DEVELOPMENT AND IMPLEMENTATION OF ANDROID-BASED *COLEEGA* APPLICATION WITH REPRESENTATION LEARNING CYCLE MODEL: AN EFFORT TO IMPROVE REPRESENTATION COMPETENCE IN COLLIGATIVE PROPERTIES OF SOLUTION

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Abstract. *This study investigates the effectiveness of Coleega, an Android-based application integrated with the Representation Learning Cycle (RLC) model, in enhancing students' representational competence on colligative properties of solutions. The RLC model, adapted from Problem-Based Science, structures learning into six phases: orientation, questioning, planning, execution, analysis, and presentation. Conducted at a senior high school in East Java with 68 students selected via cluster random sampling, the study employed pretests and posttests to measure conceptual understanding and representational skills. Validation confirmed feasibility (Aiken's V = 0.74) and readability (92%). Effectiveness was demonstrated by independent t-test (p < 0.001), showing significantly higher posttest scores in the experimental group (M = 87.94) compared to the control (M = 80.94). Findings highlight the novelty of embedding RLC into mobile technology, demonstrating that Coleega is both feasible and effective in strengthening representational competence in chemistry learning*.

Keywords: *conceptual understanding, chemical representations, representational competence, representation learning cycle, android-based applications*

INTRODUCTION

Conceptual understanding is a critical determinant of success in chemistry learning. Chemistry differs from other sciences such as biology, physics, and mathematics because it requires the integration of conceptual knowledge the meaning, theory, and properties of chemical phenomena with algorithmic knowledge, which involves mathematical procedures and symbolic representation [1]. When students struggle with fundamental concepts, they often face difficulties in mastering more advanced.

Chemistry learning is characterized by three levels of representation: macroscopic, sub-microscopic, and symbolic [2]. These levels are essential for building complete mental models that allow students to connect observable phenomena with molecular explanations and symbolic equations [3]. However, many students encounter challenges in navigating these representations, particularly in the topic of colligative properties of solutions, which demands both conceptual and algorithmic mastery. Studies have reported persistent misconceptions and errors in this area, especially in freezing point depression and vapor pressure lowering [4-6].

To address these challenges, the notion of representational competence has become central. Representational competence refers to the ability to interpret, translate, and connect different forms of chemical representation [7]. It encompasses five levels, ranging from interpreting meaning to establishing relationships between representations and concepts [8].

In response to the need for innovative learning strategies, this study introduces ***COLEEGA***, an Android-based application designed to integrate the Representation Learning Cycle (RLC) Model [9]. This model consists of six interconnected phases orientation, posing questions, planning, execution, analysis, and presenting findings each emphasizing the use of multiple representations such as diagrams, molecular models, and symbolic equations. By embedding this cycle into a digital platform, *COLEEGA* aims to provide students with interactive, accessible, and systematic learning experiences.

The choice of an Android-based application is grounded in students' everyday use of mobile devices and the proven effectiveness of electronic media in enhancing chemistry learning outcomes. Previous studies have shown that mobile applications can simplify abstract chemical concepts, increase student engagement, and receive positive responses from both learners and educators [10].

Therefore, the purpose of this research is to develop and implement *COLEEGA*, an Android-based application employing the Representation Learning Cycle Model, as an effort to improve students' conceptual understanding, chemical representation skills, and representational competence in the topic of colligative properties of solutions. This article presents the theoretical foundation, the development process of the application, and the results of its implementation, highlighting its effectiveness in fostering meaningful and representationally rich chemistry learning.

METHODS

This study employed a research and development (R&D) approach to produce Coleega, an Android-based application designed to facilitate learning of colligative properties through the Representation Learning Cycle (RLC) model. The process integrated quantitative and qualitative methods within the ADDIE framework (Analyze, Design, Development, Implementation, Evaluation) as outlined by Lee and Owens [11]. Research participants comprised 68 students from two science classes at a senior high school in Banyuwangi, East Java.

Stage 1 – Analyze

A needs analysis examined curriculum requirements, learning outcomes, and existing instructional materials, highlighting persistent challenges in representational competence. Teacher interviews confirmed the inadequacy of current resources and reinforced the necessity of embedding the RLC model into digital teaching materials.

Stage 2 – Design

A prototype was developed to align with the independent curriculum and assessment guidelines, emphasizing representational competencies across macroscopic, sub-microscopic, and symbolic domains. Initially created using Google Sites, the prototype was subsequently converted into an Android application to enhance accessibility and usability.

Stage 3 – Development

Expert validation by two chemistry lecturers assessed content accuracy, alignment with learning outcomes, clarity of representation, and conformity with RLC syntax. Validation combined qualitative feedback with quantitative ratings analyzed using Aiken's V index, ensuring content validity and inter-rater consistency. Additional testing included readability assessments with 20 students, instrument validation for pretest and posttest items (Cronbach's alpha > 0.7), bias checks, and item validity testing ($p < 0.05$).

Stage 4 – Implementation

A quasi-experimental nonequivalent control group design was employed. Both groups completed pretests and posttests; the experimental group engaged with Coleega using the RLC model, while the control group used conventional materials. Interviews with five students provided qualitative insights into learning experiences and perceptions of the application.

Stage 5 – Evaluation

Evaluation spanned all ADDIE stages. Application features were revised based on validation outcomes, questionnaire responses, and statistical analyses. Data collection included structured teacher and student interviews, Likert-scale questionnaires, and pretest–posttest assessments of conceptual understanding, chemical representation, and representational competence. Quantitative analysis employed normality tests and independent samples t-tests ($p < 0.05$), with achievement levels categorized as high (80–

100), medium (60–79), low (40–59), and very low (0–39).

This methodological framework ensured systematic development, rigorous validation, and robust testing of Coleega. By embedding the RLC model into a mobile platform, the study addressed persistent challenges in chemistry education and introduced a novel instructional innovation. The integration of structured pedagogy with interactive digital media provided compelling evidence of effectiveness in enhancing students' conceptual understanding, representational skills, and overall competence in colligative properties.

RESULT AND DISCUSSIONS

Analysis in the Development of Teaching Materials in the Material of Colligative Properties of Solutions

The study was conducted at a senior high school in Banyuwangi, East Java, chosen for its distinctive profile as a reference institution despite its distance from the city center. Students at this school demonstrate strong solidarity and collective learning attitudes, making it an ideal setting to evaluate innovative instructional approaches.

Colligative properties of solutions were selected as the focus material due to persistent student misconceptions and difficulties reported in prior studies. This topic requires integration of conceptual and algorithmic understanding, aligning with the independent curriculum (Phase F), which emphasizes student-centered learning. Curriculum outcomes demand that students explain everyday chemical phenomena, apply mathematical operations in chemical calculations, and analyze particle interactions in compound formation all of which rely heavily on representational competence.

To meet these demands, the Representation Learning Cycle (RLC) model was identified as the most suitable framework. RLC emphasizes multiple forms of representation pictures, graphs, diagrams, and molecular models integrating conceptual and algorithmic dimensions to strengthen comprehension. To maximize accessibility and engagement, the teaching materials were designed as an Android-based application. This digital format not only reflects students' daily use of smartphones but also provides a structured, interactive medium for visualizing abstract chemical concepts. The integration of RLC into a mobile platform represents a novel opportunity to systematically enhance representational competence in chemistry learning.

Description of Teaching Materials: 'Coleega' Application

The primary product of this research is an Android-based application, Coleega, designed with the Representation Learning Cycle (RLC) model to strengthen conceptual understanding, chemical representation, and representational competence in senior high school chemistry learning. The application specifically targets the topic of colligative properties of solutions, aligning with curriculum objectives and addressing persistent student difficulties. The name Coleega reflects its focus on colligative properties while signaling its role as a digital learning companion.

The application consists of four main components: a landing page (Figure 1), home page, meeting page (Figure 2, 3, & 5), and closing page. The landing page serves as the entry point, requiring teacher-provided login credentials. To stimulate initial engagement, it features images of everyday phenomena related to colligative properties, encouraging students to connect abstract concepts with real-world experiences. The home page integrates key instructional elements: (1) a concept map of colligative properties (Figure 2), (2) user instructions (Figure 3), (3) an introduction to the RLC model (Figure 5), (4) learning outcomes (Figure 5), and (5) access to meeting modules (Figure 6). The concept map, presented with high-definition visuals in a collapsible format, outlines the four subtopics vapor pressure lowering, freezing point depression, boiling point elevation, and osmotic pressure providing students with a structured roadmap of the material.

User instructions guide learners through the application's features and sequence of activities. Importantly, they direct students to progress through the four meetings, each structured around the six phases of the RLC model: orientation, questioning, planning, execution, analysis, and presentation. This systematic design ensures that students not only access content but also engage in representation-focused learning cycles that foster deeper comprehension.

By embedding the RLC model into a mobile platform, Coleega represents a novel instructional innovation. It combines structured pedagogy with interactive digital media, enabling students to visualize abstract chemical concepts more effectively while leveraging the accessibility of smartphones. This integration positions Coleega as a feasible and impactful tool for advancing representational competence in chemistry education.

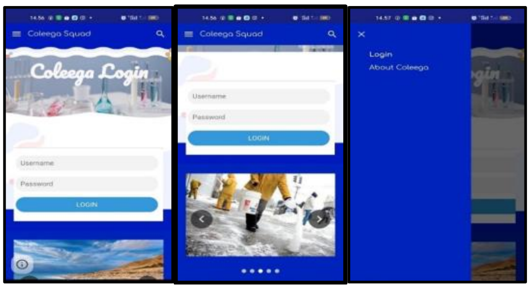

Figure 1 Landing Page

After filling their username and password, users will be directed to the home page which contains; 1) a concept map of the colligative properties of the solution, 2) instructions for using the Coleega application, 3) an introduction to the Representation Learning Cycle learning model, 4) an introduction to learning outcomes, 5) a meeting page feature consisting of four meeting icons.

The next crucial stage involves the development of an initial outline, which is an overview of the product to be developed. This initial framework includes the creation of a concept map which will then be elaborated to form a proposition analysis and material outline. In the sequence of concept maps that researchers use, it begins with understanding the colligative properties of solutions that depend on the amount of solute. This material is divided into four sub-matters including vapor pressure drop, freezing point drop, boiling point rise, and osmosis pressure. Media development products is available at the link https://appsgeyser.io/17837628/Coleega-Squad.

In the Coleega application, the concept map is located at the very top after the header and is arranged into a collapsible group with HD images. This is because the concept map is used as the first direction for students to know the order of the outline of the chapters and subchapters of the material to be explored.

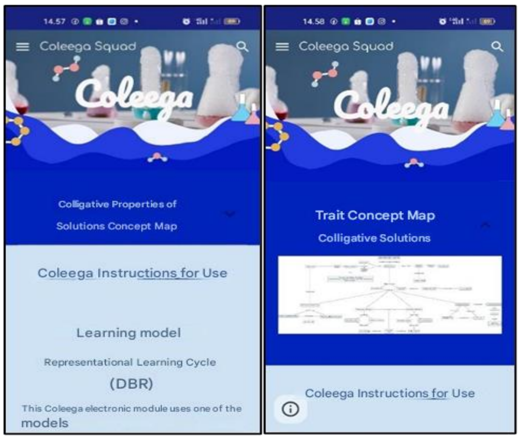

Figure 2 Home page (Concept Map)

In helping the use of the application, instructions are given on the home page which aims to guide application users in understanding the features and icons used in the application. Another function of providing instructions for using the application on the first page is to guide the learning sequence starting from the first meeting, second meeting, third meeting, to the fourth meeting by going through the 6 stages of the Representation Learning Cycle model on the Colligative Properties of Solutions material.

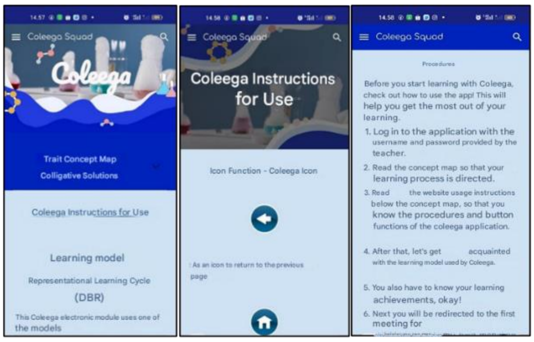

Figure 3 Home page (Instruction for Using Application)

There are three icons that can be used in this application, this is presented in Figure 4. The icon is located in each footer. The function of using the next icon to move to the next learning step, the back icon to return to the previous step. This will make it easier for students to follow a series of learning processes without the need to return to the main page.

While the last icon is the home icon which is used if the user/student wants to return to the home page.

Figure 4 Three icons on each Coleega app footer

The material on the colligative properties of solutions consists of 2 types, namely the colligative properties of electrolyte and nonelectrolyte solutions. This material also has four sub-chapters of material: decreasing vapor pressure, increasing boiling point, decreasing freezing point, and osmotic pressure. The core material presented is arranged systematically and in detail so that users can more easily understand the content of the material in the teaching materials. Therefore, researchers included an introduction to the learning model and learning outcomes on the home page. The learning model functions so that application users understand in advance about the understanding of the Representation Learning Cycle model. So that students can know the direction of learning that begins with material orientation, questioning, planning, investigation, analysis, and delivery of findings. The existence of an appropriate learning model will support an effective and efficient learning process. Learning outcomes serve to provide an explanation regarding the targets that must be achieved by students in learning the colligative properties of solutions. The existence of appropriate learning outcomes can be used in loading and developing content on teaching materials. Clear learning targets and objectives can make the content of teaching materials on target and effectively used in learning.

The content section of the application presents all sub-chapters of material based on understanding chemical concepts, chemical representations, and representation competencies with the Representation Learning Cycle learning model. This is useful for students in learning the Colligative Properties of Solutions material. At the end of each sub-chapter, evaluation questions are given as a test of self-understanding that must be done by students. In addition, there are practicums in teaching materials to support students' understanding macroscopically, and students can learn to think through the principles of the scientific method.

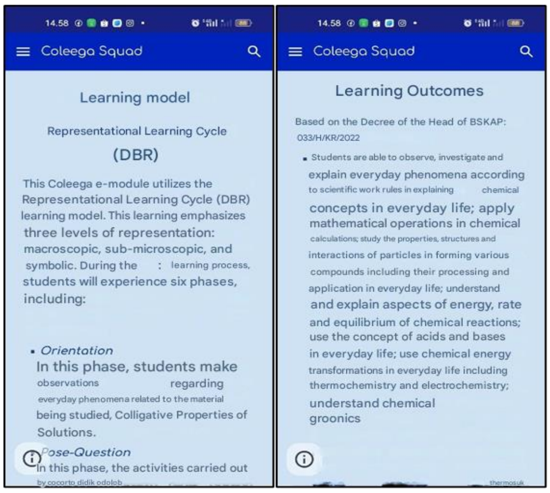

Figure 5 Home page (The Introduction to The Learning Model and Learning Outcomes

The content section is outlined in the meeting page feature that directs users to the learning page. The meeting page feature consists of four meetings starting from the first, second, third, and fourth meetings.

Figure 6 Home page (Meeting Page)

Researchers chose four meetings because they adjusted to the number of subchapters for the colligative properties of the solution. The first to third meeting is an activity of applying learning with the Representation Learning Cycle model, consisting of material orientation which contains examples of phenomena in the sub-matter to be observed by students, conveying questions that can be conveyed by students through google group discussion, planning which contains hypothesis making and relevant learning resources, investigation which contains problems that must be solved both concepts and practices, analysis, and delivery of findings obtained after going through the previous 5 phases. While the fourth meeting is giving questions to determine the final level of understanding of students after the learning process.

Validation Test Results of Teaching Materials by Validators

Validation was conducted to ensure the feasibility and quality of the Coleega application as a teaching material. Expert evaluation involved one chemistry lecturer and one chemistry teacher, who assessed the application against multiple dimensions: curriculum alignment, conceptual clarity, representation competence, integration with the Representation Learning Cycle (RLC) syntax, completeness of teaching materials, and language accuracy.

The results confirmed strong feasibility, with the validator test yielding a score **of *Indeks Aiken's V*** = 74, categorized as very feasible. A readability test with 20 students produced a score of 92%, indicating that the application is highly accessible and user-friendly. These findings demonstrate that Coleega not only meets academic standards but also engages students effectively, ensuring clarity in both conceptual and algorithmic aspects of chemistry learning.

Importantly, these scores surpass those reported in earlier studies using print-based RLC materials, which often struggled to convey abstract chemical representations due to limited visual and interactive features. By embedding the RLC model into an Android-based platform, Coleega provides structured, interactive representations pictures, diagrams, graphs, and molecular models that directly address student difficulties in mastering colligative properties of solutions. The high validation and readability scores underscore the novelty and reliability of this innovation, positioning Coleega as a feasible and impactful instructional tool for advancing representational competence in chemistry education.

Readability Test Results of Teaching Materials

The readability test was conducted to evaluate the clarity, accessibility, and user-friendliness of the Coleega application. Twenty students participated in the trial, providing feedback through structured questionnaires and Likert-scale assessments. The evaluation focused on ease of navigation, clarity of language, visual appeal, and the ability of the application to support representation-based learning.

The results demonstrated a readability score of 92%, categorized as very feasible. This high score indicates that students found the application intuitive, engaging, and effective in guiding them through complex chemical concepts. Qualitative feedback further confirmed that the integration of visual elements such as concept maps, diagrams, and molecular models helped simplify abstract ideas and strengthened comprehension.

Compared to traditional print-based RLC teaching materials, which often struggled with limited visualization and static presentation, Coleega offers a dynamic and interactive format that aligns with students' digital habits. The mobile-based design not only improves readability but also ensures continuous accessibility, allowing students to revisit materials anytime and anywhere. This represents significant advancement over earlier approaches, such as Chemo-Edutainment applications, which achieved lower presentation quality (75%) due to the absence of a structured learning model.

The strong readability outcomes highlight the novelty of embedding the RLC model into an Android platform. By combining structured pedagogy with interactive digital media, Coleega provides a feasible and innovative solution to overcome the challenges of abstract chemistry learning. The application's high readability score confirms its potential as a reliable instructional tool for enhancing representational competence in colligative properties of solutions.

Description and Analysis of Student Ability Data

After the readability test is carried out, then the implementation is carried out using the developed product. The purpose of the application of android-based applications with the Representation Learning Cycle learning model is to determine the effectiveness of the learning process of Colligative Properties of Solutions material on understanding chemical concepts, chemical representations, and representation competencies. Before conducting learning activities, first identification was carried out on student understanding and after conducting learning activities for 3 meetings, identification was carried out on the final understanding of students in two groups, experimental group and control group. The results of pretest and post-test data obtained are presented in Table 1.

Table 1 Description of Pretest and Posttest Data for Experiment and Control Group

Description	*Pretest*		*Posttest*	
	Exp. group	***Cont. group***	***Exp. group***	***Cont. group***
Number of Students	34	34	34	34
Standard Deviation	11,026	12,137	6,804	7,104
Highest Score	60	62	100	95
Lowest Score	20	18	75	68
Average	27,65	26,95	87,94	80,94

The result of pretest data on *t*-test is $t = 0.25 < 2.00$, we fail to reject H_0. Interpretation of the *t*-test shows no significant difference in pretest scores between the experimental and control groups ($p > 0.05$). This indicates that both groups started with comparable baseline understanding of colligative properties of solutions. This finding is important because it validates the experimental design: any significant differences observed in the posttest scores can be attributed to the intervention (*Coleega* application with the RLC model), rather than pre-existing disparities in student ability.

The result of posttest data on *t*-test is Since $t = 4.17 > 2.00$, we reject H_0. Interpretation of the *t*-test shows a significant difference in posttest scores between the experimental and control groups ($p < 0.001$). Students taught with the *Coleega* application achieved substantially higher scores ($M = 87.94$) compared to those taught with conventional methods ($M = 80.94$). This confirms the effectiveness of the Android-based RLC application in improving conceptual understanding, chemical representations, and representational competence. The significant gain in the experimental group validates the novelty of embedding the RLC model into a mobile platform, demonstrating its superiority over traditional approaches in addressing the challenges of abstract chemistry learning.

Description of Learning Cycle of Representation Using Android-Based Application

Statistical analyses confirmed that the *Coleega* application improved students' conceptual understanding and representational competence. Addressing the challenges identified in the introduction, the RLC model provided an innovative framework that accommodated both conceptual reasoning and representational mapping. Group discussions played a central role, enabling students to engage in scientific dialogue, articulate opinions, design solutions, and collaboratively conclude findings. This interactive structure underscores why the RLC model is effective in fostering active participation and problem-solving skills.

The learning cycle involved six stages orientation, questioning, planning, execution, analysis, and presentation applied across four meetings. The first meeting addressed concentration calculations and vapor pressure lowering; the second focused on boiling point elevation and freezing point depression; the third emphasized osmotic pressure and reinforced colligative properties in electrolyte solutions; and the final meeting assessed students' overall understanding through posttest evaluation.

By embedding this structured cycle into an Android-based application, *Coleega* represents a novel instructional innovation. It integrates systematic pedagogy with interactive digital media, enabling students to visualize abstract chemical phenomena while engaging in collaborative inquiry. The high implementation fidelity and significant learning gains confirm that the RLC-based mobile application is a feasible and impactful solution for advancing representational competence in chemistry education.

Description of Concept Understanding, Chemical Representation, and Representation Competence on the Material of Colligative Properties of Solutions

The posttest provided a comprehensive measure of students’ conceptual understanding, chemical representation, and representational competence. These outcomes were reinforced by observations of learning implementation, which had been systematically aligned with the teaching module. The assessment of the applied learning model not only captured student achievement but also illustrated how learners developed opinion-forming skills and processed information through structured representation-based inquiry.

Posttest items were carefully designed around the colligative properties of solutions presented in meetings 1–3. Each item underwent rigorous validation and reliability testing, including Cronbach’s alpha analysis, confirming their validity and reliability. Importantly, while the posttest questions were aligned with the instructional content, they differed significantly from practice questions used during lessons, ensuring that the evaluation measured genuine learning gains rather than rote recall.

Learning colligative properties requires mastery of three representational aspects—chemical symbols, formulas, and equations. Once students grasp these representations, they are expected to interpret, connect, and translate across multiple forms, a skill defined as representation competence. The Coleega application facilitated this process by explicitly embedding macroscopic, sub-microscopic, and symbolic representations into its modules. This digital integration provided students with accessible visualization tools and supported teachers in guiding representational reasoning more effectively.

Posttest items were structured according to the five levels of representational competence described in the literature review. Results revealed that 29 students achieved scores in the high category (80–100), while 5 students scored in the medium category (60–79). These findings confirm that most learners reached advanced levels of representational competence, demonstrating the effectiveness of the Android-based RLC application in bridging abstract chemical concepts with accessible, structured learning experiences. Here, an example topic were explaining.

Concentration Calculation

The sub-concept of colligative properties of solution material for the first question is about concentration calculation. Before understanding the meaning of colligative properties itself, students are expected to understand concentration and its calculation. Question number 1 is a question related to the calculation of concentration that applies the first level of representation competence, the ability to interpret the meaning of chemical representations. Where in the available problems are presented macroscopic visualization depictions in the form of images of solution molecules with various concentrations to determine the highest concentration and students are asked to explain the reasons.

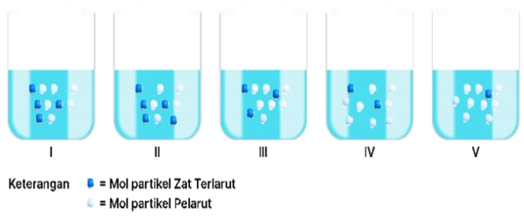

Figure 7 Macroscopic Visualization of Molecules in Solution

Concentration is the amount of solute in a solution. The questions that have been prepared require students' understanding of the concept of concentration. The concept tested is expected that students can understand the relationship between the concentration value and the solute in the solution so that they can determine the highest concentration. The depiction of solutions is a representation where the concentration value is indicated by the amount of solute. Understanding representation also requires students to understand that concentration is important knowledge to understand the colligative properties of solutions.

The maximum score on question number 1 is 15 points. In the data obtained 17 students got perfect points, 15 points. The lowest point in question number 1 is 10 points obtained from 7 students. The description of student answers with perfect points is shown in the following Figure 8.

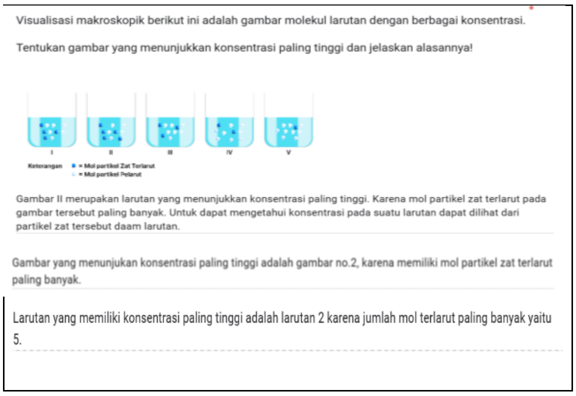

Figure 8 Variation of Student Answers to Question Number 1 with a Total of 15 Points

Students with a total of 15 points are able to describe correctly related to the macroscopic visualization presented. Students with language that is easily understood by themselves are able to explain in which picture number shows the highest concentration along with the reasons. Meanwhile, students who get 10 points are less able to explain in detail the reasons for the images they see. They tend to only show which answer is correct without any reasoning. In addition, some of them still have a wrong understanding of the concept, this is because they did not follow the lesson because they were absent from class. The variety of answers can be seen in Figure 9.

Figure 9 Variation of Student Answers to Problem number 1 with a Total of 10 Points

Based on the analysis of student answers, the average value of working on question number 1 posttest is 88% of 34 students completed this question well. This is because in the learning process with the coleega application, students are directed to the first meeting in the orientation menu section. In the orientation menu, the relationship between solutes and solvents has been presented. So that students can see that in the concentration there is a solute and solvent at a certain ratio and will affect the concentration value. Then emphasized on the plan menu where students look for relevant resources, in the coleega application itself the plan menu is filled with content that emphasizes the level of representation such as the depiction of sub-microscopic phenomena which in the case of concentration emphasizes the types of solution concentrations and calculations. Students will easily understand concepts related to concentration by studying them on the plan menu.

The contribution of the coleega application to solving posttest question number 1 is also found in the execute menu where students are asked to solve problems that relate concentration to surrounding phenomena such as the relationship between detergent concentration when washing clothes. Students are trained to solve problems with their representation skills. Students complete the problem discussion with their group friends. Discussion between students will bring up many views and opinions to draw the right conclusions so that students will have a good understanding of the concept. Therefore, the menus in the coleega application can train students' thinking skills so as to provide an understanding of the right chemical concepts and representations.

CONCLUSION

Coleega, an Android-based application for teaching colligative properties, was designed to strengthen students’ conceptual understanding and representational competence in chemistry. Its development was tailored to the learning characteristics of senior high school students, who predominantly engage with mobile devices, making the platform pedagogically relevant and accessible. Validation confirmed high feasibility, strong content and design alignment (Aiken’s V = 0.74), and excellent readability (92%). Effectiveness testing through independent t-test ($p < 0.001$) revealed significantly higher posttest scores in the experimental group (M = 87.94) compared to the control (M = 80.94). These findings underscore the novelty of embedding the Representation Learning Cycle (RLC) into mobile technology, demonstrating that Coleega is both feasible and effective in advancing representational competence within chemistry education.

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