Metacognition, Critical Thinking, Gender as predictors of Achievement of 10th Graders in Science, Technology, Engineering and Mathematic school (STEM)

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Abstract
The purpose of this study was to examine how gender , metacognition and critical thinking contributed to the achievement of 10th graders in Science, Technology, Engineering and Mathematic .school (STEM), Cairo. Achievement was measured in terms of overall grade point averages. A number of T-Tests were conducted to examine if gender significantly influenced academic achievement in Arabic Language, metacognitive skills, and critical thinking skills. The –values did not reach significance level. This indicates that there is no effect of gender on academic achievement in Science, metacognitive skills, and critical thinking skills. There was a significant positive relationship between metacognitive skills and academic achievement in Science ($r=.234$ $p < .01$), between critical thinking skills and academic achievement in Science ($r=.334$ $p < .01$), and between metacognitive skills critical thinking skills ($r=.502$ $p < .01$). A regression analysis was performed using achievement as the dependent variable and gender, metacognition, and critical thinking as the independent variables. The analysis indicated that students' critical thinking skills significantly account for differences in their academic achievement $ß = .355$, $p < .001$, metacognition significantly account for differences in their academic achievement $ß = .455$, $p < .001$, while gender $ß = .072$, $p > .05$ did not significantly account for students' achievement.

Keywords : *Think-Pair-Share Collaborative Inquiry, Reflective Thinking in Mathematics, 7th graders with Learning disabilities*

Introduction

Metacognition (Al Said Abdul Khalik,2014; Mourad Ali, 2010; Saada, 2013) refers to two aspects, namely the students' self-awareness of a knowledge base in which information is stored about how, when, and where to use various cognitive strategies and their self-awareness of and access to strategies that direct learning (e.g. monitoring difficulty level, a feeling of knowing). This awareness is developmental and lies on a continuum. Proficient readers use one or more metacognitive strategies to comprehend texts. There are three main aspects of metacognition: metacognitive knowledge, metacognitive monitoring, self regulation and control (Pintrich, Wolters and Baxter 2000). The first group consists of cognitive learning strategies which the learner uses to regulate the process of knowledge acquisition. These include, for example, elaboration strategies such as the building of links to prior knowledge, or memory strategies such as note taking. The second group consists of metacognitive control strategies. Central here are activities like the planning and monitoring of learning activities, the evaluation of learning outcomes and the adaptation to varying task demands and (unexpected) difficulties, for example, an increase in directed efforts.

The original model of Schraw and Dennison (1994) proposed metacognition composed of eight major components. These subprocesses are: (1) Declarative knowledge, (2) procedural knowledge, (3) conditional knowledge, (4) planning, (5) information management strategies, (6) monitoring, (7) debugging strategy, and (9) evaluation of learning. The initial factor analysis conducted by Schraw and Dennison where the items are rotated using oblique and orthogonal solutions extracted six factors of metacognition which largely explain a total variance of 78%. The first two factors in the original eight loaded under two factors but the fourth to eight original factors loaded separately. (Carlo Magno, 2010) .

Critical thinking is defined in numerous ways, but typically involves the ability to do some or all of the following: "identify central issues and assumptions in an argument, recognize important relationships, make correct inferences from data, deduce conclusions from information or data provided, interpret whether conclusions are warranted on the basis

of the data given, and evaluate evidence or authority" (Pascarella & Terenzini, 1991, p. 118). Critical thinking can be further broken into the following competencies (Possin, 2008):

> (a)identifying reasons or arguments, (b) dissecting arguments into premises, conclusions, and sub conclusions, (c) taxonomizing arguments as deductive or inductive, (d) assessing the cogency of arguments, (e) identifying formal and informal fallacies, (f) critically reviewing definitions and analyzing concepts, and (g) assembling these competencies so as to select and argue for positions on a diversity of issues and critically review competing positions and their arguments, all in a cogent and intellectually honest manner (p. 205).

Metacognitive understanding is vital to critical thinking because of its focus on developing reflection of how we know what we know and why it is justified (Kuhn, 1999), as well as its ability to affect "acquisition, comprehension, retention, and application of what is learned" (Hartman, 1998, p.1). Metacognitive knowing begins around the age of three years, when youth realize assertions are representative of other's beliefs (Kuhn, 1999). This group is limited in its critical thinking applications if beliefs are seen as assertions known by the individual as certainties (Kuhn, 1999). However, if assertions can be seen as belief states open to evaluation, critical thinking can emerge (Kuhn, 1999). To evaluate these belief states, individuals must develop the metacognitive skill of information organization where previously acquired knowledge can be systematically merged with newly identified information (Tsai, 2001). The level of critical thinking associated with the evaluation of belief states will be minimal, though, if the evaluations can only be deemed true or false (Kuhn, 1999).

Some factors which are thought to influence achievement levels include gender role identification(Jozefowicz, Barber, & Eccles, 1993), metacognition (Slavin, 1997), and critical thinking skills (Gadzella, Ginther, & Bryant, 1997).

The present study seeks to give answers to the following questions:

1-Do males and females differ on achievement, metacognitive, and/or critical thinking measures?

2- Do metacognition and critical thinking influence achievement levels?

3- To what degree do gender, metacognition, and critical thinking affect achievement levels?

Methods

Participants

The participants in the study consisted of a total of one hundred and twenty grade ten students from Science, Technology, Engineering and Mathematics School (STEM), Cairo .The sample involved al1 of the ten students within the participating school who agreed to participate and were granted permission from their parents to take part in the study.

Instruments

The MAI is a 52-item self-report inventory that measures two major components of metacognition: Knowledge of Cognition and Regulation of Cognition. The Knowledge of Cognition component includes three subprocesses: Declarative Knowledge (self and learning strategy knowledge), Procedural Knowledge (how to use learning strategies), and Conditional Knowledge (when and why to use learning strategies). The Regulation of Cognition component includes fi ve subprocesses: Planning (setting learning goals), Information Management Strategies (implementing strategies), Monitoring (paying attention to strategy effectiveness), Debugging (being aware of and correcting errors), and Evaluation (reviewing

use of and effectiveness of strategy) (Schraw & Dennison 1994). Schraw and Dennison (1994) report that in a factor replication analysis, the coefficient alpha derived reached .88 and .90 in the final set of items.

The WGCTA is a 30-60 minute, multiple-choice formatted test designed to measure various interdependent aspects of critical thinking through different constructs identified as inferences, recognition of assumptions, deduction, interpretation, and evaluation of arguments (Mourad Ali Eissa, 2014). The WGCTA has been utilized to assess critical thinking skills of students ranging from high school freshmen through university graduate students and provides reference norms (Hassan & Madhum, 2007). The WGCTA also possesses adequate internal consistency and test reliability over time and between alternate forms (Rust, 2002). Further, the WGCTA demonstrates adequate face, content, criterion, and construct validity (Rust, 2002).

Data Analysis

Data was analyzed using the Statistical Package for the Social Sciences (SPSS). A series of Independent Samples T-Tests were used to determine if metacognition and critical thinking were related to student grade levels. A regression analysis using gender, metacognition, and critical thinking as the independent variables were used to determine the degree to which each contributed to overall achievement levels.

Results

Do males and females differ on achievement, metacognitive, and/or critical thinking measures?

A number of T-Tests were conducted to examine if gender significantly influenced academic achievement in Science, metacognitive skills, and critical thinking skills. The – values did not reach significance level. This indicates that there is no effect of gender on academic achievement in Science, metacognitive skills, and critical thinking skills.

Table *1. T- test results for the differences between boys and girls in academic achievement in Science*

Group	N	Mean	STD	t	Sig
Male	60	50.96	2.29	.841	-
Female	60	50.50	3.63		

Table 2. *T- test results for the differences between boys and girls critical thinking skills Scale*

Group	N	Mean	STD	t	Sig
Male	60	12.23	1.28	.822	-
Female	60	12.43	1.38		

Table 3. *T- test results for the differences between boys and girls in Metacognitive Assessment Inventory*

Group	N	Mean	STD	t	Sig
Male	60	38.96	8.07	.185	-
Female	60	38.71	6.64		

2- Do metacognition and critical thinking influence achievement levels?

There was a significant positive relationship between metacognitive skills and academic achievement in Science (r=.234 p < .01), between critical thinking skills and academic achievement in Arabic Language (r=.334 p < .01), and between metacognitive skills critical thinking skills (r=.502 p < .01).

Table.4 *Correlations between Variables*

Variables	**Academic Achievement**	**Metacognitive skills**	**Critical thinking skills**
Academic Achievement	1	.234	.334
Metacognitive skills	.234	1	.502
Critical thinking skills	.334	.502	1

3- To what degree do gender, metacognition, and critical thinking affect achievement levels?

A regression analysis was performed using achievement as the dependent variable and gender, metacognition, and critical thinking as the independent variables. The analysis indicated that students' critical thinking skills significantly account for differences in their academic achievement ß = .355, p < .001 , metacognition significantly account for differences in their academic achievement ß = .455, p < .001 , while gender ß = .072, p > .05 did not significantly account for students' achievement .

Table.5 Summary of Regression Analysis of Variables Predicting Academic Achievement

Variables	**B**	**SE B**	**ß**
Gender	1.98	1.93	.072
Metacognitive skills	0.40	0.04	.455
Critical thinking skills	0.43	0.07	.355

Discussion

The purpose of this study was to examine how gender, metacognition and critical thinking contributed to the achievement of 10th graders from Science, Technology, Engineering and Mathematics School (STEM), Cairo. Achievement was measured in terms of overall grade point averages. A number of T-Tests were conducted to examine if gender significantly influenced academic achievement in Science, metacognitive skills, and critical thinking skills. The –values did not reach significance level. This indicates that there is no effect of gender on academic achievement in Science , metacognitive skills, and critical thinking skills. There was a significant positive relationship between metacognitive skills and academic achievement in Science (r=.234 p < .01), between critical thinking skills and academic achievement in Science (r=.334 p < .01), and between metacognitive skills critical thinking skills (r=.502 p < .01). A regression analysis was performed using achievement as the dependent variable and gender, metacognition, and critical thinking as the independent variables. The analysis indicated that students' critical thinking skills significantly account for differences in their academic achievement ß = .355, p < .001 , metacognition significantly account for differences in their academic achievement ß = .455, p < .001, while gender ß = .072, p > .05 did not significantly account for students' achievement .

The ability to be meta-cognition to be able to monitor and regulate one’s own learning is an important aspect of the lifelong learning process. The important of meta-cognition in the learning process is illustrated by a series of experimental studies designed to assess the impact of meta-cognition skills an learning performance across many disciplines.

Critical thinking was found to have a stronger correlation than the students' metacognitive skills. Additionally, when controlling for the effect of the other variables, critical thinking was found to significantly predict achievement levels in this sample.

Students with higher metacognitive and critical thinking skills also had higher achievement levels. This information is informative in that it helps establish that those students who have acquired higher skill levels were more successful however, it is also important that continual attention be focused on the development of these skills.

Implications and Recommendations for Further Research

This study has several implications for future research. Firstly, further research investigating the relationships between metacognition, critical thinking skills , and academic achievement in other school subjects are needed in order to reinforce the findings of this study. Also, future studies can examine these relationships with structural equation modeling, establishing a mediating or latent variable. One suggestion for future research is to sample different age groups within the general population.

Due to the relatively small number of students in this study, it is recommended that this study be conducted using a larger sample size. More extensive data may help clarify some of the relationships and therefore improve the validity of the results.

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