
The Implementation of *Chempuzzle* on Increasing Students's Understanding of Atomic Structure, Elements Periodic System, Chemical Bonding, and Basic Laws of Chemistry Concepts

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Abstract : *The aim of this study was to identify the effectiveness of Chempuzzle on increasing students's understanding of atomic structure, elements periodic system, chemical bonding, and basic laws of chemistry concepts. This study has been done in four high school in Province DIY on 2008/2009 academic year. There are 247 students become participants of this quasi-experiment study. Instructional methods including chempuzzle was conducted in this study came into three stage: chempuzzle introduction, chemdoku problem solving exercises, chemkuro problem solving exercises, and discussion. The data collection was divided into two steps. First, measurement of students' priorknowledge and the second is measurement of students' concept understanding. The result of Anacova test showed that the concept understanding of student from Gunung Kidul ($F_0 = 12.041$; $p = 0.001$), Kota Yogyakarta ($F_0 = 6.918$; $p = 0.010$), and Kulon Progo ($F_0 = 15.923$; $p = 0.000$) were significantly different for the two groups, meanwhile those from Sleman ($F_0 = 1.418$; $p = 0.237$) were not different for the two groups. This results showed that Chempuzzle is effective to be implemented on learning process of atomic structure, elements periodic system, chemical bonding, and basic laws of chemistry concepts in the three of four high school. To be an effective method on improving student concept acquisition, it need more time for preparing and introducing the game, and need teacher creativity to make the puzzle form interesting.*

Keywords : *Chempuzzle, Chemistry Concepts*

1. Introduction

The chemistry curriculum still includes some material that requires rote memorization, often including distinctions between superficially similar items. Mastering such material is seldom exciting and many students are reluctant to perform these tasks. Therefore, a method that would make these tasks more interesting is desirable. The use of games in the classroom provides a means of reviewing material in a stimulating and interactive format (Koether:2003; Russell, 1999).

The use of games in the classroom provides a means of reviewing material in a stimulating and interactive format. Sudoku and kakuro puzzles have taken the world by storm and their popularity can be used to help students learn a variety of chemical concepts.

a. Sudoku Puzzles

There are several examples of puzzles being used in the classroom including wordsearch, letter matrix, and crossword puzzles. (Crute & Myers, 2007). An example of puzzle is sudoku. Sudoku puzzles have become quite popular in recent years and routinely appear in media (Crute & Myers, 2007).

The classic sudoku puzzle is a number puzzle consisting of 9×9 grid (or a simpler 6×6 grid), divided into nine 3×3 boxes (or six 2×3 boxes). Some of the numbers are placed in the squares of the grid as “clues”. The object of the puzzle is to fill in the remaining squares of each row, column, and box with the digits 1–9 (or 1–6) so that each row contains all the numbers from 1–9 (or 1–6), each column contains all the numbers from 1–9 (or 1–6), and each 3×3 box (or 2×3 box) contains all the numbers from 1–9 (or 1–6). However, each of the numbers 1–9 (or 1–6) can appear only once on each row, column, and box (Welsh, 2007). A limited number of symbols are strategically placed in the grid as the “givens” for a starting point. Here is the example of sudoku and its solution (fig.1).

5	3			7					5	3	4	6	7	8	9	1	2
6			1	9	5				6	7	2	1	9	5	3	4	8
	9	8						6	1	9	8	3	4	2	5	6	7
8				6				3	8	5	9	7	6	1	4	2	3
4			8		3			1	4	2	6	8	5	3	7	9	1
7				2				6	7	1	3	9	2	4	8	5	6
	6					2	8		9	6	1	5	3	7	2	8	4
			4	1	9			5	2	8	7	4	1	9	6	3	5
				8			7	9	3	4	5	2	8	6	1	7	9

Figure.1. Example of *Sudoku* and its solution

Again, a completed puzzle has one instance of each number per row, column, and box. Because of this puzzle uses number, it is seen more mathematics. Actually, it is not so mathematic, even to solve the puzzle does not need any mathematic or

calculating skill. Perez & Lamoureux, (2007) added that no mathematical skill is required since it relies on “pattern-recognition” and logic to complete the grids.

The puzzle solver must use logic to determine which symbol should appear in each of the remaining spaces. The easiest puzzles only require simple logic or solving by inspection, while progressively more difficult puzzles require more sophisticated or multistep analysis and problem solving. A combination of ruling out symbols for a particular space to avoid repetition, and determining which symbol is still needed in a particular row, column, or box is a typical strategy of solving by inspection. It is known that there are three process to solve sudoku, namely *scanning*, *marking up*, an analyzing.

On the other side, because of the puzzle player has to remember the objection of this game, the player has to consider all the number of symbol filled on the box. This process is needed to avoid repetition on row, column, and subgrid. It indicates that to solve the puzzle student has to put the concept into their own memory.

b. Kakuro Puzzles

A similar puzzle that stress on logic digging is kakuro. Kakuro is known as cross sums and often referred to as a mathematical transliteration of the crossword. Kakuro plays number to be arranged in such ways that there is no double number comes on columns and rows and the sum of them fit to the number showed on the clues box. The aim of the game is to fill all the blank squares in the grid with only the numbers 1-9 so that the numbers you enter add up to the corresponding clues. A number in the top right corner relates to an "across" clue and one in the bottom left a "down" clue. (krazydad.com/puzzles : 2006).When the grid is filled, the puzzle is complete. How to complete the puzzle can be read on www.kakuro.com.

Kakuro puzzle grids can be any size, though usually the squares within them have to be arranged symmetrically. As a rule of thumb, the more blank squares a puzzle contains, the harder it is, however this isn't always true, especially if it is a good quality puzzle (www.kakuro.com).

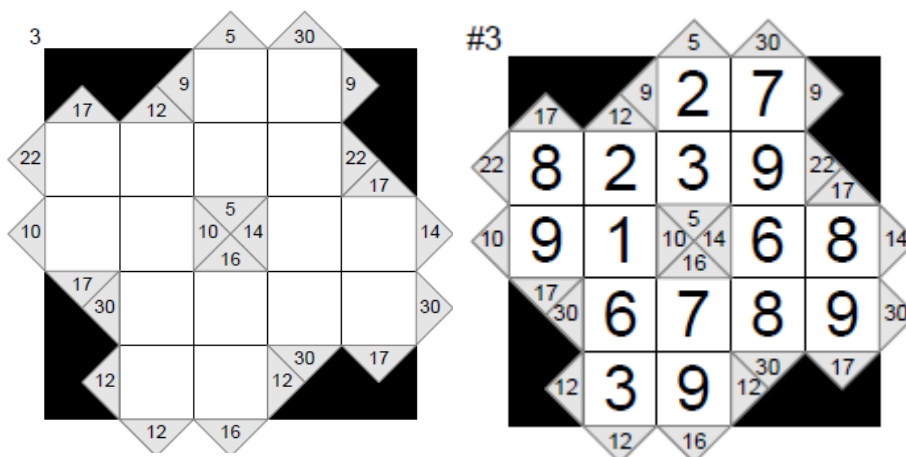


Figure 2. Example of kakuro dan its solution (krazydad.com/puzzles : 2006)

Sudoku and kakuro puzzles have taken the world by storm and their popularity can be used to help students learn a variety of chemical concepts. This article is aimed to analyze two type of logic puzzle those can be implemented on chemistry learning, namely *chemdoku* (chemistry-sudoku) and *chemkuro* (chemistry-kakuro) as a media on enhancing students' concept understanding viewed from their nature, making, implementing, concept range, and student acceptance. At the end, it will give information on logic puzzle developing and implementing on chemistry learning so teacher will know when to use *chemdoku* and *chemkuro*

When students solve a puzzle, they use short term memory certainly. They see symbols and used them. But, the repetition used on this process can fill their cognitive and long term memories. Puzzle solving process it self uses problem solving logic. Thinking process used is not directed by other people. This process raise automatically because the students enjoy to solve the problem. Moursund (2007) mentioned that this process can be applied when they face a bigger problem.

With this long term advantage of puzzle, *chemdoku* and *chemkuro* can be tried to be implemented on teaching and learning process, especially on exercise or task. With this implementation, hopefully, task becomes a fun and interesting activity because student can compete and participate into the lesson actively. This method gives a feedback directly that does not depend on the teacher.

As mentioned before, mathematic skill is not needed on puzzle solving, it needs “logical pattern” to complete blank grids. The relationship between sudoku and chemistry is tenuous but there is a connection (Perez and Lamoureux : 2007). Clearly, it is needed a modification to strengthen the connection between chemistry concept and sudoku so that the game has education value. One of this is adding the chemistry problem into the puzzle like shown on fig.1 and 2 (Sukisman Purtadi and Rr.Lis Permana Sari : 2007). Both of them does not only play the number and symbol those are not related to the chemistry concept because the problem embedded into them. Chemistry problems can come after or before puzzle.

Embedding numbers of problems that more than they are needed to fill the puzzle will give self check chance for student. Students know clearly that all of the answer they got from the concept problem has to be played on their puzzle, so when they find that one or more of their answer cannot be played, they have to re-check their answer. It will strengthen the anchor between chemistry concept and *chemdoku* or *chemkuro*. That leads us to a research question: **“how is the effectiveness of *Chempuzzle* on increasing students’s understanding of atomic structure, elements periodic system, chemical bonding, and basic laws of chemistry concepts?”**

2. Method

a. Participant and Procedure

We implemented a nonequivalent, control group, quasi-experimental design to measure the effects of *Chempuzzle* implementation on increasing students’ understanding of atomic structur and chemical bonding concepts. There are 247 students from 4 (four) year X of high schools in province DIY became participant in this study. The experiment started with classroom observation. Research teams and teachers of the school discussed to decide the classroom to be taken as sample, the classroom condition, and research schedule.

Students were divided into an experimental group and a control group. Experimental group learned one section each of *chempuzzle* introduction, *chemdoku*

problem solving exercises, *chemkuro* problem solving exercises, discussion, and quiz. Control group learned two sections of problem solving exercise on students worksheet, one section of discussion, and quiz. The problems solved on experiment and control groups are the same. There were no media added on the process to avoid biases.

b. Instructional Method

Instructional methods including *chempuzzle* was conducted in this study came into three stage: *chempuzzle* introduction, *chemdoku* problem solving exercises, *chemkuro* problem solving exercises, and discussion

First stage, introduction. *Chempuzzle* - *chemdoku* and *Chemkuro* is new for the students so it is necessary for us to introduce them clearly by giving students some simple example of sudoku and kakuro. This introduction is supposed to help student become familiar with *sudoku* and *kakuro* so that they can learn *chemdoku* and *chemkuro* without get problem on sudoku and kakuro.

Second stage, problem solving exercise with *Chempuzzle*. Experiment group students were divided into group of three - four students. They did the problem on *chempuzzle* form. *Chemdoku* came first because it is more understandable than *chemkuro*. On *chemkuro*, students had to fit nine elements into every single boxes with no double number comes on columns and rows and the sum of them fit to the number showed on the clues box. Numbers of problems had been arranged on the certain boxes that would be changed into the answer of the problem associated with the number. The others box had to be filled with numbers than, so the sum of them fit to the number showed on the clues boxes. Students could help each others to solve the problems.

Third stage, discussion. On this stage teacher and student discuss the answer of the problem. Teacher can give the answer explanation so students understand the answer.

Control group learned two sections of problem solving exercise on students worksheet. In this class, they did the same chemical problem with the experimental group but the process was dominated with informative-discussion method.

c. Data Collection and Instruments

The data collection was divided into two steps. First, measurement of students' prior knowledge, and the second is measurement of students' concept understanding. A multiple choice – paper and pencil based test was used to collect data for this study. Content questions related to the students' understanding of atomic structure, elements periodic system, chemical bonding, and basic laws of chemistry concepts. Quantitatively, one-way analysis of covariance (ANACOVA) was used to measure the effect of *chempuzzle* on increasing students' understanding of atomic structure, elements periodic system, chemical bonding, and basic laws of chemistry concepts. Students' prior knowledge was placed as covariate.

3. Results and Discussion

The effectiveness of *chempuzzle* on increasing students understanding of atomic structure, elements periodic system, chemical bonding, and basic laws of chemistry concepts was compared to problem solving exercise. This *chempuzzle* implementation was not compared to teaching methods because the *chempuzzle* was meant to be a media to strengthen concept student had before rather than a concept deliverer. Hence, *chempuzzle* still be hoped to help students on concept gathering and acquisition.

The data were kept separated based on their high school. The data for all participants on each school were coded by student number and then entered into a spreadsheet. For the null hypothesis we posited that no difference existed between the students concept understanding for the experimental group and the control group when students prior knowledge was considered. An *Anacova* test was run to compare the mean achievement on the data. The *result of Anacova* test that the concept understanding of student from Gunung Kidul ($F_0 = 12.041$; $p = 0.001$), Kota Yogyakarta ($F_0 = 6.918$; $p = 0.010$), and Kulon Progo ($F_0 = 15.923$; $p = 0.000$) were significantly different for the two groups, meanwhile those from Sleman ($F_0 = 1.418$; $p = 0.237$) were not different for the two groups. The data can be shown on table 1.

This result shows us that *Chempuzzle* is effective to be implemented on learning process of atomic structure, elements periodic system, chemical bonding, and basic laws of chemistry concepts in the three of four high school.

Table 1. Data of student concept understanding

Area	Group	Σ students	Prior Knowledge			Student's concept understanding			Stat. result
			Max	min	Average	Max	min	Average	
Sleman	C	33	53.9	15.4	36.17	64.0	32.0	49.33	$F_0 = 1.418$ $p = 0.237$
	E	31	46.2	7.7	27.32	73.0	18.0	46.74	
Gunung Kidul	C	36	76.3	23.1	50.00	81.8	31.8	57.57	$F_0 = 12.041$ $p = 0.001$
	E	36	69.2	30.7	58.55	86.4	50.0	69.95	
Kota Yogya	C	32	85.0	54.0	73.34	95.0	68.0	78.22	$F_0 = 6.918$ $p = 0.010$
	E	32	85.0	46.0	72.75	95.0	68.0	83.09	
Kulon Progo	C	34	92.5	60.0	75.10	72.7	50.0	61.10	$F_0 = 15.923$ $p = 0.000$
	E	33	97.5	57.5	75.10	86.4	59.1	68.32	

C = Control group E = Experiment Group

Chempuzzle games give more pressure on logical that helps student to remember and understand concepts. These games can train right and left part of brain. Sudoku is a simple logic and funny game. Sudoku that was implemented on chemistry learning - atomic structure, elements periodic system, chemical bonding, and basic laws of chemistry concepts- is simple games because the game only place the element symbols complete with atomic and mass number into the boxes with some opened clues. Sudoku excite students logical intelligence and gives students a challenge to solve the problem that stressed on logic ability, it will become a good learning habit to solve their own problem.

There are three process on solving sudoku (*chemdoku*): *scanning*, *marking up*, and *analyzing*. Scanning concludes two process, cross view – look at the element or other clue that has been filled in the rows, column, or subgrids, and identify any missing elements on row, column, or subgrid. Marking up is started when there are no elements have to be filled in the boxes gotten from the scanning process. This process need logical thinking. On the marking up process, we can write down the elements that can be filled on the box, it is started from the box that has less possibility. So, it can reduce

the other box possibility. The last step is analyzing. This step consists of *guess-check and eliminate*.

On the other part of this game, due to students have to remember the purpose of this game, students have to notice every elements have to be filled on the box. It helps students so they will never put double elements. This process indicates that to solve the puzzle problems, students have to put every elements on their cognitive memory. To solve the puzzle, they used short term memory, they see the symbol and use it. But the repetition used on this process can be supposed to fill their cognitive and long term memory. So, student can store the concepts on their long term memory and increase their concept understanding. The concept achievement level depends on the complexity of the concept and student development stage.

STRUKTUR ATOM

PETUNJUK
Isi kotak kosong dengan lambang unsur yang telah tersedia dengan ketentuan sebagai berikut :

- > Tidak boleh terjadi pengulangan satu sub grid
- > Tidak boleh terjadi pengulangan pada satu baris
- > Tidak boleh terjadi pengulangan satu kolom

$\begin{matrix} 28 \\ 14 \end{matrix}$ Si	$\begin{matrix} 39 \\ 19 \end{matrix}$ K	$\begin{matrix} 23 \\ 11 \end{matrix}$ Na	$\begin{matrix} 40 \\ 20 \end{matrix}$ Ca	$\begin{matrix} 32 \\ 16 \end{matrix}$ S	$\begin{matrix} 40 \\ 18 \end{matrix}$ Ar	$\begin{matrix} 27 \\ 13 \end{matrix}$ Al	$\begin{matrix} 30 \\ 15 \end{matrix}$ P	$\begin{matrix} 35 \\ 17 \end{matrix}$ Cl
$\begin{matrix} 27 \\ 13 \end{matrix}$ Al	$\begin{matrix} 30 \\ 15 \end{matrix}$ P			$\begin{matrix} 23 \\ 11 \end{matrix}$ Na	$\begin{matrix} 28 \\ 14 \end{matrix}$ Si		$\begin{matrix} 32 \\ 16 \end{matrix}$ S	
$\begin{matrix} 40 \\ 20 \end{matrix}$ Ca			$\begin{matrix} 30 \\ 15 \end{matrix}$ P	$\begin{matrix} 35 \\ 17 \end{matrix}$ Cl	$\begin{matrix} 27 \\ 13 \end{matrix}$ Al	$\begin{matrix} 39 \\ 19 \end{matrix}$ K	$\begin{matrix} 28 \\ 14 \end{matrix}$ Si	
$\begin{matrix} 35 \\ 17 \end{matrix}$ Cl	$\begin{matrix} 40 \\ 18 \end{matrix}$ Ar	$\begin{matrix} 40 \\ 20 \end{matrix}$ Ca	$\begin{matrix} 28 \\ 14 \end{matrix}$ Si	$\begin{matrix} 39 \\ 19 \end{matrix}$ K	$\begin{matrix} 30 \\ 15 \end{matrix}$ P	$\begin{matrix} 23 \\ 11 \end{matrix}$ Na	$\begin{matrix} 27 \\ 13 \end{matrix}$ Al	$\begin{matrix} 32 \\ 16 \end{matrix}$ S
		$\begin{matrix} 30 \\ 15 \end{matrix}$ P		$\begin{matrix} 27 \\ 13 \end{matrix}$ Al		$\begin{matrix} 40 \\ 18 \end{matrix}$ Ar		$\begin{matrix} 40 \\ 20 \end{matrix}$ Ca
	$\begin{matrix} 27 \\ 13 \end{matrix}$ Al		$\begin{matrix} 40 \\ 18 \end{matrix}$ Ar		$\begin{matrix} 23 \\ 11 \end{matrix}$ Na			$\begin{matrix} 30 \\ 15 \end{matrix}$ P
$\begin{matrix} 39 \\ 19 \end{matrix}$ K				$\begin{matrix} 30 \\ 15 \end{matrix}$ P	$\begin{matrix} 40 \\ 20 \end{matrix}$ Ca	$\begin{matrix} 35 \\ 17 \end{matrix}$ Cl	$\begin{matrix} 40 \\ 18 \end{matrix}$ Ar	$\begin{matrix} 28 \\ 14 \end{matrix}$ Si
	$\begin{matrix} 35 \\ 17 \end{matrix}$ Cl	$\begin{matrix} 27 \\ 13 \end{matrix}$ Al	$\begin{matrix} 23 \\ 11 \end{matrix}$ Na		$\begin{matrix} 32 \\ 16 \end{matrix}$ S			$\begin{matrix} 39 \\ 19 \end{matrix}$ K
		$\begin{matrix} 28 \\ 14 \end{matrix}$ Si		$\begin{matrix} 40 \\ 18 \end{matrix}$ Ar		$\begin{matrix} 32 \\ 16 \end{matrix}$ S		$\begin{matrix} 27 \\ 13 \end{matrix}$ Al

SOAL
Tentukan

- a. Jumlah proton, netron, dan elektron masing-masing unsur
- b. Letak unsur dalam Tabel Periodik Unsur
- c. Isotop, isoton, dan isobar




Figure 3. Example of chemdoku for atomic structure concept (Sukisman and Rr. Lis Permana Sari : 2009)

The other factor that influences the result of this study is familiarity of the game. Seldom did the lesson use the game. Learning process in the classroom is dominated by direct instruction or informative discussion. It is hard for students to see that the implementation of the puzzle in their classroom is a learning process. And, students who have been familiar with the puzzle can leave the trouble on the rule of the game, so they can learn on the chemistry concept only, but those who have not been familiar with the game they face two problem: they have to pass the trouble of the rule, and they have to learn chemistry concept. It can decrease their achievement – like those from Sleman.

This condition indicates that implementation of *chempuzzle* on chemistry learning need more time. The game still effectives to increase students achievement, but they have to be well-known first and need teacher creativity to make the puzzle form interesting.

4. Conclusion

This result shows us that *Chempuzzle* is effective to be implemented on learning process of atomic structure, elements periodic system, chemical bonding, and basic laws of chemistry concepts in the three of four high school. To be an effective method on improving student concept acquisition, it need more time for preparing and introducing the game, and need teacher creativity to make the puzzle form interesting.

References

- Crute, T. D dan Myers, S. A. (2007). *Sudoku Puzzles as Chemistry Learning Tools. Journal of Chemical Education.* 84(4): 612 - 613
<http://krazydad.com/puzzles>. 2006. *Kakuro*. [on line] accessed on 5 May 2009
<http://www.kakuro.com>. 2008. *How to play kakuro*. [on line] accessed on 5 Mya 2009
- Koether, M. 2003. **The Name Game: Learning the Connectivity between the Concepts.** *Journal of Chemical Education* • 80(4) : 421 – 422
- Moursund, D. 2006. *Introduction to Using Games in Education: A Guide for Teachers and Parents.* E-book [online] accessed via <http://uoregon.edu/~moursund/dave/index.htm>

- Perez, A.L. and G. Lamoureux. 2007. **Sudoku Puzzles for First-Year Organic Chemistry Students**. *Journal of Chemical Education*. 84(4): 614
- Russell, Jeanne V. 1999. **Using Games To Teach Chemistry: An Annotated Bibliography**. *J. Chem. Educ.* 76(4): 481.
- Sukisman Purtadi and Rr Lis Permana Sari. (2007). **Menggali Nilai Edukasi Sudoku Kimia**. *Prosiding seminar nasional kimia dan pendidikan kimia 2007 ISBN 978-979-98063-1-4 dengan tema "Peranan Kimia dan Pendidikan Kimia dalam Pengembangan Industri yang Berwawasan Lingkungan"*. Yogyakarta : FMIPA UNY.
- Sukisman Purtadi and Rr. Lis Permana Sari (2009). **Penerapan Chempuzzle Untuk Meningkatkan Pemahaman Konsep dan Motivasi Terhadap Kimia Pada Siswa SMA**. Research Grant PHK-A2 Report. Unpublished.
- Welsh, M.J. 2007. **Chemistry of Art and Color Sudoku Puzzles** *Journal of Chemical Education*. 84 (4): 610 -611