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ANALYSING INTERRELATIONSHIP OF FACTORS INFLUENCING STUDENTS' SUCCESS IN LEARNING MATHEMATICS USING FUZZY-TISM

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ABSTRACT

Students' success in learning mathematics are influenced by various factors. Amongst the most important factors are the teaching factor, the student factor, the social factor, the university factor, and the educational supports factor. These factors are interrelated as one factor may have influenced or may be influenced by other factors, depending on the direction of influence. In the context of identifying success factors in learning mathematics particularly among students majoring in a Mathematics Degree Program in UiTM Shah Alam, examining the interrelationship between factors, the direction of influence of these factors are crucial. In addition, the classification of the factors in terms of the driving and dependence power need to be examined as well. For this purpose, this paper highlights the application of the Fuzzy Total Interpretive Structural Modelling (Fuzzy-TISM) in investigating the afore-mentioned elements in relation to the five dimensions of success factors and the corresponding subfactors based on survey responses involving thirty-five randomly selected final-year mathematics students at the College of Computing, Informatics, and Mathematics, UiTM Shah Alam. The results indicated that the main factors, namely the teaching factor, student factor, social factor, university factor, and the educational supports factor exhibits equal level of influence on one another. Further investigation on subfactors with respect each main factor was carried out. Specifically, in relation to Student Factor, interest to math course, study skills and self-motivation turned out to be the driving factors that influence or enhance students' time management and mathematics skill/background.

Keywords*: Success Factors, Learning Mathematics, Fuzzy TISM.*

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1. Introduction

Students' success at higher level of education are very much influenced by various factors. In general, background knowledge, teaching approach (Saritas & Akdemir, 2009; Kazemi & Ghoraishi, 2012; Kunwar et al., 2021), curricular design (Saritas & Akdemir, 2009), student learning motivation (Anthony, 2000; Gradwohl & Eichler, 2018; Enu et al., 2015; Kunwar et al., 2021), study approach (Enu et al., 2015), and cultural expectations (Anthony, 2000) are among important factors that potentially contribute to students' learning success. In the context of mathematics teaching and learning, students' motivation, or desire to succeed is believed to trigger better and greater effort in understanding and solving mathematical problems, which could lead to better performance. Students' motivation and mathematics achievement were seen to have significant positive corelation with one another (Md. Yunus and Wan Ali (2009); Saritas and Akdemir (2009)). Learning motivation is one of the important elements of learning that expediates students' engagement in the learning content (Zheng and Chen, 2021). In other words, students tend to be highly motivated and enthusiastic in the learning process if they could be actively involved in the learning process. Appropriate instructional strategies and teaching approaches are thus necessary to promote active involvement of students in learning mathematics (Saritas and Akdemir (2009), to foster the students' interest in the subject matter (Phoong et al. 2021), and to overcome the obstacles that discourage them from learning mathematics (Kunwar et al., 2021).

Dimensions of factors attributing to students' success in learning mathematics ranging from teaching factors, students' factor, social factor, university factors, as well as educational support factors could be interrelated. In other words, one factor may directly or indirectly influence other factor, and at the same time could also be influenced by other factors as well. The level of influence of these factors may also varies hierarchically. The technique of Fuzzy Total Interpretive Structural Modelling known as Fuzzy-TISM (Khatwani et al., 2015; Jain & Kumar, 2019) is one of the powerful tools that can be used to analyze and visualize the interrelationship between factors. Some applications of Fuzzy-TISM include analyzing the performance measures affecting the flexible manufacturing system (FMS) (Jain & Raj, 2015; Jain & Kumar, 2019),

In this paper, an analysis of the interrelationship of factors influencing the success in learning mathematics based on the opinion of a group of 35 randomly selected final year students majoring in a Mathematics degree program in UiTM Shah Alam, Selangor, Malaysia is presented. The analysis was done using the technique of Fuzzy-TISM.

2. Methodology and Implementation

In this section, the application of Fuzzy Total Interpretive Structural Modelling (Fuzzy-TISM) (Khatwani, 2014; Jain and Soni, 2019) in analyzing the factors influencing the success in learning mathematics is elucidated. Generally, the procedure of Fuzzy TISM involves the following steps.

<u>*Step 1*</u>: *Determining the possible factors contributing to students' success in learning mathematics.*
Based on the literature reviews, five factor dimensions are considered namely, Teaching Factor (F1), Student Factor (F2), Social Factor (F3), University Factor (F4), and Educational Support Factor (F5). The overall factors and factors elements are presented as in Table 1. Specifically, the interrelationship among factor dimensions, and the interrelation among factor elements with respect to each factor dimension are investigated.

Table 1: Success Factors in Learning Mathematics

Factor Dimension	Factor element
Teaching factor (F1)	Well-structured teacher presentation (F11)
	Mathematics supporting teaching materials/notes/textbook (F12)
	Communication skills of lecturers (F13)
	Ability to relate to the need to study mathematics courses with careers or real-life needs (F14)
Student factor (F2)	Interest to course (F21)
	Time management (F22)
	Mathematics Background (F23)
	Study skills (F24)
	Self-motivation (F25)
	Communication skills (F26)
Social factor (F3)	Cultural Expectation (F31)
	Family support (F32)
	Peers support (F33)
	Inspiration from renowned Mathematicians successful stories (F34)
University factor (F4)	Mathematics curriculum (F41)
	Learning infrastructure facilities and online resources (F42)
	Study environment (F43)
Educational supports factor (F5)	Online mathematics learning resources (F51)
	Mathematics Clinic/ Tutorial provided by the Mathematics Department (F52)
	Personal mathematics coaching (F53)
	Mathematics Software (F54)

Step 2*: *Gathering responses and creating the fuzzy structural self-interaction matrix (SSIM)
In this step, students' responses are solicited from the questionnaires which asked them to identify the type of relationship and the corresponding degree of influence of factors being compared. The relationship between the *i*th and *j*th elements is presented as Y, Z, O, or X depending on the type of relation. Specifically, Y indicates that the *i*th element influences the *j*th element, while Z shows that *j*th element influences the *i*th element. If there is no influence between the *i*th and the *j*th elements, then the relationship is indicated as O. The notation X is assigned for equal influence between elements. The ratings on the strengths of the relationships are described by using linguistic terms which are represented by fuzzy numbers.

Generally, a (triangular) fuzzy number $\tilde{A} = (a_1, a_2, a_3)$ is a fuzzy value defined by the membership function $\mu_{\tilde{A}}(x)$ such that,

$$\mu_{\tilde{A}}(x) = \begin{cases} (x - a_1)/(a_2 - a_1) & , \ a_1 \le x \le a_2 \\ (x - a_2)/(a_2 - a_3) & , \ a_2 \le x \le a_3 \\ 0 & , \ otherwise. \end{cases}$$

The linguistic terms and the corresponding fuzzy numbers used for representing the influence levels are as shown in Table 2.

Table 2: Linguistic Terms for influence level and the corresponding fuzzy number

Linguistic term for influence level	Fuzzy numbers
Very High Influence (VH)	(0.8, 1.0, 1.0)
High Influence (H)	(0.6, 0.8, 1.0)
Moderate (M)	(0.4, 0.6, 0.8)
Low Influence	(0.2, 0.4, 0.6)
Very Low Influence (VL)	(0, 0.2, 0.4)
No Influence (N)	(0, 0, 0.2)

As an example, if Factor F1 and Factor F2 have equal influence (X), and the strength of influence is high (H), then the rating is expressed as X(H). Similarly, if Factor F1 have no influence on Factor F2, then the rating is O(N).

In constructing the aggregated fuzzy SSIM matrices, only the entries above the main diagonal are required to be determined. Specifically, the aggregated fuzzy SSIM matrix for factor dimensions (F1, F2, F3, F4, F5), and the aggregated fuzzy SSIM matrices with respect to Teaching Factor (F11, F12, F13, F14), Student Factor (F21, F22, F23, F24, F25, F26), Social Factor (F31, F32, F33, F34), University Factor (F41, F42, F43), and Educational Support Factor (F51, F52, F53, F54) are constructed based on the highest number of occurrences of the type of relationship (and the strength of influence) between compared factor dimensions (or compared factors' elements). The corresponding aggregated fuzzy SSIMs are presented in the following Table 3 to Table 8.

Table 3: Aggregated Fuzzy SSIM for Factor Dimensions

FACTOR DIMENSION	F1	F2	F3	F4	F5
F1	-	X(H)	X(H)	X(H)	X(H)
F2	-	-	X(VH)	X(H)	X(H)
F3	-	-	-	O(N)	O(N)
F4	-	-	-	-	X(H)
F5	-	-	-	-	-

Table 4: Aggregated Fuzzy SSIM for Teaching Factor (F1)

ELEMENT	F11	F2	F13	F14
F11	-	X(VH)	X(VH)	X(H)
F12	-	-	O(VH)	X(H)
F13	-	-	-	Y(M)
F14	-	-	-	-

Table 5: Aggregated Fuzzy SSIM for Student Factor (F2)

ELEMENT	F21	F22	F23	F24	F25	F26
F21	-	X(VH)	X(VH)	X(VH)	X(VH)	O(N)
F22	-	-	O(N)	X(VH)	X(VH)	O(N)
F23	-	-	-	X(H)	X(M)	O(N)
F24	-	-	-	-	X(H)	O(N)
F25	-	-	-	-	-	O(N)
F26	-	-	-	-	-	-

Table 6: Aggregated Fuzzy SSIM for Social Factor (F3)

ELEMENT	F31	F32	F33	F34
F31	-	X(VH)	X(VH)	X(VH)
F32	-	-	O(N)	X(VH)
F33	-	-	-	X(H)
F34	-	-	-	-

Table 7: Aggregated Fuzzy SSIM for University Factor (F4)

ELEMENT	F41	F42	F43
F41	-	X(H)	X(H)
F42	-	-	X(H)
F43	-	-	-

Table 8: Aggregated Fuzzy SSIM for Educational Support Factor (F5)

ELEMENT	F51	F52	F53	F54
F51	-	X(H)	X(H)	X(H)
F52	-	-	X(H)	X(M)
F53	-	-	-	O(N)
F54	-	-	-	-

Note that the following Step 3 to Step 6 apply to all fuzzy SSIMs. However, for illustrative purposes, detailed calculations in the following steps are shown based on the aggregated fuzzy SSIM for dimension of factors presented in Table 3.

Step 3**:** *Constructing the fuzzy reachability matrix.*
In this step, the fuzzy reachability matrix, *A*, is constructed such that the entries of *A* presented in the form of fuzzy numbers are generated from the aggregated fuzzy SSIM matrix based on the representation shown in the following Table 9. We have

$$A = [a_{ij}] = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}, i, j = 1,2, \dots, n.$$

Table 9: Entries of Fuzzy Reachability Matrix

Entry (i,j) in SSIM matrix	**Entry of fuzzy reachability matrix**	
	Entry (i,j)	**Entry (j,i)**
Y(VH)	(0.8, 1.0, 1.0)	(0, 0, 0.2)
Y(H)	(0.6, 0.8, 1.0)	(0, 0, 0.2)
Y(M)	(0.4, 0.6, 0.8)	(0, 0, 0.2)
Y(L)	(0.2, 0.4, 0.6)	(0, 0, 0.2)
Y(VL)	(0, 0.2, 0.4)	(0, 0, 0.2)
Z(VH)	(0, 0, 0.2)	(0.8, 1.0, 1.0)
Z(H)	(0, 0, 0.2)	(0.6, 0.8, 1.0)
Z(M)	(0, 0, 0.2)	(0.4, 0.6, 0.8)
Z(L)	(0, 0, 0.2)	(0.2, 0.4, 0.6)
Z(VL)	(0, 0, 0.2)	(0, 0.2, 0.4)
X(VH)	(0.8, 1.0, 1.0)	(0.8, 1.0, 1.0)
X(H)	(0.6, 0.8, 1.0)	(0.6, 0.8, 1.0)
X(M)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)
X(L)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)
X(VL)	(0, 0.2, 0.4)	(0, 0.2, 0.4)
O(N)	(0, 0, 0.2)	(0, 0, 0.2)

As an example, Table 3 can be transformed into Table 10 as follows.

Table 10: Fuzzy Reachability Matrix

FACTOR	F1	F2	F3	F4	F5
F1	-	H	H	H	H
F2	H	-	VH	H	H
F3	H	VH	-	N	N
F4	H	H	N	-	H
F5	H	H	N	H	-

Step 4: *Calculation of driving power and dependence power for factors for MICMAC Analysis.* In this step, the fuzzy values $(l_{F_k}, m_{F_k}, u_{F_k})$, of the driving power and the dependence of factors F_k, k=1,2,…,5 are derived by taking the sum of the row entries, or column entries of F1 to F5, respectively. The overall calculated values are displayed in Table 11.

Table 11: Fuzzy Reachability Matrix with Driving and Dependence Power

FACTOR	F1	F2	F3	F4	F5	**Driving Power**	**Crisp Value**
F1	(1,1,1)	(0.6,0.8,1)	(0.6,0.8,1)	(0.6,0.8,1)	(0.6,0.8,1)	(3.4,4.2,5)	4.152
F2	(0.6,0.8,1)	(1,1,1)	(0.8,1,1)	(0.6,0.8,1)	(0.6,0.8,1)	(3.6,4.4,5)	4.316
F3	(0.6,0.8,1)	(0.8,1,1)	(1,1,1)	(0,0,0.2)	(0,0,0.2)	(2.4,2.8,3.4)	2.868
F4	(0.6,0.8,1)	(0.6,0.8,1)	(0,0,0.2)	(1,1,1)	(0.6,0.8,1)	(2.8,3.4,4.2)	3.458
F5	(0.6,0.8,1)	(0.6,0.8,1)	(0,0,0.2)	(0.6,0.8,1)	(1,1,1)	(2.8,3.4,4.2)	3.458
Dependence Power	(3.4,4.2,5)	(3.6,4.4,5)	(2.4,2.8,3.4)	(2.8,3.4,4.2)	(2.8,3.4,4.2)		
Crisp Value	4.152	4.316	2.868	3.458	3.458		

Note that the corresponding crisp values representing the dependence and driving powers are calculated using the defuzzification technique of converting fuzzy data into crisp scores (CFCS) (Opricovic and Tzeng, 2003). As an illustration, the fuzzy value (3.4,4.2,5) of the driving power with respect to Factor F1 i.e. 4.152 is obtained as follows:

Let $(l_{F_k}, m_{F_k}, u_{F_k})$, k=1, 2, …, 5, represent the fuzzy values representing the driving powers of F1 to F5. We have $L = \min_k l_{F_k} = 2.4$, $R = \max_k u_{F_k} = 5$, and Δ=R-L=2.6. Note that for F1 with l_{F_k}=3.4, m_{F_k}= 4.2, $u_{F_k} = 5$, the normalized fuzzy values are calculated as

$$x_{F1,l} = \frac{l_{F1} - L}{\Delta} = \frac{3.4 - 2.4}{2.6} = 0.385$$

$$x_{F1,m} = \frac{m_{F1} - L}{\Delta} = \frac{4.2 - 2.4}{2.6} = 0.692$$

$$x_{F1,u} = \frac{m_{F1} - L}{\Delta} = \frac{5 - 2.4}{2.6} = 1$$

The normalized left score and the normalized right score are obtained as follows:

$$X_{F1}^{ls} = \frac{x_{F1,m}}{(1 + x_{F1,m} - x_{F1,l})} = \frac{0.692}{(1 + 0.692 - 0.385)} = 0.529$$

$$X_{F1}^{rs} = \frac{x_{F1,u}}{(1 + x_{F1,u} - x_{F1,m})} = \frac{1}{(1 + 1 - 0.692)} = 0.764$$

Based on the normalized left, and right score, the total normalized crisp value is obtained as

$$X_{F1}^{crisp} = \frac{X_{F1}^{ls} \cdot (1 - X_{F1}^{ls}) + \left(X_{F1}^{rs}\right)^2}{(1 - X_{F1}^{ls} + X_{F1}^{rs})} = \frac{0.529(1-0.529)+(0.764)^2}{(1-0.529+0.764)} = 0.674$$

Hence, the crisp value can be calculated as,

$$A_{F1}^{crisp} = L + X_{F1}^{crisp} \cdot \Delta = 2.4 + 0.674 \times 2.6 = 4.152 .$$

The crisp values for the driving power and the dependence power with respect to the rest of factors are obtained in similar manner.

Step 5: *Cross-impact matrix multiplication applied to classification (MICMAC) analysis.*

The MICMAC analysis classifies the factors into linkage factors, independent factors, dependent factor, and autonomous factor according to their performances by means of a scatter plot graph with four quadrants representing each type of performances. Figure 1 below visualizes the classifications of factors into quadrants representing four types of factors namely, autonomous, dependent, linkage, and independent categories. The vertical and horizontal lines that form the quadrants are determined from the means of the crisp driving power and the dependence power. The plots of points with respect to factors are based on the pair of their corresponding crisp values for dependence and driving powers.

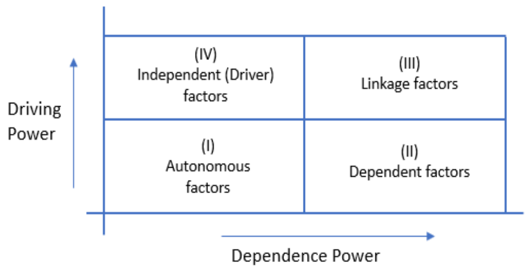


Figure 1: Classifications of Factors

Step 6: *Constructing Initial and Final Reachability Matrices*

The initial reachability matrix is constructed based on the fuzzy the fuzzy reachability matrix (Table 4). Entries in the initial reachability matrix are assigned a value of '1' if the corresponding entries in the fuzzy reachability matrix are Very high (VH), or High (H). However, if the entries in the fuzzy reachability matrix Low (L) influence, Very Low (VL) Influence, or No Influence (N), then '0' value will be assigned. The resulting reachability matrix of factor dimension is shown in Table 12. The final reachability matrix presented in Table 13 is formed by incorporating the transitivity (Jain and Raj, 2015) into the initial reachability matrix**.** Transitivity of the matrix is determined based on the relation that if factor (F1→F2) and (F2→F3) then necessarily (F1→F3). The notation 1* of entries in the final reachability matrix signifies transitivity. For Teaching Factor, Student Factor, Social Factor, University Factor, and the Educational Support Factors, the corresponding final reachability matrices displayed in Table 14 to Table 18 are generated in the same manner.

Table 12: Initial Reachability Matrix of Factor Dimensions

DIMENSION	F1	F2	F3	F4	F5
F1	1	1	1	1	1
F2	1	1	1	1	1
F3	1	1	1	0	0
F4	1	1	0	1	1
F5	1	1	0	1	1

Table 13: Final Reachability Matrix of Factor Dimensions

DIMENSION	F1	F2	F3	F4	F5
F1	1	1	1	1	1
F2	1	1	1	1	1
F3	1	1	1	1*	1*
F4	1	1	1*	1	1
F5	1	1	1*	1	1

Table 14: Final Reachability Matrix of Teaching Factor

ELEMENT	F11	F12	F13	F14
F11	1	1	1	1
F12	1	1	1*	1
F13	1	1*	1	1
F14	1	1	1*	1

Table 15: Final Reachability Matrix of Student Factor

ELEMENT	F21	F22	F23	F24	F25	F26
F21	1	1	1	1	1	0
F22	1	1	0	1	1	0
F23	1	0	1	1	1	0
F24	1	1	1	1	1	0
F25	1	1	1	1	1	0
F26	0	0	0	0	0	1

Table 16: Final Reachability Matrix of Social Factor

ELEMENT	F31	F32	F33	F34
F31	1	1*	1	1
F32	1*	1	0	1
F33	1	0	1	1*
F34	1	1	1*	1

Table 17: Final Reachability Matrix of University Factor

ELEMENT	F31	F32	F33
F41	1	1	1
F42	1	1	1
F43	1	1	1

Table 18: Final Reachability Matrix of Educational Support Factor

ELEMENT	F51	F52	F53	F54
F51	1	1	1	1
F52	1	1	1	1
F53	1	1	1	1*
F54	1	1	1*	1

Step 7*: *Reachability Matrix Partition using Relation and Level Partitioning

The final reachability matrices of the factors are partitioned into levels which may involve some iterations. After the first iteration, factors classified at the first level are discarded. The partitioning procedure is repeated on the remaining factors at the next level, and so on. These iterations are continued until the level of each factor has been determined. Table 14 to Table 19 display the level partitioning of Factor Dimensions, Teaching Factor, Student Factor, Social Factor, University factor and Educational Support Factor, respectively.

Table 14: Level Partitioning of Factor Dimensions

Dimension	Reachability Set	Antecedent Set	Intersection Set	Level
F1	F1,F2,F3,F4,F5	F1,F2,F3,F4,F5	F1,F2,F3.F4,F5	I
F2	F1,F2,F3,F4,F5	F1,F2,F3,F4,F5	F1,F2,F3.F4,F5	I
F3	F1,F2,F3,F4,F5	F1,F2,F3,F4,F5	F1,F2,F3.F4,F5	I
F4	F1,F2,F3,F4,F5	F1,F2,F3,F4,F5	F1,F2,F3.F4,F5	I
F5	F1,F2,F3,F4,F5	F1,F2,F3,F4,F5	F1,F2,F3.F4,F5	I

Table 15: Level Partitioning of the Teaching Factor (F1)

Factor Element	Reachability set	Antecedent set	Intersection set	Level
F11	F11,F12,F13,F14	F11,F12,F13,F14	F11,F12,F13,F14	I
F12	F11,F12,F13,F14	F11,F12,F13,F14	F11,F12,F13,F14	I
F13	F11,F12,F13,F14	F11,F12,F13,F14	F11,F12,F13,F14	I
F14	F11,F12,F13,F14	F11,F12,F13,F14	F11,F12,F13,F14	I

Table 16: Level Partitioning of the Student Factors (F2)

Factor Element	Reachability set	Antecedent set	Intersection set	Level
F21	F21,F22,F23,F24,F25	F21,F22,F23,F24,F25	F21,F22,F23,F24,F25	I
F22	F21,F22,F24,F25	F21,F22,F24,F25	F21,F22,F24,F25	I
F23	F21,F23,F24,F25	F21,F23,F24,F25	F21,F23,F24,F25	I
F24	F21,F22,F23,F24,F25	F21,F22,F23,F24,F25	F21,F22,F23,F24,F25	I
F25	F21,F22,F23,F24,F25	F21,F22,F23,F24,F25	F21,F22,F23,F24,F25	I
F26	F26	F26	F26	I

Table 17: Level Partitioning of the Social Factors

Factor Element	Reachability set	Antecedent set	Intersection set	Level
F31	F31,F32,F33,F34	F31,F32,F33,F34	F31,F32,F33,F34	I
F32	F31,F32,F33	F31,F32,F33	F31,F32,F33	I
F33	F31,F32,F33,F34	F31,F32,F33,F34	F31,F32,F33,F34	I
F34	F31,F33,F34	F31,F33,F34	F31,F33,F34	I

Table 18: Level Partitioning of the University Factors

Factor Element	Reachability set	Antecedent set	Intersection set	Level
F41	F41,F42,F43	F41,F42,F43	F41,F42,F43	I
F42	F41,F42,F43	F41,F42,F43	F41,F42,F43	I
F43	F41,F42,F43	F41,F42,F43	F41,F42,F43	I

Table 19: Level Partitioning of the Educational Supports

Factor Element	Reachability set	Antecedent set	Intersection set	Level
F51	F51,F52,F53,F54	F51,F52,F53,F54	F51,F52,F53,F54	I
F52	F51,F52,F53,F54	F51,F52,F53,F54	F51,F52,F53,F54	I
F53	F51,F52,F53,F54	F51,F52,F53,F54	F51,F52,F53,F54	I
F54	F51,F52,F53,F54	F51,F52,F53,F54	F51,F52,F53,F54	I

Step 8**:** *Creating TISM Digraphs*

The TISM diagraphs are constructed based on the final reachability matrices and the partition levels to visualize the interaction between factor dimensions, as well as the interaction between factor elements with respect to each factor dimension. The analysis of the diagraphs with respect to each of the factor dimensions are further explained in Section 3.

3. Results and Discussion

This section discusses the findings based on the MICMAC analysis performed in Step 5 of the fuzzy TISM procedure presented in Section 2. The MICMAC analysis clustered the factors based on their driving and dependence powers into categories as either autonomous, dependent, linkage, or independent factors. The interrelationship or interaction between elements of factors are visualized in the form of digraphs. The first part of the discussions is based on the classification of factor dimensions as portrayed in Figure 2. Note that the Social Factor (F3) lies in the autonomous quadrant due to its low driving and dependence powers. This indicates F3 is less dependent on the other factors and have low influence towards students' success in learning mathematics. On the other hand, Teaching Factor (F1), Student Factor (F2), University Factor (F4) as well as Mathematics Educational Support Factor (F5) were clustered as linkage factor that are strongly interrelated to one another and have strong driving power. Factors F1, F2, F4, F5 are key factors that contribute to the success in learning mathematics. Improving any one of these factors will directly affect the rest of the factors in the system. As such, greater attention should be given to these factors to enhance and promote effective mathematic teaching and learning experience amongst students. In terms of driving power, F2 is ranked in the first position followed by F1, F4, F5, and F3.

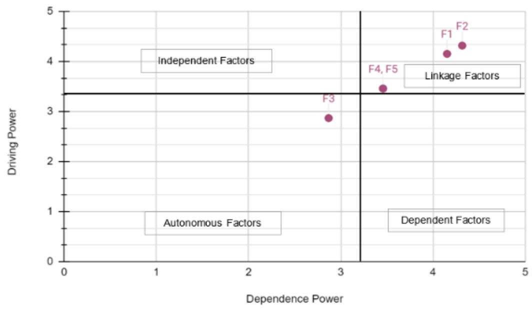


Figure 2. Classification of Factor Dimensions

The directions of the interrelationship between dimension of factors is illustrated in Figure 3.

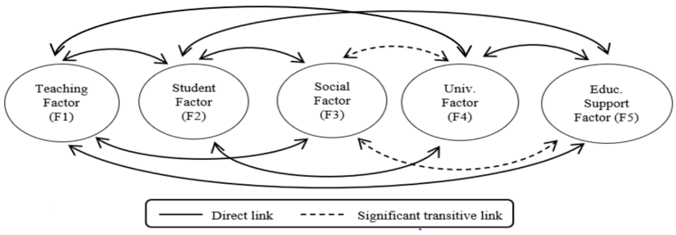
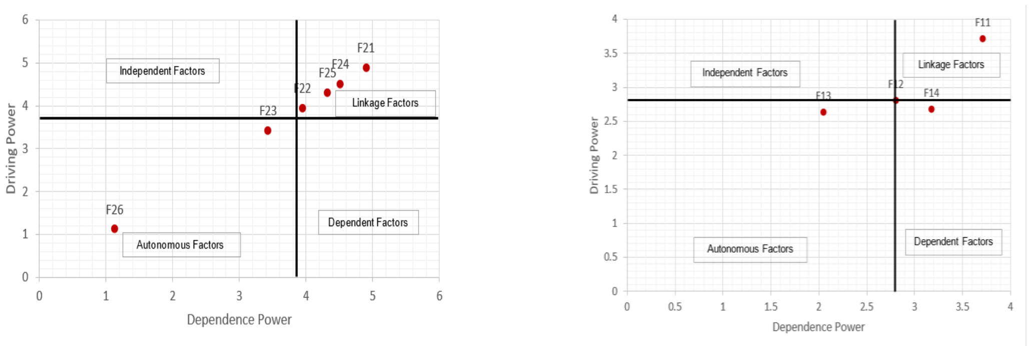


Figure 3. Digraph for Factor Dimensions

In the second part of the discussions, MICMAC analyses were further caried out to identify the classifications of the elements with respect to each factor dimension following the aforementioned ranking order i.e. Student Factor (F2), followed by Teaching Factor (F1), University Factor (F4), Educational Support Factor (F5), and Social Factor (F3). Figure 4(a) and Figure 4(b) illustrate the scatter plots of elements characterizing the student factor and the teaching factor, respectively.



(a) Student Factor (F2)
(b) Teaching Factor (F1)

Figure 4. Classifications of elements with respect to F1 and F2

The respondents agreed that the student factor played the most important roles in ensuring their own success in learning mathematics. As highlighted in Figure 4(a), the elements of student's interest (F21) in learning mathematics posed the highest driving power followed by study skills (F24), self-motivation (F25), time management (F22), Mathematics background (F23), and the least being the students' communication skill (F26). Various activities that promote students' interests, motivations as well as necessary study skills in learning the subject need to be planned and conducted be at the classroom level, faculty level, or university level.

In the context of Teaching Factor (F1) which was ranked the second among factor dimensions, the element 'Well-structured teacher presentation (F11)' has the highest driving power, followed by 'Mathematics supporting teaching materials/notes/textbook (F12)', Ability to relate to the need to study mathematics courses with careers or real-life needs (F14), and Communication skills of lecturers (F13). Lecturer's communication skills (F13), and Lecturer's ability to relate mathematical concept with real life application (F14) have equal importance in driving students' success in learning mathematics. These findings suggested that effective instructional approaches supported by appropriate teaching materials need to be employed by the instructors to encourage active learning and improve students' understanding on the contents being delivered. In addition, lecturers' ability to relate mathematical concept with real life application helps inculcate students' awareness on the importance and applicability of mathematics in everyday life. As such, students' have better interest in learning mathematics.

The interrelationship amongst elements of the teaching factor, and amongst elements of the student factor are illustrated in Figure 6 and Figure 7, respectively.

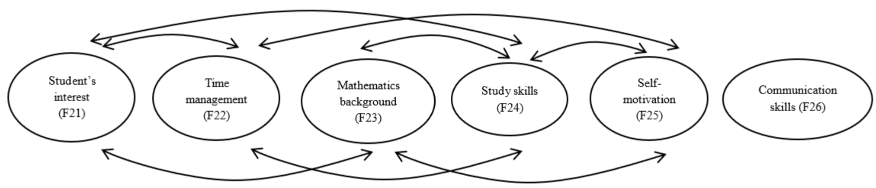


Figure 6. Digraph for Student Factor

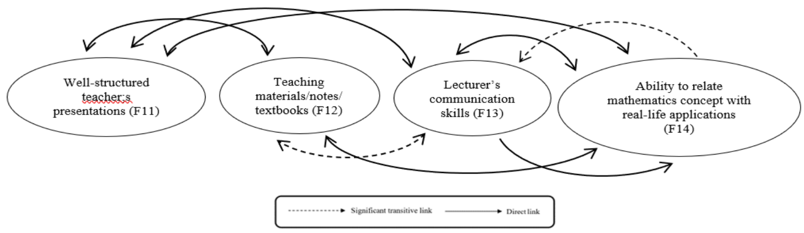
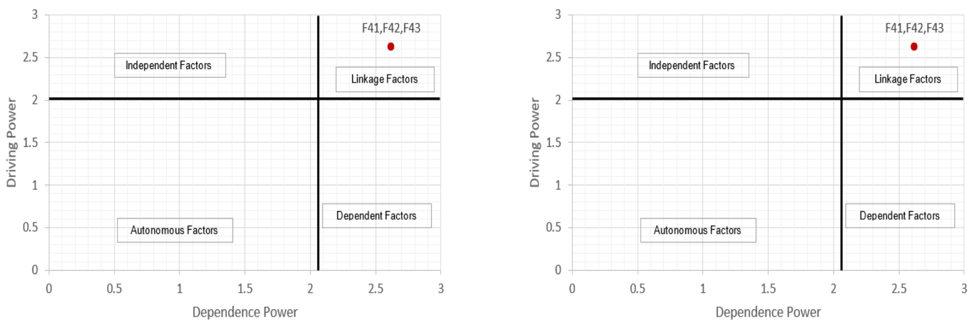


Figure 7. Digraph for Teaching Factor

The university factor (F4) and the educational support factor (F5) were equally positioned as the third important factor dimension contributing to the success of learning mathematics. Specifically for university factor as displayed in Figure 8(a), the mathematics curriculum (F41), the learning infrastructures and online resources (F42), and the study environment (F43) have equal driving power and they are clustered as linkage factor that are strongly interrelated. Meanwhile, for the educational support factor, Figure 8(b) indicated that the students placed the online mathematics learning resources (F51) as the first important influencing factor, followed by mathematics clinic/tutorials provided by the department (F52), personal mathematics coaching (F53), and the use of mathematics software (F54).



(a) University Factor (F4) (b) Educational Support Factor (F5)

Figure 8. Classifications of elements of F4 and F5

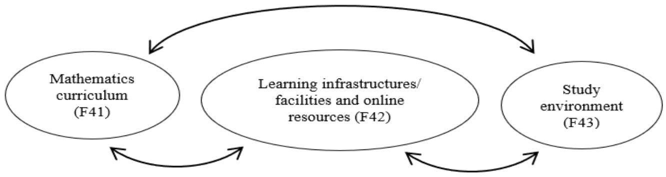


Figure 9. Digraph for University Factor

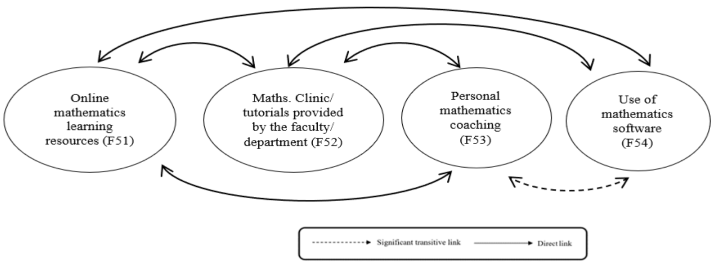


Figure 10. Digraph for Educational Support Factor

Finally, the fifth contributing factor to students' success in learning mathematics is the social Factor (F3). In the context of social factor, as depicted in Figure 11, the elements of cultural expectation (F31) and peer support (F33) have higher driving powers as compared to the elements of family support (F32), and inspiration from renowned mathematicians' successful stories (F34). The digraph of the interaction between elements of Social Factors is presented in Figure 12.

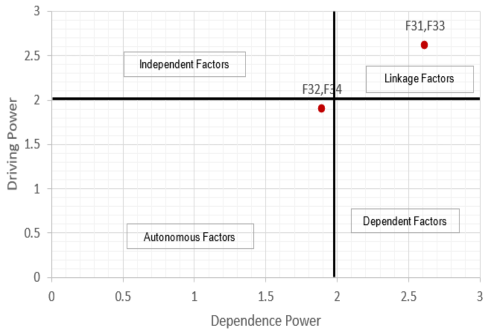


Figure 11. Classifications of elements with respect to Social Factor (F3)

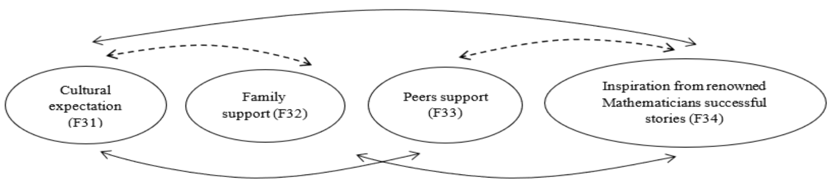


Figure 12. Digraph for Social Factor

4. Conclusion and Recommendations

Generally, students' success in learning mathematics is attributed to various factors. In this paper, the interrelationship of five factor dimensions namely, the teaching factor, student factors, social factor, university factor, educational support factors, and the corresponding elements based on the point of views by a group of final year mathematics major were analysed by using the technique of Fuzzy-TISM. Investigations on the factors' interrelationships and level of influence are important because this information can provide some valuable insights to the academia and other related parties in strategizing and to carry out necessary plans and actions towards improving the factors contributing to students' success in learning mathematics. For future studies, additional factors related to students' learning approaches and teaching styles could also be taken into consideration. Appropriate weight determination techniques involving pairwise comparison of level of influence among factors such as Consistent Fuzzy Preference Relation (CFPR), Fuzzy DEMATEL, and other methods of similar nature can be employed in prioritizing students' success in learning mathematics.

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7. Conflict of Interest

The authors have no conflicts of interest to declare.

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