# Predicting Progression Trends of Scientific Reasoning Skills and Metacognitive Awareness among Secondary Level Students

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**Abstract:** Since metacognition and scientific reasoning are essential factors in student learning processes and outputs, this study focused on predicting the progression trends of the two constructs among secondary level students. Literature suggests that acquiring the two aspects require two similar skills. Therefore, it is hypothesized that the two correlates with each other. However, limited studies were done to support the hypothesis. In this study, the relationship between the two constructs, as well as with the different factors that may affect them such as grade level, age and gender, was explored. 250 students from Grade 7 to Grade 12 were encouraged to take the LCTSR and MAI. Results showed that scientific reasoning skills significantly increased across the six grade levels while metacognitive awareness remained stable. A significant positive correlation between scientific reasoning and metacognitive awareness was established. Multiple linear regression showed that procedural knowledge and information management strategies significantly predicted scientific reasoning. Findings also revealed that age is positively correlated to scientific reasoning skills but not to metacognitive awareness. Independent t-test results showed no significant difference between male and female in terms of metacognitive awareness and scientific reasoning. The results of this study can be used as a basis for educators in improving the science curriculum especially in the secondary level.

**Key Words:** metacognitive awareness, scientific reasoning, progression

## 1. INTRODUCTION

In the present society, Science has become very important and necessary. Therefore, it is imperative for the students to learn not just the concepts but also the science process in general. Educators should focus on developing reasoning among students which is essential in scientific inquiry (Bybee and Fuchs, 2006; Zhou, Han, Koenig, Raplinger, Pi, Li, Xiao, Zhao, Bao, 2016). According to Lawson (2004), reasoning skills are intellectual approaches, procedures and plans that that are used to dealing with information and drawing conclusions. Successful scientific reasoning needs both inductive and deductive skills. Students should possess the ability to evaluate existing knowledge, formulate questions, conduct experiments to test assumptions and make valid conclusions from the results of the experiments and from the existing principles and models (Ellsworth, 2011; Morris, Crocker, Masnick and Zimmerman, 2012). Based on the neo-Piagetian perspective, the progress in students scientific reasoning skills is associated with the content learning, educational background and the learning setting (Demetriou, Shayer, Efklides, 2006); Ding, 2013). It may be expected that as students learn more content related to their field, their scientific reasoning skills could improve. This is quite reasonable since as they learn, they use critical thinking and logical reasoning.

Metacognition is simply 'thinking one's own thinking". It is one of the important factors influencing students learning (Pintrich, 2002). It allows the learners to become conscious of their learning. Being aware of one's own strengths and weakness and being able to use different strategies in learning allows the students to gain more advanced knowledge.

Basically, metacognition have two major components: knowledge of cognition and regulation of cognition. It is also divided into eight subcomponents. Declarative knowledge, procedural knowledge and conditional knowledge falls under the knowledge of cognition. On the other hand, planning, information management strategies, comprehension monitoring, debugging strategies and evaluation are under the regulation of cognition. Studies suggest that students' metacognitive awareness starts to develop during elementary level and continuously develop more rapidly during high school (Veenman 2012; Veenman, Hout-Wolters & Afflerbach 2006; Veenman, Wilhelm & Beishuizen 2004, Hadi, 2014).

## *1.1 Research Question*

Metacognition and scientific reasoning generally plays important role in the holistic development of the learners. Therefore, it is important determine the level of metacognitive awareness and scientific reasoning skills in order to employ interventions if deemed necessary. This study aims to determine the progression of the scientific reasoning skills and metacognitive awareness of students in the high school level.

An early research discussed that two basic skills associated to acquiring metacognitive awareness are also required in attaining scientific reasoning skills (Sodian, Zaitchik and Carey, 1991; as cited in Morris, Crocker, Masnick and Zimmerman, 2012). However, a little to no research available clearly established the relationship between metacognition to scientific reasoning. This study also aims to explore the relationship between scientific reasoning and metacognitive awareness as well as to investigate if the components of metacognition significantly predicts scientific reasoning skill. Moreover, it wishes to know if both construct significantly vary depending on students' age and gender.

Findings of this study will not only give us understanding on the development of metacognitive awareness and scientific reasoning skills in the high school level, but also help us to decide what instructional approaches and interventions are needed to develop the two constructs among our learners.

# 2. METHODOLOGY

The participants of this study were 166 junior high school students from Grade 7 (n=45), Grade 8 (n=40), Grade 9 (n=41), Grade 10 (n=40) and 84 senior high school students from Grade 11 (n=43) and Grade 12 (n=41) levels. Participants in each grade levels are from heterogeneous classes; therefore, it represents the population of high school students. In total, the participants who willingly answered the tests involves 97 males and 153 females aged from 12 to 23 years. Lawson's Classroom Test of Scientific Reasoning (LCTSR) (Lawson, 1978) was used to measure students scientific reasoning skill, whereas Metacognitive Awareness Inventory (MAI) (Schraw and Dennison, 1994) was used to measure the students' metacognitive awareness.

# 3. RESULTS AND DISCUSSION

## *3.1 Scientific Reasoning*

The mean LCTSR scores of the six groups, each representing the four grade levels in junior high school and two grade levels in senior high school, was computed for the comparison. Figure 1 shows the students' average scientific reasoning skills measured by the LCTSR across the six grade levels. The pattern showed that the students scientific reasoning increased from Grade 7 Grade 9 but remained fairly stable from Grade 9 to Grade 10. It then increased from Grade 9 to Grade 12. One-way Analysis of Variance (ANOVA) showed that there is a significant difference in the LCTSR scores across the different grade levels [$F(5,244)=7.967$, $p=.000$]. This implies that students in the higher grade level has relatively higher scientific reasoning skills compared to lower grade levels. A Tukey post hoc test revealed that Grade 7 has no significant difference from Grade 8 ($p=.999$) but has significant difference from Grade 9 ($p=.035$), Grade 10 ($p=.035$), Grade 11 ($p=.014$) and

Grade 12 (p=.000). Grade 8 has no significant difference from Grade 9 (p=.116), Grade 10 (p=.116) and Grade 11 (p=0.56) but has significant difference from Grade 12 (p=.000). Grade 9 has no significant difference from Grade 10 (p=1.000) Grade 11 (p=1.000) and Grade 12 (p=.118).

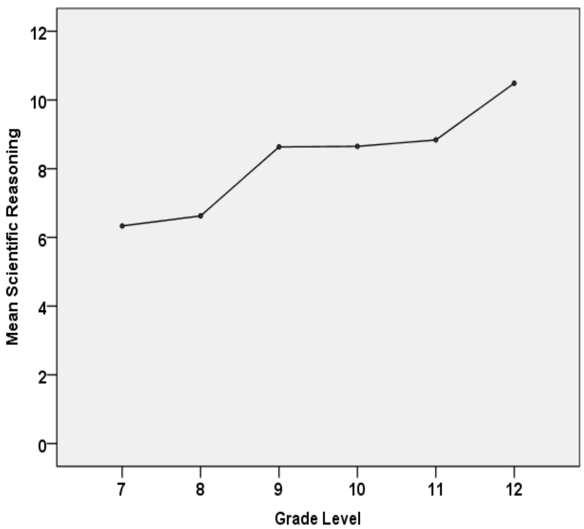


Figure 1. Average scientific reasoning skills across different grade levels

Given that students in the lower level are generally younger that those in the higher level, it is assumed that scientific reasoning varies with age. To verify this assumption, Pearson-r correlation was used. Results revealed that there is a moderate positive correlation between age of the students and their scientific reasoning skills (r(250)=.318, p=.000).

## 3.2Metacognitive Awareness

On the other hand, Figure 2 shows the average of students' responses in the MAI. It can be noted that the students have already acquired relatively high metacognition in Grade 7. The trend is nearly unchanging across grade levels. Furthermore, one-way Analysis of Variance (ANOVA) showed that there is no significant difference in terms metacognitive awareness across the grade levels [$F$(5,244)=.321, p=.900), suggesting no improvement. From these results, it may be assumed that students' metacognitive awareness does not correlate with the students age. The result of Pearson's correlation (r(250)=.158, p=.090) supported this supported this assumption.

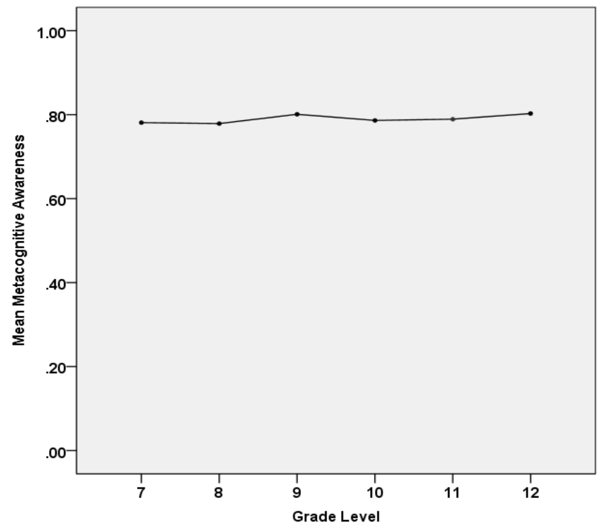


Figure 2: Levels of students' metacognitive awareness across the different grade level

## 3.3 Scientific Reasoning vs. Metacognitive Awareness

Table 1 revealed a significant medium positive correlation between the students scientific reasoning skills and average metacognitive awareness. Moreover, taking a closer look on the different components of metacognition, it can be deduced that scientific reasoning skills have a significant positive relationship with declarative, procedural, conditional, planning, information management strategies, comprehension monitoring, and debugging strategies. It has no significant relationship with evaluation.

To test if the components metacognitive awareness significantly predicted the scientific reasoning skills of the students, multiple regression analysis was used. The result of the regression showed that the eight predictors explained the 46.2% of the variance ($R^2$=.21, F(8,241)=8.160, p=.000). It was revealed that scientific reasoning was significantly predicted by procedural knowledge (β=.16, p=.008) and information management strategies (β=.256, p=.000).

Table 1. Pearson correlation between scientific reasoning and metacognitive awareness and its components

| | | SR | DK | PK | CK | P | IMT | CM | DS | E | AMA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Scientific Reasoning (SR) | r | 1 | | | | | | | | | |
| | Sig. | | | | | | | | | | |
| | N | 250 | | | | | | | | | |
| Declarative Knowledge (DK) | r | .263** | 1 | | | | | | | | |
| | Sig. | .000 | | | | | | | | | |
| | N | 250 | 250 | | | | | | | | |
| Procedural Knowledge (PK) | r | .241** | .237** | 1 | | | | | | | |
| | Sig. | .000 | .000 | | | | | | | | |
| | N | 250 | 250 | 250 | | | | | | | |
| Conditional Knowledge (CK) | r | .311** | .367** | .217** | 1 | | | | | | |
| | Sig. | .000 | .000 | .001 | | | | | | | |
| | N | 250 | 250 | 250 | 250 | | | | | | |
| Planning (P) | r | .139* | .284** | .013 | .243** | 1 | | | | | |
| | Sig. | .028 | .000 | .836 | .000 | | | | | | |
| | N | 250 | 250 | 250 | 250 | 250 | | | | | |
| Information Management Strategies(IMS) | r | .375** | .404** | .129* | .417** | .315** | 1 | | | | |
| | Sig. | .000 | .000 | .041 | .000 | .000 | | | | | |
| | N | 250 | 250 | 250 | 250 | 250 | 250 | | | | |
| Comprehension Monitoring (CM) | r | .231** | .266** | .193** | .468** | .370** | .397** | 1 | | | |
| | Sig. | .000 | .000 | .002 | .000 | .000 | .000 | | | | |
| | N | 250 | 250 | 250 | 250 | 250 | 250 | 250 | | | |
| Debugging Strategies (DS) | r | .210** | .243** | .081 | .245** | .010 | .345** | .125* | 1 | | |
| | Sig. | .001 | .000 | .201 | .000 | .876 | .000 | .049 | | | |
| | N | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | | |
| Evaluation (E) | r | .113 | .306** | .135* | .363** | .398** | .347** | .514** | .130* | 1 | |
| | Sig. | .076 | .000 | .033 | .000 | .000 | .000 | .000 | .039 | | |
| | N | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | |
| Average Metacognitive Awareness(AMA) | r | .388** | .617** | .422** | .696** | .548** | .687** | .712** | .449** | .674** | 1 |
| | Sig. | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 | |
| | N | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 |

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

## *3.4 Metacognitive Awareness, Scientific Reasoning and Gender*

T test was used to determine if there is a significant difference on the scientific reasoning and level of metacognitive awareness of male and female students. Results showed that there is no significant difference in terms of scientific reasoning for male (M=8.77, SD=4.01) and female (M=7.90, SD=3.627); t=1.776, p=.077. Similarly, there is no significant difference in terms of the average metacognitive awareness for male (M=.796, SD=.109) and female (M=.786, SD=.115); t=.713, p=.476. It can be also inferred from the table that the different components of metacognition are somehow similar in for both male and female.

Table 2. Independent t-test for scientific reasoning skills, metacognitive awareness and its 8 component: male vs female

| Constructs | t | df | Sig. |
|---|---|---|---|
| SR | 1.776 | 248 | .077 |
| **DK** | .341 | 248 | .733 |
| **PK** | 1.156 | 248 | .249 |
| **CK** | 1.722 | 248 | .086 |
| **P** | -1.238 | 248 | .217 |
| **IMT** | -.759 | 248 | .449 |
| **CM** | .564 | 248 | .573 |
| **DS** | .280 | 248 | .780 |
| **E** | .341 | 248 | .733 |
| **AMA** | .713 | 248 | .476 |

## 4. CONCLUSION

Scientific reasoning and content learning are said to be linked to each other. As students, acquire knowledge, their scientific reasoning improves as well (Demetriou, Shayer, Efklides, 2006; Ding, 2013). This agrees with the results of the study as shown by the trend of scientific reasoning skills across the junior high school and senior high school levels. This may be somehow attributed to the design of the Kto12 science curriculum in the Philippines. It follows a spiral progression in which the concepts in the different levels are somehow similar but varies only in terms of difficulty and complexity.

Literature says that the development of metacognition is steeper at high school age (Veenman 2012; Veenman, Hout-Wolters & Afflerbach 2006; Veenman, Wilhelm & Beishuizen 2004, Hadi, 2014). This is in contrary with the result of MAI where no improvement on the level of metacognitive awareness was observed across the year levels. The result is quite saddening since the 6 years of stay in school caused no change in the metacognitive awareness of the students. The bright side is that metacognition can be taught to the students (Henter and Indreica, 2014). Through various metacognitive activities, educators could help students develop their metacognitive awareness.

It is interesting that while increasing trend was observed in scientific reasoning but not in the metacognition, a positive relationship was still established between the two constructs. This is due to the fact that students with high and low levels of metacognitive awareness are widely distributed in the six grade levels and those with high awareness generally possess relatively high scientific reasoning skills.

It is also noteworthy the equality among male and female in terms of the two constructs. This may imply that teachers can give equal treatments in terms of classroom activities and tasks regardless of the students' gender. This also eliminates the issue of superiority and inferiority. These findings are in contrast with the results of study by Bogdanović, Obadović, Cvjetićanin, and Segedinac (2015). They found out that metacognitive awareness highly depends on the gender. Girls showed higher metacognitive awareness compared to boys.

While this study gives a glimpse of the status of education in the country especially in the high school level, this can be a stepping stone to other future studies that will aim to improve the education system.

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