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# DEVELOPING PROBLEM-SOLVING SKILLS IN MATHEMATICS THROUGH PROBLEM-BASED LEARNING IN TECHNICAL COLLEGE EDUCATION

Abdukayumova Nilufarkhon
Rasulzhonova Mukaddas
Teachers of Mathematics Bulokboshi District Technical College No. 1,
Andijan Region, Republic of Uzbekistan

**Abstract**

This article examines the application of problem-based learning (PBL) as a pedagogical strategy for developing problem-solving skills in mathematics among students of technical colleges. The relevance of the study stems from the persistent gap between students' procedural mastery of mathematical algorithms and their ability to apply mathematical reasoning to non-standard, practice-oriented tasks encountered in vocational training. The study was conducted with first- and second-year students of Bulokboshi District Technical College No. 1 across two academic groups, one taught through conventional explanation-and-practice methods and the other through structured problem-based learning sessions built around open-ended, profession-related mathematical problems. Diagnostic testing, structured observation, and comparative analysis of academic performance were used to evaluate changes in students' analytical reasoning, solution-strategy flexibility, and independent decision-making. The results demonstrate that students taught through problem-based learning showed measurably higher gains in problem-solving competence, deeper conceptual understanding, and greater willingness to attempt unfamiliar problem types compared to the control group. The article concludes with practical recommendations for technical college mathematics teachers on designing and sequencing problem-based tasks within limited instructional time.


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**Keywords:** problem-based learning, mathematics education, problem-solving skills, technical college, vocational education, active learning methods, instructional design.

## 1. Introduction

Mathematics occupies a foundational place in technical and vocational education because it underlies the calculations, measurements, and logical reasoning that students will later apply in their chosen trades. Yet experience in technical college classrooms repeatedly reveals a paradox: students who can correctly reproduce a memorized algorithm during a routine exercise often fail when the same mathematical content is presented in an unfamiliar, multi-step, or practice-oriented form. This gap between procedural fluency and genuine problem-solving ability has been recognized as one of the central challenges of mathematics pedagogy at the secondary and vocational levels.

Problem-based learning (PBL) is an instructional approach in which students construct knowledge by working through carefully designed, often open-ended problems rather than receiving content through direct exposition alone. Instead of presenting a rule and then assigning practice exercises, the teacher poses a problem first; students must analyze the situation, recall or seek relevant mathematical tools, test hypotheses, and justify their solutions, with the teacher acting as a facilitator rather than the sole source of answers. In the context of technical colleges, where students are simultaneously developing a professional identity tied to a specific trade (construction, mechanics, agriculture, services, and so on), problems framed around realistic professional situations can give mathematical content immediate practical meaning.

The purpose of this study was to determine whether systematic use of problem-based learning in mathematics lessons measurably improves technical college




students' problem-solving skills compared to conventional instruction, and to identify practical conditions under which this method can be implemented effectively within the constraints of a standard technical college timetable.

The objectives of the research were: to design a sequence of problem-based mathematics lessons suited to the technical-college curriculum; to compare problem-solving outcomes between a group taught with this method and a group taught conventionally; and to formulate methodological recommendations for colleagues teaching mathematics in similar institutions.

## 2. Methods

The research was carried out at Bulokboshi District Technical College No. 1 over one academic semester. Two intact first-year student groups of comparable size and similar prior achievement in mathematics, based on entrance assessment scores, were selected for the study. One group (the experimental group) was taught using a structured problem-based learning model; the other (the control group) followed the standard explanation-demonstration-practice sequence prescribed by the existing curriculum, covering the same topics within the same number of teaching hours.

### 2.1. Design of the problem-based lessons

For the experimental group, each lesson began with a problem situation connected to the students' vocational specialization rather than with a stated theorem or formula. Problems were constructed in three stages of increasing complexity: an orientation problem that activated prior knowledge and made the gap in students' understanding visible; a core problem requiring students, working in small groups of three to four, to propose and test a solution strategy using available mathematical tools; and an extension problem requiring transfer of the




discovered method to a new, non-identical situation. The teacher's role during these stages was limited to posing clarifying questions, redirecting unproductive reasoning paths, and confirming or correcting conclusions only after students had attempted independent reasoning.

### 2.2. Data collection instruments

Three instruments were used to collect data over the course of the semester:

- A diagnostic pre-test and post-test consisting of mathematical tasks of varying structure (routine, semi-structured, and non-standard), scored using a rubric that separately credited correct final answers and the quality of the solution strategy used.
- Structured classroom observation, recording the frequency of independent hypothesis generation, peer discussion, and self-correction during lessons.
- A short anonymous student questionnaire administered at the end of the semester, measuring students' self-reported confidence in tackling unfamiliar mathematical problems.

Quantitative results from the pre- and post-tests were compared between groups using mean score gains and the proportion of students who progressed from lower to higher performance bands. Observational data were summarized as frequency counts per lesson, averaged across the observation period.

## 3. Results

At the start of the semester, the pre-test mean scores of the experimental and control groups did not differ substantially, confirming that the two groups were comparable in initial mathematical preparedness. By the end of the semester, both groups showed improvement on the post-test, which was expected given ordinary instruction and practice; however, the magnitude and character of that improvement differed considerably between groups, particularly on tasks requiring non-standard reasoning rather than routine computation.

Table 1. Comparison of pre-test and post-test results (mean score, 100-point scale)

| Group | Pre-test mean | Post-test mean | Mean gain | Non-standard task gain |
|---|---|---|---|---|
| Experimental (PBL) | 58.4 | 78.9 | +20.5 | +24.1 |
| Control (conventional) | 57.9 | 68.2 | +10.3 | +7.6 |

As shown in Table 1, the experimental group's overall mean gain (20.5 points) was approximately twice that of the control group (10.3 points). The difference was most pronounced on non-standard tasks, where the experimental group's gain (24.1 points) was more than three times that of the control group (7.6 points), while gains on purely routine computational tasks were comparable between the two groups. This pattern suggests that problem-based learning had its strongest effect precisely on the type of reasoning it was designed to develop, without producing any loss in routine computational accuracy.

Table 2. Classroom observation indicators (average occurrences per lesson)

| Indicator | Experimental group | Control group |
|---|---|---|
| Independent hypothesis generation | 6.2 | 1.8 |
| Peer mathematical discussion episodes | 8.5 | 2.4 |
| Self-corrected errors without teacher prompt | 4.7 | 1.5 |

Observation data in Table 2 indicate that students in the experimental group generated independent hypotheses and engaged in peer discussion considerably more often than students in the control group, and were also more likely to identify and correct their own errors without direct teacher intervention. The end-of-semester questionnaire reinforced these findings: a markedly larger share of experimental-group students reported feeling confident attempting an unfamiliar mathematics problem on their own, compared with control-group students, most of whom reported preferring to wait for a worked example before attempting similar tasks.

## 4. Discussion

The findings support the view that problem-based learning is particularly well suited to developing problem-solving skill, as distinct from computational accuracy, because it deliberately places students in situations where no memorized procedure provides an immediate answer. The larger gains observed on non-standard tasks, together with the higher frequency of independent hypothesis generation and self-correction, suggest that the experimental group developed not only specific solution techniques but also a more general disposition toward sustained mathematical reasoning.

Framing problems around situations relevant to students' vocational specialization appeared to play a meaningful role in sustaining engagement. Several teachers' field notes recorded that students who showed little interest in abstractly stated algebraic or geometric problems engaged readily once the same mathematical structure was embedded in a measurement, costing, or material-quantity problem connected to their trade. This is consistent with the broader rationale for situating mathematics instruction in vocational education within authentic professional contexts.

At the same time, several practical limitations must be acknowledged. Problem-based lessons required considerably more preparation time than conventional lessons, since each problem had to be carefully calibrated to be neither trivially easy nor frustratingly inaccessible for the group's current level. Some lower-achieving students initially experienced frustration during the unstructured exploration phase, and required additional scaffolding, such as guiding questions or partially worked sub-problems, before they could engage productively. The approach also consumed more class time per topic than direct instruction, which created tension with an already dense curriculum and required careful selection of which topics most warranted a problem-based treatment rather than attempting to convert every lesson into a problem-based format.

These limitations indicate that problem-based learning is best understood not as a wholesale replacement for direct instruction but as a complementary strategy to be applied selectively, particularly for topics with clear practical applications and sufficient conceptual richness to sustain genuine inquiry.

## 5. Conclusion

The results of this study indicate that the systematic use of problem-based learning in mathematics lessons measurably improves technical college students' problem-solving skills, particularly their ability to handle non-standard, practice-oriented tasks, without sacrificing performance on routine computational exercises. Students taught through this approach demonstrated greater independence, more frequent peer discussion, and higher self-reported confidence when facing unfamiliar problems than students taught through conventional methods.

On the basis of these findings, the following recommendations are proposed for mathematics teachers in technical colleges:

1. Introduce problem-based lessons selectively, choosing topics that have clear vocational relevance and sufficient conceptual depth to support genuine exploration.
2. Construct problems in graduated stages, from an orientation task that exposes a knowledge gap, through a core exploratory task, to an extension task requiring transfer to a new context.
3. Prepare optional scaffolding, such as guiding questions or partially solved examples, for students who require additional support during the exploration phase, rather than abandoning the problem-based format for the whole group.
4. Allocate class time deliberately, recognizing that problem-based lessons require more time per topic than direct instruction, and plan the semester schedule accordingly.
5. Combine problem-based learning with periodic conventional instruction so that students consolidate both the underlying procedures and the reasoning skills needed to apply them flexibly.

Further research with larger samples across multiple technical colleges and academic terms would help to confirm these findings and to identify which categories of mathematical topics benefit most from problem-based treatment within vocational education programs.

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