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Impact of Teaching Methods and Curriculum Design on Biophysics Engagement Across Three Medical Faculties

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ABSTRACT

Background: Biophysics is integral to medical education, yet student engagement varies across faculties, influenced by teaching methods, curriculum structure, and perceived career relevance. This study examines students' engagement with the biophysics curriculum in Medicine, Pharmacy, and Dentistry, focusing on how instructional approaches and curricular design enhance the application of biophysics knowledge in healthcare.

Methods: A cross-sectional study was conducted from October 2023–March 2024 at the University of Duhok, Duhok City, Kurdistan Region, Iraq. Guided by Kolb's Experiential Learning Model (ELM), a 22-item five-point Likert survey was developed to assess three domains: teaching methods, curriculum structure, and application of biophysics in healthcare. The survey was administered to 428 students. Data were analyzed using JMP software (SAS Institute).

Results: Medical students reported the highest satisfaction with teaching methods (mean=9.58) and confidence in understanding biophysics (mean=12.92), exceeding Dentistry and Pharmacy. For healthcare applications, Dentistry showed the highest relevance scores (mean=20.02), reflecting practical uses (e.g., imaging, biomechanics). *t*-tests and R^2 analyses indicated that active learning significantly improved application of biophysics concepts ($p < 0.001$). A well-structured curriculum strongly predicted knowledge application ($p < 0.001$), with the largest effect in Pharmacy.

Conclusion: Active learning strategies and a well-structured curriculum were associated with significantly higher engagement and application of biophysics concepts across all faculties.

Key words: Biophysics education; Kolb's experiential learning model; Curriculum structure; Teaching methods; Student engagement

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INTRODUCTION

Biophysics is a critical component of medical education, bridging the principles of physics with their applications in medicine and healthcare [1]. Student engagement is vital for academic success, influencing knowledge retention, motivation, and the application of concepts in practical medical contexts [2]. Learning theories, such as Kolb's Experiential Learning Model, indicate that engagement is heightened when students actively experience, reflect on, conceptualize, and apply knowledge [3, 4]. In the dominion of medical education, where both theoretical understanding and practical application are essential, engagement with subjects such as biophysics can significantly vary based on curriculum delivery and the context within each discipline [1] .

The structure and delivery of biophysics courses vary across medical, pharmacy, and dentistry faculties, reflecting the distinct professional focuses of each field.

In medicine, students typically emphasize physiological and imaging applications. Pharmacy students focus on molecular interactions and drug mechanisms, while dentistry students concentrate on imaging technologies and biomechanics. These distinctions raise critical questions regarding how teaching strategies and curriculum design influence engagement levels across these disciplines and the application of their knowledge in healthcare.

In order to understand these concepts deeply, the study used Kolb's Experiential Learning Model (ELM) as a theoretical framework, which is widely recognized for understanding how individuals learn through experience [4].

The model is based on a four-stage learning cycle that consists of: concrete experience (CE) learning through direct engagement or hands-on experience, reflective observation (RO) analyzing and reflecting on the experience to gain insights, abstract conceptualization (AC) forming theories or concepts based on reflections, active experimentation (AE) applying newly acquired knowledge to real-world situations [5]. Kolb's model is particularly useful in medical education, where learning involves both theoretical knowledge and practical application [6].

In the context of biophysics education, this model helps explain how students engage with the curriculum and how different teaching methods influence their learning process [7]. First, for teaching methods, medical students may experience biophysics differently based on how the subject is taught. Although active learning strategies such as simulations, case-based learning, and problem-solving exercises align with Kolb's AE stage, enhancing engagement [8]. While passive lecture-based approaches, may not fully support the CE and RO stages, leading to lower engagement levels [9].
Second, regarding curriculum content and student reflection. When biophysics content is directly linked to clinical applications (e.g., medical imaging, biomechanics, or pharmacokinetics), students are more likely to engage in RO and AC stages, strengthening their understanding [10]. Moreover, if the curriculum lacks real-world relevance, students may struggle to relate biophysics concepts to their professional fields, reducing motivation and engagement [11].
Finally, the application of biophysics concepts in different faculties: Medicine, Pharmacy, and Dentistry students may vary in how they apply biophysics concepts to their future careers. Besides, Kolb's model suggests that students who can actively experiment with knowledge in clinical or laboratory settings will retain and apply concepts more effectively. This explains why engagement levels may differ across faculties, as some students may see more immediate practical value in biophysics than others [11, 12].
On the other hand previous research advocated that student engagement in medical education has its impact on academic performance, motivation, and knowledge retention [12]. In medical education, biophysics serves as a foundational subject linking physics principles to real-world applications in healthcare [13].
However, research indicates that student engagement with biophysics is often low due to its perceived abstraction and lack of direct clinical relevance [14, 15]. Previous studies have explored how teaching methods and curriculum design influence engagement in medical sciences. Tsekhmister Y et al. (2024) conducted a systematic review showing that while medical informatics and biophysics are essential for training healthcare professionals, their integration into European medical curricula varies widely [1]. Similarly, the role of active learning strategies in enhancing student engagement in medical biophysics has been discussed in educational research [16]. Traditional lecture-based approaches often fail to sustain students' motivation and participation, leading to disengagement and limited conceptual understanding [17]. Another study examined the implementation of PBL in medical biophysics education among applied medical sciences students at a university in Egypt [18]. They found that 70% of students viewed PBL as relevant to learning biophysics, and 90% reported major benefits, particularly in problem-solving, teamwork, and motivation, highlighting the impact of teaching methods on student engagement.
These results align with the broader literature on student engagement and active learning, which suggests that interactive and student-centered teaching methods significantly enhance learning outcomes [19].
While previous research has established the importance of student engagement in medical education and its impact on their learning outcome [16, 20], there remains a gap in understanding faculty-specific differences in student engagement with biophysics curricula. Existing studies have primarily fo-

cused on general teaching methods, such as problem-based learning [18], and interdisciplinary approaches [1], or strategies to improve student motivation in physics-related courses [20, 21].

Although research on student engagement in medical education is available [22, 23], few studies have examined faculty-specific differences in engagement with biophysics or the effects of teaching approaches on students' knowledge and learning outcomes. Understanding these differences is crucial for refining biophysics curricula to enhance student motivation, promote knowledge application, and strengthen long-term professional preparedness.

This study aims to compare engagement levels in biophysics among first-year students in Medicine, Pharmacy, and Dentistry. Additionally, it seeks to assess the impact of teaching methods by examining how active and passive learning approaches influence students' ability to apply biophysics concepts. Furthermore, it aims to evaluate the role of curriculum structure in shaping student engagement by investigating whether a well-structured biophysics curriculum enhances knowledge application in healthcare.

MATERIALS AND METHODS

A cross-sectional study design was conducted to explore how student engagement with biophysics differs between medicine, pharmacy, and dentistry, and to examine whether active learning and a well-organised curriculum help them apply biophysics concepts in healthcare. A total of 428 students from medical faculties at the University of Duhok were included in the study between October 2023–March 2024 in Duhok City, Kurdistan Region, Iraq.

The inclusion criteria were students enrolled in the first year of medicine, pharmacy, or dentistry programmes during the academic year 2023-2024 and students who were actively attending classes and eligible to complete the entire biophysics course. The exclusion criteria were students who were not actively attending classes and students who had not yet begun or completed the biophysics course during the study period.

To identify the engagement of students in biophysics in three medical faculties and to determine whether active learning and a well-organised curriculum influence the application of knowledge by students, a biophysics engagement and application survey was developed, which consists of 22 questions divided into two parts. The first part elicits demographic information about the students with respect to their gender and area of residence. The second part consists of 20 questions in the form of a 5-point Likert scale (1 = strongly agree to 5 = strongly disagree) and is formulated based on the Kolb reflection model. The survey items are divided into three main categories. First: teaching methods that consist of 4 items focus on the strategies that the lecturer uses to deliver the subject, and to what extent it engages the students with the biophysics subject. Second: The curriculum structure comprises six items that focus more on the framework of biophysics and its relevance to the academic field of students. Finally, the application of knowledge section, which consists of 10 items that highlight to students can apply their knowledge in their professional healthcare in the future.

The survey elements were validated and reviewed by five experts in biophysics education, measurement, and evaluation. Based on the feedback of the experts, minor modifications were made to the questionnaire items. The survey was also administered to a sample of 30 students from the three faculties who were excluded from the main investigation to identify the reliability of the survey. The reliability coefficient was 0.91, which indicates high reliability [24].

The final version of the biophysics engagement and application survey questionnaire was administered to 428 first-year undergraduate students enrolled in Bachelor's degree programs in Medicine, Pharmacy, or Dentistry at the University of Duhok, who participated in the study. Verbal consent was obtained from the participants, and they were asked if they would like to participate in the study. They received the necessary instructions and information on how to complete the questionnaire.

Data were analysed using JMP software to assess student engagement with the biophysics curriculum and its impact on their ability to apply biophysics concepts in healthcare. Descriptive statistics (mean, standard deviation, frequency, and percentage) were used to summarise students' responses across the faculties of Medicine, Pharmacy, and Dentistry.

Statistical assumptions regarding data normality were examined prior to conducting inferential analyses. The Shapiro-Wilk test was employed to evaluate this, confirming that the main engagement and application variables were approximately normally distributed.

Furthermore, the homogeneity of the variances was tested using Levene's test, and no significant violations were detected. In order to compare students' responses based on teaching method (active vs. passive) and curriculum structure (well-structured vs. poorly structured), independent samples t-tests (two-tailed) were conducted within each faculty. These tests assessed whether differences in mean application scores were statistically significant between groups (e.g., active vs. passive learners).

RESULTS

Across the three faculties, gender distribution was broadly balanced (Table 1). In Medicine, 82/153 (53.59%) were male and 71/153 (46.41%) female; in Pharmacy, 71/138 (51.44%) were male and 67/138 (48.55%) female; and in Dentistry, 73/137 (53.28%) were male and 64/137 (46.72%)

Table 1. First-Year Students' Socio-demographic Characteristics Across Faculties of Medicine, Pharmacy, and Dentistry

Variables (Categories)	Medicine	Pharmacy	Dentistry
	Frequency distribution, n (%)		
Gender			
Male	82 (53.59)	71 (51.44)	73 (53.28)
Female	71 (46.41)	67 (48.55)	64 (46.72)
City of Residence			
Duhok City	131 (85.62)	121 (87.68)	117 (85.40)
Erbil City	7 (4.58)	4 (2.90)	5 (3.65)
Sulaymaniyah City	15 (9.80)	13 (9.42)	15 (10.95)
Totals	153	138	137

female. Most students resided in Duhok City—Medicine 131/153 (85.62%), Pharmacy 121/138 (87.68%), and Dentistry 117/137 (85.40%)—with smaller proportions from Erbil (4.58%, 2.90%, 3.65%, respectively) and Sulaymaniyah (9.80%, 9.42%, 10.94%, respectively), indicating predominantly local enrollment with limited representation from other major cities of the Kurdistan region.

Engagement with the biophysics curriculum was moderate to high across faculties (Table 2). Mean scores for teaching methods and student engagement were highest in Medicine (9.58 ± 2.69) compared with Pharmacy (9.06 ± 2.79) and Dentistry (9.08 ± 2.76). For curriculum structure and relevance, Medicine again showed the highest mean (12.92 ± 3.26), followed by Dentistry (12.75 ± 3.51) and Pharmacy (12.47 ± 3.37). Perceived application of biophysics in healthcare was high and comparable across faculties, with Dentistry slightly higher (20.02 ± 5.00) than Pharmacy (19.77 ± 4.92) and Medicine (19.70 ± 4.89).

When stratified by teaching method, students exposed to active learning consistently achieved higher application scores than those taught via passive approaches in all faculties (Table 3). In Medicine, active learning (n = 102) was associated with a mean of 21.02 ± 4.48 versus 17.05 ± 4.63 for passive learning (n = 51); in Pharmacy, 21.82 ± 4.38 (n = 81) versus 16.85 ± 4.13 (n = 57); and in Dentistry, 21.78 ± 4.47 (n = 80) versus 17.56 ± 4.68 (n = 57), with all comparisons statistically significant ($p < 0.001$). Similarly, students reporting a well-structured curriculum scored higher than those reporting a poorly structured curriculum in each faculty: Medicine 22.13 ± 4.67 vs 17.04 ± 3.57, Pharmacy 22.82 ± 4.69 vs 17.28 ± 3.52, and Dentistry 22.57 ± 4.82 vs 17.37 ± 3.64 ($p < 0.001$). The corresponding R^2 values (0.271–0.314) indicate that approximately 27–31% of the variance in application scores is explained by curriculum structure quality, with the largest effect in Pharmacy ($R^2 = 0.314$). Collectively, these findings highlight the practical importance of active learning strategies and coherent curriculum design for strengthening first-year students' ability to apply biophysics concepts.

Table 2. First-Year Students' Engagement with the Biophysics Curriculum Across Faculties of Medicine, Pharmacy, and Dentistry

Themes (Categories)	Item Numbers	Medicine	Pharmacy	Dentistry
			Mean ± SD	
Teaching Methods & Student Engagement				
• Teaching strategies & instructional approach • Teaching materials & resources • Engagement in biophysics learning • Communication in teaching biophysics	(10, 11, 14, 15)	9.58 ± 2.69	9.06 ± 2.79	9.08 ± 2.76
Curriculum Structure & Relevance				
• Confidence in understanding biophysics concepts • Importance of biophysics in medical education • Learning support & guidance • Interest in learning biophysics • Academic performance in biophysics • Real-world applications & clinical relevance	(1, 2, 3, 4, 5, 12)	12.92 ± 3.26	12.47 ± 3.37	12.75 ± 3.51
Application of Biophysics in Healthcare				
• Biophysics contribution to medicine & science • Advancement of biophysics in healthcare • Applications in medical practice • Biophysics in diagnosis & treatment • Career aspirations in biophysics • Interest & future contributions • Future contribution of biophysics • Treatment improvement • Medical innovation • Future of biophysics in healthcare	(6, 7, 8, 9, 13, 16, 17, 18, 19, 20)	19.70 ± 4.89	19.77 ± 4.92	20.02 ± 5.00
Totals		**153**	**138**	**137**

Note: Values are means with standard deviations (SD). Item numbers refer to questionnaire items contributing to each theme. Sample sizes shown by faculty.

Table 3. 1st-Year Students' Ability to Apply Biophysics Concepts by Engagement with Teaching Methods and Curriculum Structure

Themes (Categories)	Faculties											
	Medicine				Pharmacy				Dentistry			
	n (%)	Mean ± SD	R^2	*p*-value	n (%)	Mean ± SD	R^2	*p*-value	n (%)	Mean ± SD	R^2	*p*-value
By engagement with teaching methods												
Active learning	102	21.02 ± 4.48	0.147	< 0.001*	81	21.82 ± 4.38	0.248	< 0.001*	80	21.78 ± 4.47	0.174	< 0.001*
Passive learning	51	17.05 ± 4.63			57	16.85 ± 4.13			57	17.56 ± 4.68		
By curriculum structure												
Well structured	80	22.13 ± 4.67	0.272	< 0.001*	62	22.82 ± 4.69	0.314	< 0.001*	70	22.57 ± 4.82	0.271	< 0.001*
Poor structured	73	17.04 ± 3.57			76	17.28 ± 3.52			67	17.37 ± 3.64		
Totals	**153**				**138**				**137**			

Notes: SD = Standard Deviation. R^2 = coefficient of determination. *Statistically significant.

DISCUSSION

Biophysics serves as a foundational bridge between basic science and clinical decision-making across Medicine, Dentistry, and Pharmacy, yet students' ability to transfer its concepts into practice depends heavily on pedagogy and curriculum design. Across first-year cohorts in the three faculties, active, student-centred teaching (e.g., problem-based learning, guided discussion, skills practice) and a well-structured biophysics curriculum were each associated with higher self-reported ability to apply concepts in healthcare—an effect observed across faculties, with the largest mean differences for curriculum structure in Pharmacy. These patterns align with evidence that active methods enhance engagement and application compared with didactic teaching [11, 25, 26] and can be interpreted through Kolb's experiential learning model, wherein effective transfer emerges as learners cycle through Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC), and Active Experimentation (AE) [27]. Within this framework, discipline-specific sequencing and relevance cues (e.g., clinical imaging in Dentistry, pharmacokinetics simulations in Pharmacy) likely scaffold—or constrain—perceived applicability of biophysics, highlighting faculty-specific opportunities to strengthen experiential pathways.

The participation of students by each faculty can be understood as a reflection of how well their curriculum and teaching strategies support these stages of learning. One of the key el-

ements for student's engagement is teaching methods [28]. Active teaching strategies such as problem-based learning, communication and interactive discussions were associated with higher engagement scores. These strategies align with Kolb's Active Experimentation (AE) stage, where students apply knowledge in practical settings [25].
Although all three faculties incorporated active methods, Medicine students reported the highest engagement, indicating that they received more practical and context-based instruction. Furthermore, they appear to be strongly engaging with both AE and Concrete Experience (CE) through practical experience, as well as RO and AC by reflecting and building conceptual understanding from those experiences.
In addition, Dentistry students, who showed slightly lower engagement, may be receiving similar experiential learning opportunities, but with less structured reflection or conceptual integration. Their findings suggest moderate participation in CE and AE, but potentially weaker emphasis on RO, where learners reflect critically on experiences to build insights. These results suggest that Dentistry faculty needs to refine their instructional strategies to strengthen reflective and conceptual phases to enhance their students' engagement.
In contrast, Pharmacy students demonstrated the lowest engagement with active teaching methods, which may indicate a curriculum that emphasizes Abstract Conceptualization (AC) without sufficiently supporting Concrete Experience (CE) or Active Experimentation (AE). The lack of hands-on, real-world learning tasks may limit their ability to apply knowledge meaningfully, resulting in lower engagement. The results corroborate previous research highlighting the importance of teaching strategies in shaping engagement levels [18]. As previous research also noted that traditional lecture-based approaches often fail to sustain student motivation, underscoring the necessity for interactive, student-centered methods [11, 25].
Research advocated that another core element for student's engagement is curriculum structure and relevance [29], medical students again reported the highest confidence in understanding biophysics followed by Dentistry and Pharmacy. These differences specify how well the curriculum in each faculty supports the Reflective Observation (RO) and Abstract Conceptualization (AC) stages of Kolb's model. The Medicine curriculum appears well-structured to guide students through meaningful reflection and theory-building, enhancing their understanding and perceived relevance of biophysics. While, Pharmacy students' lower scores suggest that the curriculum may lack the integration of clinical or applied contexts, affecting their ability to reflect on theoretical knowledge (RO) and develop a solid conceptual framework (AC) as those stages emphasize the necessity of linking knowledge to real-world situations, reinforcing the need for faculty-specific curriculum adjustments to enhance the relevance of biophysics for each discipline.
Besides, the third factor that linked to student's engagement is student's ability to apply the biophysics concepts in healthcare this factor was recognized as important by all faculties. Especially, Dentistry students reported the highest relevancy probably due to their experience to direct applications of biophysics such as dental imaging. This indicates strong engagement with both CE and AE, reinforcing Kolb's idea that applied, hands-on learning fosters meaningful knowledge transfer. Medicine and Pharmacy students also valued biophysics' role in healthcare, but slight variations in their scores may reflect differences in how clearly these applications are integrated into their curricula. These findings align with Fredricks et al. who emphasize that student engagement directly affects academic performance, motivation, and knowledge application [26].
A goal supported by broader educational research advocating for discipline-specific curriculum adjustments to enhance learning outcomes. Overall, these results show that applying biophysics to real healthcare situations is closely linked to how the subject is taught and how the curriculum is organized. When students get practical, real-world examples along with clear guidance and chances to reflect, they are more likely to stay engaged and use what they learn effectively.
Finally, the study results confirmed that both active teaching methods and a well-structured curriculum significantly enhance students' ability to apply biophysics concepts in healthcare. These findings strongly support Kolb's model, illustrating that experiential learning not only increases engagement but also enables students to transfer classroom knowledge into professional practice.
While this study has primarily attributed differences in engagement to curriculum design and teaching methods, it is important to acknowledge other potential influencing factors. Variations in prior physics knowledge among students, availability of faculty resources, and the extent of instructor training in active learning strategies may also play a role in shaping engagement levels. Furthermore, differences in student motivation, learning preferences, or cohort culture could influence how effectively students participate in and benefit from biophysics instruction.
This study has several limitations. First, the use of a purposive sampling design may limit the generalizability of the findings beyond first-year students at the University of Duhok, as the sample may not represent students from other institutions or academic years. Second, the study relied solely on quantitative methods; incorporating qualitative approaches, such as focus group discussions, could provide deeper insights into the reasons behind varying levels of student engagement. Additionally, the potential for survey bias and self-reporting bias should be acknowledged, as students' responses may be influ-

enced by subjective perceptions or social desirability. Finally, the single institution scope of the study further limits the applicability of results to broader educational contexts.

The findings offer valuable guidance for educators and curriculum planners. Faculties can use this data to revise and better structure biophysics curricula to enhance clarity and relevance. Targeted training programmes for instructors can help promote more active learning strategies, which have been shown to improve student engagement and application of concepts. In addition, interdisciplinary collaboration, such as the integration of biophysics with pharmacology or dentistry, could bridge knowledge gaps and reinforce the real-world importance of biophysics in healthcare education.

CONCLUSION

Active learning, coherent curricular sequencing, and clinically anchored content are associated with higher engagement and stronger perceived transfer of biophysics across Medicine, Dentistry, and Pharmacy. Engagement appears strongest in Medicine, reflecting clearer links to clinical practice; Dentistry reports high relevance—especially in imaging and biomaterials—while Pharmacy shows comparatively lower engagement, signaling the need to more explicitly connect biophysics to pharmaceutical applications.

Tailoring biophysics education to the distinct requirements of each discipline and aligning objectives, teaching activities, and assessments with authentic professional contexts should enhance motivation and learning outcomes. Priority actions include embedding discipline-specific cases and simulations, strengthening longitudinal integration, and diversifying assessments that require application and interpretation.

Future evaluations should incorporate objective performance metrics, track the durability of engagement over time, and test targeted curriculum adjustments—particularly in Pharmacy—to determine causal impact on learning and transfer.

ETHICAL DECLARATIONS

- ### Ethics Approval and Consent to Participate

The study was granted ethical approval number (506) by the research ethics committee of the faculties of medicine, pharmacy, and dentistry at the University of Duhok on 20 August 2023. Prior to data collection, informed consent was gathered from all participants, who participated voluntarily and anonymously.

- ### Consent for Publication

None.

- ### Availability of Data and Material

The datasets are available from the corresponding author upon reasonable request.

- ### Competing Interests

The authors declare that there is no conflict of interest.

- ### Funding

Self-funded.

- ### Use of Generative Artificial Intelligence

The authors declare that no generative AI tools were used in the preparation, writing, or editing of this manuscript.

- ### Authors' Contributions

All authors contributed to the literature review, study design, data collection, statistical analysis, and manuscript preparation. All authors have read and approved the final version of the manuscript.

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