JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/
https://doi.org/10.33225/jbse/19.18.39

A STUDY OF FACTORS AFFECTING SCIENCE ACHIEVEMENTS OF JUNIOR HIGH SCHOOL FEMALE STUDENTS

Chun-Chu Liu,
Tse-Yu Wang

Abstract. *This research was the first research integrating decision making trial and evaluation laboratory (DEMATEL) and structural equation modeling (SEM) to analysis factors, including interest in science, value in science and confidence in science, affecting female students' science achievements from the Trends in International Mathematics and Science Study (TIMSS) 2011. The research constructed two causal models base on mutual effect of value in science and confidence in science by DEMATEL analysis. The causality of two factors in model 1 was value in science affected confidence in science and model 2 vice versa. According to the results of SEM analysis, fit indices of CFI, GFI and AGFI in model 1 were 0.851, 0.796 and 0.745; in model 2 were 0.818, 0.772, and 0.873. And results showed that female students had better fitness in model 1; in other words, the causality of value in science to confidence in science might have an important effect on the science achievement of female students. Lastly, these findings could provide not only a different perspective for future researches but also a useful insight as a reference for policy making and improvement by relevant decision makers.*

Key words: *decision making trial and evaluation laboratory, science achievement, structural equation modeling, TIMSS.*

Chun-Chu Liu
Chang Jung Christian University, Taiwan
Tse-Yu Wang
National Sun Yat-sen University, Taiwan

Introduction

Regarding topics related to science and mathematics achievements of students, the debate over whether there is a significant difference between male and female students in science and mathematics achievements has been ongoing. Thus far, some scholars still believe that there is a significant difference between male and female students in learning achievement, while other scholars hold an opposite view that there is no significant difference in learning achievement between male and female students (Preckel, Goetz, Pekrun, & Kleine, 2008; White, 2007). With the continuous advancement in research tools and techniques, many scholars have applied different research methods and techniques to study and verify the differences in learning achievement between male and female students (Anglin, Pirson, & Langer, 2008; Ary, Jacobs, Irvine, & Walker, 2018; Ertl, Luttenberger, & Paechter, 2017; Kerkhoven, Russo, Land-Zandstra, Saxena, & Rodenburg, 2016; Quinn & Cooc, 2015; Yarnell et al., 2015). Meanwhile, these tools and techniques have also made it possible for researchers to make progress in the exploration of physiological and psychological factors that impact learning achievement as well as to obtain a greater understanding of the difference in learning achievement between the two genders. In particular, following large-scale assessments of students' learning achievement, such as the Trends in International Mathematics and Science Study (TIMSS) held by the International Association for the Evaluation of Educational Achievement (IEA) and the Programme for International Student Assessment (PISA) held by the Organisation for Economic Co-operation and Development (OECD), many scholars began to use results of the assessments to study the differences in learning achievement between the two genders and attempted to explore the actual situation and influencing factors that impact the differences in performance between male and female students, to solve the black box of performance differences in learning achievement between the two genders (Mills & Simon, 2015; Nosek et al., 2009; Patrick, 2012; Preckel, Goetz, Pekrun, & Kleine, 2008; White, 2007). With more discovering of factors influenced the difference in learning achievement of male and female students, many research results

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

of learning achievement showed that there was no significant difference between male and female students. Additionally, under the influence of various factors on learning achievement, there is no significant performance difference in learning between the two genders. In other words, in terms of learning ability, there is no significant innate advantage for either gender.

In terms of the outstanding academic performance by Taiwanese students in various international assessment tests, it is easy to find that the performance of female students in science and mathematics is not inferior to that of male students. For instance, in the TIMSS 2011, the assessment results of 8th-grade students indicated that female students scored higher on mathematics and chemistry than did male students. However, according to the statistics of the Ministry of Education of Taiwan, the number of female students in natural sciences, computer science, industrial engineering, architecture, and urban planning accounts for less than 30% of all students in colleges and universities in Taiwan (Ministry of Education Republic of China (Taiwan), 2017). In terms of career development, very few female students continue to choose careers related to the majors or other scientific research that they originally studied. This condition shows that Taiwan's current social stereotype still exists and that there is still room for improving gender equality in education in Taiwan. However, review of past relevant research revealed that the discussions on science achievement have mostly focused on gender differences; few researchers have explored and analysed female students. There is a significant difference between East Asian students and European and American students in the psychological factor of self-enhancement, which has a more significant impact on learning achievement (Falk, Heine, Yuki, & Takemura, 2009; Green, Nelson, Martin, & Marsh, 2006; Heine, 2003; Heine & Hamamura, 2007; Trope, 1986). Therefore, it is necessary to further clarify and discuss the causality between the factors that impact the learning achievement of students in Taiwan and other East Asian countries.

The TIMSS assessment was held every four years, since Taiwan jointed TIMSS assessment in 1999, there were five assessments in 1999, 2003, 2007, 2011 and the latest assessment was in 2015, respectively. However, in present researches on gender difference in science and mathematics achievements included for Taiwan, most researches still used TIMSS 2007 as the data to analyse the gender difference in science and mathematics achievements without progressing (Tsai, Yang, & Chang, 2015). For this reason, this research first reviewed the relevant literature and integrated the Decision Making Trial and Evaluation Laboratory (DEMATEL) method and Structural Equation Modeling (SEM) method (Baye & Monseur, 2016; Mills & Simon, 2015; Neuschmidt, Barth, & Hastedt, 2008; Hoyle, 1995; Nosek et al., 2009; Pavešić, 2008; Reilly, Neumann, & Andrews, 2015; Tomson, 2008; Tsai, Yang, & Chang, 2015). Then, a causal model for impact on science achievement was constructed through the DEMATEL method, and the TIMSS 2011 assessment results on science achievement of Taiwanese 8th grade female students as well as the SEM were used to test the model. Finally, based on the analysis results, the research proposed practical suggestions and future research directions for decision makers and researchers of current educational institutions.

Literature Review

There had been many related researches and discussions before the TIMSS regarding the issue of gender differences in mathematics and science achievements. Weinburgh (1995) used meta-analysis to analyse the literature from 1970 to 1991 on gender differences in attitudes towards science. The results showed that male and female students have significant differences in their attitudes towards science. For average students, male students have a higher positive attitude towards science, while for high-achieving students, female students have a higher positive attitude towards science. Anglin, Pirson, and Langer (2008) used mindful learning as a moderating variable to explore the differences in mathematics achievement between the two genders. In the absence of mindful learning, male students outperform female students in terms of mathematics achievement.

However, when both male and female students are engaged through mindful learning, there is no difference in their mathematics achievement. Therefore, this research believes that mindful learning can effectively enhance female students' mathematics learning performance and narrow the gap between the two genders with regard to mathematics learning. Costes, Rowley, Britt, and Woods (2008) explored the difference between male and female students in terms of self-perception and self-awareness in mathematics and science capabilities based on 4^{th}, 6^{th} and 8^{th}-grade students in schools in the southeast region of the United States (US). The results showed no significant difference between male and female students in their mathematics and science capabilities. However, male students tend to be affected by the stereotype that male students perform better in mathematics and science than female students, which in turn affects their self-awareness. Under the influence of stereotype, the impact of self-awareness of female students is not significant. Tomson (2008) used the TIMSS 2003 to analyse the differences

https://doi.org/10.33225/jbse/19.18.39

in science achievement between the two genders of Australian eighth-grade students. The results showed that there is a significant difference in science achievement between the two genders, and the educational level of the parents as well as books in the family have a significant impact on the differences in science achievement between the two genders. Pavešić (2008) used the TIMSS 2003 to analyse the difference between the two genders in the science achievement of Slovenian eighth-grade students after the implementation of the new compulsory education system. It was found that the new nine-year compulsory education system significantly narrowed the differences in science achievement between the two genders. Lindberg, Hyde, Petersen, and Linn (2010) used the meta-analysis to analyse 242 researches on the mathematics achievement of the two genders between 1990 and 2007. No significant difference in mathematics learning achievement was found between the two genders; this research also analysed the educational database of long-term surveys of adolescents in the US. The results also showed that there was no significant difference between the two genders in mathematics performance. Wai, Cacchio, Putallaz, and Makel (2010) collected 30 years of Scholastic Aptitude Test (SAT) scores from Duke University to analyse the low participation rate of women in STEM careers. They found that women have better performance in language and writing ability, while there are still more male students than female students with high scores on mathematics and science tests. This finding showed that the effects of physiological factors continue to decrease for the low participation of women in careers related to science, engineering, and mathematics. The low participation of women should be attributed to social factors. Abu-Hilal, Abdelfattah, Shumrani, Dodeen, and Abdulajabber (2014) used the TIMSS 2007 assessment results to explore the relationship between variables such as the self-concept, subject value, and mathematics and science achievement of Saudi Arabia's eighth graders. At the same time, they explored the difference in the relationship models between male and female students. Their analysis showed no significant difference between male and female students in the overall model, but the self-concept of male students in mathematics and science is higher than that of female students. However, self-improvement in mathematics and science of female students is better than that of male students. Reuben, Sapienza, and Zingales (2014) first conducted a test in mathematics and science to examine the differences in abilities between male and female students. Their results showed that even though there is no significant difference between male and female students in mathematics and science abilities, the number of male students who are employed is twice as that of female students in job-seeking situations, indicating that the negative impact of stereotype on female education and career choice may not decrease with the progress of society but may actually increase. This result echoes the research result and conclusion of Nosek et al. (2009).

Review of relevant research showed that scholars believe that in recent years, there has been a significant decrease in differences between the two genders in their learning performance. Some scholars have even further discovered that in terms of performance in mathematics and science, women are superior to men in certain abilities, such as verbal reasoning, in the content of textbooks (Ding, Song, & Richardson, 2007; Lohman & Lakin, 2009; Preckel, Goetz, Pekrun, & Kleine, 2008; Spelke, 2005; Strand, Deary, & Smith, 2006). Therefore, even though many researches on mathematics and science abilities and the learning achievement of male and female students have confirmed that there are no innate differences in learning ability between the two genders, the current state of female students in science learning and career development in science related fields still shows women at a disadvantage, which indicates that there is still room for improvement for the development of science careers for female students.

In the case of Taiwan, gender-related issues in science learning have been taken more attention after implementing the *Gender Equality Education Act* and renaming of the Gender Equality Education Committee in 2004. However, compared with the exploration of the factors impacting mathematics and science learning achievement of students, there has been a lack of research on issues related to gender differences or learning achievement of women, and there is still a significant difference in social stereotypes and the confidence and value of learning between male and female students. In other words, the notion that men are more suitable for mathematics and science-related learning activities, mathematics and science-related research, and mathematics and science-related careers also exists in Taiwan. In view of this, the research questions arose as follows:

- What was the causality of factors that impact science achievements of female student based on TIMSS?

Therefore, considering the differences in self-enhancement between East Asian and European and American students as well as the lack of research on issues such as the learning achievement of women, this research first constructed a causal model for the impact of the relevant factors on science achievement of female students through the DEMATEL method using the assessment results of the TIMSS 2011 as analysis data. It then verified the model through SEM, to understand the correlations between the learning achievement and its influencing factors of Taiwanese students as well as the current inadequacy of female students and the factors and aspects that required special attention in enhancing science learning achievement.

https://doi.org/10.33225/jbse/19.18.39

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Methodology of Research

Decision Making Trial and Evaluation Laboratory (DEMATEL)

DEMATEL is a multi-criteria decision-making (MCDM) method developed and formally proposed by Gabus and Fontela (1972). DEMATEL has been used to study and understand complex and difficult problems such as race, famine, environmental protection and energy issues (Falatoonitoosi, Leman, Sorooshian, & Salimi, 2013). The DEMATEL method first analyses problems through hierarchical structure and causality and then establishes a network relationship map (NRM) like SEM to find the corresponding solutions (Fontela & Gabus, 1976; Kuo & Cheng, 2013; Lin, Chen, & Tzeng, 2009). Because the DEMATEL analysis method is mainly based on experts' experience and judgement to evaluate the correlations of the factors and therefore the correlations of the factors constructed through this method can help researchers to clarify the correlations between unknown and complex factors, and these correlations are more in line with reality (Fontela & Gabus, 1976; Gandhi, Mangla, Kumar, & Kumar, 2015; Ilieva, 2017; Si, You, Liu, & Zhang, 2018).

According to the summary of Fontela and Gabus (1976) and Kumar and Dixit (2018), the analytical calculation process of the DEMATEL method was mainly divided into the following five steps: defining the research questions and factors and identifying relationships, establishing the initial relation matrix, establishing the normalized initial relation matrix, establishing the total initial relation matrix, and calculating the degrees of prominence and relation and plotting the causal diagram. The steps were described as follows:

1. Defining the research questions and factors as well as identifying causality:
   The factors in the system as well as their definitions were determined through discussion, literature review, and brainstorming, and the factors were used for paired comparison to evaluate the cognition of impact on the factors of each respondent; the integer numbers 0, 1, 2 3, and 4 were used for evaluation scale. Among them, 0 means no impact at all; 1 means low impact; 2 means medium impact; 3 means high impact; and 4 means extremely high impact.

2. Establishing the initial relation matrix:
   After the identification of the factors in pairs with the help of H number of experts in the research field and confirming the degrees of prominence and influence of each factor, the n.n non-negative matrix was obtained as $X^k = x_{ij}^k$. Then, the scoring matrix of H number of experts was synthesized and averaged, which is called initial relation matrix A = $a_{ij,}$ as shown in formula (1):

$$A = a_{ij} = \frac{1}{H}\sum_{k=1}^{H} x_{ij}^k \quad (1)$$

where K=the number of respondents with 1 ≤ *ik* ≤ H; and N=the number of barriers criteria.

3. Establishing the normalized initial relation matrix:

When the initial relation matrix is normalized, a normalized relation matrix D can be obtained, as shown in formula (2):

D=A.S (2)

where $S = \min\left[\frac{1}{max\sum_{j=1}^{n} aij}, \frac{1}{max\sum_{i=1}^{n} aij}\right]$

4. Establishing the total initial relation matrix:
   After the normalized initial relation matrix is established, the formula T=D/(I-D) can be used to calculate the total initial relation matrix; I is the identity matrix.

5. Calculating the degrees of prominence and relation and plotting the causal diagram:
   Calculating the sums of rows $[r_i]_{n \cdot 1}$ and columns $[c_j]_{n \cdot 1}$ according to the total initial relation matrix; ($r_i + c_j$) is the prominence, denoting the degree of factor being affected; and ($r_i - c_j$) is the relation. If positive, it means that this factor can impact other factors and is a "cause". If negative, it means that this

https://doi.org/10.33225/jbse/19.18.39

factor is an impacted factor and is a "result". Finally, a causal diagram is plotted based on the degrees of prominence and relation.

Currently, the DEMATEL method has been widely used in various fields. In addition to being used to explore the correlations between multiple criterions, it has also been used for supplier selection, business strategy derivation, waste management and organizational improvement. Wang, Lin, Chung, and Lee (2012) applied the DEMATEL method to analyse and improve the design of high-tech factory buildings. Li, Hu, Deng, and Mahadevan (2014) used DEMATEL to identify key success factors for disaster management. Gandhi et al. (2015) and Li and Mathiyazhagan (2018) applied the DEMATEL method to explore the key elements of supply chain management for heavy equipment and automotive parts manufacturers. Uygun, Kaçamak, and Kahraman (2015) applied DEMATEL to analyse and select the outsourcing suppliers of telecommunications companies. Kumar and Dixit (2018) evaluated the key barriers to e-waste management with the DEMATEL method. Applying this method to manufacturing companies, Quezada, López-Ospina, Palominos, and Oddershede (2018) constructed strategic maps and identified the relationships between factors in the strategy map.

Data Collection

As to DEMATEL analysis, this research invited a total of 12 experts, including scholars with backgrounds related to this research, teachers from the national high school who teach science-related courses and women with scientific backgrounds and working in science-related fields. The distribution of 12 experts was shown as Table 1.

Table 1. Aggregation of experts.

Experts' background	Number of experts
Scholars with backgrounds related to this research	4
Teachers from the national high school who teach science-related courses	4
Women with scientific backgrounds and working in science-related fields	4
Total	12

As to SEM analysis, from the TIMSS 2011 Science Achievement Assessment Report, there were 304,037 8th-grade students participated in TIMSS 2011 of Taiwan, and 5,042 students were valid sample. In these 5,042 students, the numbers of male students were 2,594, and female students were 2,448. Therefore, this research used 2,448 female students as the research sample to analyse the fitness of causal model.

Instrument and Procedures

In DEMATEL analysis, the research designed expert questionnaires based on the TIMSS 2011 Science Achievement Assessment Report. The four factors which were also the variables of the research including the interest in science, value in science, confidence in science, and the science achievement of eighth-grade students. The factors were used for paired comparison to evaluate the cognition of impact on the factors of each respondent; the integer numbers 0, 1, 2 3, and 4 were used for evaluation scale. Among them, 0 means no impact at all; 1 means low impact; 2 means medium impact; 3 means high impact; and 4 means extremely high impact.

As to SEM analysis, the analysis variables and items in this research also were gathered from the TIMSS 2011 Science Achievement Assessment Report same as to the factors of DEMATEL analysis. Therefore, the four variables to be analysed in this research also were the interest in science, value in science, confidence in science, and the science achievement of eighth-grade students. According to the TIMSS 2011 Science Achievement Assessment Report, there were five questions for the variable interest in science, six questions for the variable value in science, and six questions for the variable confidence in science. The scores of science achievement were summed and averaged. The research items of four variables were shown as Table 2.

https://doi.org/10.33225/jbse/19.18.39

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 2. Research factors/variables and items.

Factor/Variable	Items
Interest in science	I enjoy learning science. I wish I did not have to study science. Science is boring. I learn many interesting things in science class. I like science.
Value in science	I think learning science will help me in my daily life. I need science to learn other school subjects. I need to do well in science courses to get into the University of my Choice. I need to do well in science courses to get the job I want. I would like a job that involves using science. It is important to do well in science courses.
Confidence in science	I usually do well in science courses. Science is harder for me than for many of my classmates. I am just not good at science. I learn things quickly in science courses. My teacher tells me I am good at science. Science is harder for me than any other subject.
Science achievement	Average of all science test subjects

Source: TIMSS 2011 Science Achievement Assessment Report.

Therefore, the analysis procedure of the research was to construct the casual model by DEMATEL analysis in the first place. Secondly, SEM analysis was conducted to analyse the fitness of the casual model.

Data Analysis

The research used Microsoft Excel 2010 to run all analytical processes of DEMATEL analysis included matrix calculating and plotting the causal diagram. The IBM SPSS Amos 20.0 was used to run the fitness indices of SEM analysis.

Results of Research

DEMATEL Analysis

As part of the DEMATEL analysis, after collecting the questionnaires from the 12 experts, the average initial relation matrix (A) was calculated through the initial relation matrix of each expert, as shown in Table 3.

Table 3. The average initial relation matrix (A).

Factors	Interest in science	Value in science	Confidence in science	Science achievement
Interest in science	0	2.2	1.4	2.2
Value in science	1.8	0	2.2	2.6
Confidence in science	1.8	1.8	0	2.8
Science achievement	1	1.8	2	0

By normalization the average initial relation matrix (A), the normalized initial relation matrix (D) was calculated, as shown in Table 4.

https://doi.org/10.33225/jbse/19.18.39

Table 4. Normalized initial relation matrix.

Factors	Interest in science	Value in science	Confidence in science	Science achievement
Interest in science	0	0.333	0.212	0.333
Value in science	0.273	0	0.333	0.394
Confidence in science	0.273	0.273	0	0.424
Science achievement	0.152	0.273	0.303	0

After the normalized initial relation matrix (D) was calculated, the total initial relation matrix (T) was further calculated using the identity matrix (I), as shown in Table 5.

Table 5. Total initial relation matrix.

Factors	Interest in science	Value in science	Confidence in science	Science achievement
Interest in science	0	1.971	0	2.383
Value in science	0	0	2.142	2.64
Confidence in science	0	2.053	0	2.585
Science achievement	0	0	0	0

Finally, the sums of rows and columns in the total initial relationship matrix (T) were calculated separately to obtain the prominence and relation, as shown in Table 6.

Table 6. Degree of the total initial relation of factors.

Factors	ri	cj	ri + cj	ri - cj	Group
Interest in science	4.354	0	4.354	4.354	cause
Value in science	4.782	4.024	8.806	0.758	cause
Confidence in science	4.638	2.142	6.78	2.496	cause
Science achievement	0	7.608	7.608	-7.608	effect

Based on the prominence and relation, the causal diagram between the four factors was plotted, as shown in Figure 1.

https://doi.org/10.33225/jbse/19.18.39

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

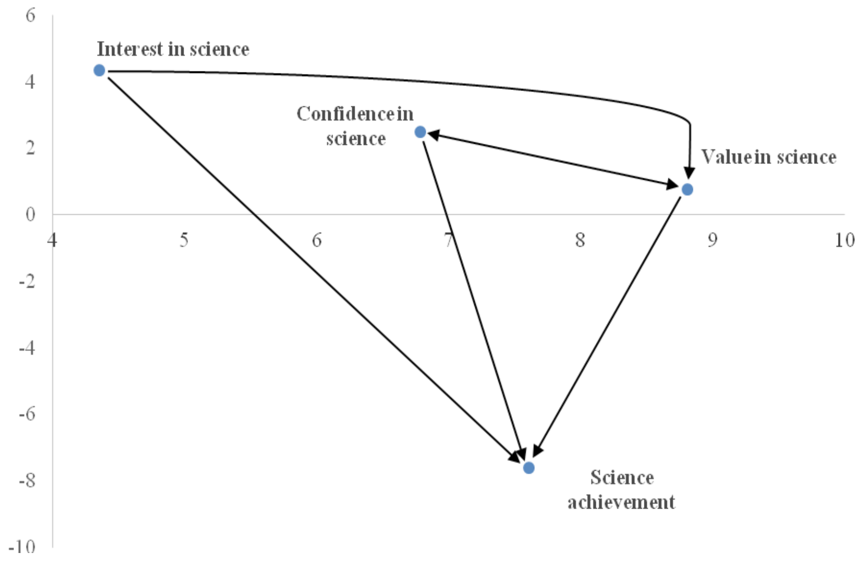

Figure 1. Causal diagram of factors.

Analysis of SEM

The results of the DEMATEL analysis indicated that the three factors such as interest in science, value in science and confidence in science could impact science achievement, and interest in science could impact value in science. However, further analysis showed that value in science and confidence in science could impact each other. Therefore, in the analysis of SEM, this research needed to put the factors in two models for further analysis, as shown in Figure 2. In Model 1, the causality between value in science and confidence in science was that value in science could impact confidence in science. In Model 2, the causality between value in science and confidence in science was that confidence in science could impact value in science.

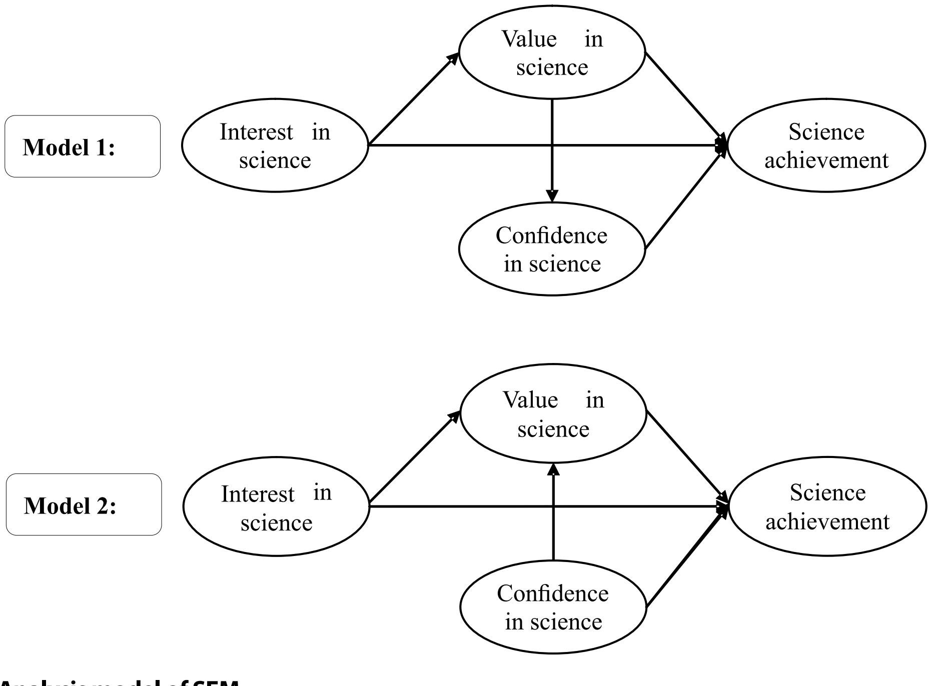

Figure 2. Analysis model of SEM.

https://doi.org/10.33225/jbse/19.18.39

The analysis results of the two models were summarized in Table 7.

Table 7. Analysis results of two models.

Fitness indices		Model 1		Model 2	
		Female	All students	Female	All students
χ^2/df		28.309	84.536	24.298	78.193
RMSEA		0.107	0.129	0.099	0.124
CFI		0.851	0.779	0.818	0.719
GFI		0.796	0.709	0.772	0.647
AGFI		0.745	0.636	0.873	0.796
CR	value-> confidence	29.341***	44.884***	-	-
	confidence -> value	-	-	4.832***	12.013***

In Model 1, the research first used the data of all Taiwanese students in the TIMSS 2011 for analysis. The results of the analysis showed that the degree of freedom ratio of chi-square test is 84.536, Root Mean Square Error of Approximation (RMSEA) is 0.129, comparative fit index (CFI) is 0.779, goodness-of-fit (GFI) is 0.709 and adjusted-GFI (AGFI) is 0.636. The composite reliability (CR) value for the path of value in science to confidence in science is 44.884, and the p-value is significant. However, in analysing data of female students, the overall fitness index improved significantly. The degree of freedom ratio of chi-square test was 28.309, RMSEA was 0.107, CFI was 0.851, GFI was 0.799, and AGFI was 0.745. The CR value for the path of value in science to confidence in science was 29.341; the ρ value was significant.

In Model 2, in analysing the data of all students, the results showed that the degree of freedom ratio of the chi-square test is 78.513, RMSEA was 0.124, CFI was 0.718, GFI was 0.646, and AGFI was 0.796, while the CR value for the path of confidence in science to value in science was 12.013; the p value was significant. However, in analysing data of female students, the overall fitness index was also significantly improved. The degree of freedom ratio of chi-square test was 24.298, RMSEA was 0.099, CFI was 0.818, GFI was 0.772, and AGFI was 0.873. The CR value for the path of confidence in science to value in science was 4.832; the p value was significant.

Discussion

Nowadays, the proportion of women in science and careers has continually increased in many countries. And the issue of gender differences in science achievement was noticed and researched with it by governments and scholars too. Moreover, since 1995, IEA held the first TIMSS assessment, it helped not only the research scope of gender differences extend from single country to international comparison, but also explored more factors which might affect gender differences of science achievement (Baye & Monseur, 2016; Miller, Eagly, & Linn, 2015; Mills & Simon, 2015; Neuschmidt, Barth, & Hastedt, 2008; Nosek et al., 2009; Pavešić, 2008; Penner, 2003; Tomson, 2008). However, results of these researches were all focus on differences of male and female students on respective factors, and these results have merely explained the cause of gender differences in science achievement. That's Scantlebury (2012) considered that gender issue in science education still was part of the conversation. Although some researches employed SEM to link science achievement with different factors and examined the invariant across gender to explain gender differences in science achievement, there were measurement errors which existed under the premise of examining male and female students with the same model (Abu-Hilal, Abdelfattah, Shumrani, Dodeen, & Abdulajabber, 2014; Tsai, Yang, & Chang, 2015).

Therefore, this research used the DEMATEL method to construct a causal model that could impact science achievements of female students through experts' judgments at first and then applied the SEM to verify the model. According to the analysis results of DEMATEL, the factors of cause were interest in science, value in science, confi-

https://doi.org/10.33225/jbse/19.18.39

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

dence in science, and science achievement was the factor of effect. Among these four factors, interest in science, value in science and confidence in science all could impact science achievement and interest in science also could impact value in science too. However, the two factors of value in science and confidence in science could impact each other. In consideration of this result, it implied the causality of value in science and confidence in science might have key impact to the science achievements of female students. This is one of the main research findings in this research.

Furthermore, based on the result of DEMATEL analysis, two causal models occurred and compared the analysis results of fitness and significance, and that female students have better results under the path of model 1. In other words, the science achievement of female students was impacted by the causality of value in science to confidence in science. This is the second major research finding, progress and difference compared to previous researches (Abu-Hilal, Abdelfattah, Shumrani, Dodeen, & Abdulajabber, 2014; Baye & Monseur, 2016; Miller, Eagly, & Linn, 2015; Mills & Simon, 2015; Neuschmidt, Barth, & Hastedt, 2008; Nosek et al., 2009; Pavešić, 2008; Penner, 2003; Tomson, 2008; Tsai, Yang, & Chang, 2015).

Conclusions

In real life, the factors that the social sciences seek to explore often impact each other. Exploring how to make the correlations between multiple factors better in line with actual situations has always been a very important research topic. Therefore, this research was the first research for integrating MCDM method and statistical method to propose a more practical approach to explore the relation between science achievement and factors influencing it on students. This approach could provide different and realistic way to construct research models for future research.

As to research issue, present researches still focus on the difference between male and female students in science and mathematics achievements and proposed some way to enhance the science and mathematics achievements of female students. Few researches used female students as the main body of analysis in research. The findings of this research included casual model and the causality of value in science and confidence in science could provide not only more integral analysis model but also a different perspective and insight to explore the research issues, like gender difference and science and mathematics achievements of female students for future researches and also could be used as a reference for policy making and improvement by relevant decision makers. These statements were also the importance and contribution of this research.

Acknowledgements

The authors would like to thank the support from Ministry of Science and Technology (MOST), Taiwan. (MOST 104-2511-S-309-001-).

References

Abu-Hilal, M. M., Abdelfattah, F. A., Shumrani, S. A., Dodeen, H., & Abdulajabber, A. S. (2014). Mathematics and science achievements predicted by self-concept and subject value among 8th grade Saudi students: Invariance across gender. *International Perspectives in Psychology: Research, Practice, Consultation, 3*(4), 268-283.

Anglin, L. P., Pirson, M., & Langer, E. (2008). Mindful learning: A moderator of gender differences mathematics performance. *Journal of Adult Development, 15*(3/4), 132-139.

Ary, D., Jacobs, L. C., Irvine, C. K. S., & Walker, D. (2018). *Introduction to Research in Education*. Boston, MA, US: Wadsworth, Cengage Learning.

Baye, A & Monseur, C. (2016). Gender differences in variability and extreme scores in an international context. *Large-scale Assessments in Education, 4*(1), 1-16.

Costes, B. K., Rowley, S. J., Britt, A. H., & Woods, T. A. (2008). Gender stereotypes about mathematics and science and self-perceptions of ability in late childhood and early adolescence. *Merrill-Palmer Quarterly, 54*(3), 386-409.

Ding, C. S., Song, K., & Richardson, L. I. (2007). Do mathematical gender differences continue? A longitudinal study of gender difference and excellence in mathematics performance in the U.S. *Educational Studies, 40*(3), 279-295

Ertl, B., Luttenberger, S., & Paechter, M. (2017). The impact of gender stereotypes on the self-concept of female students in STEM subjects with an under-representation of females. *Frontiers in Psychology, 8*, 1-11.

Falatoonitoosi, E., Leman, Z., Sorooshian, S., & Salimi, M. (2013). Decision-making trial and evaluation laboratory. *Research Journal of Applied Sciences, Engineering and Technology, 5* (13), 3476-3480.

Falk, C. F., Heine, S. J., Yuki, M., & Takemura, K. (2009). Why do Westerners self-enhance more than East Asians? *European Journal of Personality, 23*(3), 183-203.

https://doi.org/10.33225/jbse/19.18.39

Fontela, E. & Gabus, A. (1976). *The DEMATEL observer, DEMATEL 1976 Report*. Switzerland Geneva: Battelle Geneva Research Centre.
Gabus, A. & Fontela, E. (1972). *World Problems an Invitation to Further Thought within the Framework of DEMATEL*. Switzerland Geneva: Battelle Geneva Research Centre.
Gandhi, S., Mangla, S. K., Kumar, P., & Kumar, D. (2015). Evaluating factors in implementation of successful green supply chain management using DEMATEL: A case study. *International Strategic Management Review, 3*(1/2), 96-109.
Green, J., Nelson, G., Martin, A. J., & Marsh, H. (2006). The causal ordering of self-concept and academic motivation and its effect on academic achievement. *International Education Journal, 7*(4), 534-546.
Heine, S. J. & Hamamura, T. (2007). In search of East Asian self-enhancement. *Personality and Social Psychology Review, 11*(1), 1-24.
Heine, S. T. (2003). Making sense of East Asian self-enhancement. *Journal of cross-cultural psychology, 34*(5), 596-602.
Hoyle, R. H. (1995). *Structural equation modeling: Concepts, issues, and applications*. Thousand Oaks, CA, US: Sage Publications.
Ilieva, G. (2017). Group Decision Analysis with Interval Type-2 Fuzzy Numbers. *Cybernetics and Information Technologies, 17*(1), 31-44.
Kerkhoven, A. H., Russo, P., Land-Zandstra, A. M., Saxena, A., & Rodenburg, F. J. (2016). Gender stereotypes in science education resources: A visual content analysis. *PLoS ONE, 11*(11), 1-13.
Kumar, A. & Dixit, G. (2018). Evaluating critical barriers to implementation of WEEE management using DEMATEL approach. Resources, *Conservation & Recycling*, 131, 101-121.
Kuo, S. Y., & Chen, S. C. (2013). Causal analysis of air passenger decision-making. *Journal of Aeronautics, Astronautics and Aviation, Series A, 45*(2), 85-92.
Li, Y. & Mathiyazhagan, K. (2018). Application of DEMATEL approach to identify the influential indicators towards sustainable supply chain adoption in the auto components manufacturing sector. *Journal of Cleaner Production, 172*, 2931-2941.
Li, Y., Hu, Y., Zhang, X., Deng, Y., & Mahadevan, S. (2014). An evidential DEMATEL method to identify critical success factors in emergency management. *Applied Soft Computing, 22*, 504-510.
Lin, C. W., Chen, S. H., & Tzeng, G. H. (2009). Constructing a cognition map of alternative fuel vehicles using the DEMATEL method. *Journal of Multi-Criteria Decision Analysis, 16*(1/2), 5-19.
Lindberg, S. M., Hyde, J. S., Petersen, J. L., & Linn, M. C. (2010). New trends in gender and mathematics performance: A meta-analysis. *Psychological Bulletin, 136*(6), 1123-35.
Lohman, D. F. & Lakin, J. M. (2009). Consistencies in sex differences on the Cognitive Abilities Test across countries, grades, test forms, and cohorts. *The British Journal of Educational Psychology, 79*(2), 389-407.
Miller, D. I., Eagly, A. H., & Linn, M. C. (2015). Women's Representation in Science Predicts National Gender-Science Stereotypes: Evidence from 66 nations. *Journal of Educational Psychology, 107*(3), 631-644.
Mills, J. D. & Simon, M. E. (2015). Exploring eighth-grade minority and female students' statistical literacy skills using TIMSS. *Middle Grades Research Journal, 10*(3), 1-22.
Ministry of Education Republic of China (Taiwan). (2017). e100-1 Enrollment. All Levels-by year & gender. Retrieved from https://english.moe.gov.tw/cp-28-14508-95005-1.html
Neuschmidt, O, Barth, J., & Hastedt, D. (2008). Trends in gender differences in mathematics and science (TIMSS 1995-2003). *Studies in Educational Evaluation, 34* (2), 56-72.
Nosek, B. A., Symth, F. L., Sriram, N., Linder, N. M., Devos, T., Ayala, A., Bar-Anan, Y., Bergh, R., Cai, H., Gonsalkorale, K., Kesebir, S., Maliszewski, N., Neto, F., Olli, E., Park, J., Shiomura, K., Tulbure, B. T., Wiers, R. W., Somogyi, M., Akrami, N., Ekehammar, B., Vianello, M., Banaji, M. R., & Greenwald, A. G. (2009). National differences in gender-science stereotypes predict national sex differences in science and math achievement. *Proceedings of the National Academy of Science of the United States of America, 106*(26), 10593-10597.
Patrick, A. O. (2012). Unequal achievement of science undergraduates: Does sex influence the differences? *US-China Education Review B, 6*, 578-594.
Pavešić, B. J. (2008). Science achievement, gender differences, and experimental work in classes in Slovenia as evident in TIMSS studies. *Studies in Educational Evaluation, 34*(2), 94-104.
Penner, A. M. (2003). International gender×item difficulty interactions in mathematics and science achievement tests. *Journal of Educational Psychology, 95* (3), 650-655.
Preckel, F., Goetz, T., Pekrun, R., & Kleine, M. (2008). Gender differences in gifted and average-ability students comparing girls' and boys' achievement, self-concept, interest, and motivation in mathematics. *Gifted child quarterly, 52*(2), 146-459.
Quezada, L. E., López-Ospina, H. A., Palominos, P., & Oddershede, A. M. (2018). Identifying causal relationships in strategy maps using ANP and DEMATEL. *Computers & Industrial Engineering, 118*, 170-179.
Quinn, D. M. & Cooc, N. (2015). Science achievement gaps by gender and race/ethnicity in elementary and middle school. *Trends and Predictors, 44*(6), 336-346.
Reilly, D., Neumann, D. L., & Andrews, G. (2015). Sex differences in mathematics and science achievement: A meta-analysis of national assessment of educational progress assessments. *Journal of Educational Psychology, 107*(3), 645-662.
Reuben, E., Sapienza, P., & Zingales, L. (2014). How stereotypes impair women's careers in science. *Proceedings of the National Academy of Science of the United States of America, 111*(12), 4403-4408.
Scantlebury, K. (2012). *Still part of the conversation: Gender issues in science education*. In B. Fraser, K. Tobin, & C. McRobbie (Eds.), *Second international handbook of science education* (pp. 499-512). New York, NY, US: Springer.
Si, S. L., You, X. Y., Liu, H. C., & Zhang, P. (2018). DEMATEL technique - A systematic review of the state-of-the-art literature on methodologies and applications. *Mathematical Problems in Engineering, 2018*, article ID: 3696457, 1-33.
Spelke, E. S. (2005). Sex differences in intrinsic aptitude for mathematics and science? A critical review. *American Psychologist, 60*(9), 950-958.

https://doi.org/10.33225/jbse/19.18.39

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Strand, S., Deary, I. J., & Smith, P. (2006). Sex differences in cognitive abilities test scores: A UK national picture. *British Journal of Educational Psychology, 76*(3), 463-480.

Tomson, S. (2008). Examining the evidence from TIMSS: Gender differences in year 8 science achievement in Australia. *Studies in Educational Evaluation, 34*(2), 73-81.

Trope, Y. (1986). *Self-enhancement and self-assessment in achievement behaviour*. In R. M. Sorrentino & E. T. Higgins (Eds.), Handbook of motivation and cognition: Foundations of social behaviour (pp. 350-378). New York, NY, US: Guilford Press.

Tsai, L. T., Yang, C. C., & Chang, Y. J. (2015). Gender differences in factors affecting science performance of eighth grade Taiwan students. *The Asia-Pacific Education Researcher, 24*(2), 445-456.

Uygun, Ö., Kaçamak, H., & Kahraman, Ü. A. (2015). An integrated DEMATEL and Fuzzy ANP techniques for evaluation and selection of outsourcing provider for a telecommunication company. *Computers & Industrial Engineering, 86*, 137-146.

Wai, J., Cacchio, M., Putallaz, M., & Makel, M. C. (2010). Sex differences in the right tail of cognitive abilities: A 30 year examination. *Intelligence, 38*(4), 412-423.

Wang, W. C., Lin, Y. H., Chung, C. H., & Lee, M. T. (2012). DEMATEL-based model to improve the performance in a matrix organization. *Expert Systems with Applications, 39*(5), 4978-4986.

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32*(4), 387-398.

White, B. (2007). Are Girls Better Readers than Boys? Which Boys? Which Girls? *Canadian Journal of Education, 30*(2), 554-581.

Yarnell, L. M., Stafford, R. E., Neff, K. D., Reilly, E. D., Knox, M. C., & Mullarkey, M. (2015). Meta-analysis of gender differences in self-compassion. *Self and Identity, 14*(5), 499-520.

Received: *September 21, 2018*	Accepted: *December 26, 2018*

Chun-Chu Liu	Ph. D., Professor, College of Continuing Education, Chang Jung Christian University, No.1,Changda Rd., Gueiren District, Tainan City 71101, Taiwan. E-mail: lcc@mail.cjcu.edu.tw
Tse-Yu Wang	Ph. D. Candidates, Department of Business Management, National Sun Yat-sen University, 70 Lienhai Rd., Kaohsiung 80424, Taiwan. E-mail: d994010003@student.nsysu.edu.tw

https://doi.org/10.33225/jbse/19.18.39