BMC Medical Education

RESEARCH

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Exploring the relationship between learning approaches and problem-based learning: insights from a longitudinal study in medical students

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Abstract

Background Problem-based learning (PBL) is expected to encourage a deep learning approach. Whether this is realised in practice remains uncertain. We investigated the relationships between learning approaches, academic achievement and student satisfaction in an integrated PBL curriculum, among students with diverse characteristics.

Methods All Year 1 students of an undergraduate UK medical programme, delivered concurrently at City St George's, University of London and the University of Nicosia, were invited to participate in 2019–2020 and 2020–2021. Students completed the validated Study Process Questionnaire (SPQ) at the beginning and end of Year 1. We explored changes in learning approaches and the associations of the learning approach with academic performance (in written and clinical examinations) and student satisfaction.

Results 129 students participated. Deep motivation decreased significantly over the year [Baseline: 11.03 ± 2.29; End of Year 1: 10.21 ± 2.26; $p < 0.05$). Graphical representations and tertile analysis further showed changes in individual learning approaches. Lower deep motivation scores were observed among male students, and those who were older, white, held biomedical sciences degrees, undergraduate degrees, or were native English speakers. Conversely, higher surface motivation was seen among female students, and those who were younger or held undergraduate degrees. Nicosia students became less strategic by the end of the year. No association was found between learning approach, or its change within the year, and examination performance. However, surface learning was negatively correlated with satisfaction regarding aspects of pharmacology learning in PBL and prescribing confidence. Strategic learners preferred lectures and had mixed perceptions about learning pharmacology in PBL, although they found student diversity facilitated their learning.

Conclusions While PBL is expected to promote deep learning, our findings show that in a real-world context, these benefits are not consistently realised. Learners adopted less favourable learning approaches over the year, with increasing reliance on surface learning and less deep motivation. Such shifts may be due to excessive workload,

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assessment burden or curriculum uncertainty. We have identified student groups that may be more vulnerable to the stresses of a PBL setting, which may represent targets for intervention. Future studies may also investigate curriculum adaptations to enhance deep learning in a PBL curriculum.

Keywords Problem-based-learning, Learning approach, Study process, Personal characteristics, Attitudes, Pharmacology

Background

Problem-based learning (PBL)

PBL is a student-centred pedagogical approach that seeks to promote active learning [1]. Students collaboratively explore and resolve complex, authentic problems in a professionally relevant context. This serves to increase intrinsic motivation for learning [2]. The PBL process typically involves a series of structured stages, starting with the identification of the problem, followed by extensive research, analysis, and collaboration among students. Facilitators guide the learning process, providing support and resources, but the responsibility for acquiring knowledge rests primarily on the students [1–4]. PBL fosters critical thinking, problem-solving skills, and self-directed learning by encouraging students to actively seek knowledge and apply it to address the presented issues [4, 5]. This approach encourages interdisciplinary thinking, and cultivates skills such as communication, teamwork, information synthesis and life-long learning [4–6].

Approaches to learning

Students have different learning approaches, which are influenced by a series of motivations in the educational environment. Deep, strategic, and surface approaches reflect distinct motivations and strategies for processing information and have been reviewed in detail previously [7–10]. Below is a brief overview of these approaches. ***Deep learners*** aim to understand material thoroughly and make meaningful connections between concepts and their prior knowledge. They focus on comprehension, seeking to grasp the significance of what is being learned rather than simply memorizing information. Deep learners exhibit a genuine interest in the subject matter and are motivated by a desire to apply their knowledge in real-world contexts. Deep learners tend to approach learning as a process of discovery and understanding. They actively engage in critical thinking and aim to explore topics beyond the immediate requirements of the course [7–10]. ***Surface learners*** are motivated by a fear of failure and aim to fulfil the basic requirements of a course with minimal effort. They tend to approach learning as a means to an end, with the primary goal of meeting immediate academic requirements. Their focus is on memorizing information to pass assessments rather than deeply understanding the material. They often resort to rote memorization to learn facts and ideas without much critical analysis, focusing on tasks in isolation. Surface learners may have little interest in the content and may struggle to see its relevance to real-world applications [7–10]. ***Strategic learners*** are motivated by the goal of achieving good grades, meeting academic requirements and outperforming their peers. While they may comprehend the material, their level of understanding may be patchy and variable since their primary focus is on completing tasks efficiently and meeting the criteria set by the educational system. As such, they adopt specific strategies to optimize their performance in assessments, with selective focus on key concepts and strategic time management. They may prioritize information likely to be assessed and aim to fulfil academic expectations while minimizing unnecessary effort [7–10]. Strategic learning can involve a combination of both deep and surface learning strategies depending on the task at hand [9, 10].

Scholars have suggested that it is desirable to adopt a deep approach to learning and this is also reflected in the Bologna declaration for successful learning and studying in higher education [11]. Understanding learning approaches is crucial for educators, as it allows them to tailor teaching methods to encourage deep learning and foster a more meaningful and lasting understanding of the subject matter among students.

Approaches to learning and PBL

While PBL is expected to motivate learners to adopt a deep learning approach [8], the literature is inconclusive about the effect of PBL on students' approach to learning. Research studies comparing PBL settings with traditional modes of delivery have shown that students in PBL medical programmes are more likely to adopt deep learning approaches, characterized by a desire to understand and integrate knowledge, whereas students in conventional curricula often resort to surface learning, focusing on rote memorization [12–14]. A major limitation of these studies is the comparison of two different medical schools, which may have other differences e.g. in curriculum content and mode of assessment. Indeed, the mode of assessment may affect a student's learning approach [15]. Consistently, De Volder and De Grave have shown that, over time, students in PBL programs increasingly favour deep and strategic learning approaches [16], although the conclusions were based on a 6-week intervention. Furthermore, while students who adopt deep [17, 18] and strategic [19, 20] approaches tend to report higher satisfaction with PBL and perform better in

examinations [17, 20], these outcomes may also be influenced by other factors such as prior academic achievement and intrinsic motivation. In concordance with the positive effects attributed to PBL, a systematic review suggested that PBL enhances deep learning, albeit with a small positive average effect size [8]. The review found that curriculum-wide implementation had a more substantial impact than implementation limited to individual courses [8]. However, the heterogeneity of study designs and methodologies in the existing literature calls for more rigorous, standardized research to confirm these findings. Indeed, the systematic review also identified studies reporting a decrease in deep learning, as well as others indicating no effect on learning approach associated with PBL [8]. McParland et al. showed that a change from traditional teaching to PBL methods in a psychiatry attachment did not result in any changes in learning approaches over 8 weeks [19]. Consistently, in a longitudinal study, Reid et al. [21] noted no change in approach over the entire medical programme, after implementation of a pre-clinical PBL curriculum. In contrast, some studies even report a move towards more surface learning [17, 20–22] and loss of self-efficacy [23] over time in medical PBL programmes, further highlighting the need for more rigorous, standardized research to elucidate the effect of PBL on learning approach. Importantly, there is also a scarcity of studies identifying the student groups that are most vulnerable to the challenges of a PBL environment [17]. Even though, a pedagogical approach should ideally cater to the needs of all learners regardless of their background, students differ in their readiness to benefit from different instructional and learning methodologies. Learning approaches are inherently complex and may be influenced by a multitude of factors, including the educational context and environment [24]. While prior studies indicate that individual characteristics—such as gender and age—might affect learning approaches, most findings are derived from non-PBL settings [25–29]. There is a marked lack of longitudinal research examining how student demographics and characteristics influence learning approaches within PBL curricula and which student groups are most vulnerable to the challenges of a PBL environment, developing less desirable learning approaches [17].

Considering the heterogeneity of results due to variations in study designs, short intervention durations, and poorly defined tools and methodologies, further studies are needed to assess the impact of curriculum-wide PBL on learning approaches, using rigorous study designs. Our study fills this gap by employing a robust study design that involves curriculum-wide implementation of PBL in two student cohorts from two medical schools following an identical curriculum and assessment. The longitudinal approach, the use of the validated study process questionnaire and thorough examination of academic performance through reliable assessments and student satisfaction in our study provide important insight into the influence of an integrated PBL environment on the learning approaches of first-year medical students over time. Furthermore, unlike previous studies, this study investigates the nuanced changes within student learning approaches in a PBL setting, focusing on how specific personal characteristics might render certain groups more susceptible to less desirable learning approaches. Addressing these elements is crucial for developing teaching strategies that are inclusive, supportive, and effective in fostering a genuine understanding among medical students, thus ensuring that varied learner needs are met effectively. The specific research aims were to:

(1) Investigate the effect of integrated PBL on learning approach. To address this aim, learning approach was assessed using the previously validated, shortened 18-item study process questionnaire (SPQ) [10] at the beginning and end of the academic year.
(2) Investigate whether diverse student background characteristics (educational background and level of education, age, gender, country of origin, ethnicity, native language) affect student learning approach in an integrated PBL curriculum. Student background characteristics were recorded and quantitative methodology addressed this research question.
(3) Assess the relationship between learning approach and academic performance in integrated PBL through the use of reliable written exams, in basic clinical sciences and pharmacology, and objective-structured clinical examinations (OSCE).
(4) Investigate the relationship between learning approach and student satisfaction in integrated PBL. A quantitative questionnaire that we have previously generated [6] was used to address this aim.

Considering the global expansion of PBL curricula in medical education [30, 31], the findings of the present study can offer important insights into learning approaches and enable educators to tailor teaching methods to promote deep, meaningful learning.

Methods

Study design and participants

Participants were first-year students in the 4-year undergraduate medical program delivered concurrently at City St George's University of London (formerly known as St George's, University of London; SGUL) and the University of Nicosia (UNIC). Specifically, all students commencing their first year in both institutions in the academic years 2019–2020 (Cohort 1) and 2020–2021

(Cohort 2) were invited to participate in this study. The same curriculum and assessment are followed at both institutions. The first two years of the Bachelor of Medicine and Bachelor of Surgery (MBBS) course use an integrative, hybrid, system-based PBL, as its main didactic methodology. Year 1 starts with a Foundation module followed by six modules, which run sequentially, covering different body systems/themes. Inclusion of students from both institutions served to increase student diversity and generalizability of results. Consent was obtained from all participants.

The following measures were taken at the beginning (baseline) and the end of the year. **Baseline.** Student characteristics and learning approach were assessed at the beginning of the year. **End of the year**. Learning approach was re-assessed while, academic performance and satisfaction were also examined at the end of the year.

Student characteristics

Background characteristics, which were recorded at baseline, included educational institution, gender, age, ethnicity, country of origin, educational background (level of education and discipline) and native language.

Learning approach

The 42-item SPQ, developed by Biggs in 1987, has been widely used to measure approaches to learning [24]. It classifies learners into three dimensions (surface, deep and achieving (or strategic); each with two subscales of motive and strategy. Shortened versions of the questionnaire have been developed for ease of administration and to update the educational terminology used. For the present study, we have used the validated, 18-item SPQ [10], which offers several key advantages, particularly its inclusion of the strategic sub-scale, which sets it apart from other shortened versions like the two-factor SPQ [32]. The strategic dimension is particularly beneficial for understanding students' approaches to learning in competitive learning environments such as medical education. The 18-item SPQ version maintains a comprehensive assessment by retaining the original three orientations (deep, surface, strategic), each with an underlying motive and strategy (i.e. six subscales of surface motive, surface strategy, deep motive, deep strategy, strategic motive and strategic strategy). The motive sub-scale refers to the underlying reasons or motivations that drive a student's approach to study and the strategy sub-scale describes the methods or techniques students employ to accomplish their learning goals. Additionally, its brevity ensures ease of administration and practical application in large-scale or longitudinal studies while preserving essential elements of the original questionnaire's factor structure. Students completed the shortened 18-item SPQ [10] both at the beginning and end of the academic year. Reliabilities for the scales/sub-scales were determined by calculating the Cronbach alpha coefficient.

Academic performance

Academic performance was assessed through (1) a written exam in basic and clinical sciences, (2) written exams in pharmacology and (3) a practical OSCE exam. The written exams used have been previously described in detail [6]. Briefly, knowledge in **basic and clinical sciences** was assessed by two summative, end-of-year, written exams (135 single-best answer (SBA) items), and assessed knowledge in anatomy, physiology, pathology, pharmacology, molecular biology and clinical sciences. **Pharmacology knowledge** was assessed through a formative 50-item, SBA test at the beginning of the year prior to the delivery of the curriculum (pre-test) and at the end of the academic year i.e. after the curriculum was delivered (post-test). The end-of-year **OSCE** comprised of 12 stations assessing clinical and communication skills.

Student satisfaction

The 15-item questionnaire, used to assess student perceptions and satisfaction with learning in integrated PBL at the end of the year, is divided into three 5-item themes, assessing: (1) PBL as a learning environment, (2) PBL as a learning environment in pharmacology, and (3) PBL as a learning environment and confidence in prescribing [6]. Responses were based on a Likert scale, which ranged from 1 (strongly disagree) to 5 (strongly agree). Reversely coded items ranged from 1 (strongly agree) to 5 (strongly disagree).

Statistical analysis

Statistical analysis was conducted on the complete cases sample. Descriptive statistics (frequencies and means) were used to analyse student background characteristics. Differences in the average scores of students' learning approaches (scales and subscales) from the start to the end of the academic year were examined with paired t-tests. Graphical representations and tertile analysis (i.e. three groups) were used to demonstrate any changes in learning approach scores at the individual student level. Motivation and strategy subscale scores, for each learning approach, were grouped into first (Q1), second (Q2) and third (Q3) tertiles based on the intervals [0, 5], [5, 10] and [10, 15], respectively. The three tertiles for overall learning approach scores were created based on the intervals [0, 10], [10, 20], and [20, 30]. Paired t-tests examined the effect of student characteristics on learning approach. The significance level of 0.05 was used in all statistical tests. However, to address the limitations of multiple hypothesis testing and control for the risk of Type I errors, both the Benjamini-Hochberg and

Bonferroni corrections were applied. Effect size was calculated, for statistically significant findings, using Cohen's d. Linear regressions were used to examine the association between the scores of each approach (continuous independent variable) or its increase within the academic year (binary independent variable, yes/no) and academic performance. Correlation analysis was used to examine the relationship between learning approach and satisfaction.

Data from students in Cohorts 1 and 2, from both institutions, were combined for statistical analysis. Cohorts 1 and 2 from both institutions followed the same curriculum and assessment. Furthermore, previous results from this study population did not reveal differences between the two cohorts or institutions [6] further providing a rationale for combining groups for statistical analysis. The potential effect of institution and entry year on learning approach were investigated, alongside other student background characteristics.

Table 1 Student background characteristics

Student characteristic	Participants
Educational Institution (n, %)	
UNIC	59 (45.7%)
SGUL	70 (54.3%)
Academic year	
2019–2020	71 (55.0%)
2020–2021	58 (45.0%)
Gender (n, %)	
Male	51 (39.5%)
Female	77 (59.7%)
Missing	1 (0.8%)
Age	
Mean, SD	25.7 (4.5)
Range	20–45
Missing (n, %)	4 (3.1%)
Ethnic Background (n, %)	
White	76 (58.9%)
Other Ethnic Background	53 (41.1%)
Educational Background (n, %)	
Biomedical Sciences	88 (68.2%)
Other than Biomedical Sciences	37 (28.7%)
Missing	4 (3.1%)
Highest Previous Degree (n, %)	
Bachelor	65 (50.4%)
Master or Doctorate	64 (49.6%)
Country of Origin (n, %)	
Great Britain	56 (43.4%)
Other country	73 (56.6%)
Native Language (n, %)	
English	99 (76.7%)
Other	30 (23.3%)

Note: Background characteristics of students in cohorts 1 and 2 from both institutions are shown in the table ($n = 129$)

Results

Student characteristics

The background characteristics of students in cohorts 1 and 2 from both institutions are shown in Table 1. 129 (out of 296) students consented to participate in the study (overall participation rate was 43.6%; academic year 2019–2020: $n = 71$ and 55%; academic year 2020–2021: $n = 58$, 45%). Participation rates were similar in the two institutions (UNIC: $n = 59$; 45.7%; SGUL: $n = 70$; 54.3%). 77 (59.7%) of participants were female and 51 (39.5%) were male. The mean ± standard deviation (SD) age of students was 25.7 ± 4.5 years old. The largest ethnicity group was White (58.9%). The remaining students (41.1%) came from a wide range of ethnicities (African-American/Black, East Asian, Hispanic/Latino, Middle Eastern and Southeast Asian) [6]. As many of the non-White ethnicity groups were small, these were combined into one group for the purpose of further statistical analysis. Similarly, in regards to country of origin, considering that the majority of students (43.4%) originated from Great Britain, non-British students (56.6%), who came from a range of different countries, including Israel, the United States, Australia, New Zealand, Canada, Lebanon, Germany, Brazil, France, Ireland, Egypt, Nigeria, Poland, Romania, Spain, and Venezuela, were grouped for statistical analysis. Most participants were native English speakers (76.7%). Most students ($n = 88$; 68.2%) had an undergraduate degree in biomedical sciences (e.g. biology, biomedicine, health studies), while 28.7% ($n = 37$) had a degree in another discipline (e.g. psychology, international studies, chemistry, history). 64 students (49.6%) additionally completed a post-graduate degree (Master and/or Doctorate); graduate degree areas of study were all in biomedical sciences. The background characteristics of students who completed the SPQ at the end of the year were similar to the sample at the beginning of the year (data not shown; $n = 70$).

Learning approach

To determine the effect on learning approach, students of cohorts 1 and 2 from both institutions were combined for statistical analysis. Cronbach α-coefficients for the scales and sub-scales are shown in Supplemental Material; Online Table 1. Paired t-test analysis of learning approach scores as quantified by the SPQ showed that deep motivation decreased significantly at the end of the year from 11.11 to 10.18 ($p < 0.05$) (Table 2). Cohen's effect size revealed that the changes were of small magnitude (d = 0.36). No statistically significant changes were noted in the mean scores of the other SPQ scales/subscales between the first and the second measurements. However, graphical representations (Fig. 1) and tertile analysis (Table 3) revealed changes in individual learning approach between the first and second measurements.

Table 2 Learning approach at the beginning and end of year 1

Learning Approach	Measurement	Mean	SD	T	Df	*p*-value
Deep motivation	1	11.03	2.29	2.12	137.97	**< 0.05**
	2	10.21	2.26			
Deep process	1	10.97	2.28	-0.52	137.96	0.60
	2	11.17	2.25			
Deep	1	22.00	3.71	0.96	137.72	0.34
	2	21.39	3.89			
Surface motivation	1	8.23	2.61	-1.27	137.52	0.21
	2	8.77	2.46			
Surface process	1	8.16	2.99	1.02	132.55	0.31
	2	7.69	2.43			
Surface	1	16.39	4.70	-0.10	135.04	0.92
	2	16.46	4.05			
Strategic motivation	1	10.70	2.74	0.79	134.77	0.43
	2	10.30	3.20			
Strategic process	1	10.66	2.70	0.34	137.94	0.73
	2	10.50	2.75			
Strategic	1	21.36	4.16	0.78	137.95	0.43
	2	20.80	4.24			

Notes:

1. The 18-item shortened SPQ assesses three primary dimensions of learning approaches: surface, deep, and strategic. Each dimension is further divided into two sub-scales: motivation and process. The motivation sub-scale refers to the underlying reasons or motivations that drive a student's approach to study. The process sub-scale, meanwhile, describes the methods or techniques students employ to accomplish their learning goals. These are described briefly below. (1) *Deep.Deep Motivation* Students in this sub-scale are driven by an intrinsic interest and personal commitment to subject matter. *Deep Process*: Involves seeking meaning, understanding underlying principles, and integrating new knowledge with existing knowledge. (2) *Surface.Surface Motivation*: Students in this sub-scale are characterized by a fear of failure and a desire to meet minimal requirements. *Surface Process*: Involves rote learning and a focus on isolated facts without understanding underlying concepts. (3) *Strategic*: *Strategic Motivation*: Students in this sub-scale are motivated by a desire to achieve high grades and compete with peers. *Strategic Process*: Learners employ effective time management and study techniques to optimize performance in assessments

2. All participating students from cohorts 1 and 2 from both institutions were included in the statistical analysis

As determined from Fig. 1, only 7 (10%), 5 (7.1%) and 6 (8.6%) had the same score in deep, surface and strategic learning, respectively.

Tertile analysis (Table 3) showed that 64.3% of students remained in the same tertile for the deep learning approach at the second measurement, 14.3% moved up a tertile and 21.4% moved down. In regards to surface learning, 74.3% of students got a score at the same tertile, 12.9% got a score at a higher tertile and 12.9% got a score at a lower tertile at the end of the year. Finally, in regards to the strategic learning approach, 71.4% of students got a score at the same tertile, 11.4% got a score at a higher tertile and 17.1% got a score at a lower tertile in the second measurement compared to their scores at the first measurement.

Learning approach and student background characteristics

Considering the changes in approach of individual learners, the potential impact of student characteristics on learning approach was investigated. Paired t-tests between the two measurements of the different scales and subscales of learning approaches categorized by the demographic characteristics are shown in Tables 4a, 4b and 4c for the deep, surface, and strategic approaches, respectively. Cohorts 1 and 2 were combined for this analysis. For all student characteristics, with the exception of analysis of the effect of institution, students from both institutions were combined for analysis. Students who were male, older, white, held biomedical sciences degrees, undergraduate degrees, or were native English speakers had on average a lower score in deep motivation at the end of the year (Table 4a). Effect size, measured by Cohen's d, revealed that the changes were of medium magnitude (gender: d = 0.53, ethnic background: d = 0.52; level of education: d = 0.53, native language: d = 0.43) and small magnitude (age: d = 0.31, educational background: d = 0.37). Furthermore, students who were female, younger than 25 years old or held undergraduate degrees showed increased surface motivation by the end of the year (Table 4b). Effect size was estimated to be d =-0.44, -0.43 and – 0.64 denoting a medium effect for gender, age and level of education, respectively. Nicosia students became less strategic by the end of the year (Table 4c; Cohen's d = 0.45). The results did not remain statistically significant after Benjamini-Hochberg or Bonferroni correction.

Considering that the academic years 2019–2020 and 2020–2021 were affected by the Covid-19 pandemic, we also analysed learning approaches of students separately for Cohort 1 and 2. Cohort 1 started their studies before the pandemic started (i.e. September, 2019) and completed their first year in June 2020 (i.e. at the peak of the

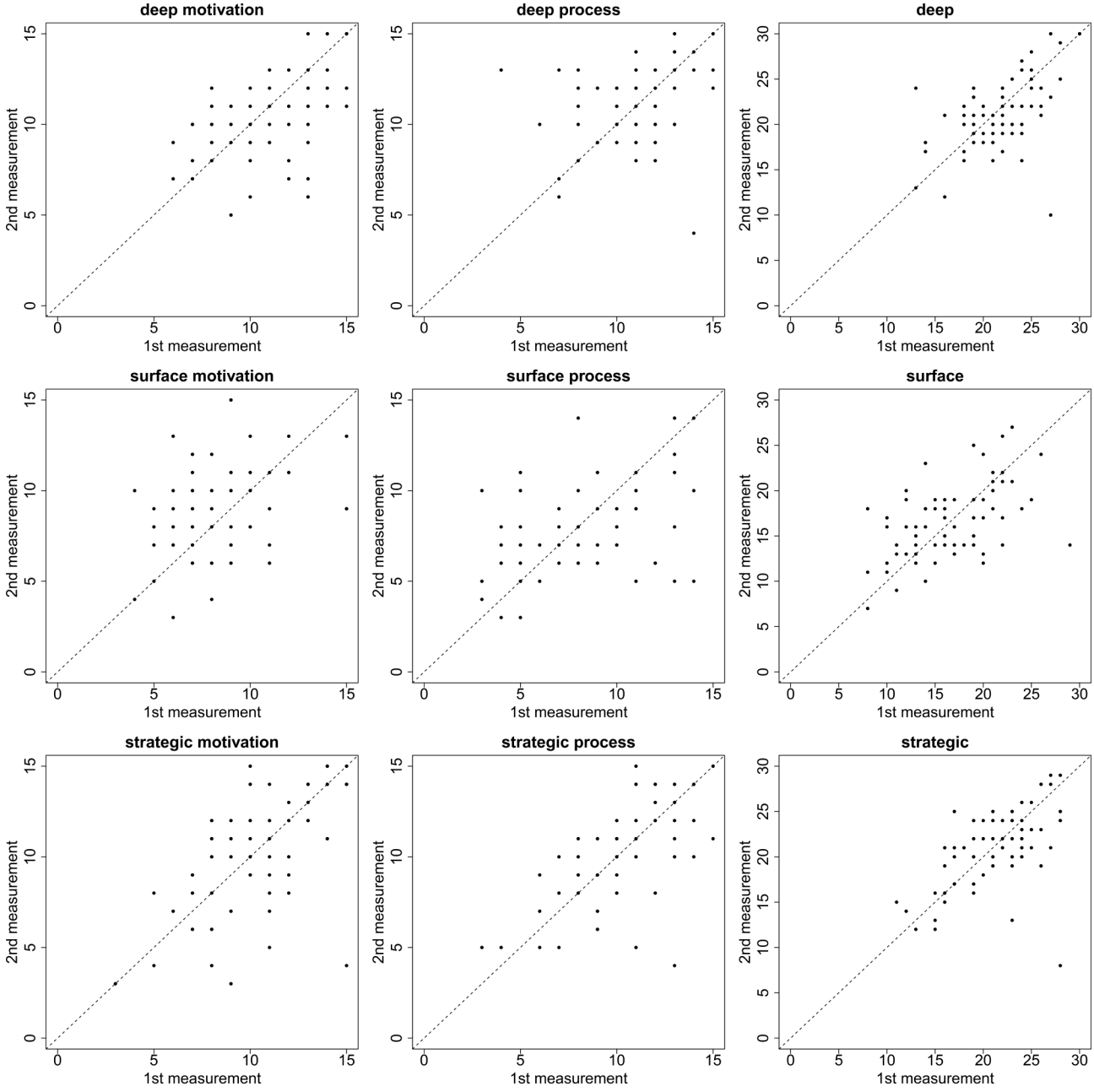

Fig. 1 Learning approach at the beginning and end of the year in individual students. **Notes**: (1) Points above the diagonal line indicate students with a higher score at the 2nd measurement compared to their 1st measurement. (2) All participating students from cohorts 1 and 2 from both institutions were included in the statistical analysis

pandemic). From March to June, 2020, similar to global trends, we transitioned to an online learning environment. The curriculum content, process and assessment were overall unchanged. Cohort 2 started Year 1 in September, 2020, when we transitioned to a blended learning environment. Our results (Online Table 2) showed that Cohort 2 had on average a higher score in deep process and deep learning, as compared to Cohort 1 students, in the beginning of the year (***Deep process***: Cohort 1: 10.67 ± 2.43, Cohort 2: 11.48 ± 2.15; $p = 0.048$; ***Deep***: Cohort 1: 21.46 ± 4.17, Cohort 2: 22.98 ± 4.05; $p = 0.039$). Similarly, students from Cohort 2 showed on average a higher score in strategic motivation and strategic learning at the beginning of the year (***Strategic motivation***: Cohort 1: 9.83 ± 3.01, Cohort 2: 11.36 ± 2.60; $p = 0.002$; ***Strategic***: Cohort 1: 20.36 ± 4.38, Cohort 2: 22.71 ± 3.52; $p = 0.001$). No differences were noted in surface learning between the two cohorts. However, no changes were noted between Cohorts 1 and 2 by the end of the year.

Table 3 Tertile analysis of changes in learning approach scores in year 1

		Measurement 2		
	Measurement 1	Q1	Q2	Q3
Deep motivation	**Q1**	0 (0%)	0 (0%)	0 (0%)
	Q2	1 (1.4%)	20 (28.6%)	6 (8.6%)
	Q3	0 (0%)	18 (25.7%)	25 (35.7%)
Deep process	**Q1**	0 (0%)	0 (0%)	1 (1.4%)
	Q2	0 (0%)	11 (15.7%)	11 (15.7%)
	Q3	1 (1.4%)	15 (21.4%)	31 (44.3%)
Deep	**Q1**	0 (0%)	0 (0%)	0 (0%)
	Q2	0 (0%)	12 (17.1%)	10 (14.3%)
	Q3	1 (1.4%)	14 (20%)	33 (47.1%)
Change in deep learning approach tertile		No change	Increase	Decrease
		64.3%	14.3%	21.4%
Surface motivation	**Q1**	4 (5.7%)	5 (7.1%)	0 (0%)
	Q2	2 (2.9%)	36 (51.4%)	10 (14.3%)
	Q3	0 (0%)	6 (8.6%)	7 (10.0%)
Surface process	**Q1**	7 (10.0%)	10 (14.3%)	1 (1.4%)
	Q2	2 (2.9%)	30 (42.9%)	3 (4.3%)
	Q3	3 (4.3%)	9 (12.9%)	5 (7.1%)
Surface	**Q1**	1 (1.4%)	6 (8.6%)	0 (0%)
	Q2	2 (2.9%)	43 (61.4%)	3 (4.3%)
	Q3	0 (0%)	7 (10.0%)	8 (11.4%)
Change in surface learning approach tertile		No change	Increase	Decrease
		74.3%	12.9%	12.9%
Strategic motivation	**Q1**	2 (2.9%)	1 (1.4%)	0 (0%)
	Q2	2 (2.9%)	16 (22.9%)	10 (14.3%)
	Q3	2 (2.9%)	12 (17.1%)	25 (35.7%)
Strategic process	**Q1**	2 (2.9%)	0 (0%)	0 (0%)
	Q2	2 (2.9%)	20 (28.6%)	6 (8.6%)
	Q3	2 (2.9%)	5 (7.1%)	33 (47.1%)
Strategic	**Q1**	0 (0%)	0 (0%)	0 (0%)
	Q2	0 (0%)	18 (25.7%)	8 (11.4%)
	Q3	1 (1.4%)	11 (15.7%)	32 (45.7%)

Notes:

1. For learning approach scales, Q1 denotes score less than 10, Q2 denotes score between 10 to 20 and Q3 denotes score more than 20. For learning approach subscales, Q1 denotes score less than 5, Q2 denotes score between 5 to 10 and Q3 denotes score more than 10

2. All participating students from cohorts 1 and 2 from both institutions were included in the statistical analysis

Learning approach and academic performance

We investigated whether learning approach was associated with academic performance. Students from both cohorts and from both institutions were combined for this analysis. Table 5 shows the estimated coefficients and their standard errors from simple linear regressions between each pair of a dependent and independent variables. In the first set of models, each learning approach scale/subscale at the 2nd measurement is regressed on the three academic performance outcomes (basic clinical sciences exam, pharmacology test and OSCE). The estimates indicate the average change (i.e. increase or decrease if the estimate is positive or negative respectively) of the scores in each outcome with the increase of one unit of the score of a learning approach at the 2nd measurement. None of the estimates were statistically significant. Online Tables 3a-3c show the estimates for the association between learning approach and academic performance in models adjusted by students' characteristics. We found that none of the estimates of learning approach scales or subscales became statistically significant after controlling for students' characteristics.

In the second set of models, we created binary variables (yes/no) indicating whether a student has an increase on each learning approach scale/subscale score. The estimates indicate the average difference (positive or negative depending on the sign of the estimate) in the scores of each assessment between the students who had an increase on their learning approach score within the year and the students who did not have an increase on their learning approach score (reference group). One regression model gave a statistically significant estimate ($p < 0.05$). Specifically, students with an increase in their Strategic Motivation score between the beginning and the end of the year, obtained on average 2.77 more marks on the pharmacology post-test compared to the students with no increase in their Strategic Motivation score. Considering that we have previously shown that baseline pharmacology knowledge is associated with pharmacology performance at the end of the year [6], the same regressions have been applied also adjusting by the pre-test scores for the pharmacology test at the end of the year. The results showed no association between learning approach and examination performance at the pharmacology test after adjusting for the pre-test scores (estimated coefficient: 1.87; standard error 1.33).

Learning approach and student satisfaction

We investigated the relationship between learning approach and student satisfaction with PBL using a 15-item questionnaire [6] (Table 6). Students from both cohorts and from both institutions were combined for this analysis. ***Deep learning*** did not correlate with student satisfaction in any of the three themes of the questionnaire i.e [1]. PBL as a learning environment [2], PBL as a learning environment in pharmacology and [3] PBL as a learning environment and confidence in prescribing. ***Surface learning*** and surface process learning were negatively correlated with satisfaction with PBL-generated drug learning objectives (Question 7; ρ=-0.39: surface; ρ=-0.37: surface process). Furthermore, a negative correlation was noted between surface learning and confidence in prescribing upon graduation (Question 15; ρ=-0.30), including negative correlations of surface motivation with satisfaction with pharmacology lectures in increasing prescribing confidence (Question 11; ρ=-0.31)

Table 4a Impact of student background characteristics on **Deep learning approach** in year 1

	Deep motivation Measurement 1 Mean (SD)	Deep motivation Measurement 2 Mean (SD)	*p*-value	Deep process Measurement 1 Mean (SD)	Deep process Measurement 2 Mean (SD)	*p*-value	Deep Measurement 1 Mean (SD)	Deep Measurement 2 Mean (SD)	*p*-value
Educational Institution									
UNIC	11.08 (2.61)	10.47 (2.30)	0.257	11.17 (2.48)	10.93 (2.35)	0.661	22.25 (4.57)	21.40 (4.12)	0.377
SGUL	11.13 (2.51)	9.95 (2.24)	0.354	10.93 (2.22)	11.35 (2.18)	0.335	22.06 (3.84)	21.32 (3.83)	0.341
Gender									
Male	11.47 (2.44)	10.19 (2.37)	**0.028**	11.04 (2.28)	11.43 (2.38)	0.483	22.51 (4.08)	21.63 (4.04)	0.366
Female	10.83 (2.60)	10.17 (2.22)	0.154	11.00 (2.38)	11.00 (2.16)	1	21.83 (4.22)	21.17 (3.90)	0.400
Age									
20–25	10.90 (2.43)	10.17 (2.11)	0.119	10.88 (2.20)	11.14 (1.97)	0.551	21.78 (3.73)	21.31 (3.47)	0.528
> 25	11.51 (2.63)	10.27 (2.53)	**0.037**	11.25 (2.55)	11.23 (2.58)	0.971	22.76 (4.64)	21.50 (4.50)	0.226
Ethnic Background									
White	10.96 (2.62)	9.68 (2.05)	**0.006**	11.21 (2.15)	10.87 (2.17)	0.426	22.17 (4.00)	20.55 (3.51)	**0.030**
Other	11.32 (2.46)	10.80 (2.40)	0.350	10.79 (2.58)	11.55 (2.32)	0.172	22.11 (4.44)	22.37 (4.25)	0.798
Educational Background									
Biomedical Sciences	11.07 (2.37)	10.20 (2.35)	**0.038**	10.92 (2.45)	11.26 (2.19)	0.390	21.99 (4.04)	21.47 (4.11)	0.474
Other	11.16 (3.01)	9.94 (1.98)	0.088	11.30 (2.16)	10.63 (2.28)	0.325	22.46 (4.61)	20.56 (3.03)	0.084
Level of Education									
Bachelor's	11.35 (2.39)	10.12 (2.25)	**0.024**	11.22 (2.00)	11.19 (2.51)	0.956	22.57 (3.77)	21.31 (4.35)	0.202
Master's or Doctorate	10.86 (2.70)	10.21 (2.30)	0.194	10.86 (2.64)	11.16 (2.09)	0.509	21.71 (4.54)	21.38 (3.70)	0.681
Country of Origin									
Great Britain	11.02 (2.64)	9.97 (2.43)	0.060	11.22 (2.07)	11.39 (2.10)	0.704	22.24 (3.85)	21.38 (3.88)	0.315
Other country	11.18 (2.50)	10.38 (2.10)	0.091	10.90 (2.52)	10.94 (2.40)	0.942	22.08 (4.43)	21.32 (4.04)	0.383
Native Language									
English	11.00 (2.48)	10.00 (1.97)	**0.007**	11.09 (2.25)	11.21 (2.02)	0.729	22.09 (3.90)	21.22 (3.29)	0.148
Other	11.47 (2.76)	10.86 (3.16)	0.542	10.87 (2.64)	11.00 (3.09)	0.890	22.33 (5.03)	21.86 (5.92)	0.797

Notes:

1. Cohorts 1 and 2 were combined for this analysis. For all student characteristics, with the exception of analysis of the effect of institution, students from both institutions were combined for analysis

2. Measurement 1: $n = 129$; Measurement 2: $n = 70$; distribution of participants sub-groups is shown in Table 1

and independent learning increasing confidence in prescribing (Question 14; ρ=-0.37 correlation with surface process; ρ=-0.38 correlation with surface). ***Strategic learning*** was also negatively correlated with PBL satisfaction. Specifically, strategic learners showed a preference for lectures over PBL (Question 1; ρ=-0.29 correlation with Strategic Motivation and ρ=-0.30 correlation with Strategic learning approach) and were not satisfied with the integration of pharmacology with PBL (Question 10; ρ=-0.28). There was a positive correlation between strategic motivation and pharmacology lectures increasing confidence in prescribing (Question 11; ρ = 0.29) while strategic learners perceived clinical placements not to be helpful in becoming a competent prescriber (Question 12; ρ = 0.36 correlation with Strategic Motivation). Strategic process learners perceived that student diversity facilitated their learning in PBL (Question 5; ρ = 0.35).

Discussion

Learning approach and PBL

The literature presents disparate findings on the impact of PBL on learning approaches. This is likely related to heterogeneity of study designs, length of intervention and research tools [8]. Our findings from curriculum-wide implementation of PBL in two student cohorts from two medical schools, using the validated study process questionnaire and reliable assessments, provide important insight into the influence of an integrated PBL

Table 4b Impact of student background characteristics on **Surface learning approach** in year 1

	Surface motivation Measurement 1 Mean (SD)	Surface motivation Measurement 2 Mean (SD)	*p*-value	Surface process Measurement 1 Mean (SD)	Surface process Measurement 2 Mean (SD)	*p*-value	Surface Measurement 1 Mean (SD)	Surface Measurement 2 Mean (SD)	*p*-value
Educational Institution									0.345
UNIC	8.41 (2.59)	8.53 (2.34)	0.817	7.75 (2.94)	7.50 (2.50)	0.681	16.15 (4.99)	16.03 (4.31)	0.907
SGUL	8.26 (2.27)	8.95 (2.55)	0.162	8.20 (2.94)	7.85 (2.43)	0.502	16.43 (4.16)	16.74 (3.91)	0.701
Gender									0.260
Male	8.53 (2.41)	8.04 (2.25)	0.367	8.39 (2.95)	8.00 (2.83)	0.568	16.92 (4.42)	15.93 (4.38)	
Female	8.18 (2.44)	9.26 (2.49)	**0.026**	7.70 (2.93)	7.50 (2.19)	0.673	15.86 (4.62)	16.76 (3.89)	
Age									0.324
20–25	8.30 (2.42)	9.32 (2.36)	**0.039**	8.14 (2.92)	8.03 (2.58)	0.836	16.42 (4.53)	17.31 (4.23)	0.469
> 25	8.31 (2.47)	8.07 (2.52)	0.671	7.84 (2.96)	7.40 (2.36)	0.460	16.15 (4.56)	15.47 (3.84)	
Ethnic Background									0.487
White	8.37 (2.28)	9.00 (2.21)	0.159	7.78 (2.92)	7.71 (2.25)	0.895	16.12 (4.25)	16.66 (3.66)	0.706
Other	8.26 (2.62)	8.48 (2.74)	0.720	8.30 (2.96)	7.68 (2.71)	0.329	16.57 (4.96)	16.16 (4.58)	
Educational Background									0.567
Biomedical Sciences	8.34 (2.47)	8.77 (2.42)	0.316	7.88 (3.07)	7.90 (2.53)	0.952	16.20 (4.74)	16.63 (4.12)	0.583
Other	8.27 (2.38)	8.88 (2.68)	0.443	8.35 (2.71)	7.06 (2.21)	0.078	16.62 (4.16)	15.94 (4.11)	
Level of Education									0.079
Bachelor's	8.02 (2.37)	9.52 (2.26)	**0.006**	8.09 (2.96)	8.33 (2.57)	0.697	16.11 (4.45)	17.85 (4.16)	0.238
Master's or Doctorate	8.65 (2.44)	8.30 (2.48)	0.477	7.89 (2.93)	7.29 (2.31)	0.240	16.51 (4.66)	15.52 (3.79)	
Country of Origin									0.637
Great Britain	8.38 (2.53)	9.28 (2.50)	0.101	8.30 (3.08)	7.86 (2.57)	0.458	16.65 (4.55)	17.09 (3.97)	0.756
Other country	8.29 (2.34)	8.24 (2.32)	0.914	7.75 (2.82)	7.53 (2.35)	0.669	16.04 (4.55)	15.76 (4.13)	
Native Language									0.870
English	8.40 (2.42)	8.98 (2.24)	0.133	8.09 (2.90)	7.64 (2.38)	0.297	16.47 (4.44)	16.58 (3.84)	0.956
Other	8.10 (2.44)	7.93 (3.15)	0.859	7.67 (3.08)	7.93 (2.79)	0.781	15.77 (4.89)	15.86 (5.02)	

Notes:

1. Cohorts 1 and 2 were combined for this analysis. For all student characteristics, with the exception of analysis of the effect of institution, students from both institutions were combined for analysis

2. Measurement 1: $n = 129$; Measurement 2: $n = 70$; distribution of participants sub-groups is shown in Table 1

environment on the learning approaches of first-year medical students. The study process questionnaire reliability was in line with the findings from Fox [10]. Our results showed that deep motivation decreased significantly by the end of the year, contrasting with the expectations that PBL would promote deep learning [8, 12–14, 16]. A decrease in deep motivation may denote reduction in personal satisfaction, excitement and engagement with the medical studies [10]. Our findings are in agreement with two studies conducted in Year 1 medical students from an Australian medical school [22, 23], which showed that students shifted away from deep learning towards a more surface approach by the end of the year. Similarly, a more recent study [20], which employed both longitudinal and cross-sectional designs, revealed decreases in deep and strategic approaches and an increase in surface learning from pre-admission to mid-Year 5 in a UK medical school. Factors such as assessment pressures [12, 15, 25], curriculum demands [8, 22, 23], adaptation to self-directed learning [20, 23] and competition amongst students [26] may contribute to a decline in motivation over time. A more recent study showed that stress, related to lack of knowledge and skills, the clinical environment, workload, peers, daily life and patient care responsibilities, led to a decrease in deep learning and an increase in the surface learning in nursing students [33]. These stressors are also relevant to medical schools and may further explain our results. Indeed, we have previously identified challenges with PBL in our study population, including uncertainty with self-directed learning and depth of knowledge required, perceived lack of guidance and a demanding curriculum [6]. These findings collectively underscore the importance of addressing personal factors, environmental and curricular factors, alongside providing effective metacognitive support, to sustain deep learning motivation among medical students.

Impact of student characteristics on learning approaches

Our results also highlight that learning approach changes over time in individual students, suggesting that PBL does not influence all students in the same way, in line with a preliminary study that recruited a small number of students [7]. Even though the literature suggests that student characteristics, such as gender and age, may have an impact on learning approach, most findings have been reported in non-PBL environments [25–29]. Longitudinal studies investigating how student characteristics impact learning approaches over time are also lacking. Our study contributes to this body of knowledge by identifying student groups that may be more vulnerable to the stresses of a first-year integrated PBL medical programme.

Gender

Two studies have shown that female medical students were more likely to use a strategic learning style [19, 20], while Mogre et al. [34] found no association. The only study that looked at changes in learning approach longitudinally was conducted by Groves and colleagues, who showed a trend for females to be surface learners by the end of the year, although this was not statistically significant [22]. Consistent with the aforementioned study, our results show that the score of surface motivation increased in female students by the end of the year. Surface learners are motivated by fear of failure and desire to complete their course of study with the end goal of job security and/or good pay rather than an intrinsic interest in the medical field [10]. While the reasons for these differential effects in female students is not well understood, it has been suggested that while women show better organization, time-management skills [27] and better study habits [35], they are more likely to be affected by external pressures [36], such as those in a PBL environment. At the same time, our results showed that male students also developed unfavourable learning approaches and their deep motivation decreased suggesting that the stressors of the first year of their studies resulted in reduced personal satisfaction and enthusiasm about the acquired knowledge.

Age

We found that surface motivation increased in younger, but not older students. Consistently, McParland et al. showed that older students were less likely to use a surface learning style [19] and Mogre and colleagues [34] showed that an increase in age predicted a decrease in surface approach scores, which could be due to more metacognitive awareness in older students.

Educational background

Students with fewer years of tertiary education (i.e. undergraduate degrees only) showed an increase in surface motivation and a decrease in deep motivation. It is possible that students with postgraduate degrees are more mature, have a clearer understanding of expectations and have taken a more conscientious decision to study medicine [25, 27], which could allow them to maintain their motivation at the end of the year. The effect of educational background in a PBL environment has only been investigated by Groves et al., who showed that a biology background did not affect a student's learning approach [22]. The ASSIST questionnaire used in the study does not measure deep motivation separately though. We found that although students with a background in biomedical sciences had no change in the deep learning approach overall, they showed decreased scores in the deep motivation sub-scale at the end of the year.

Table 4c Impact of student background characteristics on **Strategic Learning Approach** in Year 1

	Strategic motivation Measurement 1 Mean (SD)	Strategic motivation Measurement 2 Mean (SD)	*p-value*	Strategic process Measurement 1 Mean (SD)	Strategic process Measurement 2 Mean (SD)	*p-value*	Strategic Measurement 1 Mean (SD)	Strategic Measurement 2 Mean (SD)	*p-value*
Educational Institution									
UNIC	10.83 (2.85)	10.13 (2.87)	0.286	11.17 (2.59)	10.07 (3.20)	0.109	22.07 (4.18)	20.20 (4.14)	0.050
SGUL	10.27 (2.97)	10.43 (3.46)	0.815	10.61 (2.59)	10.83 (2.35)	0.665	20.89 (4.11)	21.25 (4.31)	0.666
Gender									0.574
Male	10.57 (3.15)	11.04 (3.49)	0.559	10.67 (2.36)	10.71 (2.45)	0.934	21.24 (4.05)	21.75 (3.78)	0.131
Female	10.45 (2.77)	9.81 (2.94)	0.253	10.95 (2.73)	10.36 (2.96)	0.289	21.45 (4.21)	20.17 (4.45)	
Age									0.652
20–25	10.70 (2.88)	10.46 (3.04)	0.699	11.50 (2.48)	11.46 (2.30)	0.933	22.26 (3.81)	21.92 (3.65)	0.321
> 25	10.22 (3.06)	9.93 (3.46)	0.707	10.05 (2.59)	9.30 (2.94)	0.244	20.27 (4.48)	19.23 (4.62)	
Ethnic Background									0.554
White	10.45 (3.01)	10.36 (3.51)	0.887	10.88 (2.52)	10.54 (2.71)	0.513	21.39 (4.08)	20.90 (4.22)	0.420
Other	10.62 (2.81)	10.23 (2.84)	0.537	10.85 (2.73)	10.45 (2.85)	0.534	21.47 (4.33)	20.68 (4.33)	
Educational Background									0.383
Biomedical Sciences	10.63 (2.87)	10.26 (3.16)	0.491	11.00 (2.50)	10.77 (2.59)	0.612	21.68 (4.10)	21.04 (4.26)	0.415
Other	10.16 (3.13)	10.25 (3.47)	0.931	10.62 (2.77)	9.50 (3.18)	0.233	20.78 (4.24)	19.75 (4.16)	
Level of Education									0.363
Bachelor's	10.92 (2.80)	10.70 (3.41)	0.769	10.92 (2.53)	10.26 (2.89)	0.305	21.85 (3.87)	20.96 (4.32)	0.738
Master's or Doctorate	10.11 (3.01)	10.05 (3.09)	0.915	10.81 (2.68)	10.65 (2.69)	0.762	20.98 (4.44)	20.70 (4.23)	
Country of Origin									0.759
Great Britain	10.25 (3.12)	10.19 (3.33)	0.936	10.70 (2.70)	11.03 (2.25)	0.526	20.95 (4.18)	21.22 (4.21)	0.108
Other country	10.74 (2.76)	10.41 (3.12)	0.606	11.00 (2.53)	9.94 (3.14)	0.091	21.79 (4.16)	20.35 (4.28)	
Native Language									0.752
English	10.24 (2.98)	10.18 (3.15)	0.898	10.69 (2.70)	10.57 (2.59)	0.794	20.97 (4.26)	20.75 (4.07)	0.217
Other	11.43 (2.54)	10.79 (3.49)	0.541	11.47 (2.18)	10.21 (3.42)	0.225	22.90 (3.54)	21.00 (5.02)	

Notes:

1. Cohorts 1 and 2 were combined for this analysis. For all student characteristics, with the exception of analysis of the effect of institution, students from both institutions were combined for analysis.

2. Measurement 1: n = 129; Measurement 2: n = 70; distribution of participants sub-groups is shown in Table 1

Table 5 Academic performance and learning approach

	Basic and clinical sciences	Pharmacology test	OSCE
Learning approach score			
Deep motivation learning	0.50 (0.52)	0.04 (0.31)	-0.98 (0.51)
Deep process learning	0.67 (0.52)	0.30 (0.33)	-0.93 (0.54)
Deep learning	0.39 (0.30)	0.11 (0.18)	-0.54 (0.28)
Surface motivation learning	-0.84 (0.47)	-0.39 (0.28)	0.72 (0.52)
Surface process learning	0.09 (0.49)	0.14 (0.32)	0.74 (0.56)
Surface learning	-0.27 (0.29)	-0.12 (0.19)	0.49 (0.31)
Strategic motivation learning	0.16 (0.37)	0.21 (0.22)	-0.14 (0.50)
Strategic process learning	0.24 (0.43)	0.21 (0.25)	-0.01 (0.47)
Strategic learning	0.19 (0.28)	0.23 (0.17)	-0.08 (0.35)
Change of scores between the two measurements			
Increase in deep motivation learning score (yes)	-0.16 (2.62)	-0.79 (1.48)	2.26 (3.80)
Increase in deep process learning score (yes)	3.61 (2.39)	1.06 (1.39)	2.70 (3.39)
Increase in deep learning score (yes)	4.29 (2.39)	0.81 (1.40)	1.02 (3.44)
Increase in surface motivation learning score (yes)	-0.19 (2.36)	-0.12 (1.37)	-0.11 (3.34)
Increase in surface process learning score (yes)	2.70 (2.49)	2.24 (1.46)	0.12 (3.45)
Increase in surface learning score (yes)	0.74 (2.37)	1.98 (1.35)	2.12 (3.18)
Increase in strategic motivation learning score (yes)	1.38 (2.44)	**2.77 (1.37)*$**	1.85 (3.81)
Increase in strategic process learning score (yes)	1.48 (2.41)	1.17 (1.38)	2.55 (3.79)
Increase in strategic learning score (yes)	-1.26 (2.38)	1.04 (1.38)	-0.27 (3.34)

Notes:

1. $n = 70$;*:$p < 0.05$; $: No statistically significant association was noted between increase in strategic motivation learning score and examination performance at the pharmacology post-test after adjusting for the pre-test scores (estimated coefficient: 1.87; standard error 1.33)

2. All participating students from cohorts 1 and 2 from both institutions were included in the statistical analysis

We speculate that students with a degree in the biomedical sciences may have lost interest in the material if they had studied it previously.

Language

We further found that native speakers had reduced deep motivation by the end of the year. The sustained motivation of international students (who are more likely to be non-native speakers) may be due to their active decision to pursue medicine away from home.

Ethnic background

We found that white students had decreased deep motivation at the end of the year, which was not observed in the combined other ethnicity group. Though educational researchers have called for more work to identify the effects of race on student learning [37], literature remains scarce and the reasons for this finding are unclear, despite suggestions that cultural contexts [25], including expectations, may have an impact on learning approach.

Our findings suggest that demographic (or student) factors may play a role in how students adapt their approach in a PBL environment [27, 38]. However, a student's learning approach is determined by multifaceted aspects and is quite complex. For example, the findings from Kek et al. [38] have suggested that parent involvement, teaching approach, educational background of parents, hours spent studying and sleep problems are also important in medical students. According to Biggs 3P model [24], learning approach is not static but rather it is influenced by the learning environment, this underscores the importance of considering student diversity when designing and implementing PBL curricula. It is clear that further research is needed particularly looking at changes over time and investigating how to best encourage deep learning.

Learning approach and academic performance

The relationship between learning approach and academic performance is poorly studied in a PBL context. It has been postulated that the type of assessment may affect how a student modifies their approach to achieve the best outcome. For example, it is expected that oral and clinical examinations, such as the OSCEs and essays, may promote deep learning, as compared to multiple choice exams, which may rely on knowledge recall [19, 39]. In our study, we have therefore looked at the association with both written and clinical exams. We found no association between learning approach, or its increase within the year, and examination performance in either written exams (basic and clinical sciences, pharmacology test) or the OSCE. Furthermore, we have previously shown that students with a background in biomedical sciences outperformed students with other educational backgrounds in their pharmacology knowledge tests in the same study population [6]. In the present study, we showed that students with biomedical sciences had lower scores in deep motivation at the end of the year, therefore the better performance was not related to a positive change in learning approach.

These findings may appear counterintuitive, as one may expect that deep learning is associated with better academic outcomes. Our results reinforce the findings of Groves et al., who found no effect of learning approach on Year 1 scores [22]. On the other hand, McParland and colleagues found that strategic learners performed better in both multiple-choice and viva examinations, although the findings may be confounded by including students from both a traditional and a PBL curriculum in the statistical analysis [19]. A subsequent study [23]

Table 6 Student satisfaction and learning approach

	Deep motivation	Deep process	Deep	Surface motivation	Surface process	Surface	Strategic motivation	Strategic process	Strategic
PBL as a learning environment									
1. I learn better in a PBL setting rather than in a lecture	-0.19	-0.03	-0.13	0.03	0.09	0.07	**-0.29***	-0.10	**-0.30***
2. PBL helps me develop my independent learning skills	0.01	0.14	0.09	-0.03	0.003	-0.02	-0.06	0.02	-0.04
3. PBL was not that helpful in developing my presentation and communication skills	0.15	0.20	0.20	-0.0003	0.04	0.02	-0.24	0.26	-0.02
4. Regarding the PBL tutor, being a content expert is more important than being a good facilitator.	-0.10	-0.10	-0.12	0.12	-0.13	-0.01	-0.07	0.22	0.08
5. Student diversity (different backgrounds and learning styles) facilitates my learning in the PBL environment	0.19	0.08	0.16	0.05	0.02	0.04	-0.14	**0.35***	0.11
PBL as a learning environment in pharmacology									
6. My pharmacology learning is enhanced when there is a content expert in the room (tutor or fellow student)	-0.09	0.15	0.04	0.09	-0.04	0.03	0.06	-0.12	-0.03
7. PBL-generated drug LOBs do not facilitate in-depth pharmacology	-0.27	-0.002	-0.16	-0.24	**-0.37***	**-0.39***	-0.12	-0.01	-0.10
8. Pharmacology lectures are the cornerstone of learning pharmacology in depth	-0.12	-0.06	-0.11	0.06	0.05	0.07	-0.04	-0.06	-0.07
9. I am satisfied with the amount of pharmacology LOBs generated in PBL cases	-0.11	-0.02	-0.08	-0.16	-0.16	-0.21	-0.16	0.18	-0.02
10. I don't feel that there is enough integration between the pharmacology taught in lectures and the pharmacology delivered in PBL	-0.026	0.12	0.04	-0.21	-0.16	-0.24	-0.24	-0.15	**-0.28***
PBL as a learning environment and confidence in prescribing"									
11. Pharmacology lectures increase my confidence in being able to prescribe	0.04	0.03	0.04	**-0.31***	-0.002	-0.20	**0.29***	-0.01	0.22
12. Clinical placements are not helpful in becoming a competent prescriber	0.02	0.12	0.08	0.25	-0.13	0.07	**0.36***	-0.03	0.26
13. Drug LOBs generated in PBL enhance my confidence in becoming a competent prescriber	-0.09	-0.02	-0.06	-0.10	-0.01	-0.07	-0.18	0.03	-0.12

Table 8 (continued)

	Deep motivation	Deep process	Deep	Surface motivation	Surface process	Surface	Strategic motivation	Strategic process	Strategic
14. Independent learning using evidence-based guidelines / sources increases my confidence in prescribing	0.20	0.17	0.22	-0.23	**-0.37***	**-0.38***	0.25	0.01	0.20
15. Upon completion of my MBBS course, I believe I will be a competent prescriber	-0.04	-0.03	-0.04	-0.23	-0.24	**-0.30***	0.15	0.12	0.20

Notes:

1. Pearson correlation coefficients between each score on students' satisfaction and each learning approach scale and subscale are shown in the table. Correlation coefficients in bold indicate statistically significant correlations ($p < 0.05$)

2. All participating students from cohorts 1 and 2 from both institutions were included in the statistical analysis

observed that deep strategic learners achieved higher written examination scores, compared to surface learners, but this advantage did not extend to the OSCE, with the authors noting the small sample size as a limitation. It is also possible that the assessment items used in the two studies have favoured strategic learning approaches, which focus on optimizing performance in specific tasks. More recently, Maudsley [20] indicated that a deep approach was associated with high examination attainment across years 1–4, while a surface approach was associated inversely with the Year 1 outcome. It should be noted that the nature of the examinations (i.e. written and/or clinical) is not explained in the study. Overall, while some studies suggest a positive link between deep or strategic learning and academic success, the evidence is not uniform, and the impact of assessment formats and context should be considered for future studies.

Relationship between learning approaches and student satisfaction

Measuring student satisfaction in educational contexts is important because it provides insights into the effectiveness of teaching methods and the overall learning environment from a student perspective. Despite this, the associations between satisfaction and learning approach haves not been well-studied in the literature in a PBL setting. ***Deep learners.*** Contrary to expectations that deep learners would be better suited to PBL and express more satisfaction with PBL [18, 20, 23], we found no correlation between deep learning and satisfaction. Regarding ***surface learners***, Maudley [20] showed that surface learning was negatively associated with satisfaction with PBL. Our results shed further light on aspects of PBL that surface learners struggled with. Though surface learners did not perceive the PBL environment to impact their learning adversely overall, when it comes to pharmacology, they were not satisfied with PBL-generated drug LOBs. They also perceived that lectures and independent learning did not increase their prescribing confidence. We have previously shown that our study population of Year 1 medical students struggled with pharmacology learning in the PBL environment and lacked confidence in prescribing [6]. The current study reveals that surface learners may be more vulnerable to the stresses of PBL. The study of pharmacology can be challenging and if students approach this discipline with rote memorization, i.e. as surface learners would, this can lead to low confidence and satisfaction, as shown in the present study. Likewise, Papinczak and colleagues showed that surface apathetic learners described feelings of stress and frustration due to uncertainty with self-directed learning, lack of direction from the medical school and heavy workload [23]. We have further identified areas of lower satisfaction in ***strategic learners.*** The finding that they prefer lectures over PBL, and that they perceive that pharmacology lectures increase their confidence in prescribing, might suggest that they consider lectures a more efficient way of learning, conveying the most important points for academic attainment. In contrast, even though medical educators advocate for early clinical exposure, strategic learners did not perceive that clinical placements helped them become competent prescribers. This could also possibly be explained by the format of assessment, which does not rely on making prescribing decisions, where clinical experience may be more important, but rather focuses on the basics of pharmacological action in this early stage of student learning. Interestingly, strategic process learners perceived that student diversity facilitated their learning in PBL. These findings support a previous study in Australian medical students that showed that deep strategic learners highlighted collaboration and the social interaction as positive aspects of PBL in their learning [23]. This could be because PBL allowed them to rank information from different perspectives to help them prioritize knowledge for academic success. These findings provide evidence that learning approach has an important relationship with students' perceptions and satisfaction with the PBL environment.

Limitations

The participation rate was moderate, with about half of the students participating, and we therefore cannot exclude the effect of a self-selection bias. This is mitigated to an extent by the measurement of changes within individual students, though the 38% drop-out rate at the end of Year 1 may have compromised this. Such drop-out rates are not unusual in longitudinal studies [22]. While student numbers could limit the generalizability of our findings to the entire student population and pose limitations for statistical analysis, the demographic characteristics of students at the beginning and end of the year were similar and statistically significant effects were noted in our study. Our study did, however, lack the necessary power to identify differential effects within a smaller subset of the cohort, e.g. among ethnicity groups that were combined for the purposes of analysis. Importantly, the results failed to show statistically significant differences after Benjamini-Hochberg or Bonferroni correction suggesting that our results are prone to type I error. Larger study samples can further elucidate the effect of student characteristics on learning approach in a PBL environment. We acknowledge that this group is heterogeneous. Part of the study was carried out during the Covid-19 pandemic and part of the curriculum, particularly in Cohort 1 (2019–2020), was delivered using online PBL, albeit the curriculum and processes were otherwise unchanged. Even though students in Cohort 1 had a higher score in deep process, deep learning, strategic motivation and strategic learning, as compared to Cohort 2, in the beginning of the year, no differences were noted between the two cohorts in any of the scales/sub-scales by the end of the year. The reasons for the differences at baseline are not clear and they could be at least partially attributed to the pandemic. Nonetheless, our results are consistent with other studies conducted before and after the pandemic [7, 20, 22, 23].

Conclusion

Our longitudinal study, from two medical schools, in a diverse student population, provides valuable insights into the relationships between PBL and learning approaches in first-year medical students. We identified demographic factors that may have relevance for how students adapt their learning approaches. We further identified aspects of PBL that surface and strategic learners struggled with. Recognizing the factors that affect learning approach can support faculty and mentors in designing curricula and learning activities that foster motivation and deep learning. Tailored support services addressing various stressors can further address diverse student needs. Future research should investigate the effect of curriculum interventions and support services in enhancing deep learning.

Abbreviations

PBL	Problem-Based Learning
SPQ	Study Process Questionnaire
SGUL	St George's, University of London
UNIC	University of Nicosia
MBBS	Bachelor of Medicine and Bachelor of Surgery
OSCE	Objective-Structured Clinical Examination
SD	Standard Deviation
SBA	Single-Best Answer
Q1, Q2, Q3	First, Second, Third Tertile

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-025-07171-1.

Supplementary Material 1

Acknowledgements

Not applicable.

Author contributions

PN conceived research; DA, IT, SN, AP, AA, AH, PM and PN designed research; SN, AP and IT acquired data; DA analyzed data; DA, IT, SN, AP, AA, AH, PM and PN interpreted results; DA and PN prepared figures and tables; DA and PN drafted manuscript; DA, IT, SN, AP, AA, AH, PM and PN edited and revised manuscript; DA, IT, SN, AP, AA, AH, PM and PN approved final version of manuscript.

Funding

This project was funded by the "Excellence Hubs" Programme (contract number EXCELLENCE/0198) of the RESTART 2016–2020 Programmes for Research, Technological Development and Innovation administered by the Research and Innovation Foundation of Cyprus and the University of Nicosia Medical School Research Seed Fund (2022 programme).

Data availability

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

The study was approved by the St. George's Research Ethics Committee (REC Reference: 2019.0262) and the Cyprus National Bioethics Committee (Reference No: EEBK E 2019.01.121). Students gave their informed consent to participate in the study.

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Received: 24 October 2024 / Accepted: 11 April 2025
Published online: 26 April 2025

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