Effects of Problem-Based Learning and Traditional Instruction on Self-Regulated Learning

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ABSTRACT The authors used the Motivated Strategies for Learning Questionnaire to investigate the effectiveness of problem-based learning (PBL) and traditional instructional approaches on various facets of students' self-regulated learning, including motivation and learning strategies. Participants included 61 tenth-grade students from 2 intact classes instructed by the same biology teacher. The authors randomly assigned 1 class as the experimental group and the other class as the control group. Teachers instructed the control group with teacher-centered, textbook-oriented traditional instruction; they taught the experimental group with problem-based learning, in which students worked with ill-structured problems. Results revealed that PBL students had higher levels of intrinsic goal orientation, task value, use of elaboration learning strategies, critical thinking, metacognitive self-regulation, effort regulation, and peer learning compared with control-group students.

Key words: motivation, problem-based learning, self-regulation

Over the last 3 decades, the framework for understanding the psychological basis of learning has shifted gradually from a teacher-centered approach to a student-centered approach. That perspective has placed an increasing responsibility on learners for their own learning. The learners become aware of, and reason about, conceptual relations or describe learning as a process of conceptual refinement, and they construct their own conceptualizations and solutions to problems. Hence, students should not depend on teachers to learn; instead, they should be independent learners throughout their lives.

Education research reveals that beliefs and cognition that enable students to be independent learners are related highly to academic learning. That viewpoint has led to an increased emphasis on how classroom context and other contextual factors shape and influence student learning and motivation. Therefore, educators focus their attention on students' strategic efforts to manage achievement through specific beliefs and processes. Those self-regulatory processes and beliefs have been the focus of systematic research (Zimmerman & Risemberg, 1997). Efforts made by researchers in the field of educational psychology to define self-regulation resulted in the description of self-regulated learning as the degree to which students metacognitively, motivationally, and behaviorally participate in their learning process.

Barry Zimmerman (2002), renowned scholar in the field of self-regulated learning, defined self-regulation as the process that students use to activate and sustain their thoughts, behaviors, and emotions to reach their goals. According to Zimmerman, self-regulated students set goals effectively, plan and use strategies to achieve their goals, manage resources, and monitor their progress. From that perspective, the value of self-regulation in schools is readily obvious. Students who can initiate learning tasks, set goals, decide on appropriate strategies to achieve their goals, then monitor and evaluate their progress are likely to achieve at higher levels than are students who rely on teachers to perform these functions. Zimmerman argued that self-regulated learners continuously adjust their goals and choices of strategies in response to changing intrapersonal, interpersonal, and contextual conditions.

However, self-regulatory skills are of little value if students do not motivate themselves to use them. Several self-motivational beliefs form a basis for goal setting and strategic planning. The self-motivational beliefs are self-efficacy, outcome expectations, intrinsic interest or value, and goal orientation. Self-efficacy refers to students' beliefs about their capability to learn or to perform effectively; outcome expectations refer to students' beliefs about the ultimate end of performance. Self-regulated learners appear to be self-efficacious about their ability to master a learning task. Research findings reveal that students with a high sense of self-efficacy tend to use cognitive and metacognitive strategies and persist in difficult or uninteresting tasks (Dembo & Eaton, 2000; Neber & Schommer-Aikins, 2002; Pintrich & DeGroot, 1990; Shu-Shen, 2002). Intrinsic interest or value and goal orientation essentially concern students' reasons for performing a task (Pintrich & DeGroot; VanderStoep, Pintrich, & Fagerlin, 1996; Zimmerman, 2000).

Two general goal orientations that learners can adapt are (a) learning-goal orientation, which students perceive as important for developing new skills, and, thus, learning and mastering subject material and (b) performance or ability orientation, in which students focus on ability and performance in relation to other students (Wolters, Yu, & Pintrich, 1996). Education researchers have reported that learning-goal orientation and the belief that a task is interesting and important are related positively to reports of cognitive, metacognitive, and self-regulatory strategies, such as elaboration, organization, planning, monitoring, and regulating learning (Ames & Archer, 1988; Meece, Blumenfeld, & Hoyle, 1988; Neber & Schommer-Aikins, 2002; Nolen, 1988; Pintrich & DeGroot, 1990).

From a social cognitive perspective, researchers view *self-regulation* as an interaction of personal, behavioral, and environmental triadic, and, simultaneously, cyclic processes. *Personal processes* involve students' knowledge, metacognitive processes, goals, and effects. *Behavioral processes* involve self-observation, self-judgment, and self-reaction. *Environmental processes* involve enactive outcomes, modeling, and verbal persuasion. Social cognitive theory proposes that those self-regulatory processes and accompanying beliefs are affected by social and physical environments. On the basis of that idea, researchers consider that modeling and instruction are primary vehicles through which self-regulatory skills can be taught (Schunk & Zimmerman, 1997; Zimmerman, 2002). Researchers also have suggested that *problem-based learning* (PBL), which places responsibility on students to access information, to achieve goals, and to monitor understanding, can be used by teachers to support the development of self-regulated learning (Karabulut, 2002; Paris & Paris, 2001; Perry, Vandekamp, Mercer, & Nordby, 2002).

In PBL environments, students act as professionals and are confronted with problems that require them to (a) clearly define an ill-structured problem; (b) develop hypotheses; (c) access, analyze, and use data from different sources; (d) revise the initial hypothesis as data are collected; and (e) develop and justify solutions according to evidence and reasoning (Barrows, 1986; Gallagher, Stepian, Sher, & Workman, 1995). Therefore, students in a problem-based classroom must seek information, access learning material, and communicate acquired knowledge to other students and teachers while they work in small groups with ill-structured problems (Rosing, 1997). Results of research on PBL in elementary and high school settings revealed that PBL creates an environment in which students (a) participate actively in the learning process, (b) take responsibility for their own learning, and (c) become better learners in terms of time-management skills and ability to define topics, access different resources, and evaluate the validity of these resources (Gallagher et al.; Krynock & Robb, 1996).

Moreover, PBL appears to improve critical thinking, communication, mutual respect, teamwork, and interpersonal skills and increase students' interest in a course (Achilles & Hoover, 1996; Gordon, Rogers, Comfort, Gavula, & McGee, 2001; McBroom & McBroom, 2001; Sage, 1996; Savoie & Hughes, 1994; West, 1992). In PBL classes, students can confront meaningful problems because of their real-life context. When PBL students solve problems, teachers encourage them to explore possibilities, invent alternative solutions, collaborate with other students, try out ideas and hypotheses, revise their thinking, and, finally, present their best solutions.

Savery and Duffy (1995) pointed out that the focus in PBL is on students as constructors of knowledge in a context similar to the context in which they use that knowledge. The students are encouraged to think critically and creatively and to monitor their understanding. PBL students have ownership of the problem, and all learning occurs as a result of considering the problem. Facilitation is focused on metacognitive processes. Therefore, PBL allows students to interact with their environment and their peers, which eventually leads to evolvement of knowledge through social negation. Moreover, ill-structured problems encourage students to apply their newly constructed knowledge and to consider alternative points of view and strategies. Hoffman and Ritchie (1997) stated that when students use that approach, problem-based learning can promote transfer of knowledge and skills gained in the school to daily life.

However, there are few studies that provide empirical evidence concerning the effectiveness of PBL on students' self-regulation (Galand, Bentein, Bourgeois, & Frenay, 2003; Lohman & Finkelstein, 2000). Given the general lack of empirical knowledge concerning the comparative impact of problem-based learning and traditional instruction on different facets of students' self-regulated learning (including motivation and use of learning strategies), we posed three research questions to investigate the effect of PBL in high school biology classes:

Does PBL affect students' self-reported motivation?
Does PBL affect students' self-reported use of learning strategies?
Is there a relationship between students' self-reported motivation and self-reported use of learning strategies?

Method

We used a quasi-experimental design; the independent variable was instructional methods (PBL and traditional instruction). The dependent variable was students' scores on each of the subscales of the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia, & Mckeachie, 1991) that we used to assess students' self-reported motivation and self-reported use of learning strategies. To address the research questions, we used two multivariate analyses of variance (MANOVAs): (a) MANOVA for determining the effect of various methods on students' self-reported motivation, as indicated by six

subscale scores on the MSLQ and (b) MANOVA for decid-
ing the effect of various methods on students' self-reported
use of learning strategies, as indicated by nine subscale
scores on the MSLQ. We performed follow-up analyses as
needed to evaluate the mean differences between the
groups with respect to each dependent variable. Prior to
examining multivariate effects, we checked multivariate
normality and homogeneity of variance and covariance
matrices assumptions of MANOVA. Because one can
detect multivariate normality assumption by examining
univariate normality of observations on each variable, we
conducted the Shapiro-Wilk test (Stevens, 2002). Results
revealed that dependent variables were normally distrib-
uted across treatment conditions ($p > .05$). The nonsignif-
icant F tests from Box's M statistics were the sign of homo-
geneity of variance and covariance matrices ($p > .05$).

Participants

Sixty-one high school students (39 boys and 22 girls)
from a large urban district of Ankara, Turkey, participated
in this study. Students were from two intact classes taught
by the same biology teacher. We randomly assigned one of
the classes as the experimental group ($n = 30$) and the
other as the control group ($n = 31$). The mean ages of the
students in the experimental group and the control group
were 16 years and 16.6 years, respectively. Students came
from middle- to upper-class families.

Instrumentation

We measured students' motivation and use of learning
strategies by the MSLQ, which is a self-report question-
naire developed by Pintrich and colleagues (1991). It con-
sists of two sections, a motivation section and a learning-
strategies section, which the researchers designed to
determine students' motivational orientations and use of
various learning strategies. The motivation section
includes 31 items in six subscales that assess students' (a)
goals and value beliefs, (b) beliefs about their ability to suc-
ceed, and (c) anxiety about tests. The motivation subscales
tap into three broad areas:

1. *Value components* refer to the reasons why students
   engage in an academic task. Three subscales included in
   the MSLQ to measure value beliefs include *Intrinsic Goal
   Orientation* (a focus on learning and mastery), *Extrinsic
   Goal Orientation* (a focus on grades and approval from
   others), and *Task Value* (judgments of how interesting,
   useful, and important course content is to the student).
2. *Expectancy components* focus on students' beliefs that
   they can accomplish a task. We constructed two
   expectancy-related subscales to assess students' Control
   of Learning Beliefs and Self-Efficacy for Learning and
   Performance.
3. *Affect component* refers to students' worry and concerns

over taking examinations and includes one subscale, Test
Anxiety.

Students' scores on each of the subscales constituted the
dependent variables that related to the first research ques-
tion. We based all subscales on a 7-point scale, ranging
from 1 (*not at all true of me*) to 7 (*very true of me*). In gen-
eral, a higher score such as 4, 5, 6, or 7 was better than a
lower score like 1, 2, or 3. The only exception was the Test
Anxiety scale, where a higher score meant more worrying.

The learning-strategy section of the MSLQ includes 31
items in nine subscales regarding students' use of various
cognitive and metacognitive strategies and management of
different resources. We based the learning-strategies sec-
tion on three broad components:

1. Cognitive learning provides a measure of use for
   Rehearsal (e.g., memorizing lists of keywords), *Elaboration*
   (e.g., paraphrasing, summarizing), and *Organization* (e.g.,
   outlining). In addition, we included a subscale on *Criti-
   cal Thinking* that concerns students' use of strategies to
   apply previous knowledge to new situations or to make
   critical evaluations of ideas.
2. Metacognitive strategy consists of one large subscale,
   Metacognitive Self-Regulation, which assesses the use of
   strategies that help students control and regulate their
   own cognition, such as planning, monitoring, and regu-
   lating strategies.
3. Resource management includes *Time and Study Environ-
   ment* (e.g., using time well, having an appropriate place
   to study), *Effort Regulation* (e.g., persisting in the face of
   a difficult or boring task), *Peer Learning* (e.g., using a
   study group or friends to help learn), and *Help Seeking*
   (e.g., seeking help from friends or teachers when needed;
   Pintrich et al., 1993).

Students' scores on each of the nine subscales constitut-
ed the dependent variables that were related to the second
research question. Scores on each dimension were a mea-
sure of how often students use different kinds of study skills
and learning strategies.

The MSLQ has been reviewed in the *Mental Measure-
ments Yearbook*, and content validity has been supported
through extensive literature on college students' learning
and teaching (Gable, 1998). Although developed for col-
lege students, researchers have used the MSLQ successfully
with high school students (Barlia & Beeth, 1999; Higgins,
2000). In the present study, a group of educators and high
school teachers examined the questionnaire and evaluated
its content appropriateness for high school students. We
tested factor validity of the MSLQ subscales by running
two confirmatory factor analyses: (a) one analysis for the
set of motivation items and (b) an analysis for the set of
learning-strategies items.

Two goodness-of-fit statistics that we used in this study
were the root mean square error of approximation
(*RMSEA*) and the chi-square and degree of freedom (χ^2/df)

ratio. The *RMSEA* was based on the analysis of residuals; values below .10 indicated a good fit to the data. We determined the χ^2/df ratio by taking the ratio of χ^2 and its degrees of freedom; we determined that χ^2/df ratios of less than 5 indicated a good fit to the data (Kelloway, 1998). The *RMSEA* value and the χ^2/df for the motivation section were .09 and 5.3, respectively. The learning-strategies section of the MSLQ had an *RMSEA* value of .08 and a χ^2/df value of 4.5. The fit statistics appeared to indicate a good fit. Following factor analyses, we calculated zero-order correlations between the different motivational and cognitive subscales (see Table 1). Moreover, we computed coefficient alpha to assess the internal consistency of the subscales, yielding coefficients ranging from .54 to .89 for the motivation section and from .61 to .81 for the learning-strategy section. In general, subscales correlated with each other in expected directions, and reliability coefficients were reasonable. The original developers (Pintrich et al., 1991) of the MSLQ found similar internal consistency estimates of reliability, ranging from .62 to .93 for the motivation section and from .52 to .80 for the strategy section.

We administered the MSLQ as pretest and posttest to students in experimental and control groups to determine their motivation and use of learning strategies before and after treatment. The teacher administered the questionnaire to both classes at one time and advised students to (a) complete the questionnaire in its entirety, (b) not discuss their responses with others near them, and (c) be as sincere as possible.

Treatment

We assigned one class as the experimental group and other class as the control group. The teacher instructed the experimental group with PBL. The control group received traditional biology instruction. The teacher covered the topics related to the human respiratory system and the excretory system as part of the regular biology curriculum. Students in the experimental group and in the control group received identical syllabus-prescribed learning content. The classroom instruction was four 45-min sessions per week. Because the methods of instruction employed in the two groups were implemented by a regular classroom teacher, the first author trained the teacher to ensure fidelity of treatment. To that end, the teacher received a handout that clarified the underlying theoretical background and outlining overview and organization of the implementations.

Because PBL was a novel approach for students in the experimental group, we prepared a similar manual focusing on the description of a typical PBL class to make students familiar with their expected roles. Prior to implementations in the classroom, we fully discussed the manuals with students and the teacher. After the start of the implementations, we held subsequent meetings with the teacher to ensure that she was conducting the treatments appropriately in both groups. We contacted the teacher several times a week to address practical or implementation difficulties and to review the treatment procedure. In addition, we completed classroom observations to document fidelity of the treatment.

The traditional biology instruction involved lessons with lecture and questioning methods to teach the concepts related to the human respiratory system and the excretory system, such as ventilation, alveolar gas exchange, filtration, reabsorption, secretion, and homeostasis. The students studied the textbooks on their own before the class hour. The teacher structured the entire class as a unit, wrote notes on the chalkboard about definitions of concepts, and drew figures of structures related to the organ systems. The teacher described and defined the concepts, and, after her explanation, students discussed the concepts with teacher-directed questions. For the majority of instruction time, students received instruction and engaged in discussions stemming from the teacher's explanation and questions. Therefore, teaching strategies in the control group relied on teacher explanation, classic textbooks, and worksheet study within a discussion environment.

TABLE 1. Zero-Order Correlations for Learning Strategies

Variable	Intrinsic goal orientation	Extrinsic goal orientation	Task value	Control of learning beliefs	Self-efficacy for learning and performance	Test anxiety
Rehearsal	.550**	.174	.487**	.509**	.365**	.124
Elaboration	.712**	.114	.740**	.498**	.571**	.060
Organization	.618**	.194	.574**	.556**	.445**	.008
Critical thinking	.644**	.061	.668**	.256*	.558**	.056
Metacognitive self-regulation	.687**	.261*	.657**	.503**	.550**	.029
Time and study environment	.567**	.187	.691**	.510**	.569**	−.096
Effort regulation	.504**	.202	.705**	.489**	.542**	.086
Peer learning	.548**	.359**	.479**	.269*	.287*	.242
Help seeking	.424**	.196	.285*	.216	.160	.121

*$p < .05$. **$p < .01$.

Before treatment in the experimental group, we formed five heterogeneous groups ($n = 6$) focusing on learning styles, academic performance, and gender to optimize interaction among students having various characteristics. We determined students' learning styles by administering the Learning Style Inventory developed by Kolb (1985) and categorized students by their performance as high achievers, middle (average) achievers, and low achievers on the teacher-made biology examinations. The teacher assigned volunteer roles, such as reader, scribe, doctor, and patient to students in each group. During the treatment, groups dealt with ill-structured problems posed to them as cases from real life. Each case was based on an actual patient. The teacher distributed seven pages of patient information to students, one page at a time. The first page contained brief information about the patient, including age, gender, and major complaint. The data presented on subsequent pages included responses to predictable questions related to patient history, possible symptoms, results of laboratory tests, diagnosis, and treatment. The teacher provided the additional data over time, which allowed for hypothesis generation and for testing every step. The teacher monitored the group process, remained nondirective, and intervened only to the extent necessary.

In general, the PBL group process, in accordance with the PBL model used by Curry, Lubbers, and Tijoe (2001), consisted of three phases. In the first phase, readers read the case while note takers wrote the facts, ideas, hypotheses, and learning issues; facts were listed as they were read. Students then began to discuss the facts to identify as a group which facts were important and which were irrelevant and to probe for scientific explanation. Those steps were accomplished by first using the prior knowledge of the group members. At that point, students had to question whether the information presented was accurate and fully understood. Also, students listed the ideas, generated hypotheses, and identified related learning issues that the group designated as areas in which they had inadequate knowledge for understanding patient events. At the conclusion of each session, the groups decided which learning issues to pursue and which resources to use to gather information. As a final activity of each session, students evaluated their performance individually and as a group. They expressed their opinions about which actions to continue, change, or modify to improve group process.

The teacher also advised students how to determine learning issues and select and use resources. For example, the teacher said that learning issues should not be too specific or too general. The teacher stated that learning issues should be selected in response to the need to answer a question and should be a relatively complete topic representing the body of information within which the answer can be found. Moreover, the teacher told the students to focus on the underlying basic science rather than on making a diagnosis. Therefore, if students thought that they needed to learn about how kidneys function to better understand a patient's situation, they would identify "basic renal processes" as a learning issue, rather than "tubular reabsorption," because it was more specific to addressing the question under investigation. Teachers also reminded students that they could bring any books or materials to class to help them work efficiently during group processes. Students could go to the school library and use written, electronic, or human resources.

During the second phase of the PBL group processes, students participated in independent study outside the small group meeting by addressing the learning issues identified as a result of group discussion. Students used books, encyclopedias, the Internet, and compact disks to obtain information. Some students interviewed doctors, nurses, or patients.

During the third phase of PBL, students met to discuss the new knowledge they had acquired from their independent study. In light of the new information, students revised their previous ideas, listed new ideas, and formulated new hypotheses and learning issues. That process was followed by another self-evaluation, a period of independent study, and a meeting. Group members repeated the process of group discussion, selection of learning issues, identification of resources, self-evaluation, and independent study until they believed that they had adequate knowledge of basic science. After implementation of PBL, students evaluated each other with respect to participation, preparation, interpersonal skills, and contribution to group progress by using peer evaluation. In that way, we expected that students became aware of the extent to which they behaved as intended, individually and as a group. At the end of each case, students wrote reports explaining how they dealt with ill-structured problems. Also, teachers expected students to report specifically the academic knowledge and skills that they gained as a result of PBL. The purpose for teachers assigning that activity was to help students monitor their learning, evaluate themselves, and set goals for further learning. We did not use results of the peer evaluation or analysis of reports in the statistical analysis. We used the MSLQ results obtained at the end of the treatment to determine the effect of PBL on students' motivation and use of learning strategies.

Results

Table 2 shows the descriptive statistics of students' pretest and posttest scores on the motivation and learning-strategies sections of the MSLQ. MANOVA results, based on pretest scores, revealed no preexisting differences between experimental and control groups with respect to students' self-reported motivation, as indicated by six subscale scores, $F(6, 52) = 1.21$, $p = .32$, and self-reported use of learning strategies, as indicated by nine subscale scores on the questionnaire, $F(9, 49) = 0.56$, $p = .82$. Therefore, we found that two groups were similar to each other with respect to the collective dependent variable for motivation

TABLE 2. Descriptive Statistics for Students' Motivation and Use of Learning Strategies

| | Pretest | | | | Posttest | | | |
| | Control group (n = 31) | | Experimental group (n = 30) | | Control group (n = 31) | | Experimental group (n = 30) | |
Variable	M	SD	M	SD	M	SD	M	SD
			Motivation					
Intrinsic goal orientation	3.69	1.28	3.79	1.11	3.94	1.43	5.23	0.90
Extrinsic goal orientation	4.69	1.50	4.86	1.40	4.91	0.85	5.16	0.88
Task value	4.29	1.20	4.14	0.10	4.52	1.38	5.39	0.90
Control of learning beliefs	4.63	1.03	4.83	1.40	5.25	1.05	5.27	0.76
Self-efficacy for learning and performance	3.99	1.15	4.07	1.43	4.99	0.10	3.90	1.08
Test anxiety	3.38	1.61	3.54	1.44	3.44	1.11	4.69	0.86
			Learning strategies					
Rehearsal	3.90	1.27	4.20	1.16	4.06	1.54	4.69	0.86
Elaboration	4.09	1.33	4.00	1.10	4.28	1.36	5.22	0.88
Organization	4.31	1.55	4.23	1.29	4.40	1.59	4.95	1.08
Critical thinking	3.46	1.32	3.64	1.25	3.81	1.39	4.87	0.95
Metacognitive self-regulation	4.06	1.14	4.27	1.11	4.55	1.12	5.24	0.64
Time and study environment	4.04	1.13	4.36	1.05	4.60	1.15	5.00	0.76
Effort regulation	3.90	1.43	3.94	1.29	4.73	1.51	5.38	0.90
Peer learning	3.04	1.29	2.90	1.51	3.49	1.64	4.51	0.76
Help seeking	4.35	1.52	4.14	1.63	4.02	1.53	4.28	0.94

and use of learning strategies. A nonsignificant Shapiro-Wilk test and Box's M test revealed that normality and homogeneity of variance and covariance matrices assumptions of MANOVA were met ($p > .05$).

Effect of PBL on Students' Self-Reported Motivation

The F ratio for MANOVA indicated that the posttest mean scores were statistically significant at the .05 level, $F(6, 54) = 3.99$, $p = .002$. That is, the experimental and control groups had statistically significant mean scores on the collective dependent variables of intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, and test anxiety. The multivariate eta squared of 0.31 (based on Wilks's lambda) implied that the magnitude of the difference between the groups was not small. That value indicated that 31% of multivariate variance of the dependent variables was associated with the treatment.

Because we obtained a statistically significant MANOVA F for the collective dependent variables, we conducted univariate ANOVAs to further understand how the two groups would be affected by the interventions regarding each of the dependent variables on posttest scores. Table 3 displays results of the univariate ANOVA analyses on students' motivation subscale scores. As shown in Table 3, a statistically significant mean difference existed between the groups with respect to intrinsic goal orientation and task value ($p < .05$)

When we examined the mean scores shown in Table 2, we found that the intrinsic goal orientation of students in the experimental group was higher than that of students in the control groups. Students in the experimental group tended to study biology for reasons such as challenge, curiosity, and mastery. For instance, although 60% of students in the experimental group agreed with the statement that "When I have opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade," the percentage of agreement in the control group was 37.7 when we used the high end of the scale. Moreover, students in the experimental group appeared to perceive biology as a more interesting, important, and useful course than their other courses because of a high mean score on the task value scale of the MSLQ. That finding also was apparent in the percentage of students who agreed with the statements in the scale. For example, whereas 86% of students in the experimental group agreed with the statement that "I think the course material in this class is useful for me to learn," only 61.3% of students in the control group agreed with that statement.

Effect of PBL on Students' Self-Reported Use of Learning Strategies

We conducted MANOVA to determine the effect of PBL on students' self-reported use of learning strategies. We found a statistically significant mean difference

between the experimental and the control groups regarding the collective dependent variables of rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, effort regulation, peer learning, and help seeking, $F(9, 51) = 2.40$, $p = .002$. On the basis of Wilks's lambda, the multivariate eta squared showed that 30% of multivariate variance of the dependent variables was associated with the treatment. That finding implied that the magnitude of the difference between the groups was not small.

Table 4 shows univariate ANOVA results for each dependent variable. The univariate ANOVAs for elaboration, critical thinking, metacognitive self-regulation, effort regulation, and peer learning were significant ($p < .05$). When we examined the mean scores shown in Table 2, we found that students in the experimental group had higher mean scores on these dependent measures. The experimental-group students appeared to use elaboration strategies and metacognitive self-regulatory strategies more than did the control-group students. For example, whereas 70% of students in the experimental group indicated their agreement with the statement that "I try to apply ideas from course readings in other class activities such as lecture and discussion," only 38.7% of students in the control group agreed with this statement. We noted similar results regard-

ing agreement with the statement that "I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying": 86.7% of the experimental group agreed, and only 61.3% of the control group agreed. In addition, students in the experimental group tended to apply previous knowledge to new situations to solve problems, reach decisions, or make critical evaluations regarding standards of excellence more than did students in the control group, as indicated by their responses on the critical thinking subscale of the MSLQ.

For instance, 60% of experimental-group students thought the statement that "I treat the course material as a starting point and try to develop my own ideas about it" reflected their thinking. However, only 32.2% of control-group students agreed with the statement. Students in the experimental group also tended to control their effort and attention when there were distractions or difficulties. For example, 83.3% of students in the experimental group indicated their agreement with the statement that "Even when course materials are dull and uninteresting, I manage to keep working until I finish." However, just 67.8% of students in the control group agreed with that statement. Students in the experimental group appeared to collaborate with their peers more than did students in the control group. For instance, 80% of the students in the experimental group

TABLE 3. Follow-Up Pairwise Comparisons for Motivation

Dependent variable	F	p	η^2
Intrinsic goal orientation	17.74	.000	.23
Extrinsic goal orientation	1.25	.268	.02
Task value	8.37	.005	.12
Control of learning beliefs	0.21	.646	.01
Self-efficacy for learning and performance	1.45	.234	.02
Test anxiety	2.69	.106	.04

Note. $df = 1$.

TABLE 4. Follow-Up Pairwise Comparisons for Learning Strategies

Dependent variable	F	p	η^2
Rehearsal	3.82	.055	.06
Elaboration	10.26	.002	.15
Organization	2.46	.122	.04
Critical thinking	11.92	.001	.17
Metacognitive self-regulation	8.45	.005	.13
Time and study environment	2.48	.121	.04
Effort regulation	4.23	.044	.07
Peer learning	9.56	.003	.14
Help seeking	0.67	.416	.01

Note. $df = 1$.

thought that the following statement reflected their behavior: "When studying for this course, I often set aside time to discuss the course material with a group of students from the class." For the control group, 38.7% of students believed that the statement reflected their behavior.

Furthermore, Figures 1 and 2 reveal that pre-MSLQ and post-MSLQ scores did not appear to change considerably for students in the control group. However, PBL appeared to improve experimental-group students' use of various learning strategies—intrinsic goal orientation and task value.

Relation Between Students' Self-Reported Motivation and Self-Reported Use of Learning Strategies

We computed zero-order correlations to determine the relation among scores on the motivation subscales and learning strategies subscales of the MSLQ. Table 1 shows that higher levels of intrinsic goal orientation and task value correlated with higher levels of rehearsal strategy use ($r = .550$ and $r = .487$, respectively), elaboration strategy use ($r = .712$ and $r = .740$, respectively), organization strategy use ($r = .618$ and $r = .574$, respectively), critical thinking ($r = .644$ and $r = .668$, respectively), metacognitive self-regulation ($r = .687$ and $r = .657$, respectively), management of time and study environment ($r = .567$ and $r = .691$, respectively), effort regulation ($r = .504$ and $r = .705$, respectively), peer learning ($r = .548$ and $r = .479$, respectively), and help seeking ($r = .285$). Moreover, higher levels of control of learning beliefs and self-efficacy for learning and performance were related to higher levels of

use of all learning strategies except help seeking ($r = .196$ and $r = .216$, respectively). Extrinsic goal orientation was associated with only metacognitive self-regulation ($r = .261$) and peer learning ($r = .359$).

In addition to those results, we found no statistically significant relationship between test anxiety and use of any of the learning strategies. The results, in general, were consistent with findings in the literature: self-efficacy, learning-goal orientation, and the beliefs that the task is interesting and important are related positively to reports of cognitive, metacognitive, and self-regulatory strategies (Ames & Archer, 1988; Meece et al., 1988; Neber & Schommer-Aikins, 2002; Nolen, 1988; Pintrich & DeGroot, 1990).

Discussion

We examined the effect of PBL and traditional instruction on students' self-reported motivation (intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, test anxiety) and self-reported use of learning strategies (rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, effort regulation, peer learning, help seeking).

Before the treatment, we administered the MSLQ to students in the experimental and control groups to determine whether the groups differed with respect to the collective dependent variables. MANOVA results revealed no preexisting differences between the two groups regarding stu-
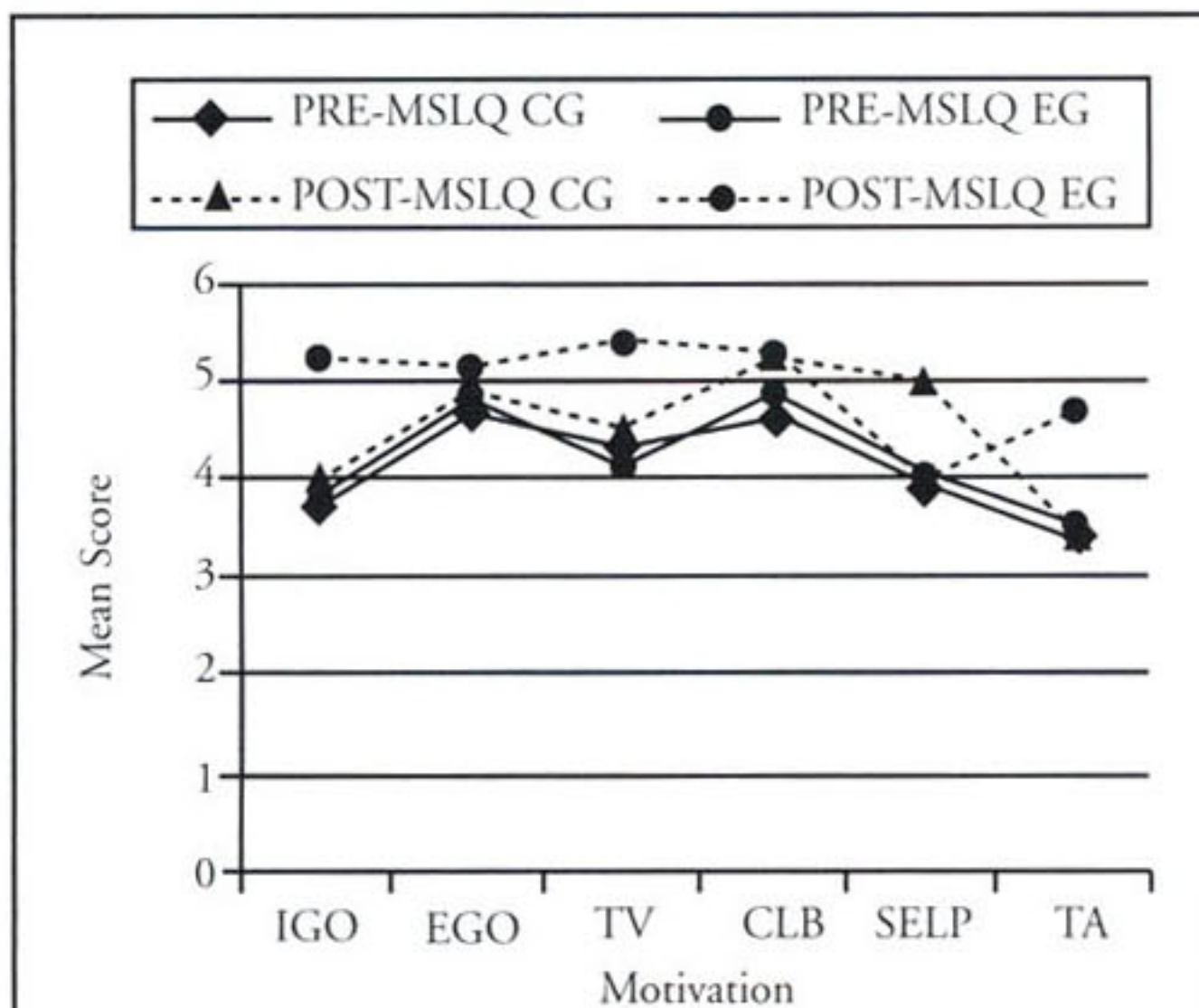
FIGURE 1. Pre-MSLQ (Motivated Strategies for Learning Questionnaire) and post-MSLQ scores with respect to motivation. CG = control group; EG = experimental group; IGO = intrinsic goal orientation; EGO = extrinsic goal orientation; TV = task value; CLB = control of learning beliefs; SELP = self-efficacy for learning and performance; TA = test anxiety.
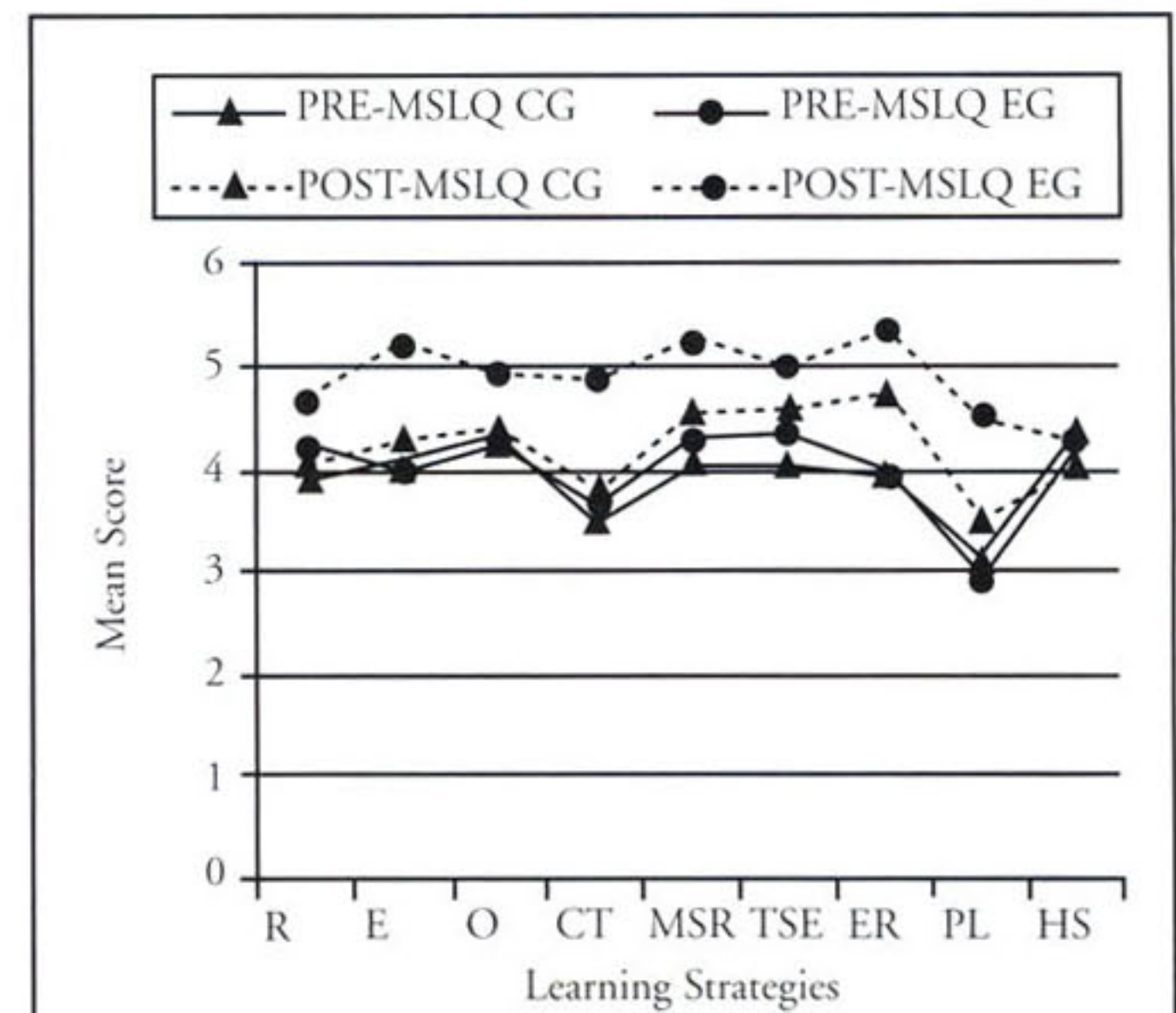
FIGURE 2. Pre-MSLQ (Motivated Strategies for Learning Questionnaire) and post-MSLQ scores with respect to learning strategies. CG = control group; EG = experimental group; R = rehearsal; E = elaboration; O = organization strategies; CT = critical thinking; MSR = metacognitive self-regulation; TSE = time and study environment; ER = effort regulation; PL = peer learning; HS = help seeking.

dents' motivation and learning strategies ($p > .05$). Determining the similarity between students in the experimental and control groups regarding dependent variables was a good starting point for the treatment. Experimental-group students learned PBL, and control-group students received traditional instruction with traditional textbooks. Results revealed that PBL students, more than control-group students, tended to participate in a task for reasons such as challenge, curiosity, and mastery, and they appeared to perceive biology as interesting, important, and useful.

Gordon and colleagues (2001) similarly found that PBL students value the student-centered nature of PBL, including information seeking, high levels of challenge, group work, and personal relevance of the material. According to Evenson and Hmelo (as cited in Galand et al., 2003), PBL fosters students' motivational beliefs, self-regulation strategies, and learning strategies. Although we showed that PBL had a positive influence on students' intrinsic goal orientation and task value, it did not affect control of learning beliefs, self-efficacy for learning and performance, and test anxiety perhaps because we implemented PBL in just 6 weeks. That time period might not be adequate for students to develop the beliefs that their efforts to learn will result in positive outcomes. Moreover, because PBL was a student-centered, novel approach, students might have had concerns about their performance on the examinations, resulting in test anxiety. Post-MSLQ results regarding test anxiety revealed that although not statistically significant, the scores of experimental-group students were higher than were those of control-group students, indicating a higher level of test anxiety in the PBL group.

Regarding learning strategies, we found that PBL enhances students' use of elaboration strategies, critical thinking, metacognitive self-regulation, effort regulation, and peer learning. Galand and colleagues (2003) showed that PBL students use more deep-processing strategies (especially criticizing) and fewer surface-processing strategies (especially rehearsing). Furthermore, the researchers reported that PBL students use more adaptive strategies (especially information searching and monitoring) than do students from a traditional curriculum. As indicated by students' responses to the MSLQ, PBL students used cognitive strategies, such as paraphrasing, summarizing, and generative note taking, which helped them integrate and connect new information, more than did control-group students. Moreover, the extent to which students applied previous knowledge to new situations to solve problems and reach decisions was higher for PBL students than for control-group students. In addition, PBL students appeared to use metacognitive self-regulatory activities, such as planning and monitoring, more than did control-group students.

Glaser (as cited in Karabulut, 2002) claimed that PBL students analyze and discuss problems so that they can (a) realize gaps in their knowledge base, (b) determine their strengths and weaknesses, (c) control their own learning, and (d) develop self-regulatory skills. According to Perry

and colleagues (2002), students engage in self-regulated learning in classrooms where they (a) receive opportunities to participate in complex, open-ended activities, (b) make choices that influence their learning, and (c) evaluate themselves and others. Moreover, the researchers reported that because of instrumental support that teachers provided through questioning, clarifying, correcting, elaborating, modeling, and creating an environment in which students can support one another through collaborating, sharing ideas, and problem solving, students demonstrated attitudes and actions expected from independent, academically effective learners—metacognition, intrinsic motivation, and strategic action.

According to Karabulut (2002), PBL creates an environment in which students actively participate in the learning process, take responsibility for their own learning, and become better learners in terms of time management skills and ability to identify learning issues and to access resources. Perry and colleagues proposed that one of the characteristics of PBL classes contributing to self-regulated learning is cooperation among students working in small groups. In the present study, student responses to the MSLQ revealed that PBL students tended to cooperate with their peers and to appreciate the importance of cooperation more than did the control-group students; informal talks with students verified this finding. Most of the students indicated that while discussing and listening to their friends in the PBL groups, they revised their ideas and realized the deficiencies in their thoughts. That was a metacognitive process that helped students reflect on their thinking.

King (2002) claimed that some peer-learning tasks, such as (a) working together to solve ill-structured problems, (b) working on problems with several possible solutions, (c) analyzing and integrating ideas that reach beyond presented material to build new knowledge, (d) making decisions within groups, and (e) assessing learning demand a highly complex level of cognitive processing. We propose that presentations made at the beginning of each PBL session and student reports regarding what they learned as a result of PBL activity in relation to the patient's case further helped students monitor their learning, evaluate themselves, and set goals for further learning. In those reports, students critically reviewed the information about the patient, revised their hypotheses continuously, and presented their opinions about the problem on the basis of their previous knowledge, as well as new knowledge acquired from independent study.

According to Torp and Sage (1998), the reflective nature of debriefing is a metacognitive examination of solutions and loose ends, thinking back along the path of the student journey. Paris and Paris (2001) claimed that PBL, which places responsibility on students to (a) find information, (b) coordinate actions and persons, (c) realize goals, and (d) monitor understanding can be used by teachers to support the development of self-regulated learning. That development is important because students who can

initiate learning tasks, set their goals, decide on appropriate strategies for setting goals, then monitor and evaluate their own progress are likely to achieve at higher levels than are students who rely on teachers to perform these functions (Risemberg & Zimmerman, 1992).

Our results revealed that PBL enhances the self-regulatory skills of 10th-grade students. Therefore, we suggest that high school teachers use PBL to improve students' academic performance by going beyond teaching content to teaching students how to learn. PBL is different from other instructional strategies because it places students in the center of an authentic, ill-structured problem with no correct answer (Sage, 1996). The problem stimulates students to carry out investigations to satisfy their need to know, then links the new knowledge into their thinking and decision-making processes (Gordon et al., 2001). Therefore, as students struggle with a problem, they develop the skill to critically evaluate and acquire new knowledge, and attain a commitment to life-long learning (Curry, 2002).

Although we did not intend to investigate the effect of PBL instruction on students' academic achievement along with their self-regulatory skills, we suggest this focus as a next step for further study.

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