of such technologies in medical curricula remains limited. The findings of this study emphasize the need for further curricular integration, particularly in preclinical medical education, where cross-sectional prosections have been shown to significantly enhance radiological image interpretation [48]. The feedback collected at the end of each session of the cross-sectional anatomy SSM revealed that 47.8% of the students found the module beneficial and important, while 52.2% reported an improvement in their presentation skills. Integration was the most emphasized theme, noted by 73.9% of the students, and most students found the module useful for their careers. Based on this feedback, future iterations of the Cross-Sectional Anatomy SSM should prioritize the further integration of anatomical knowledge with clinical practice, emphasizing radiological applications. To enhance the module's impact, additional focus could be placed on interdisciplinary teamwork and collaborative learning, given the significant value that students placed on these aspects. Furthermore, increasing faculty-student interactions through mentorship and research opportunities may enhance learning experiences and support career development. Finally, the inclusion of diverse topics in SSMs beyond traditional medical content can address students' interests and support their professional growth.

This study differentiates itself from previous research by providing a detailed analysis of the impact of Cross-Sectional Anatomy SSM on various aspects of medical education, specifically focusing on the integration of anatomical knowledge with clinical practice. While previous studies have emphasized the importance of integrating clinical case discussions and teamwork in anatomy education, this study is unique in its focus on radiological interpretation and the use of cross-sectional anatomy as an educational tool for teaching clinical skills.

Key findings that are original to this study include the high value placed by students on clinical integration (73.9%) and the statistical significance found in the areas of integration, teamwork ($p = 0.025$), and presentation skills (52%). The study also identifies the primary factors influencing module choice, such as personal interest in the topic and the educator's influence, providing students with motivation to select these types of educational modules.

In comparison to earlier research that indicated the benefits of SSMs in terms of knowledge, research skills, and teamwork, this study builds upon these findings by specifically analyzing the effectiveness of Cross-Sectional

Anatomy SSMs and offers an understanding of how these modules support student learning, particularly in terms of radiological and clinical skills.

Implications for practice

The results suggest that integrating clinical case discussions and radiological practice into anatomy education significantly improves students' spatial visualization and diagnostic skills. This aligns with previous research emphasizing the importance of experiential learning in medical education. These findings demonstrate that cross-sectional anatomical SSMs play a crucial role in bridging theoretical knowledge and clinical practice. By enhancing radiological interpretation skills, fostering professional decision-making, and improving presentation abilities, these modules significantly contribute to medical education. Implementing similar modules in other institutions may improve educational outcomes and prepare students for clinical practices.

Limitations

One limitation of this study is its reliance on self-reported data, which, although a common method in medical education [27, 28], has inherent limitations. Self-reported data are susceptible to several biases, such as the Dunning-Kruger effect [49], where individuals may overestimate their abilities or the effectiveness of a learning experience. This bias could result in participants rating their expectations and outcomes more favorably than they would if they were measured using objective criteria. Additionally, the absence of objective academic performance measures, such as exam scores [50] or practical assessments, further limits the ability to quantitatively assess the true impact of the elective module. Without such objective measures, this study cannot definitively conclude that students' reported gains in knowledge, clinical learning, and presentation skills translate into improved academic or clinical performance.

Moreover, this study's focus on a single institution introduces additional limitations. The sample may not be representative of the wider population of medical students, as it is influenced by specific institutional factors, such as faculty teaching style, curriculum design, and student demographics. The diversity of student backgrounds, educational experiences, and clinical exposure may vary significantly among institutions, potentially affecting the applicability of the results to other settings.

Additionally, the short-term nature of this study restricts its ability to evaluate the long-term impact of SSM on students' academic and professional development. Future research should consider longitudinal studies that assess how the skills and knowledge gained from such modules affect students' careers and clinical practices over time. Furthermore, multi-institutional comparisons would provide a wide perspective on the effectiveness of the SSM and allow for the identification of institutional factors that may influence the learning outcomes. This would enhance the external validity of the findings, provided they are applicable to a wider range of educational contexts.

Future research

Future longitudinal studies tracking students' clinical performance and career outcomes could offer a more comprehensive understanding of the long-term benefits of such modules. This would help address the current limitations of a short-term study design and contribute to validating the impact of these educational practices beyond the classroom.

Conclusion

In conclusion, the cross-sectional anatomy SSM effectively met the diverse expectations of students, providing valuable educational experiences that integrated basic and clinical anatomical knowledge, enhanced presentation skills, and fostered clinical learning and analytical abilities of the students. The module's balanced approach to addressing various educational needs highlights its potential as a beneficial component of medical education. The integration of anatomical and radiological learning proved to be a critical component of the module, with students expressing high levels of satisfaction and recognizing the relevance of this approach to their future medical careers. The results of this study offer a strong foundation for future improvements and potential expansion of similar educational initiatives.

Abbreviations

CT	Computed Tomography
CTA	Computed Tomography Angiography
GMC	General Medical Council
MRI	Magnetic Resonance Imaging
Q	Question
QSR	Qualitative Solutions and Research
SSC	Student Selected Component
SSM/s	Special Study Module/s
3D	Three-Dimension
PET	Positron Emission Tomography

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Author contributions

EO, FBY, YS, and AUS conceived of and designed the study. FBY, EO, and YS were responsible for data collection and acquisition. FBY, EO, and YS contributed to the data management and interpretation. EO and YS analyzed the data. EO, FBY, YS, and AUS participated in drafting the manuscript, critically revising it for important intellectual content, and writing the manuscript. All authors have given final approval of the version to be submitted.

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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
All procedures involving human participants adhered to the ethical standards of Akdeniz University, as approved by the Ethics Committee of the Akdeniz University Faculty of Medicine (protocol ID: TBAEK-251), and were conducted in accordance with the 1964 Helsinki Declaration and its subsequent amendments, or comparable ethical standards.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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