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EXPLORING THE RELATIONSHIP BETWEEN METACOGNITION AND ATTITUDES TOWARDS SCIENCE OF SENIOR SECONDARY STUDENTS THROUGH A STRUCTURAL EQUATION MODELING ANALYSIS

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Abstract. *Attitudes towards science is an important construct of science learning which has been affected by many factors. The main purpose of this research was to investigate whether the metacognition strategies predict students' attitudes towards science. Accordingly, a total of 347 senior secondary students were asked to complete a questionnaire about their metacognition strategies and attitudes towards science. Structural equation modeling (SEM) was used to evaluate the validity of a structural/latent variable model. Findings revealed several direct and indirect effects among the factors under investigation. Of special importance, metacognition strategies positively predicted attractiveness of science (science is fun), class/teacher activities and family model as variables of students' attitudes towards science. Attractiveness of science was also found to have effects on the science anxiety and family model was found to have effects on class/teacher activities. One important finding was that metacognition strategies could decrease students' science anxiety. According to this information, it is recommended that science educators encourage students to employ metacognition strategies in science that may lead to more positive students' attitudes towards science.*
Key words: *metacognition strategies, attitudes towards science, senior secondary students, structural equation modeling.*

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Introduction

Attitudes towards science is an important construct of science learning. Therefore, the examination of students' attitudes towards studying science has been a substantive attribute of the work of the science education research community for the past decades and remains one of enduring focus (Osborne, Simon & Collins, 2003; Osborne, Simon & Tytler, 2009). Attitudinal and motivational constructs serve useful purposes in the science education program. Also, effective science instruction has the potential to improve attitudes toward science and heighten the motivation to learn science (Koballa & Glynn, 2007). An important reason for examining attitudinal and motivational constructs in science education is to understand the ways in which they affect student learning in cognitive arena. In fact, these constructs are moderators of a learner's conceptual change and may influence science learning in short term and over long periods of time (Pintrich, Marx, & Boyle, 1993). If the source of students' interest is a positive attitude to education, aroused curiosity, desire to acquire knowledge of something new or desire to be able to do something capably students are willing to undergo different cognitive activities (Zahorec, Ha kova & Bilek, 2014). Zacharia & Barton (2004), contend that across the domain of research covering student's attitudes towards science, four major attitude attributes appear to exist: attitudes are tenacious over time, attitudes are learned, attitudes and behavior are correlates, and attitude is a function of personal beliefs.

Attitudes towards science can be described as students' emotional conception of science - beliefs, values, and feelings - (Newell, Tharp, Moreno, Zientek & Vogt, 2015; Osborne et al., 2003). Attitudes not only influence scientific views and desires for future careers, they can also influence attainment. Children with more positive attitudes towards science show raised attention to classroom instruction and participate more in science activities (Jarvis & Pell, 2005). Also, one important outcome of the attitudes research has been the demonstrated correlation between attitudes toward science and student achievement and future access to science experiences. (Jarvis & Pell, 2005; Zacharia & Barton, 2004). But, in general, students' attitude toward science in high school is moderately low and there is a decrease in attitude toward science during secondary school (Zacharia & Barton, 2004). The lack of interest in science often reveals itself during secondary school when adolescents must choose the major they will study (Van Aalderen-Smeets, Van Der Molen, & Asma, 2012). Therefore, it is important to identify approaches to increase younger students' positive attitudes toward science and to understand the aspects of these attitudes most closely related to positive student achievement levels (Newell et al., 2015). Accordingly, some studies have focused on the ways that could increase positive attitudes toward science. For example, Gibson & Chase (2002), examined the long-term impact of an inquiry-based program aimed to stimulate larger interest in science and scientific careers among middle-school students.

Attitudes towards science is a complex, multifaceted construct (Newell et al., 2015). Some studies have identified a number of factors influence students' attitudes towards science (Osborne, et al., 2003; Osborne, et al., 2009; Zacharia & Barton, 2004). These studies have focused on a variety of constructs such as the gender, identity, perception of the science teacher, perceived difficulty of science, science anxiety, enjoyment of science, attitudes of peers and friends towards science, parental support, and the nature of the classroom environment such as classroom / teacher factors and curriculum variables. Sex is one of the most significant variables related towards students' attitude to science (Osborne, Simon & Tytler, 2009). The differences between males and females' attitudes toward science widen as students move from elementary to secondary school (Jones, Howe & Rua, 2000).

On the other hand, science learning has been used in studies focused on metacognition. Leopold & Leutner (2015), assessed students' science text understanding through metacognitive self-regulation when applying learning strategies. White & Frederiksen (1998), hypothesized that making scientific inquiry accessible to a wide range of students could be achieved by creating an instructional approach that develops students' metacognitive knowledge and skills through a process of scaffolding, reflection, and generalization. Spence, Yore & Williams (1999), investigated the correlations between metacognitive skills and comprehension of science text and the differential of reading ability and gender on the acquisition on metacognition and science reading comprehension among an intact group of 27 students. Yilmaz-Tüzün & Topcu (2010), investigated the relationships among elementary school students' epistemological beliefs, metacognition, and science learning environment. Zhao, Wardeska, McGuire & Cook (2014), examined how educators incorporate metacognition in college science classrooms, and the increased cognitive and affective learning of students indicated its significance. They concluded that implementation of metacognition strategies will contribute to increased learning in chemistry and across other courses and curricula. Peters & Kitsantas (2010), using an explanatory mixed-method design, examined teaching the nature of science using metacognitive prompts embedded in an inquiry unit. The results revealed that students in the experimental group reported that scientists were creative and had to explain events using evidence, which is aligned to the nature of science. Kristiani, Susilo, Rohman, and Aloysius (2015), investigated the correlation between students' metacognitive skills and scientific attitudes simultaneously towards their academic achievements in a class taught. Schraw, et al. (2006), reviewed studies on self-regulated learning and discussed the implications of this research for science education. They draw on examples of self-regulated learning from the science education literature to summarize and illustrate effective instructional methods and the development of metacognitive understanding. Rozencwajg (2003), in a study determined whether and to what extent students' metacognitive level is linked to their conceptualization and performance in problem solving at school, especially science problems. Kaberman & Dori (2009), in a study focused on guided question posing while using a metacognitive strategy by 12th grade honors chemistry students. They investigated the ways by which the metacognitive strategy affected students' skills to pose complex questions and to analyze them according to a specially designed taxonomy. However, Thomas (2012), argues that what we already know about how to improve science education and learning through the enhancement and development of students' metacognition is not finding its way into either the everyday practice of classroom teachers or the mindset and/or curricula of teacher educators and their teacher education programs.

In the 1960s, cognitive theories shifted the focus of human functioning away from environmental variables and onto learners -specifically, how they encoded, processed, stored, and retrieved information (Schunk, 2008). Metacognition was originally referred to as knowledge about regulation of one's cognitive activities in learning processes (Veenman, Van Hout-Wolters, & Afflerbach, 2006). Metacognitive monitoring emerged as a construct, stemming from writings on meta-processes such as meta-memory. In John Flavell's seminal writings on metacognitive monitoring, he set the stage for this construct by describing the developmental aspects of how one monitors or thinks about one's own cognition. Flavell (1979), forwarded the conceptual definition of metacognition as

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"thinking about thinking" and is defined in similar terms as awareness and management of one's own thought (Kuhn & Dean). Flavell went on to operationalize metacognition into four key areas: metacognitive knowledge, metacognitive experience, goals, and the activation of strategies (Dinsmore, Alexander, & Loughlin, 2008). Following the seminal work of John Flavell and his ideas, however, others have attempted to establish the pre-eminent role of metacognition in children's developing abilities to think and learn and as concepts lie at the very roots of the learning process" (Whitebread, 1999).

Lai (2011), argues that metacognition has constituent two parts: knowledge about cognition and monitoring of cognition. Metacognition researchers have offered a slightly various framework for categorizing cognitive knowledge. They have used concepts of declarative and procedural knowledge (Schraw et al., 2006). Flavell (1979) classifies cognitive knowledge into person knowledge, task knowledge and strategy knowledge. On the other hand, researchers have contended that regulation of cognition includes activities of planning, monitoring or regulating, and evaluating (Lai, 2011). These strategies include ways in which individuals plan, monitor, and regulate their cognition. For example: set sub-goals, ask themselves questions as they read a text, and re-read something they do not understand (Kaberman & Dori, 2009). In fact, metacognitive awareness enables control or self-regulation over thinking and learning processes and products (Hartman, 1998). In other words, metacognition is generally as the activity of monitoring and controlling one's cognition (Young & Fry, 2008).

The most common distinction in metacognition separates metacognitive knowledge from skills. The former refers to a person's declarative knowledge about the interactions between person, task, and strategy characteristics, whilst the latter refers to a person's procedural knowledge for regulating problem solving and learning activities (Veenman et al., 2006). Most researchers make a distinction between two components of metacognition, *knowledge of cognition* and *regulation of cognition*. Most accounts of metacognition make a basic distinction between metacognitive knowledge (i.e., what one knows about cognition) and metacognitive control processes (i.e., how one uses that knowledge to regulate cognition) (Schraw, et al., 2006; Hartman, 1998; Schraw & Moshman, 1995; Schraw, 1998). In the present research we consider metacognition strategies as regulation of cognition which include planning strategies, evaluating and controlling strategies, and regulating strategies.

The literature on science learning and metacognition implies that students' metacognition knowledge and strategies play an important role in their approaches to learning science. Furthermore, attitudes towards science has been known as an important construct of science learning, but the role of metacognition knowledge and strategies in attitude towards science has not been examined in an independent research. Exploring this issue one could determine the relations between metacognition strategies and their direct and indirect effects on factors of attitudes towards science and shed light on this crucial topic of science learning. Therefore, the purpose of the present research is to examine the structural relationships between students' attitudes towards science and their metacognition strategies in studying school science.

Accordingly, the main research question here is:

- Could metacognition strategies predict senior secondary students' attitudes towards science?

Methodology of Research

Research Design

This research is a correlational research. It used structural equation modeling (SEM) to examine the structural relationships between students' metacognition strategies and their attitudes towards science. Participants were asked to complete the survey questionnaires, consisting of a series of questions about their attitudes towards science and metacognition strategies. All of the participants were informed about the purpose of the research prior to responding the questions during the 2014-2015 academic year.

Sample

According to the information provided by Iranian Ministry of Education, the participant population comprised of 3453 senior secondary students who enrolled in secondary schools of Kerman city. Cluster sampling method identified 360 as a research sample. Participants were 347 senior secondary students. They ranged from 15 to 18. More than 400 questionnaires were distributed to 10 secondary schools and finally 347 (a total of 139 males and 209 females) valid questionnaires were returned to the researchers which were used as data for this research.

Instrument

The instrument used in this research was comprised of two parts. The first one included the Iranian Students' Attitudes towards Science Scale (ISASS) based on Simpson - Troost Attitude Questionnaire (STAQ) (1982). STAQ was designed to determine whether affective factors related to self, home and family, and school and classroom, influenced student commitment to an achievement in science. The Simpson and Troost (1982) definition of commitment to science included attitudes, interests, values, and other affective behaviors identified in the study (Owen, Toepperwein, Lichtenstein, Blalock, Liu, Pruski, & Grimes, 2008). ISASS was a 53-item instrument measuring various aspects of the students' attitudes towards science, including demographic items. ISASS categories (science is fun, classroom / teacher model, science anxiety and family model) included from six to twenty-two items and was presented in a five-point Likert mode.

The second part included the Metacognition Strategies Inventory (MSI), a researcher-made questionnaire based on the works of Mokhtari and Richard (2002) and Sperling, Howard, Miller, & Murphy (2000), that was designed to determine metacognition strategies, especially *regulation of cognition*, (planning strategies, evaluating and control strategies, and regulating strategies). *Knowledge of cognition,* as the second component of metacognition, was not under consideration in MSI. MSI was a 40-item instrument measuring various aspects of students' metacognition strategies, namely the regulation of cognition that each category (first-order factor) included from four to twenty-three items and was presented in a five-point Likert mode.

Procedure

After randomly selecting 10 secondary schools, according to the database of Iranian Ministry of Education, a list of students that had enrolled in the science courses was identified in each high school. Prior to distributing the questionnaires among participants, all of them were told about the purposes of the research. They were also told that participation is voluntary and that refusal to participate will not result in any consequences or any loss of benefits. They were informed that the length of participation would be about 20 minutes. The participants administered the questionnaire approximately between 15 to 25 minutes. The questionnaires were collected and returned to the researchers. Questionnaires did not include the name of participants and were completely anonymous in order to meet confidentiality.

Validity and Reliability

In addition to content validity, since there was not sufficient theoretical background that could confirm relations between metacognition strategies and attitude towards science, we used exploratory factor analysis (EFA) to examine experimental data in order to explore and determine the factors and their correlations (Stevens, 1996). Results showed that the metacognition strategies have significant effect on students' attitudes towards science (β=.49, $p<0.001$). Also, we examined two indicators to determine whether the sample was appropriate for this type of analysis. The KMO measure of sampling adequacy index was found to be 0.75, and Bartlett's test was significant (χ^2= 1081.75, $p<0.001$), indicating the validity of the factor analysis. The principal components analysis and a varimax rotation with the factor analysis revealed a two-dimensional structure that explained 65.91% of total variance.

To assess the internal consistency and reliability of the questionnaires, Cronbach`s alpha coefficient was used. Cronbach's alpha coefficient of internal consistency was found to be 0.83 for the ISASS and 0.84 for the MSI. This coefficient also was found to be 0.94 for the entire instrument.

Data Analysis

Table 1 shows the correlations between the scales of the ISASS and those of the MSI. According to the Table 1, the "science is fun" (attractiveness of science) was significantly correlated with all categories of the MIS. The "science anxiety" exhibited significant correlation between "P," "E & C," and "R." The "class/teacher" was significantly correlated with "P," "E & C," and "R"; and the "family model" had a significant correlation between "P," "E & C", and "R." According to Tabachnick and Fidell (2007) all data were screened via SPSS 23 software for exploration multivariate outliers. Also, data were tested for multivariate normality, skewness and kurtosis, and the results demonstrated moderate kurtosis (Table 2).

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Table 1. Correlation matrix of factors for the full SEM model (N =347).

	SF	SA	C/T	FM	P	E&C	R
1. SF	-	-0.78**	0.60**	0.33**	0.29**	0.29**	0.20**
2. SA		-	-0.54**	-0.31**	-0.33**	-0.28**	-0.20**
3. C/T			-	0.43**	0.38**	0.31**	0.29**
4. FM				-	0.23**	0.22**	0.07*
5. P					-	0.57**	0.46**
6. E&C						-	0.39**
7. R							-

N = 247
Key: Science is Fun = SF; Metacognition Strategies = MS; Science Anxiety = SA; Class / Teacher = C/T; Family Model = FM; Planning = P; Evaluation & Control = E&C; R = Regulating.
***p <0.05 (2-tailed).*

Results of Research

Descriptive Results

Table 2 shows the 347 students' average item scores and the standard deviations of the four factors of the ISASS. According to the Table 2, students attained high scores on the "class / teacher" factor (an average of 3.61 per item), the "family model" factor (an average of 3.55 per item), and the "science is fun" factor (an average of 3.46 per item). Their scores on the "science anxiety" factor, an average of 3.12 per item, were relatively lower of other factors. Such results indicate that secondary students have relatively positive attitudes toward science. Moreover, Table 2 also shows the 347 students' average item scores and the standard deviations of the three factors of the MSI. According to Table 2, students attained high scores on the "regulating" factor (an average of 3.84 per item), the "evaluating and control" factor (an average of 3.69 per item), and the "planning" factor (an average of 3.57 per item). Such results show that senior secondary students relatively employ these metacognition strategies in their science learning activities.

Table 2. The Scale Mean, Standard Deviations, *Kurtosis and Skewness* of the ISSAS and MSI (N=347).

	Mean	SD	Kurtosis	Skewness
ISSAS				
Science is fun	3.46	0.73	0.16	-0.43
Science anxiety	3.12	0.84	-0.55	-0.004
Classroom / Teacher	3.61	0.52	0.07	-0.14
Family model	3.55	0.75	0.15	-0.37
MSI				
Planning	3.57	0.47	-0.17	-0.04
Evaluating and Control	3.69	0.68	-0.62	-.018
Regulating	3.84	0.56	-0.71	-.013

SEM Analysis

The hypothesized structural model that resulted from the correlations between the ISASS and the MSI was specified by imposing the structural relations among the factors (Figure. 1). In order to conduct proposed structural relationships between variables through LISREL software, all students' responses on the questionnaires were subjected to SEM analysis (n=347).

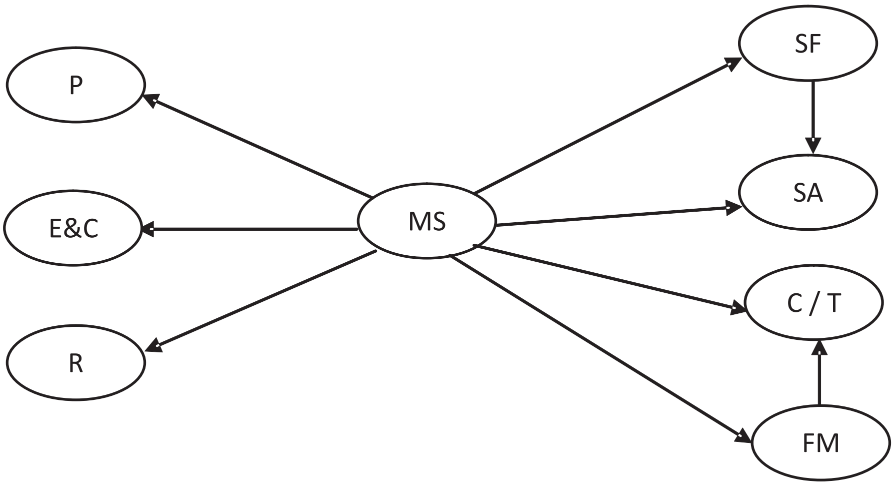

Figure 1: Hypothesized full structural equation model (SEM). Key: Science is Fun = SF; Metacognition Strategies = MS; Science Anxiety = SA; Class / Teacher = C/T; Family Model = FM; Planning = P; Evaluation & Control = E&C; R = Regulating.

According to Table 3, the hypothesized full SEM model demonstrated relatively good fit to the data, (χ^2 = 4320.73, df= 1479, p <0.001, RMSEA = .07, GFI = 0.69, NFI = 0.85, NNFI = .90, CFI = 0.91, IFI = .91).

Table 3. Fit Index of the full SEM Model (N=347).

Fit Index	Full SEM Model	Recommended Value
Chi-square	4320.73	-
Chi-square per degree of freedom	2.92	<5
Root mean square error of approximation (RMSEA)	0.075	<0.08
Goodness-of-fit index (GFI)	0.69	>0.90
Normed fit index (NFI)	0.85	>0.90
Non-normed fit index (NNFI)	0.90	>0.90
Comparative fit index (CFI)	0.91	>0.90
IFI	0.91	>0.90
P-value	0.001	

p <0.05(2-tailed).

Figure 2 includes the full SEM with all relevant structural path coefficients. Also, Table 4 contains the explained variances (R^2), t-values, and standardized and unstandardized structural coefficients (β and b) of the final model. It is important to note that the statistically significant positive relationships are shown by solid lines, while dashed structural paths are not statistically significant.

Figure 2 and Table 4, also include direct and indirect structural paths and the coefficients presented in the final model. In addition, as shown in Figure 2 and Table 4, MS was observed to have significant direct effects on SF (β = .63, t = 9.11, p <0.05), C / T (β = .55, t = 7.17, p <0.05), and FM (β = .42, t = 5.12, p <0.05). Moreover, SF was found to have direct effect on SA (β = -.11, t = -4.56, p <0.05) and also FM was found to have direct effect on C / T (β =.31, t = 3.91, p <0.05).

Furthermore, according to the Figure 2, MS was found to have a significant indirect effect on SA (β = -.06, p <0.05, mediated by SF) and also a significant indirect effect on C /T (β = .13, p <0.05, mediated by FM).

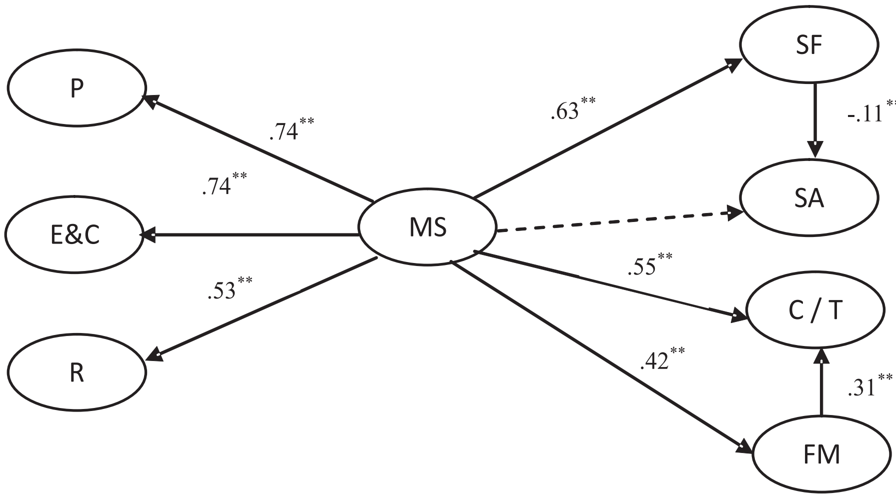

Figure 2: Final full structural equation model (SEM). Dashed structural paths were not statistically significant. Key: Science is Fun = SF; Metacognition Strategies = MS; Science Anxiety = SA; Class / Teacher = C/T; Family Model = FM; Planning = P; Evaluation & Control = E&C; R = Regulating.

According to the Table 4, in terms of effect sizes (R^2): MS explained 40% of the variance in SF; SF and MS contributed 5% of the variance in SA; FM and MS accounted for 54% of the variance in C / T; and finally, MS contributed 18% of the variance in FM.

Table 4. Factor loadings, R^2, and error variances of indicators of the final measurement model.

Factor / indicator	β	b	T	R^2	Ei
SF * MS	0.63	0.63	9.11	0.40	0.60
SA * SF	-0.11	-0.29	-4.56	0.05	0.94
SA * MS	-	0.27	-		
C/T * FM	0.31	0.31	3.91	0.54	0.46
C/T * MS	0.55	0.55	7.17		0.82
FM * MS	0.42	0.43	5.12	0.18	

N = 247
Key: Science is Fun = SF; Metacognition Strategies = MS; Science Anxiety = SA; Class / Teacher = C/T; Family Model = FM.
p <0.05 (2-tailed).

Discussion

Attitude towards science has an important role in science teaching and learning. Many research studies show that some factors could affect students' attitude towards science and make it more positive which in turn could lead to improved science learning and students' achievement in school science (Pintrich et al., 1993; Zahorec et al., 2014; Nasr & Soltani, 2011). Metacognition strategies are also known as a substantial construct in student learning. Literature review shows that despite various studies on relations between metacognition and science learning (Leopold & Leutner, 2015; White & Frederiksen, 1998; Spence et al., 1999; Yilmaz-Tüzün & Topcu, 2010; Wardeska et al., 2014; etc.), no study has examined the relationship between these two constructs. Accordingly, the question is whether metacognition strategies could predict secondary students' attitude towards science. It is important to know the direct and indirect effects of metacognition strategies on factors of attitude toward science through a structural equation modeling study. Overall, the results of the correlational study between these two constructs showed that the metacognition strategies have some significant and positive effects on students' attitude towards science.

Also, the results of the full SEM model revealed that the metacognition strategies have significant direct effects on the attractiveness of science (science is fun), class / teacher activities and family model. In fact, one-unit standard deviation increase in metacognition strategies will increase .63 unit standard deviation in attractiveness of science, .55 unit standard deviation in class / teacher activities and .42 unit standard deviation in family model's attitude toward science,. Accordingly, one-unit standard deviation increase in attractiveness of science will decrease .11 unit standard deviation in science anxiety and one-unit standard deviation increase in family model will increase .31 unit standard deviation in class / teacher activities. Furthermore, metacognition strategies were found to have a significant indirect effect on science anxiety (mediated by science attractiveness) and a significant indirect effect on class / teacher activities (mediated by family model). It means that one-unit standard increase in metacognition strategies, mediated by science attractiveness, will decrease .06 unit standard in science anxiety and will increase .13 unit standard in class / teacher activities on attitude toward science.

One important finding of SEM model was that metacognition strategies could decrease science anxiety as a major problem of students in learning science. This finding could have implications for the studies that have examined science anxiety in science learning (Westerback, 1982; Simpson & Oliver, 1990). Generally, metacognition strategies could increase all of the attitudes toward science components. This implies that, using these strategies in science teaching and learning is useful and recommended. Also, according to the results, the major percentage of endogenous variables changes (attitude toward science) is explained by explanatory variables (metacognition strategies) of the model.

Conclusions

It seems that students' attitudinal and motivational difficulties in science learning have been a persistent problem in science education. So, it is important to find some strategies and methods that could make adolescents' attitudes towards science more positive. Accordingly, this research aimed to examine the relations between metacognition strategies and attitudes towards science through a SEM analysis. The results show that metacognition strategies have some direct and indirect effects on senior secondary students' attitudes towards science. Accordingly, metacognition strategies have significant direct effects on the attractiveness of science, class / teacher activities and family model. Also, metacognition strategies were found to have a significant indirect effect on science anxiety (mediated by science attractiveness) and a significant indirect effect on class / teacher activities (mediated by family model). According to the results obtained from this research, improving students' metacognition strategies such as planning, evaluating and regulating improves their attitudes towards science that finally may increase students' learnings in science and science achievements. The results have some implications for researchers who are studding on students' attitudes towards science and many factors of influence. It is recommended that science educators encourage students to employ these strategies in science that in turn could lead to more positive students' attitudes toward science. It is also recommended that science educators adopt some strategies to make school science more fun and reduce science anxiety. Whether the results could be generalized to other countries needs further investigation. Future studies also could investigate the relations between *Knowledge of cognition* (as the second component of metacognition) and attitudes towards science and examine gender differences in the relations between metacognition and attitudes towards science.

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