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Article

Student-Centered Active Learning Enhances Performance in Solving Higher-Level Cognitive Questions in Health Sciences Education

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Simple Summary: Student-centered active learning (SCAL) shifts the focus from teachers to students and requires new assessments beyond memorization and comprehension. This paper demonstrates the effectiveness of SCAL by analyzing student performance at different cognitive levels in flipped classrooms. The tests measured knowledge, comprehension, application and analysis. SCAL assesses content acquisition and critical skills for health sciences education. Over three academic years, student performance in expository learning was compared with SCAL in the Anatomy and Embryology I course. Opinions from 326 anonymous surveys were also collected. While low-level cognitive performance showed no difference, SCAL significantly improved higher-level problem solving and knowledge application. Despite the benefits of SCAL, it requires more effort from teachers and students, and the current teaching quality assessment system penalizes teacher´s effort.

Abstract: Student-centered active learning (SCAL) shifts the focus from the teacher to the student. Implementing SCAL requires the development of new forms of assessment beyond memorization and comprehension. This paper aims to demonstrate the effectiveness of SCAL by analyzing student performance at different cognitive levels. In flipped classrooms, students completed tasks with varying cognitive demands. The tests measured knowledge (level 1), comprehension (level 2), application (level 3) and analysis (level 4). This approach to assessment assesses not only the acquisition of content, but also skills that are critical to a health science student's future career. The results of expository learning were compared with student-centered collaborative learning in the Anatomy and Embryology I course over three academic years. Student opinions were collected through 326 anonymous Wooclap® surveys. No differences in performance were found for low cognitive level questions. However, SCAL significantly improved performance on higher cognitive level questions that required problem solving and application of knowledge. Despite the benefits of SCAL, it requires more effort from both teachers and students. The current assessment system, which measures the quality of teaching, penalizes this effort and requires teachers to believe strongly in the effectiveness of SCAL.

Keywords: anatomy teaching; EAEVE; ESG; flipped classroom; teaxhing assessment; health sciences education

1. Introduction

The shift towards active learning in higher education, driven by the Bologna process and EU directives, marks a significant departure from traditional lecture-based teaching practices [1]. Traditional lectures focus on one-way communication, where teachers deliver information and students passively listen and take notes, emphasizing memorization. This method typically involves structured, linear presentations with little flexibility or student input, and assessment often relies on exams that test recall rather than understanding or application [2].

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In contrast, active learning engages students directly and requires active participation through reading, writing, discussion and problem solving. This approach encourages higher-order thinking skills such as analysis, synthesis and evaluation. Active learning helps students acquire professional skills that are not achievable through lecture-based instruction [4,5]. In addition, evidence shows that active learning strategies that engage students mentally produce better educational outcomes than traditional lectures [6–8].

In student-centered active learning (SCAL), students construct knowledge and teachers guide and facilitate learning. In the veterinary medicine program at Complutense University we have implemented three SCAL methods: Team-Based Learning (TBL) in laboratory sessions [9], Flipped Classroom in theory sessions [10,11], and Problem-Based Learning (PBL) integrated into all courses. This study focuses on the effectiveness of the flipped classroom compared to expository teaching.

The flipped classroom method, based on constructivism, cooperative and active learning, considers individual learning differences [12]. It involves self-directed and self-regulated learning, problem solving, collaboration and inquiry-based activities. Students actively participate and develop skills such as analytical thinking, problem solving and metacognitive activities [13–15].

In the flipped classroom, students use theoretical knowledge to solve real-world problems through cognitive exercises. To assess performance, we designed tests to measure skills beyond memorization and comprehension. This article presents our experience of evaluating the same content taught by the same teacher using both expository and active learning methods, with comparable questions at four cognitive levels adapted from Bloom's Taxonomy for teaching anatomy [16]. We also present students' opinions of both teaching methods.

2. Materials and Methods

The research was conducted in the subject Anatomy and Embryology I at the Faculty of Veterinary Medicine of Complutense University of Madrid (UCM), during the academic years 2015/16, 2022/23, 2023/24. Participants included recent high school graduates, some with previous higher education, and some repeating the subject.

Theoretical Lectures: A total of 10 lectures for the cardiovascular block were delivered twice or thrice a week for one hour. Traditional lectures involved presenting objectives and content using Microsoft PowerPoint®, with some interaction through questions and examples of anatomical reasoning.

Flipped Classroom Learning: Flipped classroom sessions focused on practical, student-centered activities. Students watched H5P videos available on the Virtual Campus four days before class. In-class activities included individual, and group cognitive exercises based on real clinical cases, requiring students to apply their knowledge and seek additional information as needed. Groups were color-coded, and discussions were facilitated using portable microphones and thumbs-up/down paddles. In class, students were first given cognitive exercises to complete individually and then with their assigned groups, responding in writing or through Wooclap®. Some of these exercises, based on real clinical cases, required not only the content taught in the H5P videos but also the application of knowledge acquired during their training or the search for additional information needed to understand the clinical case.

Informative Sessions: In 2022/23, an information session introduced active learning and its teaching strategies to students and teachers, emphasizing their new roles. In 2023/24, two seminars focused on active learning philosophy and the TBL methodology for practical sessions and flipped learning for theoretical sessions. This session was attended by 170 students who completed an initial 7-question non-anonymous survey. In the academic year 2023/24, two informative seminars were held on the active learning methods to be used. The first seminar covered active learning in general as a teaching philosophy and introduced the TBL methodology for practical sessions. The second seminar focused on the flipped learning method.

Student Surveys: Surveys during the 2022/23 and 2023/24 information sessions gathered data on students' academic backgrounds, previous experience with active learning, and teaching preferences. In-class surveys used the Wooclap® tool to assess student opinions on theoretical

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teaching and active learning experiences. Responses were scored using a Likert scale and analyzed for positive, negative, and suggestive comments.

Learning Outcomes Assessment: Performance data from Anatomy and Embryology I for the academic years 2015/16, 2022/23, and 2023/24 were compared. The number of students taking the test was 158, 193, and 180, respectively. The tests covered the same syllabus and were taught by the same lecturer. Questions were classified according to Bloom's Taxonomy [17] revised in 2001 [18], which defines cognitive levels. The four cognitive levels were adapted for anatomy teaching (Table 1) [16]. In this study four cognitive levels were used: knowledge (level 1), comprehension (level 2), application (level 3), and analysis (level 4). Anomalies were addressed by reassessing questions.

This study evaluates the effectiveness of flipped classroom learning compared to traditional expository teaching, presenting students' opinions and performance data across different cognitive levels.

Table 1. Cognitive levels according to Bloom's Taxonomy adapted to the assessment of anatomical content. Adapted from Thompson and O'Loughlin, 2015.

	Lower order		**Higher order**	
Bloom´s levels	**1 (Knowledge)**	**2 (Comprehension)**	**3 (Application)**	**4 (Analysis)**
Distinguishing features of questions	Questions are straight forward with answers likely stated verbatim in notes or text Questions usually not placed in a clinical context Students not required to make independent connections from the information		Anatomic information may be placed in a clinical scenario or a new setting (although not all clinical questions are higher order) Students must interpret and make independent connections from the information	
Key skills assessed	Identify, recall, repeat, memorize	Describe or distinguish	Infer or predict	In addition to infer or predict, interpret, judge, critique, or analysis
Types of anatomical information assessed	Basic definitions Facts Straightforward recall	Anatomical concepts Basic spatial organization Basic understanding of pathways, blood supply, and innervation	Interaction between two or more body systems Functional aspects of anatomical features beyond memorization	Interaction between two or more body systems and applying information to a potentially new situation Interpretation of anatomical images Potential to use clinical judgment
Type of question	**MEM**	**DI**	**AR; MEM+AR; AC**	**AR+SP; ADI**

AC: Association of concepts; **ADI**: Anatomy and diagnostic imaging; **AR**: Anatomical reasoning; **AR+SP**: Anatomical reasoning to solve real-life problems; **DI**: Diagram or image interpretation; **MEM**: Memorization; **MEM+AR**: Memorization and anatomical reasoning.

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3. Results

3.1. Survey Conducted during the Information Session on Active Learning

3.1.1. Academic Year 2022/23

A total of 170 students responded to the survey. It was found that:

- 27% of the students had experience with problem-based learning.
- 72% had experienced collaborative learning.
- 27% were familiar with flipped learning.

3.1.2. Academic Year 2023/24

A total of 151 students responded to the survey. The results showed:

- Almost all students indicated they had no prior experience with any form of active learning.
- 79% had experience with collaborative learning.
- 56% knew what flipped learning was.

When asked which form of learning they identified with:

- 10% of the students chose option a): "Expository teaching, where the teacher tells me everything I need to know."
- 89% of students chose option b): "Active teaching, where I learn to think about and use the content I am learning under the guidance of the teacher."
- 1% of students chose option c): "I don't care, I can always be a GoogleVet."

3.2. Anonymous Survey Conducted at the End of the Experience

3.2.1. Academic Year 2022/23

A total of 164 students responded to the survey. When asked about their preferred type of education:

- 52% of students chose "I prefer when the teacher is the only one explaining the material and I take notes."
- 48% chose "I prefer when the teacher explains, teaches thinking, and guides my learning."

3.2.2. Academic Year 2023/24

A total of 160 students responded to the survey. The results showed:

- 100% of students agreed that learning how to think is important for becoming a good veterinary professional.
- When asked about their preferred type of education:
  - 56% of students chose "I prefer when the teacher is the only one explaining the material and I take notes."
  - 44% chose "I prefer when the teacher explains, teaches thinking, and guides my learning."

Table 2 shows the categorized comments made by the students

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Table 2. Summary and classification of student comments in the 2022/23 and 2023/24 surveys.

Academic Year	Comments and students' opinions about the active learning experience.			
2022-23 (n = 152)	**Positive**	**76** 49.66%	Expressing satisfaction	**11** 7.18%
			With suggestions for improvement included	**65** 42.48%
	Negative	**31** 20.36%	Expressing dissatisfaction	**26** 17.18%
			With suggestions for improvement included	**5** 3.26%
	Not taken into account	**35** 22.80%	Disagreement on methodology	**18** 51.43%
			Comment contradiction	**15** 42.85%
			Comment of a personal kind	**2** 5.72%
	Without comment			**11** 7.18%
2023-24 (n = 148)	**Positive**	**60** 40.54%	Expressing satisfaction	**14** 9.45%
			With suggestions for improvement included	**46** 31.08%
	Negative	**35** 23.64%	Expressing dissatisfaction	**29** 19.59%
			With suggestions for improvement included	**6** 4.05%
	Not taken into account	**24** 16.21%	Disagreement on methodology	**10** 6.75%
			Comment contradiction	**9** 6.08%
			Comment of a personal kind	**5** 3.37%
	Without comment			**29** 19.59%

3.3. Learning Outcomes Assessment

Table 3 shows the average scores obtained by the students for all questions, as well as for each question at different cognitive levels. The results compare teaching (year 2016/2016), partially inverted teaching (year 2022/23) and fully inverted teaching for the entire class and all content (year 2023/24). In the 2023/24 academic year, an unexpected result was detected in a level 1 memorization

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question. Upon review, a reading comprehension issue was found, affecting 69% of students. This led to the question being discarded and replaced with another question at the same cognitive level.

Table 3. Average scores obtained by groups and at each cognitive level.

Year	Total average score	Level 1	Level 2	Level 3	Level 4
2015/16	3.23	4,31	3.05	2,90	2.76
2022/23	4.11	3.73	4.04	4.20	4.50
2023/24	4.71	4.15	4.81	4.23	5.66

The average scores obtained by the flipped classroom groups for each cognitive level question are shown in Table 4. These scores include both students who attended the class and those who did not.

Table 4. Average scores obtained by the flipped classroom groups for each cognitive level question.

		COGNITIVE LEVELS			
		Level 1	**Level 2**	**Level 3**	**Level 4**
Year 2022/23 n = 190	**Attending to class n = 79** 41,57%	4,40	4,90	4,80	5,70
	Not attending to class n = 111 58,43%	3,10	3,20	3,70	3,30
Year 2023/24 n = 180	**Attending to class n = 125** 69,44%	6,16	6,26	5,53	6,31
	Not attending to class n = 55 30,56%	3,12	4,96	3,57	5,10

4. Discussion

At our school, active learning methods are implemented by only a few teachers; most courses remain teacher centered. As a result, students are accustomed to traditional teaching methods. During an information session and initial survey, students were asked about their experience with active or collaborative learning. It was confirmed that most students had worked in groups before university but were unclear about the concept of active learning.

In the fully flipped classroom year 2023/24, the most notable finding from the survey was that, after explaining active learning, 89% of students identified with the active learning methodology. Flipped classes consisted of practical lessons with student-centered activities, including peer discussions and feedback to peers and instructors.

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Students' opinions and learning outcomes were analyzed over two academic years. In 2022/23, the flipped methodology was applied to part of the content. Since the method proved effective, all content was taught using the flipped class model in 2023/24.

Comparing the percentages of positive comments, we observe a slight increase in partially flipped classes, while negative comments increase slightly in fully flipped classes. We believe these results reflect some students' resistance to active methods that require more effort and preparation. Most students preferred working in groups to working individually or in pairs, confirming that collaborative learning is a valuable active learning experience. These findings are in line with those of other researchers [19,20].

However, some students complained about peers who preferred to play a passive role rather than participate in group discussions. This passive attitude hindered group discussions and penalized the overall group dynamic. Uneven motivation among students can lead to uneven participation, disrupting the flow of collaborative exercises and diminishing the overall learning experience. The method was found to be too time consuming due to some students' lack of motivation or experience of working in groups. Surveys are a convenient tool for receiving and giving feedback to students.

Some students emphasized that the course was overloaded and that they were working under time pressure. The use of active learning increased the amount of time needed, and in theoretical classes traditional lecturing was often seen as an easier and more efficient method. This is likely to have had a negative impact on students' opinions. As seen in other experiences [20], almost all students were concerned about the stress caused by the lack of time. Although this report only evaluates the first and last surveys, surveys were always conducted on learning with flipped videos, in class and at the end of the thematic block [11].

In SCAL, it is important to use a variety of strategies to obtain continuous feedback from students to determine whether the preparation materials, H5P videos and classroom sessions have helped them to learn. The cognitive exercises carried out and reviewed in the flipped sessions help students to learn at their own pace. Each class began and ended with a Wooclap® survey to assess what students had learned from the H5P video and class session. It is important for students to understand that a survey is not the same as an evaluation of the lesson or the teacher; the focus should be on feedback that provides information for the teacher to understand each student's experience of the lesson.

Feedback should be collected from the beginning of the experience, as in these SCAL experiences, and at the end of active training methods. Students should not be treated as consumers, asked if they liked the lesson or found it easy. Instead, they should be taught the importance of mistakes as learning opportunities. Understanding their difficulties, thought processes, successes and failures can help make learning effective [21]. Student feedback is crucial as it can show whether the innovative methods used have worked [22]. The impact of feedback on teaching depends on how teachers perceive, process and use the information received [23].

In this experience, teachers and most students disagreed about the most effective pedagogical method for learning anatomy. Teachers preferred collaborative learning, while some students found lectures and note-taking more effective. Teachers rated higher order cognitive exercises as more effective for learning. In the 2022/23 and 2023/24 surveys, 52% and 56% of students respectively wanted all the material presented by the teacher in expository lectures. Many students felt that an excellent teacher would provide detailed notes, negating the need for other sources of information. In a practical curriculum such as veterinary medicine, it is surprising that some first-year students value theoretical knowledge over its application. This highlights the importance of information sessions at the beginning of the course.

In the first academic year of flipped learning, only an information seminar was held at the beginning of the course, before the theoretical classes started. The survey in that year showed that students wanted more information about the methodology. In the last academic year, two information seminars were held - one on TBL before the practical sessions and another on flipped

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classroom methodology before the theory sessions - which was successful, with only one student complaining about the amount of information on active methods used.

A disadvantage is that traditional and active teaching methods are taught at the same time, creating competition between them and attempts to convince students of the advantages of one system over the other. Cognitive exercises in class were structured to help students construct their thinking models to solve problems. Some classroom content was not taught in the H5P video, a deliberate omission designed to encourage investigative behavior. Both teachers and students noted the lack of time for self-learning, an effort that is neither quantified nor valued. Teachers need to move from the comfort of traditional lectures to the challenge of developing the necessary materials for SCAL.

Despite the apparent rejection of active learning methods by some students, class attendance was very high, a fact also noted by some other authors [24,25]. This contrasts with complaints from other subject teachers about low student attendance in lecture classes. Many teachers believe that traditional lecture-based teaching is not engaging enough for students to attend class. The results confirm that it does not develop competences beyond memorization and understanding of content. Even with evidence of the positive impact of SCAL strategies on learning and retention, it is difficult to convince some students and teachers that learning requires engagement with content at all levels of instruction [26].

In lecture-based classes, students feel comfortable because they know the importance of good notes. If they miss a class, they can copy notes from a classmate or buy them from online platforms. They believe that classmates who do not attend class can get better grades by getting good notes. This, combined with overcrowded timetables, may explain students' lack of interest in attending lectures. Some students find traditional teaching methods to be a comfort zone where memorizing content ensures passing exams. They prefer traditional teaching because the nature of exams gives them the impression that exams are less difficult, consisting of short and precise questions on content to be understood and remembered (data not shown). A general preference for working directly on multiple-choice questions when preparing for exams has been noted by other authors [20].

The skills acquired by the students were quantified by measuring their ability to memorize, to interpret diagrams or images, to associate concepts, to reason anatomically and to solve real problems involving anatomical reasoning or diagnostic image interpretation. We used different cognitive levels to assess learning outcomes in theoretical classes. To assess the acquisition of the different competences formulated in the learning objectives through active learning, questions with different cognitive levels were used in the theoretical assessments. Although the questions had different cognitive levels, all questions had the same weight. From the results obtained, there were virtually no significant differences in the mean scores for cognitive level 1 questions (memorization questions), regardless of the teaching method used. However, the difference in the assessment of the acquisition of important competences for future veterinary professionals was evident in the questions formulated at cognitive levels 3 and 4. There was a notable difference between traditional teaching and student-centered flipped teaching. From the results obtained using questions with different cognitive levels, there were virtually no significant differences in the mean scores obtained on cognitive level 1 questions (i.e. memorization questions), regardless of the teaching method used. The difference in the assessment of the acquisition of important competences for the future veterinary professional is assessed in the questions formulated at cognitive levels 3 and 4, where a big difference between traditional teaching and student-centered flipped teaching was quantified.

Another important observation from this study is the importance of class attendance in flipped learning, where students learn to think and share ideas with their peers in groups. The performance of the flipped classroom appeared to be related to student attendance in active learning classes. In both partially and fully flipped groups, the importance of class attendance was clear. Students who attended the flipped classes performed better on all questions. It is noteworthy that in the fully flipped classroom group, for the level 4 question - where students must use knowledge to solve a real-world problem - the results were very good for both students who attended class and those who did not. This is probably because all students take part in the anatomy laboratories, which are taught

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using Team-Based Learning (TBL), where they are trained to use anatomical information to solve real-life problems. This was also demonstrated with those repeating the subject (data not shown) who, without attending any theoretical or practical classes, maintained the skills acquired in the previous year's active training. This was only the case for the cognitive question at level 4, indicating that students develop this skill and can use it effectively in the long term.

The traditional assessment system is based on exams where students achieve high scores by memorizing information. In contrast, active learning assessment requires deep reflection and a high degree of personal responsibility, sometimes pushing students beyond their limits [13]. There is a need to validate tools that measure what students learn, rather than just their ability to memorize content. More importantly, it is crucial to validate a tool that can measure the acquisition of other competences. In this sense, we present very positive results on the usefulness of questions with different cognitive levels.

Despite these findings and the fact that student-centered curricula are a quality requirement for veterinary education in Europe [27] and are in line with European Union (EU) directives and the Standards and Guidelines for Quality Assurance in the European Higher Education Area [28], the delivery of curricula by veterinary educational institutions across Europe remains largely traditional. These guidelines recommend that veterinary institutions provide their faculty with pedagogical training to ensure the quality of teaching. We face the challenge of motivating students who are reluctant to make the extra effort, convincing them of the benefits of abandoning a passive attitude to learning and getting them to think, reason and develop a critical mind. We also need to ensure that the great personal and professional benefits of active methods are widely accepted and popularized. Another challenge is to convince our colleagues that the extra effort involved in active methods is worthwhile. We need to demand that teaching quality surveys measure the outcomes of our teaching, rather than the satisfaction of a small number of students who are often not qualified to comment on technical aspects of teaching. The pedagogical preparation of teachers is decisive and has a significant impact on student learning [20].

The SCAL approach is highly pedagogical and should be implemented by individual teachers in their classrooms, as in the active learning experiences presented here. Several active learning strategies have been used to develop SCAL: from introducing a small number of peer discussion questions in class to completely flipping the classroom, delivering content before class and using lecture time for student discussion and problem solving. Over the years we have gradually introduced active elements, moving to flipped classrooms in the last two academic years, and moving from being dispensers of facts to facilitators of the learning experience.

The effectiveness of SCAL is demonstrated when meaningful learning takes place and students can solve different problems with their new models of thinking and reflection. Teachers need to create an appropriate environment for this type of learning [6]. In flipped learning, students moved from independent to interdependent learning. Final surveys showed that collaborative learning was mutually beneficial and preferred to individual learning. Active learning involved the sharing of knowledge, ideas and experiences [20]. An active classroom not only improves student performance but also promotes a more inclusive learning environment [26], as observed in a student with autism spectrum disorder. Active learning has been shown to provide a more structured classroom where learners read before class, engage in activities during class, and practice outside of class, benefiting women and first-generation university students [29]. This study did not evaluate other social aspects of the SCAL experience, and students´ personal comments were not included in the study.

It is strongly recommended that the design of future veterinary education curricula consider and apply a change in teaching and learning philosophy across all subjects in the curriculum.

5. Conclusions

To assess the quality of teaching in an institution, it is essential to evaluate learning outcomes. Active, student-centered teaching fosters skills that are crucial for students' future careers, including self-learning, critical thinking, problem-solving and lifelong learning. To quantify the acquisition of these skills and competences, we have developed an assessment tool that measures the achievement

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of these competences through questions formulated at different cognitive levels. This tool has proved effective in testing the success of this type of learning, confirming that students not only develop these skills, but also use them effectively in the long term.

Our findings show that SCAL methods are effective in developing these essential skills. However, these methods need to be continually refined based on experience and feedback from students. Furthermore, it is crucial to adapt the SCAL methods to all subjects within the veterinary curriculum to ensure a comprehensive and coherent approach to student learning. In this way, we can further improve the quality of education and better prepare students for their careers in veterinary medicine.

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