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Computer support collaborative learning-retrosynthetic analysis model to improve students' problem solving ability

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Abstract. Problems encountered are too difficult for students to understand organic chemistry, including stereochemistry, organic reaction synthesis. So, we need a way to overcome this problem in order to increase the quality of learning processes through the implementation of the multimodel Computer Support Collaboration Learning-Retrosynthetic Analysis (multimodel CSCL-RA) in organic chemistry. This study is action research with descriptive qualitative approach with students of Organic Chemistry III in Chemical Education Program, ULM. Thirty pair dyads of students participated in a problem task. The instrument of research was in the form of problem-solving ability and cognition test instrument, observation sheet of teacher and student activity. Data were analyzed using percentage of students' problem-solving ability and achievement. The results showed that the implementation of CSCL-RA multimodel in organic chemistry increased the quality of learning with indicators of increasing students' problem-solving abilities and learning outcomes. The implication for future research could provide further: (1) students' interactions in CSCL, (2) CSCL with metacognitive training in problem-solving.

1. Introduction

The level of understanding and students' problem-solving ability of chemistry on stereochemical concepts, reactions, and organic synthesis is low. Based on the documentation of the results of the evaluation of Organic Chemistry III lecturers in the last two years, the average achievement of scores is relatively low, which is only 44.82% students who achieved mastery learning or with a value of ≥70, while 55.18% have not mastered the concept. Several factors identified the causes of students' difficulties in learning stereochemistry, among others, someone needs to imagine between three-dimensional structures with depictions of atomic molecules written or printed in two dimensions [1], students difficult to solve the problem of learning chemistry, especially chemical concepts in microscopic level [2-3]. Students also have difficulty understanding the reactions and synthesis of organic compounds. The study of TIMSS and PISA on Indonesia's students' problem-solving skills shows that the students are still at a low level [4-5]. It is important to evaluate the progress of Indonesian education by conducting pedagogical innovations such as Computer-Supported Collaborative Learning, CSCL [6-7].

CSCL is one area of study of how students learn to use computer aids [8]. CSCL environment allows many students in a team to solve problems without time and space constraints [9]. Social interaction is an important factor in learning success for students in CSCL because it greatly influences their academic achievement and participation [10-11]. Problem-solving is one of the ways of thinking of 21st-century education [12-15]. Problem-solving is the process by which a student arrives at a solution to a problem [16-17]. Problem-solving ability is the core of CSCL that trains students to solve problems to be applied in life and examines problem-solving during meaningful tasks for the promotion of higher-order thinking and the cognitive aspects of students' learning [18]. Polya [19] suggests four phases to solve the problem, namely (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) look back the problem-solving process and learning outcomes.

Chemistry learning needs to be supported by computer multimedia to visualize abstract and microscopic concepts [20] to be more real, analogous, interesting, and easily understood by students. Learning that trains problem-solving skills, utilizes ICT, and collaboration [14]. Problem-solving skills, thinking student analysis, and synthesis in learning the synthesis of organic compounds will be strengthened through retro-synthesis analysis [21-25]. Retrosynthetic analysis is a technique for planning a synthesis of complex organic molecules based on known reactions (e.g., the addition reaction, oxidation, reduction, etc). Retrosynthetic analysis (RA) will be the roadmap to guide the synthesis of the target molecule from commercially available starting material. Computer-assisted synthesis planning has been well-reviewed over the years [26-28].

Teachers are expected to help all students learn, and strategies and tactics are available to make this possible such as multimodel CSCL-RA in organic chemistry learning. Connecting and using multiple models is the practice of employing several different approaches to teaching over the course of a lesson [29]. The use of multimodel CSCL-RA on organic learning is expected: (1) teaching will attract students' attention so that it can increase learning motivation, (2) the teaching material will be more concrete and clear in its meaning so that it can be understood by students and allows mastering and achieving teaching goals, (3) the teaching method will be more varied, so that students are not bored and the lecturer does not run out of energy, especially if the lecturer teaches at each lesson. The problem statement in this research is as follows: How are students' problem-solving abilities and learning outcomes of organic chemistry using multimodel CSCL-RA?

2. Research Method

This study is action research with the descriptive qualitative approach with thirty pair students of Organic Chemistry III in Chemical Education University of Lambung Mangkurat (ULM), Banjarmasin Indonesia. Action research in three cycles [30]. Multimodel CSCL-RA syntax is modified from Van Amelsvoort, Andriessen, and Kanselaar [31] consisting of 3 phases: (1) individual preparation and problem orientation, (2) discussed and collaborative problem solving, and (3) solution evaluation and individual consolidation. Data collection using test and non-test techniques. The test technique uses 5 essay test questions and 15 short answer test questions. The non-test technique includes observation and investigating field notes. Test instrument validated by 5 panelists with score Content Validity Ratio (CVR) is 0.99 (valid) [32]. Data were analyzed qualitatively includes display data, reduction, and conclusions [33]. The success of the action is measured by the implementation of CSCL-RA, student activities, problem-solving abilities, and learning outcomes of at least 61 percent. [34-35].

3. Results and Discussion

The CSCL learning model is seen from the psychology of education, including understanding constructivism, namely students build their own knowledge. Students can learn independently or in groups, form a network of communication and interact with group members, so as to be able to form independence and a sense of responsibility for student learning, increase motivation, learning outcomes and students' ability to solve problems. Learning is done in three cycles, and each cycle consisted of four phases: plan, act, observe, and reflect.

Plan. The lecturer explained the lesson plan, then discussed it with colleagues of the organic chemistry lecturer. The problem of students is weak in understanding the material and when the discussion is not accustomed to sharing opinions/ideas. Based on the identification of learning problems, then the multimodel CSCL-RA lesson plan design is determined so that students can engage in learning, discover and communicate the concepts learned to later be subject to class discussion. Implementation of the multimodel CSCL-RA was determined based on (1) the implementation of the lesson plan for seven meetings in three cycles with the average assessment of two observers, (2) student activities during class learning, and (3) students' problem-solving ability and learning outcomes. The material applied in this study is the organic chemistry shown in Table 1.

Table 1. Application of the multimodel CSCL-RA for each cycle in the classroom

Cycle/Material	Meetings	Material characteristics
I. Stereochemistry	2	Understanding conceptual-representation
II. Organic reaction	2	Understanding conceptual-mechanistic
III. Synthesis of Organic	3	Analysis - synthesis

Act. The lecturer conducts the teaching and learning process according to the collaborative lesson plan results during the plan. It was starting with the lecturer giving motivation and apperception with a contextual example. The lecturer presented the objectives and CSCL models that will be applied. Lecturers divide groups of 2 members. Furthermore, students in groups are divided into two dyad pairs, namely dyad-1 and dyad-2. *Phase 1 Individual preparation and problem orientation.* Students prepared by constructing a representation individually and identify the problem. Determine which information resources are relevant to solving the problem. *Phase 2 Discussion and collaboration problem-solving*. They discussed the topic and wrote a text in dyads.

Figure 1 illustrates collaborative learning as a group experience that starts at time 1 (T1) with each student's activities (A1 and A2) based on previous experiences (E1 and E2). CL activities produce distributed experiences (X) with cognitive (C), social (S), and motivational (M) features. The experience was internalized differently at time 2 (T2) by student 1 as X' with features C,' S,' and M' and student 2 as X "with features C," S," and M" [36].

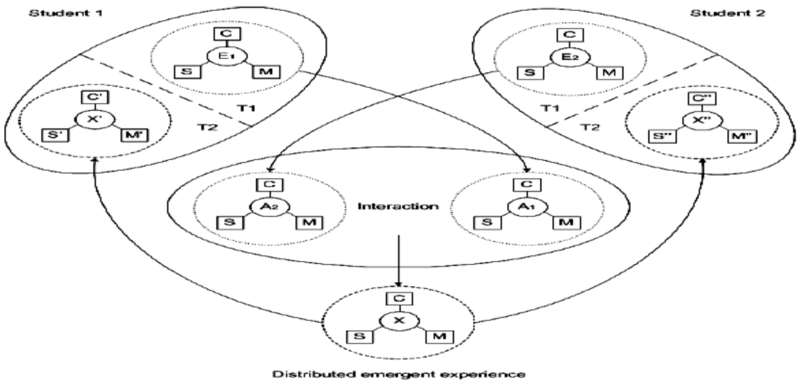

Figure 1 Collaborative learning model (adapted from Strijbos [37])

After the collaborative group agreed on the results of problem-solving, each student wrote their own complete report. The teacher appoints one group randomly to present the results of their collaborative group discussions in front of the class, students in other groups observe, examine, compare the results of the presentation, and respond. Each student in a collaborative group elaborates, inference, and revisions (if needed) on the report to be collected. Reports of each student on the tasks that have been collected, arranged in collaborative groups. *Phase 3 Solution evaluation and individual consolidation.* Evaluate your team's solution and reflect on what has been learned — students' consolidation and revising their knowledge. The final activity is to conclude the lesson, carry out a post-test, and provide questions to answer at home.

Observe. Implementation of the multimodel CSCL-RA has been applied by teachers in the classroom to experience an increase from cycle I to cycle III in learning.

Table 2. Implementation of the multimodel CSCL-RA

Rated aspect	Cycle I	Cycle II	Cycle III
Preliminary	3.00	4.17	4.28
Core activities			
Phase 1 Individual preparation and problem orientation	2.92	4.08	4.08
Phase 2 Discussion and collaboration problem-solving	2.92	4.33	4.50
Phase 3 Solution evaluation and individual consolidation	3.00	4.00	4.00
Closing activity	3.25	3.92	4.00
Time management	3.33	4.33	4.33
Class situation	3.33	4.00	4.00
The average observer's overall rating	3.17	4.13	4.22
Average percentage	63.37%	82.67%	84.36%
Category	good	very good	very good

Based on Table 2, information was obtained that observations on implementation RPP in the classroom were categorized as good with an average percentage was 63.37% in cycle I to 82.67% and 84.36% in cycle II and III, respectively. Improved implementation of CSCL-RA multimodel because teachers are able to become better facilitators in learning cycles I through cycle II and III. The teacher gives freedom to students to solve the problems they face in their own way. The multimodel stage of CSCL-RA has been run optimally by the teacher so that this increases student activity in learning. Based on Table 3, it appears that the activities of students using multimodel CSCL-RA encourage and provide more opportunities for students to active learning.

Table 3. Percentage of average scores from the observations of students' activities in cycle I to cycle III

Observed Aspects	Percentage of student activity		
	Cycle I	Cycle II	Cycle III
Understanding and identifying a task/the problem	70.00	85.00	88.33
Read teaching materials	67.70	80.00	85.00
Selecting strategies and planning problem solving with model/computer/retrosynthetic analysis	65.00	73.33	71.67
Collaboration to promote social skills interaction	60.00	75.00	91.67
Teach each other friends/sharing knowledge and information	18.33	60.25	65.00
Discussion the topic and making a solution in problem-solving with analysis-synthesis	68.50	83.75	87.50
Checking and monitoring each step about the group's process and achievement	60.00	75.00	81.67
Presenting the results of group discussions and suggesting opinion on the problem-solving method	70.00	80.45	95.00
Responding to questions and requests from others or asking assistance from a collaborative partner	66.70	80.00	93.33
Reflecting/evaluation, the process collaborative of problem-solving	55.00	75.27	85.00
Average percentage	60.12	76.81	84.42
Category	Good	Good	Very good

Students' Problem Solving Ability

Data on a test of problem-solving ability after learning process ends.

Table 4 Percentage of average students' problem-solving ability of cycle I to cycle III

Indicator of Problem Solving Ability (PSA)*	Cycle I		Com-pleteness	Cycle II		Com-pleteness	Cycle III		Com-pleteness
	PSA (%)	Category**		PSA (%)	Category		PSA (%)	Category	
Understanding	76.67	Good	Complete	80.45	Very good	Complete	87.50	Very good	Complete
Devising the plan	75.27	Good	Complete	80.83	Very good	Complete	92.08	Very good	Complete
Carrying out the plan	67.78	Good	Complete	75.00	Good	Complete	83.75	Very good	Complete
Looking back	60.25	Good	Not Complete	72.22	Good	Complete	79.19	Good	Complete
Average	69.99	Good	Complete	77.13	Good	Complete	85.63	Very good	Complete

*(1) *Understanding the problems.* Students can understand and assess the problems. Familiarize student to write what is the problem, they can think about the requirements needed and know which direction to go.
(2) *Devising the plan (planning).* Students find the relationship between data and those requested or proven. Choose the most suitable theorem or concept, and choose and determine the most appropriate way/strategy to solve the problem logically and systematically.
(3) *Carrying out the plan (monitoring).* Students involve actively in implementing collaborative strategies to solve the problems systematically. Checking and monitoring each step about the group's process and achievement. Proving that the steps are correct.
(4) *Looking back (reflection).* Re-checking the obtained result by comparing the obtained answer with the problem and writing down the conclusion. Students can do a reflection.
** PSA achievement categories: 80-100 = very good, 66-79 = good, 56-65 = sufficient, <56 = less.

Based on Table 4 students' using self-directing questions for success in problem-solving, e.g. (1) "What is the problem?", "What is the meaning of "What are the data?" (2) "How do you justify your conclusion?" (3) "What is the strategy," "Why is the appropriate strategy?" (4) "Is your strategy applied is appropriate to the planning? Why is it appropriate?'

Students' Learning Outcomes
Student learning completeness in the Organic Chemistry III course is presented in Figure 2.

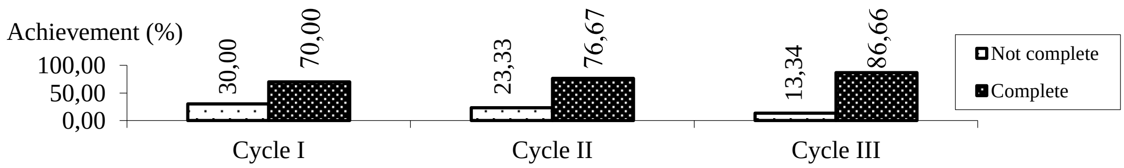

Figure 2. Student completeness in learning organic chemistry

The percentage of students' achievement of organic chemistry can be seen in Table 5.

Table 5. Percentage of students' achievement of organic chemistry

Cycle	Indicators	Students achievement		
		Percentage	Category	Completeness
I. Stereo-Chemistry	a) Analyze chirality and stereochemistry in aliphatic and cyclic compounds	80.00	Very good	Complete
	b) Analyzing stereoisomers in dissymmetric compounds	60.00	Sufficient	Not complete
II. Organic Reaction	a) Apply the concept of substitution and elimination reaction	82.50	Very good	Complete
	b) Apply the concept of addition, an oxidation-reduction reaction	70.00	Good	Complete
III. Synthesis of Organic	a) Synthesis of aromatic compounds	87.25	Very good	Complete
	b) The strategy of disconnection in C-C bond and C-X bond	91.50	Very good	Complete
	c) Protecting Group	81.00	Very good	Complete

Problem indicators 1a, 2a, 3a, 3b, and 3c learning outcomes are in the excellent category. The ease of students answering questions is inseparable from the use of representation during the learning process.Visualization with computer simulation, videos, and flash so students can understand the material and make students more active in learning. Multimodel CSCL-RA is equipped with videos, animations, flash, and music that make students not bored during learning. In addition, with the presence of representations and videos, students can find out: (1) geometric isomers in alkene and cyclic compounds, (2) analyze chirality and stereochemistry in aliphatic and cyclic compounds. Representation competence is essential for meaningful understanding in solving chemistry problems [3], [38]. The problem with indicator 2b learning outcomes in the good category, although there are still some students who have difficulty understanding. This is due to the concept of reaction addition, oxidation, and reduction associated with the reaction mechanism. Students cannot connect any physical reality with matter and the processes represented in diagrams that push electrons as amodal and the student's little experience in practice reaction in the laboratory [39-41], which requires a deep understanding to learn it. The problem in indicator 1b is that learning outcomes are in a sufficient category because there are still many students who have difficulty understanding the dissymmetric compound stereoisomer. Therefore students need to practice more to master aspects of three-dimensional space (3D) using a computer visualization software or flash simulation could be effective [42].

Reflect. Students who complete study increased from 70.00% in cycle I, 76.67% in cycle II, and reached 86.66% in cycle III because students have difficulty at the beginning of learning to get guidance for the next meeting and group discussions become more effective, which initially oriented towards completing the task shifts to sharing information among fellow group members. Social interaction was important for online collaboration in terms of strengthening group collaboration [43-44].

The average classes of students' problem-solving ability were only 69.99 in cycle I, increase the students' problem-solving abilities were 77.13 in cycle II and 85.63 in cycle III. The results were better than the achievement indicator because students' using self-directing questions for success in problem-solving [45]. Those advantages CSCL-RA have a positive impact on the students' learning process, problem-solving, and learning outcomes [46-48].

The collaboration can improve aspects of problem-solving abilities (i.e., understanding, planning, monitoring, and reflection). Students can understand and assess the problems. Cartrette and Bodner [49] observed that more participants succeeded in drawing fragments of molecular structures as they tried to complete the task.

Students' involve monitoring and reflecting actively in implementing collaborative strategies to solve the problems (execute the solution) systematically. Students' checking each step and proving that the steps are correct [39]. Reflection can be obtained a number of new knowledge or important decisions to improve the learning process. Various valuable findings in the reflection phase certainly became the capital for lecturers and observers to develop the learning process in a better direction.

The advantages of learning are carried out, namely: (1) discussions with smaller groups allow all students to think actively. (2) between students in the group have shown activities to share ideas in solving learning problems. Bode and Flynn [50] report that students in their research on solving synthetic problems are asked to show 'brainstorming' and 'analysis' assessed to help students adopt problem-solving habits. Retrosynthetic analysis strategy and task problem-solving in a small group setting successfully taught students [51]. This is in line with the opinion of Rickey & Stacey [52], who said through small groups, students can know their own knowledge so that cognition and metacognition can be empowered. Problem-solving learning is assisted by computer media, such as e-learning based Schoology, which can improve students' problem-solving ability and learning outcomes [53].

The valuable lessons gained are: (1) students are required to think independently with their partners and then share information through sharing opinions, and collaborative tasks that support knowledge and problem solving, (2) the use of interactive learning media is preferred, and students generate interest in learning, (3) appropriate learning strategies are needed to maximize the construction of knowledge by students, (4) students need scaffolding with feedback in authentic activities.

4. Conclusion

Implementation of multimodel CSCL-RA in organic chemistry can improve: (1) the average of students' problem-solving ability was only 69.99 in cycle I increase the students' problem-solving abilities were 77.13 in cycle II and 85.63 in cycle III, (2) learning outcomes in each cycle. At the end of the third cycle achieving classical completeness reached 86.66%, and (3) the quality of the lecturer learning process and student activities has increased in each cycle, from the sufficient category to being a very good category. The implication for future research could provide further: (1) students' interactions in CSCL-RA, (2) CSCL combined with metacognitive training in science education can enhance autonomous learning abilities in problem-solving.

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