Short-term Effects of Problem-based Learning Curriculum on Students' Self-directed Skills Development

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Aim To investigate short-term effects of problem-based learning on students' scientific thinking, problem solving, and conflict resolution skills.

Methods The study was conducted in two medical schools, Ondokuz Mayıs University in Samsun and Trakya University in Edirne, Turkey. The two schools used different instructional approaches in educational methods: Ondokuz Mayıs University followed a problem-based learning curriculum and Trakya University a traditional didactic curriculum. Three groups of students were included as follows: (*a*) 83 first-year from Ondokuz Mayıs University, who passed an English language proficiency exam; (*b*) 146 students who failed English language proficiency exam and had to spend a year attending preparatory English language classes before starting their first year at Ondokuz Mayıs University (first control group); and (*c*) 124 students first-year students from Trakya University (second control group). All participants completed the Problem Solving Inventory, Scientific Thinking Skills Questionnaire, and Conflict Resolution Scale at the beginning of the 2003/2004 academic year. The tests were re-administered to same students at the end of the academic year, ie, 10 months later.

Results Analysis of covariance revealed no differences in pre-test scores among the problem-based learning, first, and second control groups in their scientific thinking (9.0 ± 71.2, 8.9 ± 3.2, and 8.7 ± 1.3, respectively; $P = 0.124$), problem solving (132.2 ± 15.4, 131.2 ± 16.2, and 132.1 ± 17.4, respectively; $P = 0.454$), and conflict resolution skills (112.3 ± 14.6, 109.7 ± 12.8, and 110.2 ± 11.4, respectively; $P = 0.07$). The study group in comparison with first and second control group had significantly better post-test results in scientific thinking (13.9 ± 3.5, 9.5 ± 2.2, and 9.1 ± 2.7, respectively), problem solving (125.5 ± 12.6, 130.1 ± 11.2, and 131.1 ± 15.4, respectively), and conflict resolution skills (125.4 ± 12.7, 110.9 ± 23.7, and 111.6 ± 23.6, respectively) ($P<0.001$ for all). The skills of the two control groups did not improve in this time period and their post-test scores were not significantly different.

Conclusion Problem-based learning curricula may positively affect some of the self-directed skills, such as scientific thinking, problem solving, and conflict resolution skills of students, even in a short period of time.

As one of the best-described methods of student-centered active learning, problem-based learning has had a major impact on thinking and practice in medical education for the past two or three decades (1-9). Problem-based learning is generally understood to mean an instructional strategy in which students identify issues raised by specific problems to help develop an understanding of underlying concepts and principles (10). The focus is usually a written problem (a case presentation) consisting of "phenomena that need explanation."

Students can learn certain practices and acquire skills (inductive/deductive reasoning, analyzing, synthesizing, accessing information, interpreting, and so on) that will be useful in problem solving (11). New knowledge and understanding arise through working on a problem rather than the other way around as in traditional approaches. A more apposite term for this approach might be "problem-first learning" (4). Against the disadvantages of excessive demands on staff time (8), set-up and maintenance costs (6), and increased stress for both students and staff (8), it has been claimed that problem-based learning has the advantages of promoting deep understanding of the matter, improving collaboration between disciplines, and increasing the knowledge retention and motivation of both students and teachers (3). Academics have often focused on investigating whether or not the problem-based learning produces better clinicians. Reviews of controlled evaluation studies determined limited evidence that problem-based learning in continuing medical education increased participants' knowledge and performance and improved patients' health (12). In previous studies, the effects of problem-based learning on the improvement of students' self-directed skills were often neglected. However, this educational method, based on the principles of cognitive physiology and adult education, and using a small-group study, may have the effect of promoting students' self-potential (1,13,14).

Our aim was to investigate the short-term effects of problem-based and traditional curricula on three self-directed skills – scientific thinking, problem solving, and conflict resolution – that may contribute to the educational process as a whole.

Subjects and methods

Study design

The study was conducted at the medical schools of Ondokuz Mayıs University, Samsun, and Trakya University, Edirne, Turkey. The Ondokuz Mayıs University Ethics Committee gave the ethical approval of the study.

In the 2003/2004 academic year, Ondokuz Mayıs University Medical School has adopted a problem-based learning curriculum, according to the Maastricht University model (15), with problem-based learning tutorials as the main instructional method. The first year curriculum consisted of 60 problem-based tutorials. Generally, problem-based learning groups of 7-8 students met twice a week for 2-3-hour sessions to discuss a problem. The issues that emerged during the discussion students had to investigate on their own, report their findings on the next tutorial meeting, synthesize new knowledge, and apply it to the problem discussed. A typical problem-based learning tutorial is modeled after the Maastricht "seven-jump" process (11). A faculty member (the tutor) guided each tutorial group. Each tutor had attended a 5-day problem-based learning course and a 7-day educational skills course as part of teaching staff training program focused on the problem-based learning principles, adult education, and tutoring. The curriculum also included 30 constructed active lectures (45 minutes each), 20 basic science practices (1 hour each), and 30 communication and clinical skills practice sessions (1 hour each). A faculty member gave lectures to the entire class of 86 students, whereas for basic science and clinical practice sessions, the class was divided into groups of 20-25 and 10-12 students, respectively. Basic science sessions were held by a faculty member and 2-4 teaching assistants, whereas clinical sessions were held by a faculty member only.

In the Trakya University Medical Faculty, the first-year curriculum consisted of 546 hours of traditional didactic lectures on basic medical sciences and 168 hours of clinical and communication skills practice sessions. Basic sciences (physics, chemistry, statistics, computers, and biology) were taught in the first half of the academic year and basic medical sciences (histology, embryology, biochemistry, and anatomy) in the second half. A faculty member gave all the lectures to the class (132 students) each time. In addition, a faculty member and 2-4 teaching assistants again coached groups of 25-35 students in clinical and communications skills.

Study groups

In Turkey, students are admitted to medical schools on the basis of a country-level basic science examination. A total of 246 students enrolled to Ondokuz Mayıs University, while 132 students enrolled at Trakya University after passing in this exam in 2003/2004 academic year. Both schools selected students who came in the top 1% of those sitting the exam. At Ondokuz Mayıs University, at least a basic command of English is a mandatory prerequisite for admission, whereas knowledge of English is not obligatory at Trakya University. Students who do not pass English language test have to complete a full-year preparatory English course.

In our study, 89 students entered the problem-based learning curriculum immediately (problem-based learning group), while the remaining 157 (first control group) had to take preparatory English classes (a total of 480 hours) without attending any classes from the medical curriculum. The 124 first-year students from Trakya University were included in the second control group. At the beginning of the of 2003/2004 academic year, the Scientific Thinking Skills Questionnaire, Problem Solving Inventory, and Conflict Resolution Scale were administered to each student group on voluntary basis. Problem Solving Inventory is designed to assess perceptions of one's own capability for problem solving behavior and attitudes. Scientific Thinking Skills Questionnaire is designed to assess an individual's skills in solving day-to-day problems using scientific thinking and scientific research skills acquired during the university education process, and the Conflict Resolution Scale is designed to assess an individual's perceptions of his or her capabilities with regard to problem solving behavior and attitudes.

In the first phase of the study, we excluded 9 students who did not participate in all three tests, as well as 6 foreign students who may have had poor understanding of the tests due to their lack of familiarity with Turkish language (4 students from the problem-based learning group, 3 from the first control group, and 8 from the second control group). Thus, a total of 363 students (96%) out of 378 participated in the first phase of the study. In the second phase at the end of the 2003/2004 academic year (10 months later), the tests were administered again. Ten further students declined to participate in the study (2 from the problem-based learning group and 8 from the first control group). The final phase of the study thus included 353 (93.3%) students (83 in the problem-based learning group, 146 in the first, 124 in the second control group).

There were 83 students (38 men and 45 women) aged 18.46±1.02 years in the problem-based learning group, 146 students (64 men and 82 women) aged 18.53±1.04 years in the first control group, 124 students (58 men and 66 women) aged 18.51±1.09 years in the second control group. The problem-based learning group and the control groups did not differ in age ($t=0.775$, $P=0.508$) or sex distribution ($\chi^2_2=6.366$, $P=0.272$).

Instruments

Scientific thinking questionnaire. Gundogdu (16) designed the Scientific Thinking Questionnaire based on the Scientific Process Skills Test (17). The 20-item multiple-choice questionnaire covering all areas of sciences was designed to assess an individual's skills in solving day-to-day problems using scientific thinking and research skills acquired during the university education process. The individual's abilities to assemble a hypothesis, to identify the variables, to explain the knowledge concerned, and to establish a research axis were tested by means of the alternative possible answers. The questionnaire was scored on a 20-point scale, from 0 to 20, with higher scores indicating better scientific thinking skills. An expert team consisting of 10 faculty members of different scientific background evaluated 32 items developed by Gundogdu to establish its capacity to reflect the specific dimensions of scientific thinking abilities using a 7-point Likert scale. Three items scored below the average of 6 were omitted from the questionnaire. The constructional validity of the questionnaire was tested on 49 students who had attended scientific research technique course and 56 students who had not and the test revealed a significant difference between the two student groups ($t = -3.20$; $P<0.001$). The expert team selected the final 20 items according to their discriminatory effectiveness (0.503-0.875) using the Henderson item-analyses test. The internal consistency (Cronbach α) of the questionnaire tested on 715 university students was 0.64.

Problem solving inventory form A. This 35-item self-reported test (18) was designed to assess perception of one's own capabilities in problem-solving behavior and attitudes on a 6-point Likert scale (from "strongly agree" to "strongly disagree"). The PSI provides a single, general index of Problem-solving Confidence (self-assurance while engaging in problem solving activities), Approach-avoidance Style (a general tendency to either approach or avoid problem solving activities), and Personal Control (determining the extent of one's control over emotions and behavior while solving problems). High scores indicate general negative self-appraisal. Cronbach α of the test is 0.90 and consistency for the subinventories is between 0.72 and 0.85. The inventory adapted to Turkish (19) has a Cronbach α of 0.88. The score range is 32-192 points. A score between 32 and 80 indicates that an individual perceives him or herself as a successful problem-solver, while a score between 81 and 192 indicates that an individual lacks skills for finding effective solutions to problems (18).

Conflict resolution scale. Conflict Resolution Scale (20) was first adapted to Turkish medical students by pooling the test items according to the steps in conflict resolution (21-24). The 55 items in this self-reported inventory are evaluated on a 4-point Likert scale (from "strongly agree" to "strongly disagree"). It is designed to assess an individual's key abilities in terms of conflict resolution skills. The scale contains the 5 subinventories, each testing the factors for conflict resolution (trying to understand the person one has conflict with, listening to that person, focusing on the needs of both sides, social accommodation, and anger control). The internal consistency (Cronbach α) is 0.91 for the test and 0.75-0.86 for subinventories. The score range is 55-220 points, with higher score indicating greater conflict resolution abilities.

Statistical analysis

The numeric results of the three tests were taken as dependent variables. The paired-samples *t* test was used to investigate the relations between the pre- and post-test results of each group. The difference between the post and pre-tests within a group was tested by analysis of variance, with Bonferroni's test. Analysis of covariance (one-factor ANCOVA) were performed to test the correlation between the pre- and post-test results for each test and corrected test means were analyzed; Bonferroni's test was used to investigate the relations between pair results. $P<0.05$ was considered statistically significant. All analyses were performed with Statistical Package for Social Sciences 13.0 (SPSS Inc., Chicago, IL, USA).

Results

Scientific thinking skills

The problem-based learning group showed most significant increase between the post- and pre-test results in scientific thinking skills, followed by the first and the second control groups, which did not differ between themselves ($P=0.151$; Table 1). No significant differences were found between the groups in the corrected means of the pre-tests results (ANCOVA, $P=0.124$), whereas the post-tests results of the problem-based learning group were significantly higher than the results of the two control groups (ANCOVA, $P<0.001$). There was no significant difference in post-test results between the two control groups ($P=0.521$).

Problem solving skills

The problem-based learning group showed the most significant decrease between the post- and pre-test results (ANCOVA, $P<0.001$), followed by the first and second control groups, which did not differ ($P=0.06$; Table 1). No significant differences were found between the groups in the corrected means of the pre-test results (ANCOVA, $P=0.454$), whereas the post-tests results of the problem-based learning group were significantly lower than the results of the two control groups (ANCOVA, $P<0.001$). There was no significant difference in post-test results between the two control groups ($P=0.651$).

Conflict resolution skills

The most significance increase between the post- and pre-test results was found in the problem-based learning group (ANCOVA, $P<0.001$), followed by the second and first control groups, which did not differ ($P=0.234$; Table 1). No significant difference between the groups in the corrected means of the pre-test results was found (ANCOVA, $P=0.07$), whereas the post-test results of the problem-based learning group were significantly higher than the results of the two control groups (ANCOVA; $P<0.001$). No difference was found in post-test results between the two control groups ($P\geq0.95$).

Discussion

Our study showed that, in comparison with traditional methods, problem-based learning could have a positive effect on students' self-directed skills after a short time.

The relation between knowledge, science, and medicine is not always clearly formulated. Maudslet and Strivens (25) maintain that medicine is essentially an applied science or art, interpreting

Table 1. Scientific thinking, problem-solving, and conflict resolution pre- and post-test results of students in problem-based learning (PBL), first, and second control groups*

	Test score (mean±SD)†					
Student group	Scientific Thinking Questionnaire	*P*	Problem Solving Inventory	*P*	Conflict Resolution Scale	*P*
PBL group (n=83):						
pre-test	9.0 ± 71.2	<0.001	132.2 ± 15.4	<0.001	112.3 ± 14.6	<0.001
post-test	13.9 ± 3.5		125.5 ± 12.6		125.4 ± 12.7	
First control group (n=146):						
pre-test	8.9 ± 3.2	0.138	131.2 ± 16.2	0.359	109.7 ± 12.8	0.179
post-test	9.5 ± 2.2		130.1 ± 11.2		110.9 ± 23.7	
Second control group (n=124):						
pre-test	8.7 ± 1.3	0.352	132.1 ± 17.4	0.765	110.2 ± 11.4	0.838
post-test	9.1 ± 2.7		131.1 ± 15.4		111.6 ± 23.6	

*Control groups were not exposed to PBL (first control group attended preparatory course in English language only, and the second control group was exposed to traditional medical school curriculum).
†The tests were administered at the beginning and the end of 2003/2004 academic year.

evidence and applying it to real life, using critical thinking skills and experience. Medical students and physicians are often reminded that they are not real scientists and the competition between the basic science and clinical components of traditional undergraduate medical curricula reflects such a tension. Some authors have claimed that problem-based learning students have less preclinical knowledge (eg, of biochemistry) in comparison with traditionally taught students (7,26). Our study results showed the opposite, ie, scientific thinking abilities of our problem-based learning students were better than those of the two control groups. Moreover, scientific thinking abilities of the traditional curriculum students at Trakya University did not improve after year of taking basic science courses. A possible explanation of this finding may lie in the rich learning environment provided by problem-based learning, where competence is fostered not primarily by teaching but rather by encouraging an inquisitive learning approach, which differs from the traditional learning style (27). Patel et al (28) showed that problem-based learning students develop a backward reasoning technique (hypothetical-deductive) to explain clinical cases, while traditional lecture-based students use forward reasoning. Also, problem-based learning students produced extensive elaborations using relevant biomedical information, a feature relatively absent from traditional lecture-based students' explanations (28). From a cognitive perspective, problem-based learning students are assumed to learn new information more easily because of the activation of prior knowledge and elaboration of newly acquired knowledge (29). The result is increased retention of knowledge and enhancement of the integration of basic science concepts into clinical problems.

Barnsford and Stein (30) maintain that there are distinct stages involved in solving a problem in general science. These are to identify the problem, to define and present the problem, to explore possible strategies, to act on those strategies, and to look back and evaluate the effects of the actions taken (IDEAL model). Problem solving can be characterized differently depending on the relative emphases on creativity and clear staging. Furthermore, problem solving emphasizes creativity through the structured spontaneity of brainstorming in groups (31), which was the element absent from both control groups in our study. Brainstorming, best learned and applied in small groups (32), relates problem solving to critical thinking.

Expert problem solving in medicine is considered dependent on a wealth of prior specific experience, contributing the pattern recognition process, and elaborated conceptual knowledge applicable to the occasional problematic situation (33). There is also an important association between problem solving abilities and embedded information and long-term memory (34). In our study, the early development of medical expertise at tutorials in our problem-based learning group involved the development of general problem-solving routines and identification of situations where a particular routine could be used. While our problem-based learning group sought to identify issues raised by specific problems in the problem-based learning tutorials, the concepts and principles may have been meaningfully embedded into the existing relevant knowledge to ensure that they be retrievable when necessary from the long-term memory (11).

Another important benefit of an effective and democratically structured small problem-based learning group may be its relation with psychotherapeutic principles (listening and tolerating hostility) (35). Such a facilitated group is based on a democratic process, where group members themselves determine the rules. Also, with occasional changes in the group composition, students often have to accomplish tasks with different partners. This general problem-based learning strategy may have positive effects on students' communication skills (36). It has been shown that problem-based learning students can acquire abilities to work together, take initiative, share knowledge, and show mutual respect (29). Our results are in accordance with these previous findings.

Our study has several limitations. First of all, the faculty members who pioneered the curricular change at our university were highly motivated and may well have been more enthusiastic. Faculty members are obligated to attend courses on the principles of modern education to be able to act as tutors. These courses are expected to improve and standardize the educational skills of faculty members, such as providing constructive feedback, advancing communication skills, and using different instructional, measurement, and evaluation techniques. The first-year tutors were selected from the faculty on the basis of their educational skills or familiarity with the principles of modern education. In addition, due to the ideal number of students in the problem-based learning group, more attention could be given to the needs of individual students. These factors may have positively influenced motivation of our students and had impact on their skills. Of course, having to attend preparatory English class may lower student's self-esteem: their medical education was prolonged for a year, which inevitably increased their financial outlay, and they witnessed their peers who had passed the exam assuming a new social identity. Coover and Murphy (37) have shown that self-esteem in adults significantly correlates with social identity and context. We tried to minimize these unforeseen factors when comparing our problem-based learning group with the two control groups.

Modern theories on medical education emphasize that learning should be a constructive, self-directed, collaborative, and contextualized (38). The physician of the future is expected to resolve medical problems, to understand and advance the knowledge base, and to work in a team (39). Of all the current educational methods only problem-based learning has the theoretical basis to achieve these expectations. As Dolmans (38) points out, research into problem-based learning must focus on the theoretical concepts underlying it. In our study, we selected three self-directed skills that may contribute to problem-based learning that have not been investigated before, but our results should be verified in further problem-based learning research.

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