The effectiveness of collaborative strategy based on multiple intelligences in chemistry learning to improve students' problem-solving skill and multiple intelligences

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Abstract. This research aims to reveal: (1) the feasibility of collaborative learning strategy (henceforth CLS) based on multiple intelligences (MI) in chemistry learning; (2) the effectiveness of CLS based on MI (CLS-MI) to improve students’ problem solving (PS) skill, multiple intelligences/MI (interpersonal, visual-spatial, and logical-mathematical), and students’ achievement in chemistry. This research applied Research & Development method using 4D model. As many as 210 students from 3 public schools in Banjarmasin were involved in this study. The effectiveness of the strategy was evaluated using pre-test-post-test control group design. The experimental class implemented CLS-MI, while the control class used conventional strategy. The data were collected using test, observation, & questionnaires, and were analyzed using descriptive and t-test. The results indicated that (1) the CLS-MI is feasible to be used in chemistry with the practicability score of 51.5 (very practical); (2) Students’ PS skill and MI in the experimental class improved higher. Three categories of students’ PS skill exist in the experimental class; develop (25%), develop well (47.2%) and develop very well (27.8%). Interpersonal, logical-mathematical, and visual-spatial intelligences improved respectively by 17.8%, 8.3%, and 3.8%. (3) The students in the experimental class achieved better in learning chemistry with the N-gain 0.77 (high).

1. Introduction
Chemistry is a branch of science that studies the composition, structure, characteristic, and changes of materials. Chemistry lessons are taught from fundamental abstract concepts such as atoms, elements, compounds, and concrete concepts for example acid, base, corrosion, to mathematical topics such as concentration and reaction rate. Based on the characteristics of these topics, the general concept in chemistry can be categorized as a microscopic, mathematical, and symbolic concept.

The chemical concept characteristic causes most of chemistry learning activity done by involving visualization and problem-solving skills. In fact, the visualization skill is needed to understand microscopic concepts for instance atoms, elements, and chemical bonds. Meanwhile, the problem-solving activity is needed to solve the chemistry problems, both quantitative and involving mathematical calculations, as well as conceptual problems. Therefore, a good chemistry learning not only produces conceptual understanding but also enhances visualization and problem-solving skills.

In regard to the problem solving, it can be defined as a mental and intellectual process of finding problems and solving on the basis of accurate data and information, so that appropriate and careful
conclusions can be drawn [1]. Problem-solving activity involves 3 components, namely (1) the ability to understand and state the problem, (2) the ability to develop a plan to solve the problem, and (3) the ability to implement the plan that has been prepared [2]. According to Vygotsky [3], the problem solving process will be easier if done through interaction and cooperation with others through the process of scaffolding. The ability to interact with others or so-called interpersonal skills, in addition to help in solving problems, according to [4] it can also enrich the intellectual.

Problem-solving skill itself cannot be conducted without being supported by other abilities. Since the concept of chemistry is dominated by abstract and mathematical concepts, problem solving in chemistry requires the support of other abilities such as visualization and mathematical knowledge. The ability of visualization, to which in chemistry learning is applied when studying microscopic concepts is referred to as visual-spatial ability [4]. The visual-spatial ability is a person's ability to reflect and imagine things [5]. Meanwhile, the mathematical ability not only deals with skills in understanding mathematical operating techniques, but also the logic of mathematical and scientific logic.

All the visual-spatial abilities, interpersonal skills, and mathematical abilities are three of the eight human intelligences called Multiple Intelligences. Reference [4] divides intelligence into 8 kinds according to the work area of the brain relevant to the types of intelligence. The eight bits of intelligence are linguistic, interpersonal, logical-mathematical, visual-spatial, intrapersonal, bodily-kinesthetic, musical rhythmic, and naturalist. The eight kinds of intelligence will greatly determine the way a person in solving the problems he/she faces.

Developing interpersonal intelligences in schools can be conducted through the application of learning strategies that build social interaction. This is in accordance with Vygotsky's opinion which emphasizes the social context of learning. According to Vygotsky [3], students engage in social interaction with others to compile their knowledge. A collaborative learning strategy, which combines individual and group tasks is one of the strategies that can be applied to build interpersonal intelligence. In a collaborative strategy, students are given individual tasks to achieve understanding.

Application of Collaborative Learning Strategy Learning based on Multiple Intelligences (CLS-MI) chemistry learning in this study is expected to enhance the problem-solving skill and the multiple intelligences of students especially interpersonal, visual-spatial, and logical-mathematical intelligences.

2. Method
This research employed Research and Development method with a 4D model consisting of the stages of Define, Design, Develop, and Disseminate. At the Define stage, the development goals of the CLS-MI strategy are developed. The learning devices that will be developed for the Hydrolysis Salt material, Hydrocarbon, and Buffer Solution are planned at Design stage. At the Development stage, the effectiveness of CLS-MI strategy which was developed by conducting one to one evaluation test, small group test and large group test was tested and at the Disseminate stage, the research result was published [6].

CLS-MI learning strategy was done with classical patterns - individual - homogeneous groups - individual - heterogeneous groups. Application of individual and group patterns, in turn, is intended to develop individual and interpersonal students abilities [7]. In classical activities, students learn by the usual method. On the individual activities, the students were given questions that must be answered independently. In the homogeneous group activity, the students were grouped on the basis of the same dominant multiple intelligence. In this homogeneous group, the difficulties students experience when solving individual questions were discussed together. To solve the problem, the students perform problem-solving activities through a characteristic type of activity, according to their dominant intelligence characteristics. The students then return to the individual activities to solve the problem. In the last step, the students were grouped heterogeneously based on different types of multiple intelligences to perform concept application activities and solve problems together.

In the homogeneous group activities, 8 LKS (students worksheets) were created which were adapted to 8 types of multiple intelligences [5]. For heterogeneous group activities, there was solely one type of
LKS prepared. In the learning of Salt Hydrolysis material, activities were designed with more involving interaction among students. The learning material of Buffer Solution consisted mostly of mathematical concepts, it was designed with more involving logical-mathematical skills, whereas in Hydrocarbon materials a lot of media and more activities involving visual-spatial abilities were used.

The effectiveness of the developed CLS-MI strategy was tried out using a quasi-experimental method by applying a pre-test-post-test control group design. The samples of the study consisted of the eleventh-grade students at three public senior high schools in Banjarmasin consisting of 105 students in the experimental class and 105 students of the control class. The samples were chosen using purposive techniques based on the suitability of student characteristics, materials and learning time. The experimental class applied collaborative learning strategies integrated with the multiple intelligence, while the control class implemented the conventional learning. The data were collected using test, observation, questionnaires, and interviews. The interpersonal and visual-spatial intelligence data were obtained through the KM questionnaire instrument developed by [3], [5], and [8], the problem-solving data were obtained through the Problem Capability Testing and interviewing tests, and the mastery of the chemical concepts obtained through the concept of the conceptual test. The data then were analyzed using descriptive analysis and independent t-test.

3. Results and discussion

3.1 The practicability of CLS-MI strategy implementation

The practicability test of CLS-MI strategy implementation in the three pilot schools resulted in the following data:

| Lesson Device | Aspect of Observation | Average | Category  |
|---------------|----------------------|---------|-----------|
|               | Syntax               | 40      | Practical |
| Lesson 1      | Total                | 48.5    | Practical |
|               | Syntax               | 42      |           |
| Lesson 2      | Total                | 52      | Very Practical |
|               | Syntax               | 44      |           |
| Lesson 3      | Total                | 54      | Very Practical |
|               | Mean                 | 51.5    | Very Practical |

Table 1 shows that the three learning devices implementing the CLS-MI strategy are very practical to use in learning. The syntax is clear and the device is easy to use. This is evident from the practicability score on the three learning devices ranged from 48.5-54 from a maximum score of 60. The learning stages of the lesson plan are clear and easy to follow the teacher and students activities went well. Thus, the CLS-MI strategy is worth applying in chemistry learning.

3.2 The CLS-MI strategy try-out results of the Problem Solving (PS) ability, Multiple Intelligences (MI), and students’ concept understanding

The effectiveness of the CLS-MI strategy is seen from the success of this strategy in enhancing problem-solving skill, the development of multiple intelligences, and understanding of students concepts after learning chemistry using CLS-MI learning strategies. Based on the measurement of problem-solving skill before and after learning obtained data as in table 2.
Table 2. Development of Students Problem Solving Skill.

| Score | Category           | Pretest (%) | Posttest (%) |
|-------|--------------------|-------------|--------------|
|       | Control            | Experimental| Control      | Experimental|
| 0-20  | Not develop        | 37.5        | 12.5         | 0            |
| 21-40 | Less Develop       | 55.0        | 27.5         | 0            |
| 41-60 | Develop            | 7.5         | 48.8         | 25.0         |
| 61-80 | Well-developed     | 0.0         | 11.2         | 47.2         |
| 81-100| Very well-developed| 0.0         | 0.0          | 27.8         |

Table 2 shows that in the experimental class, there was an increase in problem-solving skill of 94.4% (not develop and slightly developed) to 100% (develop until very well developed). Analysis of problem-solving skill before and after learning on the data yields N-Gain data as follows:

Table 3. N-Gain data on students problem-solving skill.

| N-Gain Interval | Criteria | Percentage (%) |
|-----------------|----------|----------------|
| (g) > 0.70      | High     | 38.9           | 3.8           |
| 0.30 < (g) < 0.70| Medium   | 58.3           | 25.7          |
| (g) < 0.30      | Low      | 2.8            | 65.5          |

Data on Table 3 shows that in the experimental class which applied CLS-MI strategy, the students who achieved high N-Gain are higher in percentage than the control class. This means there is an increase/betterment in the problem-solving skill in the experimental class.

Furthermore, based on the results of the difference test, the two classes using independent t-test obtained the t_count (3.12) > t_table (2.00); therefore, H0 is rejected. Thus, statistically, there is a difference between students problem-solving skill between the students in the experimental class and the students in the control class.

For the multiple intelligences data, the measurements on the interpersonal, visual-spatial, and logical-mathematical intelligences resulted in the data presented in table 4.

Table 4. The increase in the students interpersonal, visual-spatial and logical-mathematical intelligences before and after learning.

| Intelligence       | Experimental Class | Control Class | Gain | Pre-test (%) | Post-test (%) | Gain | Pre-test (%) | Post-test (%) | Gain |
|--------------------|-------------------|---------------|------|--------------|---------------|------|--------------|---------------|------|
| Spatial            | 7.6               | 11.4          | 3.8  | 9.2          | 10.2          | 1.0  | 10.2         | 17.1          | 2.8  |
| Interpersonal      | 15.2              | 33.0          | 17.8 | 14.3         | 17.1          | 2.8  | 17.1         | 23.0          | 5.4  |
| Logical-mathematic | 11.1              | 19.4          | 8.3  | 0.0          | 5.4           | 5.4  | 5.4          | 7.5           | 2.1  |

As it is seen in Table 4, the students’ interpersonal, visual-spatial and logical-mathematical intelligences in the experimental and control classes have increased, but the increase in the experimental class is relatively higher. The N Gain data test using independent t-test shows t_count (2.87) > t_table (2.00); therefore, Ho statement that there is not any N-Gain different between the two classes is rejected. In other words, there are differences in the development of interpersonal, logical-mathematical, visual-spatial intelligences between the experimental and the control classes at the 5% significance level. Thus, the implementation of the CLS-MI strategy provides a better effect on improving students’ problem-solving skill and multiple intelligences than the conventional learning.
Table 5. Mean of the students’ concept understanding after the learning strategy implementation.

| Material              | Mean   |
|-----------------------|--------|
|                       | Control Class | Experimental Class |
| Salt Hydrolysis       | 60.3   | 77.9               |
| Hydrocarbons          | 69.7   | 85.4               |
| Buffer Solution       | 62.5   | 75.3               |

Analysis of students' understanding of the concept of the experimental and control classes for each indicator after applying the CLS-MI strategy is presented in figure 1.

Figure 1a. Students’ concept understanding on hydrolyzed salt, hydrocarbon, and buffer solution materials for class of experiment.

Figure 1b. Students’ concept understanding on hydrolyzed salt, hydrocarbon, and buffer solution materials for class of control.

The data in table 5 and figure 1 show that in the experimental class applying the CLS-MI strategy, the students' concept understanding is higher than the control class. The hydrocarbon material characteristic which is more conceptual makes this material is better understood in both of these classes, following salt hydrolysis and buffer solution materials. The material of buffer solution and salt hydrolysis in addition to conceptual also use a lot of mathematical calculations; therefore, it becomes one of the problems for students. In the experimental class, the students' concept understanding of both concepts is better than the control class, with the highest score on some indicators above 80.

The N Gain data calculation in both classes produce N-Gain of 0.77 in the experimental class and 0.58 in the control class. The statistical analysis of the N - gain data of the conceptual understanding of the two classes shows that $t_{\text{count}} (4.14) > t_{\text{table}} (2.00)$. Thus, there is a difference in understanding of the concept of the students’ in the experimental and control classes after the implementation of this learning strategy. In the experimental class which applied CLS-MI strategy, the students were asked to solve the problem of salt hydrolysis, hydrocarbon, and buffer solution individually and in groups through the learning strategy integrated with the multiple intelligences. According to [9], presenting a problem for students will make the students become motivated to find answers and actively investigate the subject to fulfill their curiosity. Having problems helps students learn a set of concepts and ideas. Moreover, the presence of group discussions will give students problem-solving experience. This experience activates their problem-solving abilities so that their abilities develop. According to some research results [10], the development of students' problem-solving skill is one of the advantages of a learning-oriented model of problem solving. In contrast to conventional learning in general, students are not trained and accustomed to solving a problem, so their problem solving skill is less and may not even develop.

In addition, the increase on the students' problem-solving skill is also very probable due to the increase of one type of the multiple intelligences relevant to the problem-solving skill that is the logical-
mathematical intelligence as seen in Table 4. The relationship between problem-solving skill and logical-mathematical intelligence is described by [5] in which the intelligence of logical-mathematical includes the ability to work with numbers, numeracy, geometry or arithmetic, and the ability to logic, as well as the ability to think logically, solve the problem, and sharpness patterns and relationship. Thus, it appears that the logical-mathematical intelligence improvement that occurred in the experimental class which applied CLS-MI strategy contributes to the students' problem-solving skill improvement.

Besides the problem-solving skill, collaborative learning on the basis of the CLS-MI strategy is also thought to contribute to an improved on the students’ concept understanding taking place in the experimental class. On the collaborative learning, the students worked together to implement individual tasks and enable mutual learning. In this individual task collaboration, the students who do not understand can ask questions to friends in one group. The students who understand the difficulties of other students will respond to the question and explain it so that learning takes place where both students share the benefits of the activity. According to [7], the students who can explain the material to students who do not understand will benefit more than students who do not understand it. Through the explanation given to students who do not understand, the students who already understand the first experience what is called ‘understand again’. There are several levels of understanding, namely the level of understanding and able, the level of able to explain what is understood, and even higher that is the level of able to help by answering questions from students who do not understand about what has been understood. Many students who understand get greater benefits because of the responses they provide to the questions from students who do not understand. This is in line with the opinion [11] who states that someone who is actively involved in the learning process will learn much better, for instance, thinking about something learned and applying it in real situations.

4. Conclusion
In the nutshell, it can be concluded that: (1) the developed collaborative strategy based on multiple intelligence (CLS-MI) can be implemented in chemistry materials with the practicality test score of 51.1 (very practical), (2) the developed CLS-MI strategy is effective in developing the students problem-solving skill, multiple intelligences, and concept understanding in chemistry materials in high school which include Hydrolysis Salt, Hydrocarbon, and Buffer Solution materials. The problem-solving skill is well developed (100%), the multiple intelligence develops well, especially interpersonal intelligence (17.8%), logical-mathematical intelligence (8.3%), and visual-spatial (3.8%). The concept understanding increases with N-gain of 0.77.

Acknowledgment
This research was conducted through the data of DIPA Universitas Lambung Mangkurat (ULM). The authors would like to express sincere gratitude to the Faculty of Teacher Training and Education ULM that has facilitated this research so that it can be published.

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