

## Students' Metacognitive Awareness and Physics Learning Efficiency and Correlation between Them

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### **Abstract**

This paper presents a research directed to examine the relation between students' metacognitive awareness and physics learning efficiency. Questionnaire of metacognitive awareness and physics knowledge test were applied on the sample of 746 subjects of both sexes, first graders of Grammar Schools in Novi Sad, Republic of Serbia. Obtained results were treated statistically. Results analysis shows that 15 years old girls have higher level of metacognitive awareness than 15 years old boys. It is shown that achievement in physics is not dependent on gender. The results indicate significant moderate correlation between metacognitive skills and student achievement in physics ( $r = 0.48473$ ,  $p < 0.001$ ). Important insights about metacognitive awareness and efficiency in physics learning have been generated. Our study has highlighted the benefits of developing metacognitive awareness to achieve better results in physics teaching-learning process.

**Keywords:** metacognition, metacognitive awareness, achievement in physics, physics.

### **Introduction**

Nowadays it is necessary to teach students how to become skilled problem solvers in a dynamic world they are living in. Students leaving elementary school, therefore finishing compulsory education, in the Republic of Serbia have no satisfactory operational physics knowledge, that is they don't develop the ability to use learned material in new and concrete situations. This is indicated by the results of various knowledge tests of natural sciences, such as the PISA test examination in operational knowledge, applied to fifteen-year-olds, students of the first year of Grammar school. Compulsory education in the Republic of Serbia consists of preschool education and elementary education. In elementary education natural sciences are taught within an integrated subject in first cycle, from first to fourth grade (seven to ten years old students), and later within second cycle, from fifth to eighth grade (eleven to fourteen years old students) within three separate subjects: Biology, Chemistry and Physics. Physics is taught in sixth, seventh and eighth grade. According to curriculum, by the end of compulsory education, students should have some knowledge of all fields in physics. In classical physics, those fields include mechanics, thermodynamics, sound, light and optics, and electricity and magnetism; in modern physics: atomic, nuclear, and particle physics. After finishing compulsory education students can choose

to enroll in specialized vocational secondary school or Grammar school where they can get comprehensive knowledge and where they also have a choice between departments: Science and Mathematics, Humanities and Languages, General, Specialized Science and Mathematics for gifted students, Bilingual department.

Since the first idea of “learning by doing”, given by John Dewey who thought that active learning is both cognitive and social, numerous psychologists and educators have been encouraging this way of teaching and learning (Breault & Breault, 2005). Students construct their knowledge actively by thinking and doing, through interactive experiences with the environment, rather than like passive receiver (Acikgoz, 2004; Ozel, 2005). That is self-regulation process (Zimmerman, 1989). Within of self-regulation there are students’ observation, evaluation, and the development of themselves. Some researchers are opinion that self-regulated learning has an influence on academic achievement (Mace & Kratochwill, 1985) and self-regulation is included in concept of metacognition.

Metacognition enables students to solve new problem by retrieving and deploying strategy that they have learned regarding to similar context (Kuhn & Dean, 2004). It is therefore important to examine the validity and significance of the hypothesis that development of students’ metacognition and awareness of their own abilities affects the efficiency of learning. This paper will present research conducted with that aim. Expected results should indicate the relationship between the level of metacognitive awareness and students’ achievement in physics. Also, the results should determine the direction in which following studies and research related to metacognitive skills in teaching physics should be performed. The value of metacognition in education, in addition to its correlation with the learning efficiency is reflected in the application of metacognitive and incentive programs.

#### *Conception of Metacognition*

Understanding the concept of metacognition is very useful. It can answer questions related to the development of cognitive and affective area; also it can improve understanding and analysis in all areas where the process of self-regulation is included. Research of metacognition has been carried out since the seventies of the twentieth century with the beginnings of developmental and cognitive psychology. Knowledge about the metacognition was developed in research on memory (Flavell & Wellman, 1977). John Flavell originally came up with the term metamemory, and later the term metacognition and used it in the late 1970s with meaning “knowledge and cognition about cognitive phenomena,” or simpler “thinking about thinking” (Flavell, 1979). Since then concept of metacognition is attributed with different meanings, but most researchers believe that metacognition refers to one’s thinking process, monitoring and control of thinking. Since the start of using the term metacognition, authors indicate that its precise meaning wasn’t clear (Forrest-Presley, 1985; Hacker, 1998a; Posner, 1989; Weinert, 1987). Different terms with overlapping concepts are used in connection with metacognition. All authors find it possible to separate the concepts of metacognition and cognition but distinguishing those two concepts is not always straightforward. If one knows that he is not very good at learning physics, the distinction lies in how that learner realizes and uses that information about his own learning. In Flavell’s model on metacognition, it differs from cognition in content and function, and they are similar in their form and quality. Both cognition and metacognition can be correct or incorrect, acquired and forgotten. For example text material that is heavily underlined or highlighted, suggests that a student does not know how to identify relevant information and

that indicates the inadequate metacognitive skills (Ganong, 2001). Cognitive psychology researchers have given different definitions with similar meaning for metacognition.

Cross and Paris (1988) define metacognition as the knowledge and control children have over their own thinking and learning activities. Kuhn and Dean (2004) give definition that it is awareness and management of one's own thought and Martinez (2006) that it is the monitoring and control of thought. Ormrod (2004) defines metacognition as what one knows about his own cognitive processes and how he uses these processes in order to learn and remember. According to Hennessey (1999) metacognition is understood as "awareness of one's own thinking, awareness of the content of one's conceptions, an active monitoring of one's cognitive processes, an attempt to regulate one's cognitive processes in relationship to further learning, and an application of a set of heuristics as an effective device for helping people organize their methods of attack on problems in general" (p. 3). Generally it is defined as the activity of monitoring and controlling one's cognition (Weinert & Kluwe, 1987).

Several frameworks have been developed for categorizing subcategories of metacognition. Flavell is including metacognitive knowledge, metacognitive experiences, tasks and goals, and strategies or actions in metacognition (Cooper, 1999). Brown (1978) distinguished two metacognitive activities: knowledge of cognition and activities used to regulate and have an overview over cognition. Kluwe (1982) identified declarative and procedural knowledge in metacognition, as well did Chi (1987).

According to first framework given by Flavell, metacognitive awareness can be categorized into awareness of: metacognitive knowledge, metacognitive regulation and metacognitive experiences. Knowledge of cognition usually includes three different kinds of metacognitive awareness: declarative knowledge, procedural knowledge and conditional (strategic) knowledge (Schraw & Moshman, 1995). These kinds of metacognitive awareness cover how to do something; skills, strategies and resources required to perform the task (knowledge of how to perform something); and knowledge of when to apply certain strategy, respectively. Regulation of cognition refers to awareness of the need to use certain strategies, such as planning, information management, monitoring, evaluation and debugging in process of thinking and learning (Kluwe, 1987; Schraw & Dennison, 1994). Psychologists and educators are aware of the importance of checking understanding and making changes based on the results of self-checks (Brown, 1987). Terms closely related to metacognition, slightly different and less comprehensive, used in the field of cognitive psychology are metamemory, metacomprehension, and calibration of comprehension. Maki uses the term metacomprehension to describe the process of monitoring learning from text (Maki, 1998). Calibration of comprehension is described by Otero (1998) as a measure of the relationship between how well readers think they understand text and how well they actually understand it and can answer questions about it. Within metacognition, Weinert (1983) distinguishes evaluation (in which a problem is identified) and regulation. Example of first is when student realizes that he does not understand something, and example for second is when student takes measures to increase understanding, by studying more or using different study strategies. Metacognitive experiences are for example: feeling-of-knowing, judgments-of-learning, ease-of-learning judgments (Hacker, 1998b).

Numerous attempts have been made to identify variables that influence metacognition. According to Flavell (1979) metacognition is sometimes done unconsciously. He believes that metacognition was influenced by three variables: the learner, the task and the strategy. It is important to identify relevant information and form mental representations of it (Davidson &

Sternberg, 1998). Evidence of the relationship between metacognitive and motivational components of self-regulation is given in the research conducted by Hong and O'Neil (2001). Research in the area of metacognition deals with the problem of measuring metacognitive skills, various strategies used in teaching methods for encouragement metacognitive skills and study the impact of metacognition on students' achievement and attitudes. The structure and use of metacognition have been studied also with the aid of reasoning (Halpern, 1984).

Number of authors has found cognitive functioning differences in regards to gender. Different authors have found that girl students show more metacognitive ability (Carr & Jessup, 1997; Singh, 2012). Fatin (2005) found that the gender differences for both metacognitive and problem-solving skills were significant in favor of female students. Analysis of metacognition of undergraduate students is suggesting that females are showing significantly higher levels of self-regulation and a more positive attitude to academic study than their male counterparts (Downing et al., 2008). The differences between boys and girls regarding metacognition, according to some authors, occur mainly in the case of items that measure knowledge of cognition (Ciascai & Haiduc, 2011).

Other authors have done researches about relationship between metacognition and academic achievement but not particularly regarding the physics learning. Kruger and Dunning (1999) claim that students with good metacognition demonstrate good academic performance compared to students with poor metacognition. It is also indicated that students in the metacognitive treatment group significantly improved in both mathematical problem solving achievement and metacognitive skills (Ozsoy & Ataman, 2009). Singh (2009) found that the association between metacognitive ability and academic achievement in science subject of standard 9th grade students are positive and significant. For 6<sup>th</sup> through 8<sup>th</sup> grade students, knowledge of cognition, regulation of cognition, and quick learning contributed to science achievement (Topcu & Yilmaz-Tuzun, 2009). It is shown that metacognitive awareness was significantly correlated with the performance of students in chemistry (Rahman et al., 2010). Ku and Ho (2010) showed that good critical thinkers are engaged in more metacognitive activities. Research carried out in the opposite direction indicated that both cognitive resources (expressed by achievement level) and mnemonic experience (assessed through age) reinforcing metacognitive development (Krebs and Roebbers, 2012).

## Research Methodology

### *The Research Problem*

The main problem of this research is the question of whether there is a correlation between the level of metacognitive skills and students' achievement in physics.

Findings of relevant previous research from number of authors are used as guidelines for developing researchable hypotheses and tasks to answer the research questions. Some hypotheses are proposed because all surveyed students were taught based on the same syllabus in primary school. Also, there are big similarities in way of teaching performed by different teachers in primary schools of Novi Sad.

The case study examined the influence of metacognition on the efficiency of learning in physics.

### *The research Objectives and Tasks*

The main objective of this research was to examine the correlation between the level of metacognitive awareness and students' achievement in physics. Besides, adventitious objectives were description of variables metacognition and physics knowledge and examination of dependence of metacognition and physics knowledge on gender.

The research tasks:

- To examine the statistical characteristics of the variable metacognition and to determine the correlation between the development of metacognitive awareness and gender of the surveyed students.
- To examine the statistical characteristics of the variable achievement in physics and to determine the correlation between the student achievement in physics and gender of the students.
- To determine the correlation between the development of metacognitive awareness and the student achievement in physics.

### *Research Hypotheses*

Research hypotheses:

- It is predicted that significant correlation between the development of metacognitive awareness and gender of the students exists.
- It is predicted that there is no significant correlation between the student achievement in physics and gender of the students.
- It is predicted that significant positive correlation between the development of metacognitive awareness and the student achievement in physics exists.

### *Design and Procedure*

The research was conducted as a nonexperimental screening of the state. Data collection was carried out by the use of survey prepared for that purpose. Questionnaires were given to students in groups, testing was anonymous. Students were time limited to complete the questionnaire on metacognitive awareness to a school hour (45 minutes). Also, the students had a school hour to answer questions from the physics knowledge test.

### *Data Collection Methods*

In order to achieve the research objectives studying in literature and a nonexperimental screening of the state by the use of descriptive statistics were done. Descriptive method enables recognition and description of educational empirical facts (state screening) and the detection, explanation and interpretation of the connections and relationships that exist between them.

### *The Research Sample*

The survey was conducted on a sample of 746 fifteen-year-olds, students of both genders: 358 males and 388 females that enrolled the first grade of some of the four grammar schools in Novi Sad, city in Republic of Serbia. In this sample there are no significant differences between students with respect to previous elections of vocational direction. All surveyed students were enrolled in grammar school so they were interested in gaining general knowledge. It was decided to conduct single-phase procedure on the sample.

### *Data Collection Techniques and Research Instruments*

Techniques used for data collection were: survey, testing and scaling. Pilot survey was performed in order to create an adequate instrument. On the basis of pilot survey the original instrument was adjusted. The instrument used for this research consists of: (1) questionnaire, (2) the scale for assessment of metacognitive skills, and (3) physics knowledge test.

The first part of the research instrument consists of questions concerning general information about subjects on which an assessment is made of the research sample structure. Out of this information gender was taken as variable.

The second part of the instrument is adapted questionnaire about metacognitive awareness (Metacognitive Awareness Inventory - MAI, Schraw & Dennison, 1994). MAI questionnaire is intended to assess metacognitive skills of adolescents and adults and contains items that examine each of the eight components: knowledge of cognitive processes (declarative, procedural and conditional) and regulation of cognitive processes (planning, information management, monitoring, evaluation and debugging in thinking process). MAI is constructed in the early nineties (Schraw & Dennison, 1994). Of the 52 items with five-point response Likert scale of MAI 32 items appropriate for the selected sample were retained and adjusted. The choice of items was made based on the capabilities of students to understand the items that constitute the scale, which was tested by pilot survey, and based on example of the survey about the children's awareness of metacognition that is proposed for children aged less than 14 years (Junior Metacognitive Awareness Inventory - Jr. MAI; Sperling et al., 2002). The Cronbach alpha coefficient is 0.87 so the scale of the instrument has satisfactory validity.

Examples of items in MAI:

- I ask myself periodically if I am meeting my goals;
- I try to use strategies that have worked in the past;
- I pace myself while learning in order to have enough time;
- I know how well I did once I finish a test;
- I slow down when I encounter important information.

The third part of the instrument makes a knowledge test covering entire syllabus of Physics planned for primary education, except for theme about movement (kinematics) as it is taught at the beginning of the first year of grammar school (at a time when testing is done). Of the 35 questions after the pilot test 20 questions were selected on the basis of which the assessment of student achievement (questions were on all levels of knowledge) in physics is done.

Examples of knowledge test questions in level of knowledge (1), comprehension (2) and application (3):

1. The magnetic poles are commonly called:
  - a) East and west
  - b) north and south**
  - c) plus and minus
  - d) red and blue
  - e) anode and cathode
2. Astronauts on the moon cannot hear if rockfalls happen because:
  - a) sound can't pass through thick dust on the moon
  - b) strong sunlight destroy a sound wave
  - c) the moon's magnetic field is too weak to transmit sound

- d) the atmosphere is too rare to transmit sound
  - e) sound can't pass through an astronaut's suit
3. Assume that light bulb marked with B in electrical circuit shown in a figure (Figure 1) burn out. What will happen?

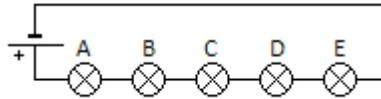


Figure 1. Sheme for electrical circuit

- a) None of the light bulbs in the circuit will light up
- b) The remaining light bulbs will continue to light up
- c) the light bulbs C, D and E will continue to light up, and the bulb A will stop
- d) the light bulbs C, D and E will stop, and A will continue to light up
- e) none of the above answer is correct

#### *Statistical Analysis of Data*

After the logic check and coding of collected data statistical analysis of results is done. Because of the 36 incomplete questionnaires from 782 surveyed students a sample of 746 respondents is received. In the statistical processing and analysis of collected data with the aim of statistical description of metacognition and physics achievements one variable analysis for both is conducted, with the statistical measure used (average measures, measures of variability and measures of distribution shape) in order to better clarity the results, the graphical representation of relevant data is given.

In order to determine differences in metacognition and achievements of physics in relation to gender differences and differences by students' orientation a one-way analysis of variance or, where needed, Kruskal-Wallis test is conducted. In doing so, the outcome variables were sum scores of metacognitive awareness inventory, students' physics achievements, and factor was gender. Higher score indicated a higher level of development of metacognition and a higher level of achievement on the knowledge test.

In order to determine the correlation of metacognition and the students' physics achievements multiple variables analysis (correlation analysis) is applied and also simple linear regression. The initial set of variables consisted of answers to the 32 items questionnaire on metacognitive awareness and 20 questions physics knowledge. In the derived regression analysis were used sum questionnaire scores of metacognitive awareness and sum knowledge test scores. Dependent variable was score on the knowledge test, and the independent variable (predictor) was sum score of questionnaire on metacognitive awareness.

### **Results Analysis and Discussion**

#### *Students' Metacognitive Awareness*

In the analysis of students' metacognitive awareness, sum score of students' responses on adjusted MAI (on a scale of 1 to 5 for each answer) is used. In this higher sum score indicates a higher level of metacognitive awareness of students. The results were possible within the range

from 32 to 160, but all scores are in range from 69 to 158. Average of this variable is 124.822 and median for it 124 (Table 1).

Table 1. Descriptive statistics for the variable Metacognitive awareness

| Sum on Metacognitive Awareness |           |
|--------------------------------|-----------|
| Count                          | 746       |
| Average                        | 124.822   |
| Median                         | 124.0     |
| Mode                           | 124.0     |
| Standard deviation             | 12.9382   |
| Coeff. of variation            | 10.3654%  |
| Minimum                        | 89.0      |
| Maximum                        | 158.0     |
| Range                          | 69.0      |
| Std. skewness                  | -0.813055 |
| Std. kurtosis                  | -1.99066  |

This table shows summary statistics for metacognition. It includes measures of central tendency, measures of variability, and measures of shape. Values of standardized skewness (-0.813055) and standardized kurtosis (-1.99066) indicate that the sample comes from a normal distribution (Figure 2).

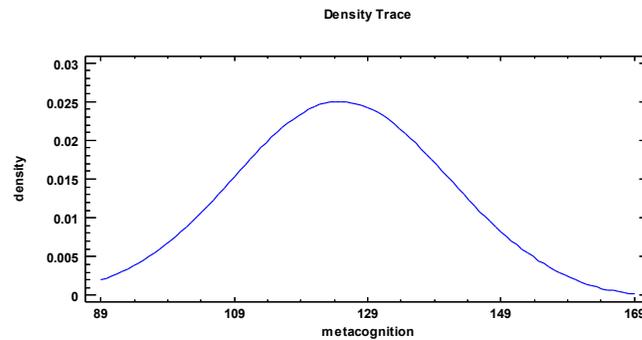


Figure 2. Density trace of variable Metacognitive awareness

An analysis of correlation between metacognitive awareness and gender of the respondents was carried out by the use of Kruskal-Wallis test. With Kruskal-Wallis test the null hypothesis that the medians of metacognitive awareness within each of the 2 levels of gender are the same is tested. Since the P-value of the Kruskal-Wallis test is  $P = 0.00121919 < 0.05$ , there is statistically significant difference between the median of metacognitive awareness in relation to gender at the 95.0% confidence level. Surveyed girls have shown higher scores on metacognitive awareness inventory than boys (average of metacognition awareness of boys and girls are 123.036 and 126.469, respectively). That means at age of fifteen years surveyed girls have developed metacognitive awareness at slightly higher level than surveyed boys at same age. Hypothesis that significant positive correlation between the development of metacognitive skills and gender of

the respondents exists is accepted. That result was expected because it is in consolidation with the findings of authors that have found similar cognitive functioning differences in regards to gender. Different authors have found that girl students show more metacognitive ability (Carr & Jessup, 1997; Singh, 2012; Fatin, 2005; Downing et al., 2008).

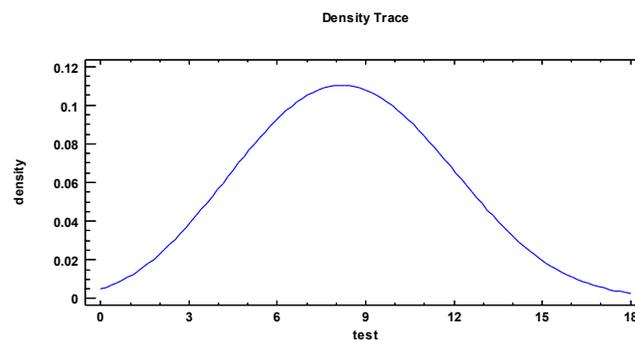
*Students' Achievement on the Physics Knowledge Test*

The total scores on the physics knowledge test of 746 tested students were in the range of 1.0 to 17.0 of maximum 20. Average of this variable is 8.36059 and median 8.0 (Table 2).

*Table 2. Descriptive statistics for the variable Physics knowledge test*

|                     | Sum on Knowledge Test |
|---------------------|-----------------------|
| Count               | 746                   |
| Average             | 8.36059               |
| Median              | 8.0                   |
| Mode                | 8.0                   |
| Standard deviation  | 2.89086               |
| Coeff. of variation | 34.5772%              |
| Minimum             | 1.0                   |
| Maximum             | 17.0                  |
| Range               | 16.0                  |
| Std. skewness       | 1.99211               |
| Std. kurtosis       | -1.93902              |

Values of standardized skewness (1.99211) and standardized kurtosis (-1.93902) indicate that the score on physics knowledge test comes from a normal distribution (Figure 3).



*Figure 3. Density trace of variable Physics knowledge test*

Since the P-value of F-test is  $P = 0.447216 > 0.05$  it is shown that there is not statistically significant difference in student achievement on the physics knowledge test in relation to gender at the 95.0% confidence level. Hypothesis that there is no significant correlation between the student achievement in physics and gender of the respondents is, therefore, accepted. This is expected because all students were taught based on the same syllabus and by the use of same teaching methods.

*Correlation between Level of Metacognitive Awareness and Students' Achievement on the Physics Knowledge Test*

The Pearson's correlation coefficient (0.4847) indicates that there is moderate positive linear relationship between tested variables, the metacognitive awareness and students' achievement on physics knowledge test, at the 95.0% confidence level ( $P = 0.0000$ ). For the purpose of further analysis simple regression was performed, where the independent variable was the level of metacognitive awareness, and the dependent variable student achievement on the physics knowledge test (Table 3):

$$\text{Score on the knowledge test} = - 5,15833 + 0,108306 \cdot \text{score on MAI}$$

Table 3. The coefficient of correlation between the level of metacognitive awareness and student achievement on the physics knowledge test

| Correlation Coefficient | R-squared | R-squared (adjusted for d.f.) | Standard Error of Est. |
|-------------------------|-----------|-------------------------------|------------------------|
| 0.48473                 | 23.4963%  | 23.3935%                      | 2.53023                |

The R-Squared statistic indicates that the model as fitted explains about 23% of the variability in test. The correlation coefficient equals 0.48473 indicates significant moderate relationship between the variables. The standard error of the estimate shows the standard deviation of the residuals to be 2.53023.

The Analysis of Variance for estimation of the statistical significance of the regression model has shown that the regression model is statistically significant at  $P = 0.0000 < 0.001$ .

Hypothesis that there is a significant positive correlation between the development of metacognitive awareness and the student achievement in physics is accepted. Hence it can be suggested that developing of metacognition enables students to be successful learners of physics contents. This finding is consistent with some findings from other authors that have done similar researches but not particularly regarding the physics learning (Kruger and Dunning, 1999; Ozsoy & Ataman, 2009; Singh, 2009; Topcu & Yilmaz-Tuzun, 2009; Rahman et al., 2010; Ku and Ho, 2010; Krebs and Roebbers, 2012).

**Conclusion**

Results analysis shows that metacognition is dependent on gender and that achievement in Physics is not dependent on gender. Surveyed girls at age of fifteen years have shown higher metacognitive awareness than boys at same age. Also it is shown that there is moderate positive ( $r = 0.48473$ ) statistically significant ( $P < 0.001$ ) correlation between metacognitive awareness and students' achievement in Physics. The highly metacognitively aware students performed well on the physics test.

Analysis results point out the importance of metacognitive awareness as a supporting factor in effective physics learning process. Metacognition is important in learning and is a predictor of success in learning physics contents. Better understanding of factors behind thinking performance enables students to learn physics contents easier. The implication for practice is that teachers, while teaching students physics contents, should also help students to establish the habit of self-checking their understanding and task approach, and related metacognitive knowledge should also be imparted. Students with poor metacognition may benefit from metacognitive training to

improve their metacognition and cognitive performance. Also maybe slightly different teaching strategy and instruction related to students' gender can result with more successful teaching. Further studies are desirable to consolidate the present findings with findings that can be gain by carrying out pedagogical experiment where physics learning efficiency will be observed while metacognitive awareness is influenced differently in control and experimental group. This would further enhance our understanding of the extent to which individuals vary in physics learning efficiency related to metacognitive ability as well as their awareness of it and that would have important implications for teaching physics.

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