frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 13 December 2023
DOI 10.3389/feduc.2023.1301269

OPEN ACCESS

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RECEIVED 24 September 2023
ACCEPTED 28 November 2023
PUBLISHED 13 December 2023

CITATION
Koriťáková E, Jivram T, Gîlcă-Blanariu G-E, Churová V, Poulton E, Ciureanu AI, Louis C, Ștefănescu G and Schwarz D (2023) Comparison of problem-based and team-based learning strategies: a multi-institutional investigation.
Front. Educ. 8:1301269.
doi: 10.3389/feduc.2023.1301269

Comparison of problem-based and team-based learning strategies: a multi-institutional investigation

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Objectives: Over time, pedagogical practices in higher education have evolved significantly, which has led to the development of collaborative learning strategies. The study aims to compare the two most prominent ones – problem-based learning (PBL) and team-based learning (TBL). The comparison, integrated with Virtual Scenarios (VSs), involves student cohorts from various European institutions, specifically focusing on both PBL and TBL methods. The study is distinctive in its use of a consistent PBL/TBL methodology, ensured via joint staff training, and explores the perspectives of students and educators on these learning techniques. The overarching aim is to examine how PBL and TBL, coupled with VSs, influence problem-solving skills, independent learning, and student engagement.

Methods: The examination was made using feedback from 399 students and 11 tutors collected in four trials held in three institutions based in Czechia, the United Kingdom and Romania. The data gathered from surveys and a focus group discussion contained qualitative as well as quantitative data, such as Likert scale questions. To analyse the overall trends in learners' satisfaction with PBL and TBL sessions, the mean score calculated from the transformed Likert scale questions was compared between sessions and among institutions using multivariate ANOVA.

Results: The students' satisfaction and learning experience are heavily influenced by specific conditions, primarily their prior experience, room and technical set-up, group composition and especially the personality of a tutor. Overall, both strategies were found to be well-received by students used to traditional teaching methods. Students accustomed to PBL did not find TBL more engaging or useful. The identified advantages of TBL over PBL were the presence of a content expert, readiness tests, acquiring the same knowledge ensured through the collective presence of all students in one session and unified pre-class materials. However, TBL is more demanding on room set-up and teaching staff coordination.

Conclusion: Both strategies have been found to have pros and cons and neither showed clear superiority over the other one. An institution newly implementing PBL or TBL needs to focus on different aspects than an institution planning to switch from PBL to TBL.

KEYWORDS

collaborative learning activities, problem-based learning, team-based learning, virtual scenario, attitude surveys

1 Introduction

The concept of knowledge societies (Guttman, 2003) emphasizes the need to advance pedagogy in higher education as the traditional approaches to teaching, which usually dedicate in-class time to delivering content, may not allow all students to achieve deeper learning and thus limit their opportunities to maximize knowledge acquisition and skills development. It is important to note that improvement in learning is not possible to be achieved by simply strengthening the role of technology, computers and the Internet, because such an approach often results in reducing knowledge to unstructured information flows. Using technology to enhance the educational process requires understanding of pedagogical principles that are specific to an instructional setting (Diaz and Bontenbal, 2000).

There is a broad range of instructional approaches which support collaborative learning (CL) (Pluta et al., 2013). The CL strategies represent an array of learning activities involving joint intellectual effort expended by students who work together in groups, test their own understanding and also understanding of the others as a mechanism for expanding comprehension of particular phenomena (Smith and MacGregor, 1992).

A well-liked and widely accepted CL approach, Problem-Based Learning (PBL), was developed in the 1960s, with its origins traced back to educational innovations at McMaster University (Barrows and Tamblyn, 1980; Barrows, 1996). It is a student-centric learning technique in which the educator acts as a moderator supporting and concentrating the discussion around a problem to be solved by a small group of students. In the process, the group identifies all learning outcomes that are crucial to be addressed in order to arrive at a solution to the problem at hand, conducts research around them and discusses the issues raised (Hu et al., 2019). A recent development in the area of novel approaches to teaching primarily applicable to higher education is Team-Based Learning (TBL), which also represents a small group learning method that has become an alternative to PBL (Burgess et al., 2017, 2020). TBL is a structured form of small-group learning, emphasizing student preparation outside of class and application of knowledge within the classroom. It typically involves three phases: individual study, a readiness assessment process featuring various forms of formative feedback, and an application-focused exercise.

PBL and TBL emphasize student engagement and active participation in learning. They both have adopted blended learning approach by mixing face-to-face instruction with online resources. A PBL session starts with a group meeting of 8 to 12 students who work together to identify learning objectives needed to be covered in order to properly understand a given problem and related principles. Individual self-study is followed by another group meeting where the findings are shared (Dolmans et al., 2015) and the problem is solved jointly, while facilitated by a tutor who keeps the group focused on tasks and guides the students to attain the learning objectives rather than answering questions or providing lectures (Azer, 2005). In contrast to PBL, TBL does not require large numbers of tutors (Burgess et al., 2017), as one facilitator typically manages several teams smaller than PBL groups in one room simultaneously in a single session. Another major difference between PBL and TBL lies in the activation of prior knowledge and exposure to new content. In PBL students are not tested, but instead, encouraged to activate their prior knowledge by means of an initial group discussion, while TBL requires students to complete a pre-class reading assignment and tests them to assess their understanding of the preparatory materials – individually using the iRAT (Individual Readiness Assurance Test) and as a team using the tRAT (Team Readiness Assurance Test) (Dolmans et al., 2015; Gullo et al., 2015). TBL can be implemented differently across institutions. The difference usually relates to two different roles teachers assume within an interdisciplinary team conducting a TBL session: (i) a Content Expert, who is knowledgeable about the subject matter, and (ii) a Facilitator, who provides pedagogical expertise and directs all questioning and discussions (Rotgans et al., 2019). Besides setting and assigning different roles to educators, the TBL methodology also provides a clear structure for students, outlining what they are expected to be doing in each part of a TBL session, and thus makes it an exemplary framework for implementing a flipped classroom (Jakobsen and Knetemann, 2017) – a pedagogical strategy in which the typical in-class and homework elements of a course are reversed and which has recently made inroads into higher education, yielding a significant improvement in student learning compared with traditional teaching methods (Hew and Lo, 2018).

In the context of evolving PBL methodologies, Scenario-Based Learning (SBL) as a derivative of Decision-PBL, has shown promising results. SBL leverages interactive scenarios termed Virtual Scenarios (VSs) in general and Virtual Patients (VPs) in medical education, to mimic real-world problems, thereby enhancing student engagement (Woodham et al., 2017) and performance (Poulton et al., 2014). This more immersive approach, involving elements of simulation (Poulton et al., 2014) and serious games (Klincova et al., 2019), aligns with our investigation into the integration of innovative educational strategies with PBL and TBL. Notably, a systematic review following Cochrane methodology (Kononowicz et al., 2019) has demonstrated the effectiveness of these scenarios in improving clinical reasoning, procedural skills, and teamwork in health professions education, which are key aspects of our study's focus.

This paper summarizes activities undertaken during the two-year TELSON project,[1] which aimed to innovate teaching and learning practices with the use of PBL and TBL teaching methods, and also to share know-how while transferring best practices from universities which have successfully implemented these authentic, motivating, competency-based learning styles into their curricula. The project is unique in the way it integrated VSs with the two CL techniques and

1 https://www.telson-project.eu/en/project/

the results achieved are presented in this paper. Specifically, a multi-institutional investigation was performed, examining the students' and other stakeholders' perspectives on PBL and TBL techniques integrated with VSs. Although the study draws on the wide experience gathered by the project consortium in the field of medical education, it covers a wider educational area by including not only curricula in General Medicine and Physician Associate courses, but also in Mathematical Biology and Neuroscience. The study consists of four trials carried out at three institutions: Masaryk University (MUNI) in Brno – Czech Republic, St George's University of London (SGUL) – United Kingdom, and Grigore T. Popa University of Medicine and Pharmacy in Iași (UMF Iași) – Romania. It aims to compare PBL and TBL strategies utilizing the same methodology ensured via joint staff training applied to various student cohorts with different prior experiences. The core of this comparison is centered on three key research questions:

(1) Does the PBL/TBL method encourage problem solving?
(2) Does the PBL/TBL method encourage independent learning?
(3) Is the PBL/TBL method engaging?

These questions, intended for learners, directly address critical aspects of the student experience in PBL and TBL environments. The subsequent Results section provides detailed answers to these questions, evaluating not only the students' but also the educators' perceptions of both learning strategies. Additionally, the paper explores broader themes such as overall satisfaction with the methods, challenges encountered, and their effectiveness compared to traditional teaching approaches.

The presented results complemented with the in-depth discussion can help educators in their efforts to innovate the curricula using PBL or TBL with or without a VS which presents a real-world problem to be solved (in PBL) or serves as an application exercise (in TBL). This paper also provides a comprehensive appendix with methodological details and pedagogical recommendations, many of which are based on the evidence derived from the performed trials.

2 Methods

2.1 Trial design

This study, aimed to compare PBL and TBL strategies, comprised four trials held in three institutions across Europe. Summary of the trials is given in Table 1 and described in the text below.

The first trial, organized by MUNI in September 2019 during a three-day, off-campus summer school, involved 30 3rd to 5th year students majoring in Mathematical Biology as well as PhD students in Biomedical Engineering and related study fields. The participation was voluntary and the students were split into PBL and TBL groups based on convenient sampling to ensure similar distribution of students in different grades within each group (i.e., 3rd year students were randomly split into eight groups, followed by random splitting of 4th year students etc.; for PBL, randomly selected pairs of groups were merged to create four PBL groups). The trial consisted of (1) four synchronous PBL sessions, each with 7–8 students and one tutor per group using the same branched VS; (2) one TBL session comprising eight groups of 3–4 students with one facilitator and one content expert using a semi-linear VS (TBL 1); and (3) one TBL session using the same design as in (2), but without a VS (TBL 2). The two types of virtual scenarios are described in Supplement 1, Chapter 2. Examples of VS can be found in the TELSON project webpage.[2]

The next two trials, organized by SGUL in October 2019 (SGUL Oct) and in February 2020 (SGUL Feb), involved 70 1st year Physicians Associate students. The trials, which replaced standard compulsory lessons, comprised (1) seven synchronous PBL sessions, each with 9–10 students and one tutor per group using the same branched VS; and (2) one TBL session with two facilitators and one content expert using a semi-linear VS. In the October TBL session, students were split into seven groups of 9–10 students per group, as in PBL, while the February TBL session comprised twelve groups of 5–6 students per group. Thus, PBL groups and TBL groups in the October session were same and students were divided into these groups through random sampling at the start of the academic year. In the February TBL session, students were randomly split on a one-time basis.

The fourth trial, organized by UMF Iași in December 2019 as an extracurricular activity with voluntary participation, involved 64 5th year students of Internal Medicine-related subjects within the General Medicine course. The trial consisted of (1) two synchronous TBL sessions, both comprising four groups of 8 students with one facilitator and one content expert using the same semi-linear VS; and (2) three synchronous PBL sessions, each with 10 students and one tutor per group using different branched VSs. Remaining 34 students, who were randomly selected, acted as observers of the PBL session which was live streamed. The TBL groups were created based on students' decision (i.e., students chose their partners to create a group) whereas the PBL groups were randomly assigned by picking up a card with a group number.

The PBL/TBL methodology was the same across all trials and was ensured via joint staff training. The length of sessions was from 3 to 4 h. The PBL session started with a meeting of a group of students working together to identify learning objectives followed by individual self-study and consequently by another group meeting to share the findings and solve the VS problem jointly via discussion, while facilitated by a tutor. The TBL session comprised iRAT to test students' understanding of a pre-class reading material; tRAT to discuss their understanding in a small group; overall discussion of correct answers moderated by a facilitator with explanations given by a content expert; application exercise containing VS; and final discussion. The last TBL trial in MUNI did not contain VS deliberately for comparison.

2.2 Data acquisition

Following each session, all students were invited to participate in an anonymous learning motivation and experience survey. The questionnaire template used for the learners' data collection was same in all trials and sessions and was partly based on a questionnaire designed for evaluating virtual patient design (Huwendiek et al., 2015) and can be found in Supplement 2. MUNI and UMF Iași trial participants were sent a link to the online version of the questionnaire (in Google Forms) accompanied by Czech/Romanian translations. SGUL participants filled in paper questionnaires and the collected data

2 https://www.telson-project.eu/en/virtual-scenarios/

TABLE 1 Summary of the four trials in the three institutions across Europe.

	N	Field of study	# of sessions	# of groups	Group size	Participation	# tutors per session	Virtual scenario	Response rates
MUNI PBL	30	Mat Biol, Bio Eng	4	1	7–8	Voluntary	1 T	Branched	27 (90.0%)
MUNI TBL 1	30		1	8	3–4	Voluntary	1 F + 1 E	Semi-linear	27 (90.0%)
MUNI TBL 2	30		1	8	3–4	Voluntary	1 F + 1 E	None	23 (76.7%)
SGUL Oct PBL	70	Phys Assoc	7	1	9–10	Compulsory	1 T	Branched	66 (94.3%)
SGUL Oct TBL	70		1	7	9–10	Compulsory	2 F + 1 E	Semi-linear	62 (88.6%)
SGUL Feb PBL	70	Phys Assoc	7	1	9–10	Compulsory	1 T	Branched	65 (92.9%)
SGUL Feb TBL	70		1	12	5–6	Compulsory	2 F[a]	Semi-linear	66 (94.3%)
UMF Iași PBL	30[b]	Gen Med	3	1	10	Voluntary	1 T	Branched	21 (73.3%)
UMF Iași TBL	64		2	4	8	Voluntary	1 F + 1 E	Semi-linear	50 (79.7%)

[a]Accidental absence of the content expert as he had to attend to an emergency.
[b]Remaining 34 students were observers. Bio Eng, Biomedical Engineering; E, content expert; F, facilitator; Gen Med, General Medicine; Mat Biol, Mathematical Biology; MUNI, Masaryk University; N, number of students; PBL, problem-based learning; Phys Assoc, Physicians Associate; SGUL, St George's University of London; T, tutor; TBL, team-based learning; UMF, Grigore T. Popa University of Medicine and Pharmacy; #, number.

were subsequently digitalized. Moreover, MUNI trial participants were also asked to fill in an anonymous additional feedback questionnaire.

All tutors and facilitators were also invited to provide their reflection. The online questionnaire template used for the tutors' experience survey is shown in Supplement 3. Besides, a focus group discussion organized at SGUL was recorded and transcribed. The tutors and facilitators were participants of the TELSON project and were trained during a 3-day joint staff training.

Ethical approval was not required for this study because our research pertains to a learning motivation and experience survey. Participation in the survey was entirely voluntary for both students as well as tutors, and the complete anonymity of the survey respondents was ensured. The studies were conducted in accordance with the local legislation and institutional requirements.

2.3 Data pre-processing

All collected data were checked for completeness and validity. The questionnaires without participants' consent with data analysis, or those with more than 50% of missing data were discarded. The questionnaires with inconsistent data, for example, with positive feedback in open-ended questions contradicted by "Strongly disagree" values in all Likert scale questions, were also discarded. The valid data can be found in Supplement 4.

Data pre-processing also involved recoding text labels from the Likert scale into numerical values, that is, "Strongly disagree," "Disagree," "Neither agree nor disagree," "Agree" and "Strongly agree" were transformed into values −2, −1, 0, 1, 2, respectively. Qualitative data gathered from open-ended questions were categorized, grouping similar answers. For example, "too much noise," "cannot hear each other," "microphone did not help" or "difficult to hear" were merged into the "bad acoustics" category.

2.4 Statistical analysis

Data representing the learners' gender and their prior experience with PBL or TBL were described as numbers and percentages and were statistically compared among the sessions using Pearson's chi-square test or two-sample binomial test, as appropriate. Descriptive statistics, such as mean, standard deviation (SD), median, minimum and maximum were used to summarize the learners' age. Consequently, Kruskal-Wallis test was applied to compare the learners' age among the sessions.

Categorical data gathered from the Likert scale questions were summarized using numbers and percentages and statistically compared between PBL and TBL sessions using Fisher's exact test. These data, transformed into the numerical scale, were visualized using median, minimum and maximum and were described also using mean and SD (Norman, 2010). To analyse the overall trends, the mean score calculated from the transformed Likert scale questions was compared between sessions and among institutions using multivariate ANOVA followed by two-sample t-tests used as post-hoc tests. Categorized data from open-ended questions were described as numbers and percentages.

The statistical analyses were performed using the IBM SPSS Statistics software (version 25) and the R software (version 3.4.1). The statistical significance level for all tests was set at $p < 0.05$ and the results were corrected for multiple comparisons using the Bonferroni correction.

3 Results

3.1 Learners' survey results

In total, 407 learners' responses were received (response rates in each trial can be found in the last column of Table 1). After data merging and validation, one response was discarded as no consent with data analysis was obtained, six responses because of data inconsistency, and one response was discarded because of incompleteness exceeding 50% of the questionnaire. The final data set thus comprised 399 valid responses.

The median age of the learners, which was comparable among the sessions ($p = 0.827$), was between 23 and 24 years of age (Table 2). Concerning gender, approximately 90% of the SGUL respondents were females as opposed to about 70% of the UMF Iași and 60% of the

MUNI respondents ($p < 0.001$). There were also statistically significant differences in prior experience with PBL and TBL among the institutions ($p < 0.001$). While the SGUL students had been used to PBL, most MUNI and UMF Iași participants had no prior experience with either PBL or TBL.

3.1.1 Results from Likert scale questions and additional feedback data

In the following paragraphs, responses to the research questions which reflect students' perception of problem solving, independent learning and engagement are evaluated in the context of the whole study and contrasted among the three institutions.

The research question about the encouragement of problem-solving skills reflected by the survey question "*The PBL/TBL session helped to develop my problem solving skills*" showed neither at MUNI nor at UMF Iași statistically significant differences between PBL and TBL. In both institutions the learners' satisfaction was high (Figure 1A; Supplementary Table S1 in Supplement 5). The percentage of learners who agreed or strongly agreed ranged between 72.7 and 92.0% at MUNI and reached as much as 97.9% at UMF Iași. At SGUL, however, the percentage of students who agreed or strongly agreed was significantly lower in TBL than in PBL (38.7% vs. 96.9% in the October trial and 28.8% vs. 93.8% in the February trial).

The second research question concerning independent learning corresponding to the survey question "*The PBL/TBL session encouraged me to learn independently*" also showed significantly higher satisfaction with PBL compared to TBL at SGUL (95.4% vs. 45.2% in the October trial and 81.5% vs. 37.9% in the February trial; Figure 1B; Supplementary Table S1 in Supplement 5). At MUNI, the satisfaction rate was consistently high in all three sessions (around 75% of the learners agreed or strongly agreed). At UMF Iași, the satisfaction rate was also high (around 85%), but there was a significant difference in the percentage of learners who disagreed or strongly disagreed, which was higher in PBL compared to TBL (19.0% vs. 8.5%). The difference, however, became statistically insignificant after the correction for multiple testing as well as merging disagree with strongly disagree and agree with strongly agree answers.

Finally, regarding the students' engagement in the sessions examined by the survey question "*The PBL/TBL activity was engaging*," all UMF Iași participants considered both PBL and TBL sessions engaging (Figure 1C; Supplementary Table S1 in Supplement 5). At MUNI, between 84.6 and 96.0% of the students stated that they were engaged in the sessions. The highest engagement was documented in TBL 1 with 60.0% of the learners strongly agreeing that the activity was engaging, which was a significantly larger percentage compared to 23.1% in PBL and 22.7% in TBL 2. The statistical significance however did not survive the correction for multiple comparisons. At SGUL, the percentage of engaged participants was significantly higher in PBL than in TBL (100.0% vs. 43.5% in the October trial and 95.4% vs. 47.0% in the February trial) even after the correction.

The remaining Likert scale questions from the learners' survey are summarized using balloon plots in Supplementary Figures S1–S5 and Supplementary Tables S2–S6 in Supplement 5. Their analysis showed a similar pattern, consistent with the above-described results, that is also clearly demonstrated in Supplementary Figure S6 in the same supplement. These trends were also confirmed by multivariate ANOVA (Figure 2; Supplementary Table S7 in Supplement 5) computed using the mean score from the questions evaluating overall satisfaction with PBL and TBL sessions (the first 7 questions from the section 7 in Supplement 2). The multivariate ANOVA showed statistically significant influence of institution ($F = 32.62$, df = 2, $p < 0.001$), session ($F = 15.71$, df = 1, $p < 0.001$) as well as their interaction ($F = 37.51$, df = 2, $p < 0.001$). Specifically, at SGUL, the learners' satisfaction rate was significantly higher in PBL than in TBL ($t = 12.91$, df = 252, $p < 0.001$). At UMF Iași, the learners' satisfaction was very high in both CL settings with no statistically significant differences between PBL and TBL sessions ($t = 0.58$, df = 61, $p = 0.565$). The MUNI students were also well-satisfied, with a trend to slightly prefer TBL more than PBL. However, the difference was statistically insignificant ($t = -1.82$, df = 67, $p = 0.073$). Similar results were obtained also for multivariate ANOVA calculated using the mean score from the questions dealing with satisfaction with PBL and TBL sessions based on virtual scenarios (10 questions from the section 8 in Supplement 2; results not shown). Nevertheless, additional feedback data gathered from the

TABLE 2 Learner's characteristics.

	N	Gender - females	Age (Mean ± SD, Median (Min-Max))	Prior experience		
				No	Just heard about it	As a participant
MUNI PBL	26	16 (61.5%)	23.5 ± 1.6, 23 (21–27)	25 (96.2%)	1 (3.8%)	
MUNI TBL 1	25	14 (56.0%)[a]	23.6 ± 1.6, 23 (21–27)	22 (88.0%)	1 (4.0%)	2 (8.0%)
MUNI TBL 2	22	15 (68.2%)	23.2 ± 1.4, 23 (21–26)	20 (90.9%)		2 (9.1%)
SGUL Oct PBL	65	58 (89.2%)[a]	24.9 ± 4.7, 23 (21–43)			65 (100.0%)
SGUL Oct TBL	62	57 (91.9%)	24.9 ± 4.3, 23 (21–40)	62 (100.0%)		
SGUL Feb PBL	65	58 (89.2%)	24.9 ± 4.4, 24 (21–40)			65 (100.0%)
SGUL Feb TBL	66	60 (90.9%)	24.9 ± 4.1, 24 (21–40)			66 (100.0%)
UMF Iași PBL	21	16 (76.2%)	23.3 ± 0.8, 23 (22–25)	20 (95.2%)	1 (4.8%)	
UMF Iași TBL	47	32 (68.1%)	23.1 ± 0.8, 23 (22–26)	43 (91.5%)	1 (2.1%)	3 (6.4%)

[a]One person chose the "prefer not to say" answer to the question "What is your gender?"; Min, minimum; Max, maximum; MUNI, Masaryk University; N, number of responses; PBL, problem-based learning; SD, standard deviation; SGUL, St George's University of London; TBL, team-based learning; UMF, Grigore T. Popa University of Medicine and Pharmacy.

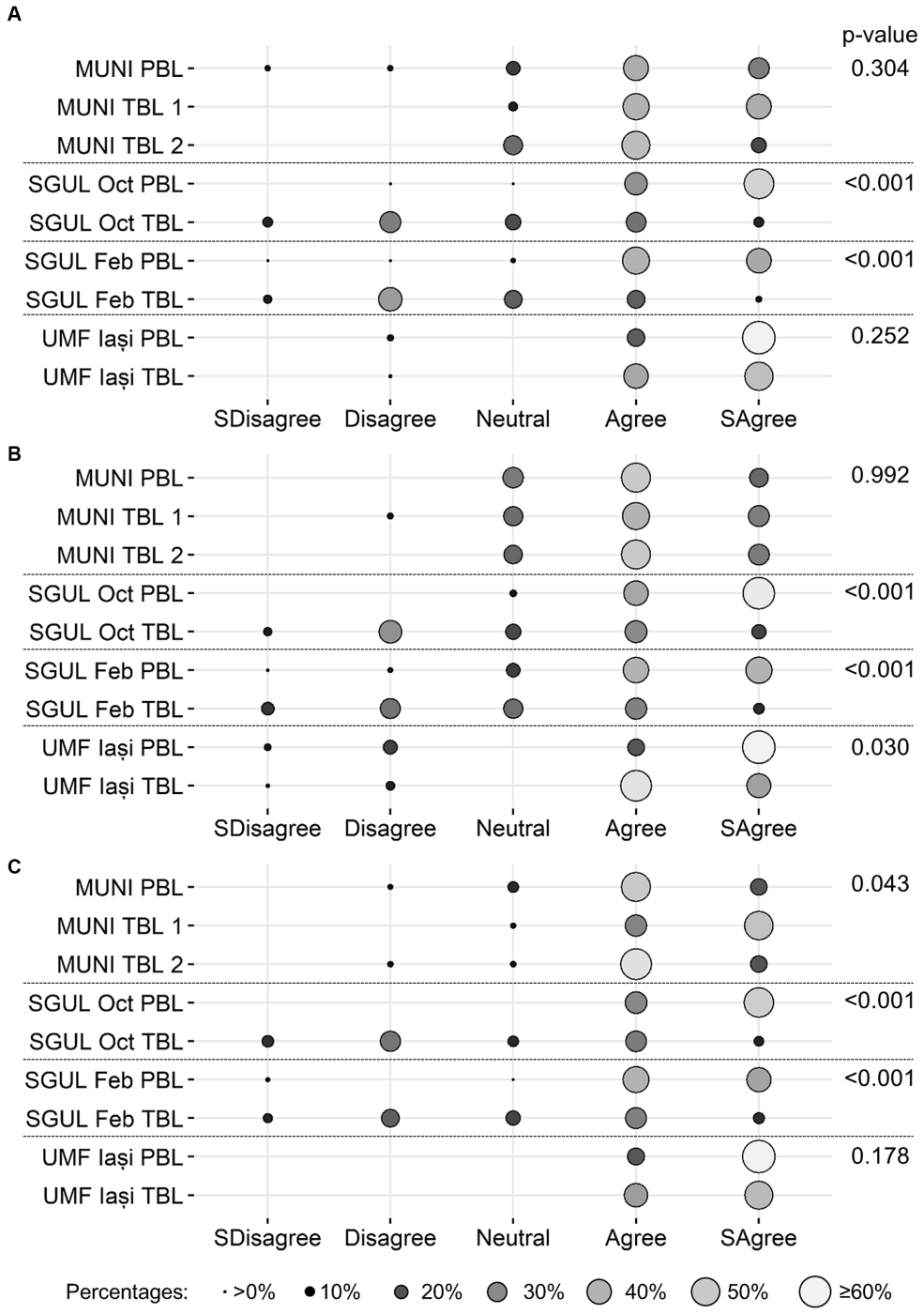

FIGURE 1
Learners' satisfaction (in percentages) with PBL and TBL activities performed in the trials. **(A)** The PBL/TBL session helped me to develop problem-solving skills; **(B)** The PBL/TBL session encouraged me to learn independently; **(C)** The PBL/TBL activity was engaging. MUNI stands for Masaryk University, SGUL for St George's University of London, UMF for Grigore T. Popa University of Medicine and Pharmacy; Neutral corresponds to Neither agree nor disagree, SAgree to Strongly agree, SDisagree to Strongly disagree.

MUNI trial showed that 24 (92.3%) students out of 26 would like the methods of collaborative learning to be implemented into standard teaching from which 14 (58.3%) would prefer TBL, only 2 (8.3%) would prefer PBL and 8 (33.3%) did not specify their preference. In TBL, students appreciated the availability of teaching materials beforehand and the presence of a content expert during a session, able to clarify any uncertainty. Since PBL methods lack these features, students felt uncertain about the correctness of information they looked up and discussed.

Apart from the differences identified among the institutions, the additional feedback data from the MUNI trial indicated that the learners' satisfaction was also influenced by a tutor (Table 3). The

table shows overall quality of PBL as evaluated by the MUNI trial participants. The satisfaction significantly varied ($p = 0.013$) across the four PBL groups that worked on the same PBL case.

3.1.2 Results from open-ended questions

At MUNI, the analysis of open-ended questions revealed that the most common challenges encountered in PBL were the following: inexperience with the statistical software (mentioned by 42.3% of students), only one notebook per group (26.9%), groups too big (11.5%), time management and time pressure issues (11.5%). In TBL 1 vs. TBL 2, the main challenge was again inexperience with the statistical software (12.0% vs. 40.9% students), followed by bad acoustics in the room (24.0% vs. 18.2%).

At SGUL, students reported the following major challenges in PBL Oct vs. PBL Feb sessions: prior knowledge (16.9% vs. 1.5%), the room too small and crowded (6.2% vs. 6.2%), thermal discomfort – too cold or too hot (4.6% vs. 7.7%), time management issues (3.1% vs. 3.1%), and a lack of whiteboards (0.0% vs. 6.2%). In TBL Oct vs. TBL Feb sessions, students struggled with bad acoustics (66.1% vs. 34.8%), room too small and crowded (29.0% vs. 4.5%), thermal discomfort – too hot (24.2% vs. 10.6%), visibility issues (0.0% vs. 15.2%), and teams too big (4.8% vs. 0.0%). Other issues encountered in PBL and TBL were related to the factual content of the virtual scenario and the difficulty of the subject matter.

At UMF Iași, students were highly satisfied with both CL strategies, mentioning only a few challenges. In PBL, one student recommended placing the laptop with the virtual scenario at the same table as the rest of the students were so that the student operating it could also participate in solving the case; one student noticed that some participants were not active; and one student considered communication and organization of ideas to be challenging. In TBL, three students (6.4%) suggested adding more images to the clinical case, two students (4.3%) wished for better time distribution and a break during the session to hold one's attention, one student emphasized the necessity that each team member is to be well prepared and actively involved, and one student noticed that some students tended to overshadow the other team members.

Overall summary of key challenges encountered in PBL and TBL is visualized in Supplementary Figure S1 and displayed in full detail in Supplementary Table S1 in Supplement 6.

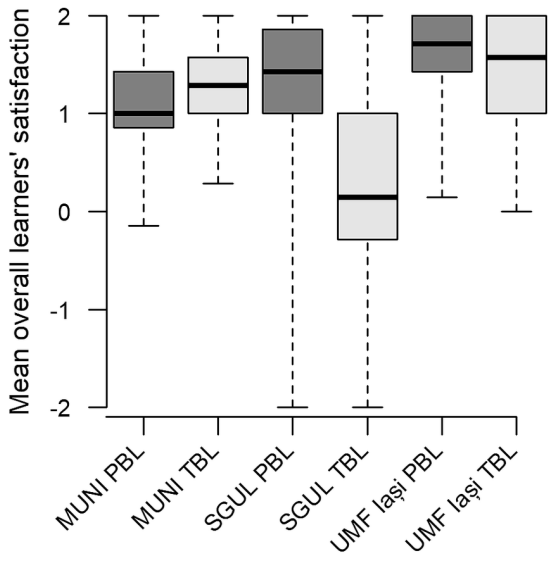

FIGURE 2
Mean overall learners' satisfaction with PBL and TBL sessions in the three institutions. The whiskers represent minimum and maximum, the box corresponds to the interquartile range and the line denotes median. MUNI stands for Masaryk University, SGUL corresponds to St George's University of London, UMF stands for Grigore T. Popa University of Medicine and Pharmacy.

3.2 Tutors' survey results

All tutors and facilitators provided their reflection. Thus the tutors' data set consisted of 11 responses: 4 from MUNI, 2 from SGUL and 5 from UMF Iași. All tutors from MUNI and UMF Iași strongly agreed that, compared to traditional teaching, students were more engaged during the session. At SGUL, one tutor agreed and one neither agreed nor disagreed. Besides, all tutors agreed or strongly agreed that the students actively participated in TBL (all UMF Iași tutors strongly agreed, both SGUL tutors agreed and one half of the MUNI tutors strongly agreed while the other half agreed).

Interestingly, the research question asking whether it was more challenging to facilitate a TBL session brought very diverse responses even within the institutions. At SGUL, one tutor strongly agreed, and the other one agreed. At MUNI, one tutor strongly agreed, two neither agreed nor disagreed, and one disagreed. At UMF Iași, two tutors agreed, one neither agreed nor disagreed, one disagreed and one strongly disagreed.

The tutors' opinions expressed in open-ended answers and the focus group discussion at SGUL revealed that the main challenges encountered in TBL were the room set-up, audio-visual issues, the need to prepare teaching materials beforehand, extra time to be devoted to go through questions with a content expert prior to each session, and finding a suitable tool for tRAT questions. In both TBL and PBL, tutors struggled with time distribution and the necessity to suppress their teaching in favour of facilitating students' discussion. A

TABLE 3 Learners' satisfaction with overall quality of the same PBL activity facilitated by different tutors in the MUNI trial.

	Number of responses	Grade A	Grade B	Grade C	Grade D	Grade E
Tutor A	5	40.0%	40.0%	20.0%		
Tutor B	8	87.5%	12.5%			
Tutor C	6	33.3%	16.7%	33.3%	16.7%	
Tutor D	7		71.4%	28.6%		

The overall quality was evaluated as school grades: A – excellent, B – very good, C – good, D – satisfactory, E – unsatisfactory.

common problem encountered in TBL and PBL was also the presence of shy, introverted students.

Tutors also identified some advantages of TBL over PBL, such as the presence of a content expert; unified teaching materials and collective presence of all students in one session enabling them to get the same information; increased motivation of students to come prepared because of the iRAT and tRAT; good group dynamics due to competitiveness between groups; and a better cooperative atmosphere within teams. On the contrary, TBL was found to be more demanding in terms of greater space requirements, room set-up and equipment needed. Also, it was harder to monitor the groups individually compared to PBL.

When contrasted with traditional teaching methods, tutors agreed that students were more active, concentrated and enthusiastic. Besides, both CL strategies facilitated the interaction between students and their tutors, improved the student's communication skills and also self-directed learning skills.

4 Discussion

The learners' survey responses were analysed, revealing that their level of satisfaction with PBL and TBL sessions differed between the institutions unveiling the importance of specific conditions despite using the same methodology. The UMF Iași students were very satisfied with both PBL and TBL without any preference towards either method while the MUNI students, also highly satisfied with both CL methods, showed a slight preference for TBL. At SGUL, PBL was strongly preferred. This may be explained by the fact that most of the UMF Iași and MUNI students were new to CL methods compared to the SGUL students who had already been used to PBL. Another reason may lie in different motivation for participation in the trials. While the UMF Iași and MUNI trials were organized as extracurricular activities with voluntary participation, they acted in place of standard compulsory lessons at SGUL. It was also found that a tutor strongly impacted the success of a session. Other factors, such as the ratio of extroverted to introverted students in PBL and TBL groups as well as group sizes, classroom equipment and set-up, were also important. Besides, time management issues and assuming specific roles were identified as another challenge by tutors. Apart from the challenges, advantages and disadvantages of the two CL methods were also analysed. The identified advantages of TBL over PBL were the presence of a content expert, the availability of pre-class teaching materials, the collective presence of all students in one room and the motivation of students to come prepared due to the readiness tests and competitiveness between teams.

To elaborate more on these findings, this in-depth study revealed that students and tutors alike considered the room set-up and audio-visual issues to be the main challenges encountered in PBL and especially in TBL. A classroom suitable for TBL sessions needs to be large enough with good acoustics. Alternatively, it can be equipped with microphones and large screens to mitigate audibility and visibility issues. This can be a problem especially for institutions based in older buildings. Although PBL is less technically demanding, it requires a suitable classroom with enough whiteboard space and a screen projector, because a laptop screen is not sufficient for a group of 7–8 students. Also, the laptop should be placed at the same table as the rest of the students are so that the student operating the laptop could also participate in solving the virtual scenario.

Other PBL and TBL related challenges identified by the tutors and learners were time management issues and group sizes. Time distribution improves with more sessions performed, so it is considered a minor issue. Regarding the group sizes in the four trials, TBL groups ranging from 3 to 10 students revealed that the optimal size is between 5–7 students, while PBL groups ranged from 7 to 10 students and a group of 7–8 students has turned out to be optimal. An overall number of students in TBL sessions also posed an issue. Some students were too scared to voice their opinions in such a large group as they were afraid of being judged by other students. Especially introverted and shy students were unlikely to speak up during the sessions. In order to better engage such students in discussion, the use of some online tool displaying questions or thoughts anonymously, such as Slido,[3] might be a good strategy. Compared to TBL, PBL is more intimate, allowing the whole group to contribute without the pressure of having to speak into a microphone or the need to share their thoughts with the whole class. Even so, some shy students may still become disinterested and bored as a result of not being involved in the conversation.

There were also a few other challenges concerning PBL and TBL reported by the tutors. The main one in PBL as well as TBL related to assuming the specific roles. It is required that a facilitator in both CL settings suppresses the urge to express their opinion and offer advice, which may be difficult for a teacher accustomed to traditional teaching methods for years; moreover, a content expert is also required not to interrupt the discussion, even if students offer wrong answers. Instead, they are expected to wait for the facilitator's approval to take the floor. Going through questions with a content expert prior to a session is another TBL challenge; this aspect is vital, yet very time-consuming. Since TBL needs pre-class teaching materials to be prepared, it makes it more demanding compared to PBL where students look for information themselves. Another issue represented the selection of a proper tool for the tRAT questions. At MUNI, teams used hold-up cards with A–E letters corresponding to answers. At UMF Iași, the tRAT answers were collected on-line, through a locally-developed web application, and the results were afterwards displayed on the main screen in the room and discussed. At SGUL, they opted for Mentimeter[4] but struggled with a limited word count available for answers. Also, it was not possible to identify which team answered what. Another platform they considered was Kahoot,[5] which shows team performance, but it has a limited word count as well and displays a correct answer immediately after the last team responses have been submitted, which would adversely affect the discussion. Thus, they combined Mentimeter, providing an overview of what the groups selected, and complemented it with a paper element, so the groups were also asked to hold up A–E cards to allow the facilitator to see what each group had selected and to ask them to elaborate on the reasoning behind their selection.

Identification of challenges in PBL and TBL was followed-up with comparison in order to identify their advantages and disadvantages. Advantages of TBL over PBL mentioned by both students and tutors

3 www.slido.com
4 https://www.mentimeter.com
5 https://kahoot.com

were the presence of a content expert and the availability of pre-class teaching materials. The content experts could share their experience and give practical examples, clarify any uncertainty and respond to student's questions. The collective presence of all students in one room and the unified nature of pre-class teaching materials used in TBL have proved highly valuable because the whole class can benefit from processing the same information and thus acquiring the same knowledge. The information, however, might be limited and might not address all students' questions raised while reading. Nevertheless, students can actively search further for more information on the topic if they want to. On the contrary, PBL is centred around self-directed study, requiring students to find every piece of information through their own research. This could offer a wider perspective and more varied information which adds a nice element to it, but brings along the risk of ending up with students having too many different resources on one topic. Trying to find appropriate information is sometimes challenging and the absence of a content expert on-site, able to provide clarification, could be a downside.

Another advantage of TBL relates to the iRAT and especially tRAT that motivate students to come prepared not to embarrass themselves among their teammates. Competitiveness among teams also adds to group dynamics in the room. However, a few disadvantages of TBL were also identified: more difficult monitoring of individual groups, greater space requirements and the need for an appropriate room set-up as well as equipment.

Despite the above-mentioned challenges and disadvantages of the two methods, the learners' open-ended answers and tutors' reflection collected from the three institutions as well as the learners' additional feedback survey from MUNI clearly demonstrated that, in comparison to traditional teaching environment, students were more active, enthusiastic and concentrated. Students held their attention throughout the class, collaborated with each other, thought actively about the details and asked lots of questions. These activities contributed to improving their communication and self-directed learning skills. The only identified drawback of the two CL strategies compared to traditional teaching methods lies in greater demands on teaching staff as it necessitates the presence of at least one facilitator and one content expert per TBL and one tutor per PBL session when taught simultaneously; when only one tutor is available, they must teach each PBL session as many times in a week as there are groups in the course.

Heterogeneity in trial design, specifically the differences in students' prior experience and motivation, the number of participants per institution, group sizes and the number of facilitators in TBL, might seem to be the major limitation of the study. However, it is important to note that the aim was not to compare the institutions but to compare PBL and TBL strategies used in diverse conditions offered by three universities, each based in a different European country, involving students and teachers from different study fields. Such diversity provided a unique opportunity to investigate advantages and disadvantages of the two CL techniques and enabled us to develop guidelines on the use of various CL methods (Supplement 1).

Apart from the aforementioned differences among trials in different institutions, even the two TBL sessions held at SGUL differed in group sizes and a classroom used; smaller group sizes in a larger classroom led to higher students' satisfaction recognizable from their open-ended answers. Another difference was accidental, caused by the absence of the content expert in the February session as he had to attend to an emergency. Since the facilitators had sufficient case-content knowledge to deal with questions raised by the students, the session was not negatively impacted.

The use of a questionnaire with Likert scale questions turned out to be a true limitation of the study as it proved to be not a very strong instrument able to adequately compare the given learning strategies. Considerably more information was gathered through open-ended questions, and especially from the tutor's focus group discussion held at SGUL which proved beneficial and so we recommend its use also for collecting students' feedback in similar studies. Besides, in-class learner engagement could also be measured by trained observers using the STROBE classroom observation tool (O'Malley et al., 2003; Kelly et al., 2005). Another limitation was anonymity of the response forms which made the use of paired sample tests for statistical evaluation impossible.

5 Conclusion

This extensive study comprising four trials held in three institutions across Europe applying the same methodology on different student cohorts revealed that both PBL and TBL were well-received by students used to traditional teaching methods with no clear preference towards either one. Students accustomed to PBL did not find TBL more engaging or useful which implies that adopting a new teaching method does not necessarily mean success. Despite that, more advantages were identified in relation to TBL than PBL in all the institutions. Specifically, the fact that all students get the same knowledge due to unified pre-class teaching materials and their collective presence in one session, clarification of any uncertainty by a content expert, motivation of students to come prepared due to the iRAT and tRAT and competitiveness between teams. On the contrary, TBL is more demanding on coordination of teaching staff because the simultaneous presence of at least one content expert and one facilitator is crucial, together with the appropriate room set-up and equipment.

Regarding the level of satisfaction with the presented methods of collaborative learning, it is not possible to come to a definite conclusion on which of the two learning strategies is better received by students. The overall experience is influenced not only by the teaching method, but also by a tutor, student's prior knowledge and experience, the ratio of extroverted to introverted students within groups, classroom equipment and other circumstances. The survey findings revealed that an institution newly implementing any of the two CL strategies needs to focus on different aspects than an institution planning to switch from PBL to TBL.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the studies involving humans because our research pertains to a learning motivation

and experience survey. It is important to note that participation in the survey was entirely voluntary. Furthermore, we ensured complete anonymity of the survey respondents. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

EK: Data curation, Formal analysis, Resources, Visualization, Writing – original draft. TJ: Data curation, Investigation, Resources, Writing – review & editing. G-EG-B: Resources, Writing – review & editing. VC: Data curation, Resources, Visualization, Writing – review & editing. EP: Conceptualization, Investigation, Methodology, Supervision, Writing – review & editing. AC: Data curation, Resources, Supervision, Writing – review & editing. CL: Data curation, Resources, Writing – review & editing. GŞ: Resources, Writing – review & editing. DS: Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – original draft.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This work was supported by the TELSON project (Problem-based and team-based learning strategies in the education of biomedical and life sciences) funded by the Erasmus+ programme of the European Union (No. 2018-1-CZ01-KA203-048197).

Acknowledgments

We would like to thank all of the TELSON partners who did not co-author this paper but actively participated in the study, namely, Terry Poulton, Luke Woodham and Alexandra Gillingham from St George's, Ionut Nistor, Bogdan Stoica, Bogdan Iliescu and Dana Mihaela Turliuc from UMF Iași, and Roman Vyškovský from MUNI. We would also like to thank Kateřina Žvaková for English language editing. Furthermore, we want to express our gratitude to all the students who filled in the questionnaires.

Conflict of interest

VC and DS were employed by company Institute of Biostatistics and Analysis Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1301269/full#supplementary-material

SUPPLEMENTARY DATA SHEET 1
Guidelines on the use of various types of scenario-based learning.

SUPPLEMENTARY DATA SHEET 2
Learner's questionnaire.

SUPPLEMENTARY DATA SHEET 3
Tutor's questionnaire.

SUPPLEMENTARY DATA SHEET 4
Data gathered from learners' survey, tutors' survey and MUNI additional feedback questionnaire.

SUPPLEMENTARY DATA SHEET 5
Additional results from learners' survey.

SUPPLEMENTARY DATA SHEET 6
Challenges identified in PBL and TBL.

References

Azer, S. A. (2005). Challenges facing PBL tutors: 12 tips for successful group facilitation. *Med. Teach.* 27, 676–681. doi: 10.1080/01421590500313001

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: a brief overview. *New Dir. Teach. Learn.* 1996, 3–12. doi: 10.1002/tl.37219966804

Barrows, H. S., and Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education*. New York: Springer.

Burgess, A., Bleasel, J., Haq, I., Roberts, C., Garsia, R., Robertson, T., et al. (2017). Team-based learning (TBL) in the medical curriculum: better than PBL? *BMC Med. Educ.* 17:243. doi: 10.1186/s12909-017-1068-z

Burgess, A., Bleasel, J., Hickson, J., Guler, C., Kalman, E., and Haq, I. (2020). Team-based learning replaces problem-based learning at a large medical school. *BMC Med. Educ.* 20:492. doi: 10.1186/s12909-020-02362-4

Diaz, D. P., and Bontenbal, K. F. (2000). Pedagogy-based technology training. *Teach Learn Netw World* 105, 50–54.

Dolmans, D., Michaelsen, L., van Merriënboer, J., and van der Vleuten, C. (2015). Should we choose between problem-based learning and team-based learning? No, combine the best of both worlds! *Med. Teach.* 37, 354–359. doi: 10.3109/0142159X.2014.948828

Gullo, C., Ha, T. C., and Cook, S. (2015). Twelve tips for facilitating team-based learning. *Med. Teach.* 37, 819–824. doi: 10.3109/0142159X.2014.1001729

Guttman, C. (2003). *Education in and for the information society*. Paris: UNESCO.

Hew, K. F., and Lo, C. K. (2018). Flipped classroom improves student learning in health professions education: a meta-analysis. *BMC Med. Educ.* 18:38. doi: 10.1186/s12909-018-1144-z

Hu, X., Zhang, H., Song, Y., Wu, C., Yang, Q., Shi, Z., et al. (2019). Implementation of flipped classroom combined with problem-based learning: an approach to promote learning about hyperthyroidism in the endocrinology internship. *BMC Med. Educ.* 19:290. doi: 10.1186/s12909-019-1714-8

Huwendiek, S., De Leng, B. A., Kononowicz, A. A., Kunzmann, R., Muijtjens, A. M. M., Van Der Vleuten, C. P. M., et al. (2015). Exploring the validity and reliability of a questionnaire for evaluating virtual patient design with a special emphasis on fostering clinical reasoning. *Med. Teach.* 37, 775–782. doi: 10.3109/0142159X.2014.970622

Jakobsen, K. V., and Knetemann, M. (2017). Putting structure to flipped classrooms using team-based learning. *Int. J. Teach. Learn. High. Educ.* 29, 177–185.

Kelly, P. A., Haidet, P., Schneider, V., Searle, N., Seidel, C. L., and Richards, B. F. (2005). A comparison of in-class learner engagement across lecture, problem-based learning, and team learning using the STROBE classroom observation tool. *Teach. Learn. Med.* 17, 112–118. doi: 10.1207/s15328015tlm1702_4

Klincova, M., Harazim, H., Schwarz, D., Kosinova, M., Smekalova, O., and Stourac, P. (2019). What can be achieved with motivation-based teaching of medical students? A monocentric retrospective audit of retention among highly motivated graduates who underwent the learning-by-doing concept in anesthesiology and intensive care medicine. *JMIR Serious Games* 7:e10155. doi: 10.2196/10155

Kononowicz, A. A., Woodham, L. A., Edelbring, S., Stathakarou, N., Davies, D., Saxena, N., et al. (2019). Virtual patient simulations in health professions education: systematic review and Meta-analysis by the digital health education collaboration. *J. Med. Internet Res.* 21:e14676. doi: 10.2196/14676

Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Adv. Health Sci. Educ.* 15, 625–632. doi: 10.1007/s10459-010-9222-y

O'Malley, K. J., Moran, B. J., Haidet, P., Seidel, C. L., Schneider, V., Morgan, R. O., et al. (2003). Validation of an observation instrument for measuring student engagement in health professions settings. *Eval. Health Prof.* 26, 86–103. doi: 10.1177/0163278702250093

Pluta, W. J., Richards, B. F., and Mutnick, A. (2013). PBL and beyond: trends in collaborative learning. *Teach. Learn. Med.* 25, S9–S16. doi: 10.1080/10401334.2013.842917

Poulton, T., Ellaway, R. H., Round, J., Jivram, T., Kavia, S., and Hilton, S. (2014). Exploring the efficacy of replacing linear paper-based patient cases in problem-based learning with dynamic web-based virtual patients: randomized controlled trial. *J. Med. Internet Res.* 16:e240. doi: 10.2196/jmir.3748

Rotgans, J. I., Rajalingam, P., Ferenczi, M. A., and Low-Beer, N. (2019). A students' model of team-based learning. *Health Prof. Educ.* 5, 294–302. doi: 10.1016/j.hpe.2018.10.003

Smith, B. L., and MacGregor, J. T. (1992). "What is collaborative learning?", in Collaborative Learning: A Sourcebook for Higher Education, in Eds. A. Goodsell, M. Maher, V. Tinto, B.L. Smith and J. T. MacGregor (Pennsylvania State University: National center on postsecondary teaching, learning, and assessment publishing).

Woodham, L., Polton, E., Jivram, T., Kavia, S., Hernandez, A., Sahakian, C., et al. (2017). Evaluation of student and tutor response to the simultaneous implementation of a new PBL curriculum. *MEFANET J.* 5, 19–27.