Integrated and Contextual Basic Science Instruction in Preclinical Education: Problem–Based Learning Experience Enriched With Brain/Mind Learning Principles[*]

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Abstract

Recently, integrated and contextual learning models such as problem-based learning (PBL) and brain/mind learning (BML) have become prominent. The present study aimed to develop and evaluate a PBL program enriched with BML principles. In this study, participants were 295 first-year medical students. The study used both quantitative and qualitative methods (mixed design). First, the students' hemispheric preferences were defined using the Human Information Processing Survey and reassessed using event-related potentials (ERPs). Then, by considering BML principles, a six-week PBL program was revised and evaluated using both quantitative and qualitative tools, including evaluation forms, exam scores, expert observations, document reviews, and interviews. With regard to hemispheric preferences, 59.9% of the students preferred both hemispheres, 28.9% preferred the right, and 11.2% preferred the left, and these partially correlated with ERP P300 recordings. The evaluation study showed that compared with the standard PBL program, the students and tutors were more satisfied with the BML-enriched PBL program, and the students' average exam scores were higher and the differences were statistically significant ($p < .001$). These results demonstrate that various learning models can be improved using BML principles, resulting in increased satisfaction and academic success.

Keywords: Learning environment/climate • Learning process • Hemispheric preference • Program evaluation • Small-group learning

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The revisiting of learning approaches and models developed on the basis of constructivist theories and the integration of these with the new evidence obtained from neuroscience studies provide a new interdisciplinary perspective and create an infrastructure for education. With the impact of the constructivist approach, learning characteristics and individual differences, real-life coherence, complexity, and contextuality/situativity with contextualized/situated cognition and learning have become more important. Consequently, the focus of learning activities has shifted to integrating related basic, clinical, and sociobehavioral knowledge and cognitive and metacognitive strategies with process-oriented learning and teaching; decision making/problem solving; reflective practice and thinking; and positive motivational, emotional, and sociocultural climate. All these support deeper knowledge and enrich learning experiences (Caine & Caine, 2010, p. 11–32; Caine, Caine, McClintic, & Klimek, 2005, p. 1-14; Durning & Artino, 2011; Fischer, 2009; Mennin, 2007, 2010; Wilkerson, Stevens, & Krasne, 2009; Vermunt & Verloop, 1999).

During the last three decades, the major viewpoint in medical education was to bring clinical context to earlier years and increase the integration among the basic, clinical, and social sciences (Norman, 2009; Wilkerson et al., 2009). Accordingly, during the preclinical period, problem-based learning (PBL) and scenario-based learning are widely used, whereas during the clinical training period, task-based learning and work-based learning are preferred. Evaluations of PBL, in general, have provided evidence that this model is effective, but some common problems have also emerged during its application. For example, a meta-analysis conducted with 43 selected articles indicated that students in PBL conditions are better at both remembering the acquired knowledge and applying it (Dochy, Segers, Van den Bossche, & Gijbels, 2003). Nevertheless, research focusing on PBL-related learning processes such as deep and meaningful learning, student motivation and participation, and group dynamics has revealed some problems. The major problems experienced are as follows: converting the method into routine and mechanical steps, inadequate integration or deep processing of knowledge, insufficient individual preparation, and poor group dynamics with unsatisfactory student participation (Antepohl, Domeij, Forsberg, & Ludvigsson, 2003; de Grave, Dolmans, & van der Vleuten, 2001, 2002; Khoo, 2003; Moust, Roebertsen, Savelberg, & de Rijk, 2002). Regarding the PBL tutorial group learning process, one of

these studies conducted with 200 first- to third-year medical students investigated students' perceptions of the occurrence of critical incidents and their inhibitory effects on group functioning (de Grave et al., 2002). Among six critical incidents (i.e., lack of elaboration, lack of interaction, unequal participation, lack of cohesion, difficult personalities, and lack of motivation), unequal participation, lack of interaction, and lack of elaboration were the most frequent success inhibitors. According to students' perception, lack of motivation and lack of elaboration were the two prominent inhibitors of learning in the tutorial groups, highlighting the strong impact of motivational influences on tutorial group functioning.

The abovementioned problems that emerged during the PBL tutorial group emphasize that studies focusing more on learning process as a whole along with its different components should be conducted. According to complex theory and contextualized cognition and learning theory, a holistic approach is needed for small-group interactive learning processes such as PBL. Therefore, in such studies, not only cognitive and metacognitive but also motivational and sociocultural components should be considered. In this context, the evaluation of PBL learning should include both decision making/problem solving with cognitive and metacognitive components and the learning experience as a socialization process with affective, motivational, and sociocultural components (Ntyonga-Pono, 2006; Vermunt & Vermetten, 2004). However, the number of studies focusing on PBL tutorial process is few.

Recently, there have been attempts to support the abovementioned learning-process-oriented holistic perspective using evidence obtained from neuroscientific studies. From an interdisciplinary perspective, there is a growing worldwide movement that aims to provide a neuroscientific ground to education by thinking together and integrating data from different fields such as physiology, cognitive science, social cognitive sciences, development, and education (Fischer, 2009). Similarly, problems experienced during PBL learning sessions can be evaluated from a neuroscientific perspective, particularly using the basic principles of brain/mind learning (BML). Based on these principles, Caine and Caine (2010), and Caine et al. (2005) stated that the major components of BML experiences and environment are "relaxed alertness" (safe and challenging learning environment), "orchestrated immersion in complex experiences," and "active processing." (2010, p. 14-20; 2005, p. 3-6). In the

BML model to promote rather than inhibit students' mental performance, physically and emotionally safe, supportive, and motivating learning environments should be created that help learners feel safe and sufficient to achieve meaningful and valuable learning. This model is expected to create a complex and contextual learning environment with graded guidance and support given based on learners' demands. Moreover, this learning environment should give learners the opportunity for deep learning enriched with social and interpersonal interactions. Thus, safe (but challenging), interactive, and socially enriched learning environments with low levels of cognitive, metacognitive, and emotional strain should be designed and studied (Arndt, 2012; Watanabe, 2013).

Considering contextualized learning theory and BML principles, the main features of small-group interactive-process-oriented learning are summarized and displayed in Figure 1. Based on the figure, it is assumed that reviewing and revising small-group interactive learning processes, including PBL, may be meaningful and challenging. Thus, the present study, designed within this framework, is the first to evaluate and enrich the PBL tutorial process from a different perspective.

While enriching the PBL learning process, the main effort has to be maintaining PBL learning groups in "learning and development zone" by providing the learning process and environmental features that are listed in the middle zone of Figure 1.

Purpose

Based on the aforementioned learning theories and newly constructed framework, it is advisable to create process-oriented and brain\mind-compatible PBL learning processes by embedding basic, clinical, and sociobehavioral knowledge into clinical situations and constructing safe but challenging learning environments (Caine et al., 2005, p. 3–6; Caine & Caine, 2010, p. 14–19; Durning & Artino, 2011; Wilkerson et al., 2009; Vermunt & Verloop, 1999; Vermunt & Vermetten, 2004). Some problems experienced in standard PBL learning may be reduced, and accordingly, two specific aims of the current study are as follows.

1. To revise a standard PBL program for enriching tutorial learning sessions with the principles of BML and students' learner styles (i.e., hemispheric preferences).
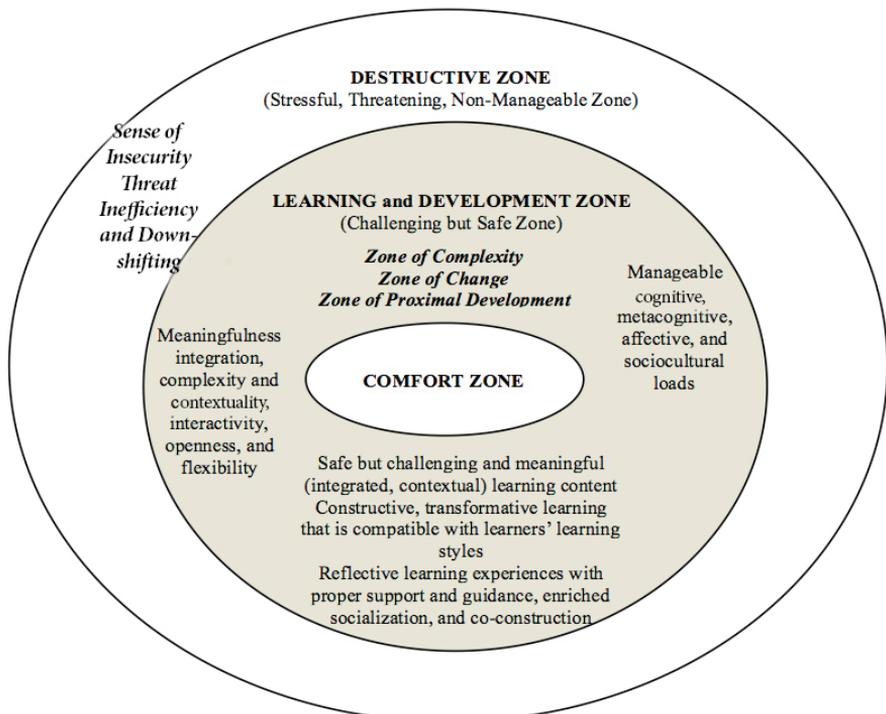

Figure 1: Learning process in a challenging environment with learning and development zones.

2. To compare the impact of the revision on students' and tutors' perceptions of PBL tutorial processes and environment and on the academic success of first-year medical students.

To achieve these aims *(i.e., to reduce some problems experienced in PBL learning sessions and strengthen the process based on students' learning styles)*, the study also sought to answer two specific questions as follows:

3. Determine the students' hemispheric preferences (learning styles) and confirm the results biophysically.

4. Evaluate the standard PBL learning process to reveal the types of problems experienced during learning sessions.

Method

Study Group

The participants in this study were 295 (77.8% of the total number of students) preclinical first-year medical students (41.0% female and 59.0% male) during two successive academic years. To control sociocultural variables, including language, foreign students were not included in the study. Of the 295 participants, 53.1% graduated from Anatolian state high schools, 23.3% from science state high schools, and 23.6% from other categories such as private, general, or vocational/technical high schools.

Research Design

The present study was designed using both quantitative and qualitative methods (mixed study) to evaluate and revise (enrich) a six-week PBL program. Because this study was designed to assess the revised (enriched) PBL program and compare it with a previously implemented one, process evaluation was the main activity (Frye & Hemmer, 2012; Goldie 2006). The study particularly focused on a small-group PBL learning process and environment and thus used preferred evaluation methods such as expert observation (of the PBL learning process using three observation forms), document content analysis (program materials such as flipchart (FC) materials and student study guides, used during group learning sessions), and participant views (a learning process evaluation form was completed by students at the end of each two- to three-hour session). Moreover, a product evaluation study was conducted by assessing student achievement (exam scores)

and participants' opinions about the program's processes and outcomes (using the PBL program evaluation form and tutor interviews).

Research Process and Evaluation Tools

Determining Students' Hemispheric Preferences: To determine the students' hemispheric preferences and thus their learning styles and to accordingly strengthen the PBL learning sessions, the Human Information Processing Survey (HIPS) was used (Taggart & Torrance, 1984). The content, construct, concurrence, and predictive validities of the HIPS, including the Turkish version, have been separately evaluated in numerous studies (Taggart & Torrance, 1984; Sürekli, 2003). During the research progress, initially, a 40-item Turkish version of the HIPS was used. The language equivalence, validity, and reliability studies of this survey were undertaken, and it was found that the values obtained were enough to be used in the study (Sürekli, 2003). With regard to the Turkish survey, the principal component analysis showed that the questions on the left, right, and integrated preferences can be assembled under three factors, and the reliability was calculated as .55. Similarly, in the present study, which was performed on preclinical medical students, the Cronbach's alpha was .48. Although a value equal to or above .70 is sought for reliability, lower values are decided on considering the differences related to test structure, such as the number of items in the inventory and the range of the scale that is used to evaluate each item (Field, 2005, p. 666-676). Because of a narrow (three-point) range of the scale, although the Cronbach's alpha was not high, the survey was considered reliable. However, the concept of hemispheric preferences and the use of related surveys were not sufficiently supported by evidence and needed further research. In this context, to evaluate the data obtained by this survey from a biophysiological aspect, event-related potentials (ERPs) were recorded from 33 volunteer students who were selected from each hemispheric preference group. Students were informed about the experimental procedures with informed consent forms.

During the ERP recording, the participants rested comfortably in a sound-proof, dimly illuminated investigation chamber with a moderate climate. Brain electrical activity (electroencephalography; EEG) was recorded from 30 electrode sites of the 10–20 system using an electro-cap system, referenced to the earlobes, with a forehead ground and electrode impedance of 5 kΩ or less. Bipolar

electrooculography was used to monitor blinking and eye movements. EEG signals were amplified with frequency limits of 0.1–70 Hz via a Neuroscan 4.1 EEG machine and filtered using a 50-Hz notch filter. EEG epochs (100 ms pre-stimulus and 900 ms post-stimulus) were digitized with a sampling rate of 1000 Hz.

Combined Auditory Oddball Paradigm and Visual Evoked Potentials (AERP + VEP): *Auditory Oddball Stimulation*: A total of 300 auditory stimuli (tones with an intensity of 80 dB sound pressure and a rise/ fall of 10 ms) were presented in a random series every 2 s (tone duration of 1 s and inter-stimulus interval of 1 s). The stimuli consisted of target (2 kHz) and standard (1500 Hz) stimuli presented with probabilities of 0.20 and 0.80, respectively. The participants were instructed to discriminate the rare (target) from the frequent (standard) stimuli and to mentally count the rare stimuli without using fingers.

Visual stimulation: Black-and-white checkerboard pattern stimuli were presented binocularly on a computer screen located 1.5 m away from the participants' eyes. The check size of the stimulus was 60 min of arc. The stimuli were presented for 1 s with a stimulus-averaged intensity of 35 cd/ m^2. While participants listened to the auditory oddball stimuli, they passively watched the visual stimulation while focusing on a small marker placed in the middle of the computer screen. There was also an instructed auditory component, discriminating the target from the standard stimuli and mentally counting the target stimuli without using fingers.

Analysis of ERP Responses: EEG epochs were collected 100 ms before and 900 ms after the stimulus presentation. Automatic online and manual offline artifacts were rejected to eliminate any artifact-based EEG epochs for amplitudes that exceeded 50 µV at any electrode. In AERP + VEP of the experiments, 40 artifact-free sweeps of data were selected for responses to target stimuli. These were averaged time-locked to the onset of the stimulus presentation, and the amplitudes and latencies of the P300 component were measured for each participant separately. The averaged P300 values were used to compare and evaluate the groups.

The P300 in response to the oddball paradigm is a well-known and extensively studied ERP related to cognitive processing. Because this study focuses on the cognitive processing of spatial visual stimuli, P300 was the major interest, and only P300 data obtained for the target stimuli are reported. It was shown that AERP + VEP as compared with the classical oddball paradigm (visual or auditory) produced P300 values with larger amplitudes and longer latencies, especially at the anterior locations (İşoğlu-Alkaç, Kedzior, Karamürsel, & Ermutlu, 2007). P300 is used as a measure of neural activity based on attentive processes, and its anterior distribution is associated with task difficulty. Although the knowledge about the foci of P300 generation is not certain yet, studies have implied that major bioelectric events that are responsible for P300 generation are the result of cross-talk between the parietal and frontal lobes (Comerchero & Polich, 1998). The new modification of the oddball paradigm, particularly the frontocentral recordings of P300, can be used to explore frontal lobe function in terms of integrative sensory and cognitive processing in healthy and clinical people (İşoğlu-Alkaç et al., 2007).

Evaluating and Enhancing PBL Experience: Based on the seven-step approach of Maastricht University, a six-week standard PBL (sPBL) program that addressed the physiological and sociobehavioral aspects of stress was implemented and evaluated in 2005–2006 academic year. The results from existing evaluation studies have revealed that problems in implementing sPBL were the high load of the learning content, difficulty managing the learning sessions (by either tutors or participants), weakness in the application of the first 5-steps, insufficient individual preparation, and unsatisfactory student participation that resulted in poor group dynamics (de Grave et al., 2001, 2002; Khoo, 2003; Moust et al., 2002).

Based on problems that have arisen in sPBL sessions, the program was reconstructed according to BML principles and was named bPBL (PBL enriched by BML principles). Although the present study specifically aimed to revise the program based on the students' hemispheric preferences, because the reliability of the Turkish version of the survey was insufficiently high and the results were partially confirmed by biophysical testing (ERP), the results related to the preferences were not used for enriching the PBL program.

The main objectives of the revised bPBL program are as follows.

- To improve learning contents and materials of each tutorial session to achieve a more integrated, contextual, meaningful, and challenging program.

- To improve the group learning environment to be safer, more supportive, and more motivating.

- To reduce the students' cognitive and metacognitive loads to more manageable levels.
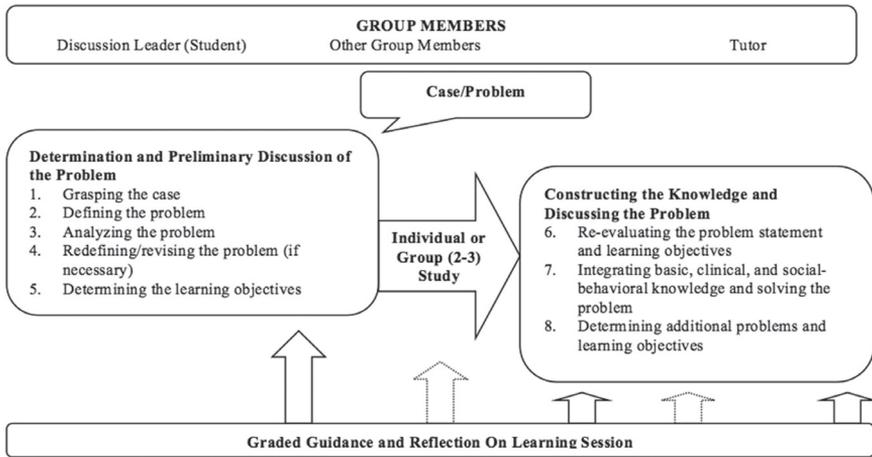
Figure 2: Eight-step approach used in the bPBL tutorial sessions.

These objectives were achieved by revising the program content, tutorial structures, small-group tutorial processes, and learning materials. In this respect, student and tutor program guides (which contained constructive questions, schemas, figures, tables, reading materials, notes for tutors, and so on) were developed to be more structured. Accordingly, the content of the PBL program was also reduced, and the seven-step approach was modified to be a newly proposed eight-step one (Figure 2).

With all these efforts, listed in Table 1, it was assumed that this newly designed bPBL program was enriched with BML principles resulting in safe but challenging content, graded guidance, and a challenging and supportive learning environment.

Evaluating PBL Programs: The sPBL and bPBL programs were evaluated during two successive academic years. For the PBL tutorial process (process evaluation), first, three observation and evaluation forms were used to assess group dynamics and tutors' performance and to analyze the efficiency of the seven- or eight-step approach. Following the review of related articles, these three forms were prepared by researchers. The group tutorial process was observed and evaluated by two instructors who had at least 8–10 years of PBL tutorial experience, and all group sessions were observed and evaluated. Second, FC pages in the sPBL groups and the student study guides in the bPBL groups were collected for content analysis, which was conducted by two researchers. Based on the quality of determined problem sentences and learning objectives, the quality of group discussion, and the number and quality of the concept maps and schemas used during discussions, all FC pages written by the groups and three randomly selected student study guides from each group were independently analyzed by two researchers and then co-evaluated. Third, at the end of each small-group tutorial session, feedback was obtained from group members on how interesting, instructive, and

Table 1

Changes Made to Enrich the sPBL Program and Achieve the bPBL Program

Main Objectives	List of Changes
To reach a more integrated, contextual, meaningful, and challenging PBL program.	• Improve learning content and delivery: reduce the learning content; strengthen the integration of related basic, clinical, and sociobehavioral knowledge; increase the relatedness of the cases used during each tutorial session and learning content with students' daily and professional lives. • Improve the learning materials: rewrite the cases; develop the students' study guide and the tutors' bPBL program guide, both of which contain constructive questions, schemas, figures, tables, reading materials and references, notes, and so on.
To improve the tutorial group learning environment to be safer, more supportive and motivating to increase group interaction and productivity	• Rewrite the cases to increase their relatedness to the learning content. • Reduce the learning content to more manageable levels. • Develop student and tutor program guides that provide more-structured tutorial sessions. • Develop an eight-step approach that improves on the seven-step approach.
To reduce the students' cognitive and metacognitive loads to more manageable levels	• Support the tutors and group members in managing the learning sessions, thereby reducing the students' metacognitive loads to more manageable levels using the eight-step approach and the revised tutor and student program guides. • Reduce the learning content to more manageable levels. • Give students graded guidance and support using structured feedback and reflection.

stressful the learning environment was. The students' opinions about stress, interest, instructiveness, and encouragement levels that had emerged throughout each tutorial session were collected using a scale prepared by the researchers.

At the end of the programs, three evaluation tools (program evaluation forms, interviews with the tutors, and the students' exam scores) were used to assess and compare the organization, tutorial processes, and outputs of the sPBL and bPBL programs. First, at the end of the last tutorial session, the students completed the standard official PBL program evaluation forms. Second, to evaluate and compare the small-group learning process and learning outputs of sPBL and bBPL, the researchers held two group interviews with all tutors, and the interview reports were evaluated by the same researchers. Finally, in both sPBL and bPBL, 10-question exams were given at the end of the programs. Of these, six case questions were designed to assess problem-solving skills, and four were structured to assess the lower levels of the cognitive domain. Academic performance was evaluated on a 10-point scale, where <5 was unsuccessful, 5–6 was moderately successful, and >7 was successful.

Data Analysis

The quantitative data related to the students' and tutors' opinions of the two programs are presented in number and percentage distributions, and the qualitative data were evaluated by content analysis. To analyze the students' academic achievements and compare the two programs, exam grades were calculated as means and standard deviations. The unpaired t-test was used to compare the student exam scores between the two PBL programs (bPBL and sPBL). After the students' hemispheric preferences were determined, group differences (left hemisphere, right hemisphere, and mixed) in the amplitude and latency of P300 responses were assessed with the multivariate analysis of variance and a post hoc Bonferroni test. The first factor included three groups (bilateral or left or right hemisphere preference), and the second factor was the location of electrodes (30 channels). Statistical analyses were performed using Statistical Package for the Social Sciences 20.0, and values of $p < .05$ were regarded as significant.

Results

Results of Hemispheric Preferences

Regarding their hemispheric preferences, 59.9% of the first-year medical students preferred both hemispheres, 28.9% preferred their right hemisphere, and 11.2% preferred their left hemisphere. To further evaluate hemispheric preferences, P300 responses obtained from 33 volunteers with different preferences were compared.

Comparison of Groups' P300 Responses: Although recordings acquired from 30 points showed that the greatest amplitude of brain electrical activity was at the midline, the left and right hemispheric responses were analyzed to assess the students' hemispheric dominances in relation to the scope of the study. Because an auditory oddball and visual stimulatory apparatus was used to evaluate cognitive function, the P300 amplitudes obtained from the left-anterior and right-anterior hemisphere electrodes were used.

The P300 amplitudes were statistically significant between the groups ($F(2,900) = 19.626$; $p < .01$) and for all 30 channels ($F(29,900) = 7.926$; $p < .01$; Table 2). In the post hoc Bonferroni tests, the P300 amplitudes for the group that preferred both hemispheres were significantly higher than those for the group that preferred the left hemisphere ($p < .01$). Moreover, the amplitudes for the group that preferred the right hemisphere were also significantly higher than those for the group that preferred the left hemisphere ($p < .01$). The P300 latency was statistically significant for the groups ($F(2,900) = 10.721$; $p < .01$) and channels ($F(29,900) = 2.407$; $p < .01$). In the post hoc tests, P300 latency for the group that preferred the right hemisphere was significantly shorter than those for the groups that preferred either the mixed hemisphere ($p < .01$) or left hemisphere ($p < .01$). Among the 30 channels,

Table 2

Analysis of P300 Responses Recorded from the Three (Left, Right, Both) Hemispheric Preference Groups Assessed by Multivariate Analysis of Variance

Source (df) (30 Channel)	Amplitude of P300		Latency of P300	
	F	*p*	*F*	*p*
Group (G) (2, 900)	19.626	**0.0001**	10.721	**.0001**
Channel (C) (29, 900)	7.926	**0.0001**	2.407	**.0001**
G x C (58, 900)	2.944	1	0.844	.791

Post hoc Analysis by Bonferroni Test.

	Amplitude	Latency
	P3	P3
30-channel		
Both vs. Right	.09	**.0001**
Both vs. Left	**.0001**	.957
Right vs. Left	**.0001**	**.002**

a comparison of the anterior locations (frontal, frontocentral) revealed that the P300 amplitudes of the bilateral and left hemispheres were significantly different ($p < .01$), and a significant difference was observed between the latencies for the groups that preferred the right and left hemispheres ($p = .01$).

Of the 11 students who preferred the right hemispheric categorized by HIPS results, six demonstrated high P300 amplitudes at the right–anterior electrodes (frontal and frontocentral locations), although only two students had significantly high amplitudes ($p < .05$). Seven students demonstrated high P300 amplitudes at the right central and centroparietal locations, but differences were significant in only four students ($p < .05$). Six students demonstrated high P300 amplitudes at the right–posterior electrodes (parietal and occipital locations) but with no statistically significant differences.

Similarly, of the 11 students who preferred the left hemisphere categorized by HIPS results, seven had high amplitudes in their left–anterior (frontal and frontocentral) P300 responses, and the differences between the two hemispheric responses were significant only in two students who preferred the left hemisphere ($p < .05$). Six students demonstrated high P300 amplitudes at the left central and centroparietal locations, but only one student had a significant difference ($p < .05$). Five students demonstrated high P300 amplitudes at the left–posterior electrodes (parietal and occipital locations) but with no significant differences.

Among the 11 students who indicated a preference for both hemispheres on the HIPS, only two had significantly higher ($p < .05$) P300 amplitudes at the left–anterior electrodes (frontal, frontocentral). None of the 11 students had significant differences in P300 amplitudes at the central or centroparietal electrodes, but one student had significantly higher ($p < .05$) amplitudes at the posterior locations (parietal and occipital).

Results of Evaluating PBL Programs

Opinions of Students and Tutors: In terms of learning environments created during the sPBL sessions, 25.0% of the students reported that the sessions were non-stressful, boring, and moderately instructive; 44.2% of the students found the sessions to be stressful but instructive; and 28.3% found them to be non-stressful and instructive (data not shown). However, the learning environments during the bPBL sessions were found to be less stressful (89.8%), moderately to highly interesting (85.1%), and moderately to highly instructive (94.5%) by most students, as presented in Table 3.

The data obtained from the program evaluation forms for assessing the organization and planning, tutorial process, and program output revealed that in the sPBL sessions, nearly 30%–40% of the students felt positively about them, with 20%–35% reporting negative opinions. Regarding the sPBL program output (assessment and gain), 20%–30% of the student opinions were positive, and 35%–45% were negative. For the bPBL sessions, program evaluation data

Table 3
Students' Opinions about the Learning Environments in the bPBL Sessions

Learning Environment	Tutorial Sessions									
	1st Session		2nd Session		3rd Session		4th Session		Overall	
	n	%	n	%	n	%	n	%	n	%
Level of Stress										
None or low stress	48	36.9	31	24.0	25	20.2	39	30.0	33	26.0
Challenging	62	47.7	82	63.6	73	58.9	70	53.8	81	63.8
Stressful	20	15.4	16	12.4	26	21.0	21	16.2	13	10.2
Total	130	100.0	129	100.0	124	100.0	130	100.0	127	100.0
Level of Interest										
Low interest, boring	35	27.1	27	21.4	28	22.4	28	22.0	19	15.0
Medium	52	40.3	56	44.4	51	40.8	43	33.9	59	46.5
Interesting	42	32.6	43	34.1	46	36.8	56	44.1	49	38.6
Total	129	100.0	126	100.0	125	100.0	127	100.0	127	100.0
Level of Instructiveness, Level of Encouragement to Learn and Inquire										
Low	30	23.4	14	11.0	12	9.8	14	10.9	7	5.5
Medium	52	40.6	56	44.1	50	40.7	51	39.8	57	44.9
Instructive, encouraging	46	35.9	57	44.9	61	49.6	63	49.2	63	49.6
Total	128	100.0	127	100.0	123	100.0	128	100.0	127	100.0

on the organization and planning, tutorial process, and program output revealed that 40%–50% of the students felt positively about the sessions, whereas the negative opinions ranged between 15% and 20% of the students. On the bPBL program output, nearly 30%–57% of the students indicated positive opinions, with 15%–25% expressing negative opinions. Overall, the students' evaluations of the two PBL programs were more often "very good/perfect" for the students in the bPBL (40.4%) program than in the sPBL (28.9%) program, and the ratings were "moderate-poor" in a smaller proportion in the bPBL (26.3%) group compared with sPBL (38.3%).

The frequent problems encountered by the tutors during sPBL were summarized by analyzing the tutor interviews. Major problems were carrying the discussions with the active participation of only 4-5 students out of groups of 13-14, insufficient individual preparation before the discussion sessions, and lack of integration and use of knowledge. In the bPBL sessions, except for the students' insufficient preparation before the sessions, the other major problems were somewhat improved.

Results of Group Observations and Flipchart/ Student Guide Content Analysis: All sessions of the two volunteer groups were observed and evaluated by two experts. The tutorial sessions were evaluated based on whether they used the seven- or eight-step process, the group dynamics, and the tutors' performance using three evaluation forms. The notes on the FC pages that were used during all of the group sessions were also analyzed. The major findings reached by observation and content analysis of the sPBL sessions are summarized in Table 4.

Similarly, expert observations were also made in two bPBL groups. For content analysis, three student guides were randomly selected in each group to study the notes taken during the sessions. On the evaluation of the expert observation of the bPBL sessions and the use of the student guides, the following results were obtained.

i. With its more structured program with better guidance for both students and tutors, bPBL facilitated the tutorial process, enhanced active discussions, and provided better interactions.

ii. Student and tutor guides facilitated the tutorial process, and the structured questions were life-saving when the discussions were blocked. However, having a more structured program somehow reduced the level of curiosity.

iii. Supportive, challenging, and instructive learning environments were created during

Table 4
Observation Results for the Major Problems Faced during the sPBL Tutorial Sessions

Components of the Tutorial Sessions	Major Problems
Scenarios	• Some of the clues given in the scenarios did not receive sufficient attention. • Scenarios that were read at the beginning of the sessions were not sufficiently referred to later in the session.
Discussion leader and reporting	• Problems arise with the discussion leader's session management, which was highly dependent on the variations among the students. • Notes taken on the FC pages were not reviewed, evaluated, or revised when needed during the following steps of the sessions.
The seven-step approach	• In defining the problem statements, there were some general difficulties. Comprehensive sentences were not clearly defined in most of the groups. • Although the learning objectives were not detailed or specific, the groups did determine most of the learning objectives for each tutorial session. • Discussions during the analysis and reporting steps were superficial and fragmented, which caused problems in applying the knowledge to solving cases with any sense of integration or deep learning. • Analysis (the 3rd and 4th steps) was quick; the students did not have sufficient time to recall and relate their previous knowledge. • The first five steps were not clearly defined and could be skipped as 2-3 steps.
Individual study and group dynamics	• Individual studies of the students before the reporting steps were not sufficient. • Students did not actively participate in the sessions; generally, only 4–6 students out of 12–13 participated. • The required group dynamics could not be established most of the time.
Tutors	• Although the tutors generally guided tutorials using the seven-step approach successfully, they could sometimes be weak in clarifying the steps, deepening the discussions, and creating interactive and supportive group dynamics.

the sessions. The cases were solved, and the sessions were more productive.

iv. Deeper discussions were held during the sessions, which suggested that the bPBL program was well constructed, enabling the students to recall their previous knowledge.

v. Individual studies and active participation of the students, who played the primary role in the group dynamics, were still not at the desired levels.

vi. Problem statements were more clearly and comprehensively defined using the eight-step approach and the constructive questions in both the student and tutor guides.

vii. Learning objectives were generally derived and were more specific and detailed.

viii. In the sPBL program, the major problems faced in integrating and applying knowledge and deepening learning were considerably improved in the bPBL program.

Students' Exam Scores

To evaluate the PBL programs, the exam scores in the sPBL and bPBL groups were compared. The proportion of successful students in the sPBL program was 41.1% but increased to 73.9% in the bPBL program (Table 5). Student's t-test showed a statistically significant difference in the average exam scores between the two PBL programs ($t_{(293)} = 8.16$, $p < .01$; Table 5).

Discussion

Although PBL is a widely used and effective instructional model, there are some common problems faced during group learning processes, such as poor group dynamics with superficial interaction and unsatisfactory student participation, inefficient group productivity, lack of integration, and lack of deep knowledge processing. In this context, the present study aimed to enrich the standard PBL small-group learning process using BML principles and students' hemispheric preferences and to evaluate the impact of the revision on reducing the common problems found in PBL tutorial sessions. Thus, the medical students' hemispheric preferences were first determined, and it was found that approximately 60% of the first-year students preferred both hemispheres, 29% preferred their right hemisphere, and 10% preferred their left hemisphere. Saleh (2001) also found that most participants (46.2%) (university students and graduates

from different disciplines) preferred both hemispheres. He showed that students majoring in education, nursing, communication, arts, literature, and law preferred their right hemisphere, whereas students majoring in business/commerce, engineering, and science preferred their left hemisphere. In another study that investigated hemispheric preferences, a higher percentage of students majoring in general chemistry, basic biochemistry, and home economics preferred their left hemisphere, whereas a higher percentage of students majoring in architecture/ interior design, and civil engineering preferred their right hemisphere (Morton, 2003a).

Because hemispheric preferences are still a subject of discussion that requires more evidence, a certain amount caution was needed when reviewing the results of studies on hemispheric preferences. Recently, to strengthen the concept, numerous verification studies were performed; these studies used different biophysiological methods to verify survey-dependent hemispheric preferences, and among these, EEG recordings revealed supportive evidence for hemispheric preferences. In a study by Merckelbach, Muris, Horselenberg, and de Jong (1997), Zenhausern's Preference Test (1978) was used to organize 20 participants as preferring their left or right hemisphere, and EEG recordings were obtained for them. It was shown that participants who preferred the right hemisphere displayed greater alpha power, which is inversely related with activation, compared with those who preferred the left hemisphere. Similarly, statistical analyses in several studies that compared biophysical methods (Dichotic Deafness Test, Phased Mirror Tracing, Best Hand Test) with surveys for hemispheric preferences (The Asymmetry Questionnaire, Polarity Questionnaire, Preference Test) have also revealed

Table 5
Students' Academic Success in Each Program

Program	Academic Success							
	Unsuccessful (<4.99/10)		Moderately Successful (5.00–6.99/10)		Successful (≥7.00/10)		Total	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Standard PBL Program (sPBL)	84	54.9	61	39.9	8	5.2	153	100.0
PBL Program Enriched with Brain/Mind Learning Principles (bPBL)	37	26.1	62	43.6	43	30.3	142	100.0

Student's t-test Results for the Students' Academic Success by Program.

Program	Academic Success*				
	n	Mean	Standard deviation	Minimum	Maximum
Standard PBL Program (sPBL)	153	4.67	1.37	.95	8.00
PBL Program Enriched with Brain/Mind Learning Principles (bPBL)	142	5.98	1.40	2.70	9.00

* $t(293) = 8.16$; $p < .01$.

significant correlations between these biophysical tests and surveys (Morton, 2002, 2003a, 2003b, 2003c, 2003d). In the present study, the results of Torrance and Taggart's HIPS were verified using P300 values in an attempt to evaluate learning as a complex cognitive process. The higher P300 amplitudes on all measured channels, specifically anterior channels (frontal and frontocentral) of groups that preferred both hemispheres, suggested the putative abundance of inter-hemispheric interaction/ information flow and activated neural networks, supporting hemispheric preferences. However, evaluations of the left and right hemispheric recordings within groups that preferred left, right, and both hemispheric preferences showed a low-to-moderate correlation between the HIPS and ERP recordings. When current data are taken together with other studies on hemispheric preferences, it appears that there is still a need for further research to provide more evidence. Therefore, in the present study, because of the moderate reliability of the HIPS and the low-to-moderate correlation between the HIPS and ERP recordings, the findings related to students' hemispheric preferences were not included in the revisions or in evaluating the PBL learning process; for the subsequent steps, only BML principles were considered.

PBL is an instructional program that integrates basic, clinical, and sociobehavioral knowledge within the clinical context during preclinical education (Charlin, Mann, & Hansen, 1998; Dahle, Brynhildsen, Fallsberg, Rundquist, & Hammar, 2002; Davis & Harden, 1999). Problem-based instructional programs are preferred worldwide in many disciplines, including medicine. Accordingly, during the past 15 years, PBL has been implemented in the education programs of several Turkish medical schools. In the present study, students gave mostly positive comments on the organization, planning, and process of the sPBL program, with negative comments ranging between 20% and 35%. The results related to the assessment method and learning outputs showed that the percentage of the students who gave positive comments decreased to 40%–50%. Most students found the learning environment to be moderately instructive, although 44.2% of them stated that the environment was stressful. These findings were supported by the data obtained from the analyses of tutor interview reports, form-based expert observations of the PBL tutorial sessions, and written materials on the FCs. Other studies that evaluated PBL programs also present similar results. In an evaluation study in which 446 graduates were asked to assess PBL education, a high level of satisfaction was declared (Antepohl et al., 2003); graduates stated that the education they had received had prepared them for professional life, specifically for building skills in patient–doctor communication, team working, critical thinking, and scientific approach. Another study that evaluated PBL instructions and associated student opinions in Asian medical faculties reported that both medical faculties and students had positive judgments and attitudes about PBL programs (Khoo, 2003).

Although evaluation studies, including the present study, provide concrete evidence for the efficiency of PBL, they also refer to some common and important problems that arise during the small-group tutorial process (Blake & Jr Parkison, 1998; Khoo, 2003; Koh, Khoo, Wong, & Koh, 2008; Moust et al., 2005; Norman & Henk, 2000). Among the major problems faced are skipping some of the steps or following them merely mechanically, insufficient analysis and reporting phases (which led to superficial learning with limited integration), lack of individual preparation, and low student participation resulting in weak group dynamics (de Grave et al., 2002; Khoo, 2003; Moust et al., 2005). Supporting our findings, de Grave et al. (2002) reported that regarding the six critical incidents (lack of elaboration, lack of interaction, unequal participation, lack of cohesion, difficult personalities, and lack of motivation), unequal participation, lack of interaction, and lack of elaboration were the most frequent success inhibitors. Among these, motivational influences had the major impact in dysfunctional tutorial groups. As stated in the results section (Table 4), similar problems were observed in sPBL, such as insufficient use of scenarios; improper management of tutorial processes; difficulties in some of the steps of the seven-step approach (determining problem sentences, analyzing problems, and defining learning objectives); insufficient individual student preparation; and tutors' difficulties during the tutorial process such as creating a supportive environment, managing group dynamics, and deepening discussions.

A challenge that researchers and instructors faced recently is working with small groups, including problems experienced during group tutorial processes. Despite this occasion , there are few studies on the subject. A study by Moust et al. (2005), rather than investigating individual preparation for standard PBL, offered a different format, PBL with study teams, and investigated its impact. A research that compared students who had participated in PBL with study teams with students who had used the traditional self-study showed that working with teams fostered deeper learning as well as increased students' workloads.

In the present study, we assumed that by considering contextualized (situated) cognition and learning theory and BML principles, our constructed frame shown in Figure 1 might be meaningful for reviewing and revising small-group interactive learning processes, including PBL group learning. Small tutorial sessions reconstructed to consider BML principles may increase students' motivation to learn in more challenging but safe and supportive learning environments (Caine and Caine et al., 2010, p. 11-20). Thus, during the design of bPBL (enrichment of the sPBL learning process with BML principles), we accomplished the modifications listed in Table 1 and evaluated the impact of the changes. Compared with sPBL, the results for bPBL revealed more positive comments on the organization, planning, and tutorial processes (an increase of 10%–15%); the assessment process; and learning output (an increase of 20%–25%). Moreover, 63.8% of the students expressed that the learning environment was "safe and challenging," 85.1% found it to be moderately to highly "interesting," and 94.5% found it to be moderately to highly "instructive and encouraging for learning." The improvements in both the instructional program and learning environment were significantly reflected in the students' academic performance. Compared with the lower percentage of passing grades in the sPBL sessions (41.1%), the overall success in the bPBL group (73.9%) was significantly higher. Regarding the small-group learning process in the bPBL tutorial sessions, expert observations and content analyses of student guides showed that the revision had resulted in noticeably improved learning processes and environments, increased interactions and group discussions, increased integration and deeper learning, and a more supportive and challenging learning environment with better structured student and tutor guidance. However, one major problem of the sPBL approach, the active participation of the students and the associated group dynamics, was not sufficiently solved with the bPBL approach. Although group dynamics were facilitated in bPBL using the guides, the tutors reported that having considerably larger groups (12–13) with insufficient time in the program for individual studies was the major cause of this problem. In general, these findings suggest that the incorporation of BML principles significantly improved the efficiency of the applied bPBL program, suggesting that BML can help to solve / reduce some of the major problems that emerge in PBL tutorial sessions.

The present study, which aimed to revise the standard PBL program to enrich small-group tutorial sessions with BML principles and to evaluate the impact of the revision, is important in that it provides evidence on small-group learning processes and environments. It is the first study designed based on both PBL and BML learning principles, which, however, also brings forth a certain limitation. Because no research focused on small-group learning processes from BML learning perspectives, the results of the present study cannot be related to or discussed in the context the results of previous studies. In this circumstance, the need becomes clear for more focused and interdisciplinary studies on small-group learning processes and environments in the contexts of interactivity, complexity, contextuality, and learning climate and socialization. For instance, studies focused on group dynamics and the levels of interaction during group tutorial sessions have shown that a positive correlation exists between the interaction within groups with the productivity of PBL sessions and the levels of deep learning. However, insufficient group member interactions or pseudo-interactions do not result in sufficient integration or deepening of learning (de Grave, Dolmans, & van der Vleuten, 1999).

In conclusion, regarding the results of hemispheric preferences, which were verified by ERP recordings, it appears that the concept of hemispheric preferences is still somewhat questionable and that there remains the need for additional research to provide new evidence. Therefore, attempting to design learning and teaching processes in safe, challenging, and supportive learning and teaching environments that are compatible with students' hemispheric preferences, we need stronger scientific evidence. However, the findings from this program's evaluation demonstrated that enhancing PBL programs using BML principles improves both the process and outcome of the program, efficiently overcoming some of the major problems of PBL and suggesting the usefulness of BML principles in different instructional models. From this perspective, additional studies are required that would provide evidence on the relation between BML and other interactive learning methods, including PBL.

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