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Effectiveness of Problem-Based Learning Models in Improving Students' Collaborative Ability on Practical Activities of the Solution Colligative Properties

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Abstract
The study aims to evaluate the effectiveness of the Problem-based Learning model in improving the students' ability to collaborate on practical activities related to the solution colligative properties. The research design uses quasi-experimental methods with control groups and experiments. The study sample consisted of 60 XI IPA class students selected using purposive sampling techniques, with 30 students in the experimental group and 30 in the control group. The research instruments include a test of collaborative abilities, a sheet of observations on collaborative activities, and an elevator of student responses. The results showed that the average pre-test scores of students' collaboration ability in experimental and control groups were relatively the same. Still, there was a significant improvement in the experimental group's post-test score after applying the Problem-Based Learning model. The pair t-test results showed a substantial improvement in both groups, but the increase in the experimental group was significantly higher ($t(30) = 12.45$, $p < 0.05$) compared to the control group ($t(30) = 3.21$, $p < 0.05$). Independent t-tests showed significant differences between the experimental and control groups after treatment ($t(60) = 6.34$, $p < 0.05$). Observations during the practice showed that students in the experimental group were more active in communicating, sharing tasks, collaborating, and solving problems than in the control group. In addition, the student response raise showed that the majority of students responded positively to the Problem-Based Learning model, with a high average score on interesting and enjoyable aspects (4.5), boosting motivation (4.6), facilitating the understanding of concepts (4.4), and enhance the ability to collaborate (4.7).

Keywords: *Collaborative Ability, Colligative Properties of Solutions, Effectiveness*, *Problem-Based Learning*

INTRODUCTION

In today's era of globalization and technology, the ability to collaborate has become one of the most essential skills for students (Trilling & Fadel, 2009; Wentzel & Watkins, 2002). Collaboration enables students to work effectively in teams, solve problems together, and develop interpersonal skills essential for success in life and career in the 21st century (Dede, 2010; Wagner & Compton, 2012). Various studies show collaborative skills are closely linked to academic and professional success (Y. Chen & Zhu, 2018; Pulgar et al., 2020). Therefore, the modern education system is working hard to implant these skills in learning (OECD, 2019). One of the main objectives in education is to develop a wide range of students' competencies, including collaborative skills, that are crucial in dealing with the challenges of the 21st century (Fitriyah et al., 2023). Collaborative skills include skills to work together, share responsibility, and appreciate the opinions of others, all of which are key elements in today's working environment and social life (Johnson & Johnson, 1999).

Although the importance of collaboration has been widely recognized, many schools still face the challenge of developing these skills in students (Friend et al., 2016; Schleicher, 2018). According to the OECD (2019) report, approximately 35% of schools worldwide face challenges in integrating collaborative skills into their curriculum. The primary factors contributing to these difficulties include the lack of teacher training in collaborative teaching methods and limited technological support for collaborative learning. A compact curriculum, traditional teacher-centered teaching methods, and a lack of resources impede effective collaborative integration into the teaching-learning process (Fullan, 2015; Oecd, 2009; Viczko, 2016). Besides, variation in students' abilities and motivation also complicates managing a collaborative classroom (Chen et al., 2019; Saadati & Reyes, 2019; Tosun & Taskesenligil, 2013; Wismath & Orr, 2015).

Learning that focuses solely on the absorption of theoretical knowledge is often less effective in developing collaborative skills (Bransford, 2000; Darling-Hammond et al., 2005). Therefore, more interactive and contextual learning models, such as Problem-Based Learning, are needed. Problem-based learning has emerged as an innovative solution for addressing these challenges. Problem-based learning is one of the models that emphasizes real-life problem-based learning relevant to student life (Schmidt et al., 2011). Problem-based learning is designed to encourage students to be active in the learning process through collaborative problem-solving (Barrows, 2006).

In Problem-Based Learning, students are given complex real-life problems and must work in groups to find solutions (Hmelo-Silver, 2004). This process not only helps students master academic content but also develops critical thinking, communication, and collaborative skills (Savery, 2015). Problem-based learning differs from traditional one-way teaching methods, where teachers are the primary source of information. Instead, Problem-based Learning requires students to find information independently and discuss and collaborate with their friends to solve problems (Barrows, 2006). Teachers act as facilitators who guide and provide support when needed. In this way, Problem-Based Learning allows students to learn how to work in teams, share tasks, resolve conflicts, and achieve common goals (Indahsari & Habiddin, 2024).

In the context of chemistry education, especially in matters of colligative properties of solutions, the material is characterized by its theoretical and experimental nature, requiring students to understand concepts such as osmotic pressure, boiling point elevation, freezing point depression, and vapor pressure lowering (Cerezo, 2004; Eberlein et al., 2008). These concepts often involve intricate calculations and the interpretation of experimental data, making them well-suited for Problem-Based Learning (PBL). The practice of solute colligative properties is one of the most complex subjects in the chemistry curriculum (Petrucci & Harwood, 2007). This material requires a profound theoretical understanding and practical skills in conducting experiments and analyzing results (Davis et al., 2014; Zumdahl & Zumdahl, 2013). Through PBL activities, students collaboratively design and conduct experiments, analyze results, and engage in discussions to solve problems related to colligative properties. This approach helps students develop a deeper understanding of the material and enhances their collaborative abilities by promoting teamwork, communication, and shared problem-solving responsibilities (Albanese & Mitchell, 1993).

Many studies have demonstrated the effectiveness of the Problem-Based Learning model in improving student skills. For example, Problem-based Learning can improve critical thinking and problem-solving skills. In addition, research by Gijbels et al., (2005) concluded that Problem-Based Learning is also effective in increasing learning motivation and student involvement in the learning process. However, special studies that evaluate the effectiveness of the Problem-Based Learning model in improving students' ability to collaborate on chemistry practices, especially on solvent colligative properties, are still limited. Therefore, this study aims to explore and evaluate how the Problem Based Learning model can be applied in the practicum of the colligative properties of solutions to enhance students' collaborative abilities.

METHOD

The study uses a quantitative approach to experimental design to evaluate the effectiveness of the Problem-Based Learning model in improving students' ability to collaborate on practical activities of the solution colligative properties. The experimental design used is quasi-experimental, with control and experimental groups (van Hezewijk, 1965).

Population and Samples

The population in this study is XI IPA class students in SMA A. Wahid Hasyim Tebuireng Jombang. The research samples were taken using purposive sampling techniques, and two classes were selected as samples: one class was an experimental group using a Problem-based Learning model, and one was a control group using conventional learning models. Each class consists of 30 students, so the total sample of research is 60 students.

Research Instruments

The instruments used in this study are collaborative skill test, observation sheet and elevate student response.

Collaborative Skill Test

This test was developed to measure students' ability to collaborate before and after treatment. The test consists of 20 questions covering aspects of collaboration such as communication, collaboration, shared responsibility, and problem-solving.

Observation Sheet

The observation sheet is used by researchers and research assistants to observe and record student collaborative activities during internship activities. It includes adapted indicators of collaboration based on Johnson & Johnson (1999). Table 1 describes the indicators and the corresponding questions/statements in the observation sheet.

Elevate Student Response

This is used to collect data on student responses and perceptions regarding applying the problem-based learning model. The lift consists of 15 items with a Likert scale.

Table 1. Collaboration Indicators and Questions in the Observation Sheet

Indicator	Question/Statement
Positive Interdependence	"Students work together to achieve a common goal."
Individual Accountability	"Each student contributes their part to the group task."
Face-to-Face Interaction	"Students actively discuss and share ideas during the activity."
Social Skills	"Students demonstrate effective communication and conflict resolution skills."
Group Processing	"Students evaluate their group's performance and identify ways to improve collaboration in the future."

Research Procedures

Preparation Stage

1) Preparing a Learning Implementation Plan (RPP) for experimental groups with a Problem-Based Learning model and control groups with conventional models.
2) Developing research instruments and conducting validity and reliability tests.
3) Conducting research permits to associated schools.

Implementation phase

1) Pre-test: perform a test of the collaborative abilities of both groups (experimental and control) before treatment.
2) Implementation of a Problem-Based Learning model: A group of experiments is given learning with a Problem-Based Learning model for four weeks, with a time allocation of two hours of lessons per week. Students in this group are given real problems related to the colligative nature of the solution to be solved collaboratively.
3) Implementation of Conventional Learning: The control group is given conventional learning with the method of lecture and answer questions about the colligative properties of solutions.
4) Observation: During the internship activities, student collaborative activities are observed using the observation sheet.
5) Post-test: After the treatment, both groups were given the same collaborative ability test as the pre-test.

Data Analysis Stages

1) Data obtained from the pre-test and post-test are analyzed using statistical tests to measure improved student collaboration skills. The tests used include a t-test for pairing samples (paired sample t-test) to identify significant differences between pre-tests and post-tests in the same group and t-tests for independent samples to compare the difference between experimental and control groups.
2) Data from the observation sheet is analyzed descriptively to describe student collaborative activity during the internship.
3) Data from student response lifts are analyzed using descriptive statistics to determine student perceptions of the Problem-based Learning model.

RESULTS AND DISCUSSION

The study aims to evaluate the effectiveness of the problem-based learning model in improving the student's ability to collaborate on practical activities related to the solution colligative properties. The study results were measured through pre-test and post-test collaborative skills, observation of collaborative activity, and elevation of student responses. Data analysis is carried out using quantitative methods with relevant statistical tests.

Pre-test and Post-test results

Table 2. Average Pre-test and Post-test Scores of Student Collaborative Ability

Group	Average Pre-test	Average Post-test
Experiment	65.3	85.7
Control	64.8	70.2

The results showed that the average pre-test scores of students' ability to collaborate in the experimental and control groups were relatively similar. After applying the Problem-Based Learning model, there was a significant improvement in the post-test score of the experimental groups compared to the control groups.

Statistical tests

Paired Sample t-test

Experimental Group: $t(30) = 12.45$, $p < 0.05$

Control Group: $t(30) = 3.21$, $p < 0.05$

Pair-test results showed a significant improvement in students' collaborative abilities in both the experimental and control groups. However, the increase in experimental groups was much higher.

Independent Sample t-test

$t(60) = 6.34, p < 0.05$

Independent t-test results showed that there were significant differences between the experimental group and the control group after treatment, with experimental groups having significantly higher post-test scores.

Collaborative Activity Observation Results

Observations were conducted during the internship to measure the student's collaborative activity. Here are the results of observations in the form of a percentage of student collaborative activity:

Table 3. Student Collaborative Activity Percentage

Activity	Experimental Groups (%)	Control Group (%)
Communication	85	65
Share Tasks	80	60
Collaboration	90	70
Solving Problems	88	68

The observation results showed that students in the experimental group were more active in communicating, sharing tasks, collaborating, and solving problems compared to students in control groups.

Student Response Results

Students' response to the application of the Problem Based Learning model showed that the majority of students responded positively. Here's the result in the form of an average score on the Likert scale (1-5):

Table 4. Average Student Response Score

Item	**Average Score**
Interesting and fun	4.5
Increasing motivation	4.6
Facilitating understanding	4.4
Increased collaboration	4.7

Student responses show that students find the Problem Based Learning model interesting, improves learning motivation, facilitates understanding of concepts, and is highly effective in improving collaborative skills.

DESCRIPTION

The results of this study show that the Problem Based Learning model is more effective in improving students' collaborative abilities compared to conventional learning models.

Pre-test and Post-test Data Analysis

Pre-test data showed that students' ability to collaborate in both groups before applying learning methods was relatively the same. However, after applying the Problem Based Learning model, the experimental group showed a significant improvement in post-test scores. This improvement

shows that the Problem Based Learning model is effective in improving students' ability to collaborate. The findings are consistent with previous research that suggested that a Problem Based Learning model can improve students' collaborative skills and involvement in learning (Gijbels et al., 2005; Hmelo-Silver, 2004).

Collaborative Activity Observation Analysis

Observations during the practice showed that students in the experimental group were more active in collaboration than in the control group. This finding aligns with the implemented Problem-Based Learning (PBL) syntax, which includes the following phases:

a. Problem Identification Phase: During this phase, students worked collaboratively to define the problem presented in the scenario. Indicators such as positive interdependence and face-to-face interaction were evident, as students shared initial ideas and clarified the problem collectively.
b. Self-Directed Learning Phase: In this phase, students individually researched relevant information before reconvening with their group. Indicators like individual accountability were strengthened, as each member contributed specific knowledge to the group discussion.
c. Solution Formulation Phase: Students engaged in collaborative brainstorming to propose solutions. Here, task-sharing and effective communication were prominent, as students divided responsibilities and discussed various approaches.
d. Reflection and Evaluation Phase: Students reflected on their group's performance and the effectiveness of their solutions. This phase highlighted the group processing indicator, as students collectively assessed their teamwork and identified areas for improvement.

These phases collectively sharpened collaborative indicators such as communication, task-sharing, problem-solving, and accountability. The structured approach provided by the PBL model created a conducive learning environment for students to develop these skills in real terms.

Analysis of elevated student response

The positive response of students to the Problem-Based Learning (PBL) model shows that students feel more motivated and better supported in understanding the material through this method. The specific items assessed in the student response sheet and their relation to the PBL syntax are described below:

a. Interesting and Fun: Students found the PBL model engaging because of its interactive nature. During the Problem Identification Phase, students collaborated to explore real-world problems, making the learning process more enjoyable and meaningful.
b. Increasing Motivation: The collaborative aspects of PBL, particularly in the Solution Formulation Phase, increased students' intrinsic motivation. By working together to propose solutions, students felt a sense of accomplishment and purpose, which encouraged active participation.
c. Facilitating Understanding: The Self-Directed Learning Phase allowed students to independently research and then share their findings with the group. This process facilitated a deeper understanding of the material, as students connected theoretical knowledge with practical applications.
d. Increased Collaboration: Throughout the entire PBL process, but especially during the Reflection and Evaluation Phase, students worked closely with peers to assess their group's performance. This phase emphasized teamwork and mutual support, sharpening collaborative skills.

These findings demonstrate that the PBL model supports students in developing conceptual understanding and fosters important social skills and engagement in learning activities. The

structured approach provided by PBL aligns with these items, ensuring a holistic learning experience that is both enjoyable and effective (Barrows, 2006; Gallagher et al., 1992).

CONCLUSIONS

The problem-based learning model has effectively improved students' ability to collaborate on practical activities with solution-colligative properties. Applying the Problem-based Learning model significantly improved student collaborative skills compared to conventional learning models. In addition, the student's response to the Problem-Based Learning model was very positive, showing that this method engages, motivates, and facilitates the understanding of concepts.

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