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Influence of Teacher-Student Relationships on Mathematics Problem-Solving

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Abstract

Literatures revealed that the cognitive and affective components are the factors affecting problem solving. In this article we identified factors considered by the students in learning mathematical problem solving. Using a descriptive phenomenological research, we explored the lived experiences of forty-five (45) student's in solving a mathematics problem. Following the Colaizzi method for data analysis, four themes emerged: emotions and self- efficacy as affective factors, and group learning activity and teacher- student relationship as social factors. Sixty items from these four themes were further explored in using an Exploratory Factor Analysis (EFA) for a new set of 200 students. These four-factor structures of the student's experiences in mathematics problem solving explained 66% of the variance in the pattern of relationships among the items. All four-factor structures had high reliabilities (all at or above Cronbach's $\alpha > .904$). The study exemplified that teacher- student interaction relationship during learning activities, which is a social factor, provides the highest correlated factor that influences the mathematical performance of the students.

Keywords: Affective skills, Colaizzi method, Exploratory factor analysis, Mathematics problem-solving, Phenomenology, Social skills

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INTRODUCTION

Problem-solving is one of the most important skills in life which requires analyzing, interpreting, reasoning, evaluating, and predicting (Wurdinger, & Qureshi, 2015). Equivalent to an expressive technological and scientific growth in the world, people are facing problems that are increasing and becoming more complicated. Finding and building up suitable solutions to these problems are needed. One of the significant components across all programs in mathematics is problem-solving (Singer, Ellerton, & Cai, 2015). The main objective of teaching Mathematics is to develop student's mathematical problem-solving skills. Moreover, in dealing with Mathematics using problem-solving can make a context that simulates a real-life, where problem-solving can facilitate the homing of skills of students in solving problems in daily life (Aydoğdu, & Keşan, 2014).

It is commonly observed by Mathematics teachers that learners experienced mathematics anxiety. Many of them either hate or love mathematics as a subject. Emotions play an important part in the learning process of the learner based on their experiences in solving math problems (Hannula, 2015). Few of them dislike mathematics specifically on the problem-solving process and complaining that they hate mathematics because "it's too difficult". These perceptions resulted in the avoidance of mathematics and declined mathematics performance (Taylor, & Graham, 2007).

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Enhancing critical thinking among the students is one of the competencies required by the 21st-century generation (Brucal, Perez, Enoslay, & Liwanag, 2019) mentioned that mathematics teaching is identified as one of the ways to raise critical thinking among students. Furthermore, Mathematics teachers have been developing students' ability in solving mathematics problems. Teachers used different strategies to cater to the needs of the students in solving a mathematics problem. However, students are still experiencing hard times in solving a mathematics problem (Fauziah, 2020). Thus, it is necessary to determine the teacher and student factors affecting problem-solving difficulties in mathematics (Agustyaningrum, Abadi, & Mahmudi, 2021). In connection with this, the researcher thinking this meaningful question that gives in-depth self-realization. "Do teachers use students' preferred teaching strategies in solving a mathematics problem? Are the efforts injected by teachers parallel to the needs of the students?"

In this study we explores the lived experiences of students towards mathematics problem-solving. We focus on the process considered by the students in learning mathematical problem solving to achieve Higher-Order-Thinking skills. Furthermore, this study provides pedagogical implications towards teacher-students interaction during mathematics problem-solving.

RESEARCH METHOD

A descriptive phenomenological approach was chosen to narrate a person's actual experiences in an attempt to enrich lived experience by drawing out its meaning (Wassler, & Kuteynikova, 2020). It used to investigate and relate the lived experience of individuals (Christensen, Welch, & Barr, 2017).

Moreover, descriptive phenomenological research encourages the researcher to explore students' experiences about their ways of solving mathematics problems. It was mentioned that the phenomenological inquiry can be considered a source of evidence beyond existing understanding and as such provide deeper and more meaningful productive insights.

Prior to the conduct of the study, researchers seek permission to the head of the institution through a request letter. After the request has been granted, all participants were informed, through consent, and voluntarily participated during the conduct of the research.

In this study, student's experiences towards mathematics problem solving were explored, transcribed, and analyzed. We explored the lived experiences of forty-five (45) student's in solving a mathematics problem through a Semi – Structured Interview. The data were collected via in-depth, open-ended interviews. It was conducted on a one-on-one basis, then follow-up questions to ensure we obtained rich answers through capturing several dimensions of the students' lived experiences and limiting socially desirable responses (Hendricks, 2017). The interview was started with the question: *What is your experience in solving mathematics problem?* Colaizzi stated that the success of phenomenological studies depends on focusing questions on the lived experiences of each participant. Follow-up questions were asked on the basis of the information provided by the respondents (Colaizzi, 1978).

The study utilized a digital audio recorder, and field notes. An audio recorder device was used to record all information expressed verbally during the interviews. Field notes were also utilized to document the emotional cues displayed by the participants during the interview. Procedures for the processing of data were detailed as follow: notes and all the data from the audio were transcribed immediately following the purpose of the study.

We analyzed the transcribed data using the Colaizzi's phenomenological approach. Transcriptions were made while listening the audios. It is a process of phenomenological data analysis showed an active strategy to achieve the description of the living experience of the respondents (Sanders, 2003). It includes the appreciation of the data and ascertains significant statements which in turn were converted into formulated meanings.

Using the seven steps of Colaizzi method, the themes and subthemes were actually taken from the words of the respondents and condensed in order to form bigger concepts and ideas. Confidentiality was maintained throughout the transcriptions procedures by utilizing pseudonyms (e.g. Student 1, Student 2, …, Student 45) to de-identify the data. This was done after the interview to minimize the risk disclosure of personal information.

Ideally, themes from subgroups with commonalities should emerge. From these, themes were developed to be analyzed and validated through Exploratory Factor Analysis based on Matsunaga concept of “How to Factor- Analyze Your Data Right: Do’s, Dont’s, How-To’s” (Matsunaga, 2010) and Hair concept of “Multivariate Data Analysis” (Hair Junior, Black, Babin, Anderson, & Tatham, 1998). This statistical technique is used to reduce data to a smaller set of underlying factors and eventually served as basis of the most preferred teaching strategy of students in solving mathematics problems. Sixty items from these themes were further explored by the new set of 200 students in different year levels of a non- STEM middle school for the School Year 2019 -2020. One hundred fourteen of the students (57%) were female and 86 of the students (43%) were male.

Table 1. Distribution of respondents

Year Level	Population
Grade - 7 Students	40
Grade - 8 Students	45
Grade - 9 Students	35
Grade – 10 Students	80
Total	200

Table 1 shows the distribution of participants according to their year level. There were 20% of the students from Grade 7, 22.5% from Grade 8, 17.5% from Grade 9 and 40% from Grade 10 leading to two hundred (200) students in totality. One hundred and twenty-seven of the students (63.5%) were below average, 48 of the students (24%) were average, and 25 of the students (12.5%) were above average.

RESULTS AND DISCUSSION

The results of the forty-five respondents’ statements were transcribed to create themes. Using the seven steps of Colaizzi method, there were four themes that emerged: emotions and self- efficacy as affective factors, and group learning activity and teacher- student relationship as social factors. The statements were grouped together based upon commonalities and these led to the creation of subthemes as shown in Table 2.

Table 2 shows that student feelings contributed to the teaching-learning process. All problem solvers encounter positive and negative feelings that influence their solution process. Emotions are an essential part of the problem solver's self-regulation (Hannula, 2015).

Table 2. Themes and sub-themes obtained from data analysis

Theme	Sub- theme
Emotions	- Feeling happy
	- Feeling anxious
	- Feeling sad
Self-efficacy	- Being independent
	- Self- determination
	- Self- confidence
Group Learning Activity	- Group discussions
	- Working with the Group
Teacher-Student Relationship	- Teacher's Guidance
	- My teacher, my mother

The data from the current study showed that the students were emotionally disturbed when dealing with a mathematical problem. The feeling of disappointment towards the subject was present. During the observations, some students were frustrated because of their deficient acquired skills. Based on their experience, they were not sure whether they draw up an acceptable solution to generate the correct answer. They felt anxious that may resulted in discouragement towards the subject. The findings revealed that their emotional attribution to their confusion, worries, and doubts contribute to their academic deficiencies.

On the positive side, some students said that they can learn the topics and are motivated to participate with peers. They feel safer and less embarrassed when working as a team. As observed, nearly all of the students prefer to have a group activity than working individually. During group discussions, the majority of them overcome their fear and less threatened because there is no emotional barrier that hinders in expressing their thoughts. As a result, they successfully perform the task and improve their self-confidence (Azimova, 2020).

There were students also said that learning mathematics problem solving depends on their subject teachers. They were motivated to learn if their teacher is easy to talk to, and subject-oriented. Most specially, if their subject teacher is like their mother that guided them until the whole period of time.

Some students were confident of their own effort in solving mathematics problem. They were determined to find solutions to the mathematical problems they encountered with their own effort. According to Bandura, this is called self-efficacy in which actualizing the adequate individual's ability or skills (Bandura, & Walters, 1977).

Table 3 presents the examples of forty-five student's narratives according to the themes and their respective subthemes based on Colaizzi method. Out of the generated themes and subthemes shown in table 3, the researcher come up with a 7-point Likert - scale from 1- *Strongly Disagree* to 7- *Strongly Agree.* A 60 Likert - scale items answered by a 200 participants to capture their experiences in mathematics problem solving. To determine how many significant factors were evident, both Kaiser's eigenvalue and scree test were used (Kaiser, 1960)

Table 3. Themes and Sub-themes and Example of Narratives

Themes and Sub- themes	Examples of Narratives
Emotions	
- Feeling Happy	- "I enjoy solving mathematical problems..." – (Student 40) - "I am happy when my teacher appreciated my work."- (Student 18)
- Feeling anxious	- "I am anxious towards the subject"- (Student 7) - "I have fear with numbers" – (Student 33) - "I am afraid to show my answer… I am doubt with my answers. –(Student 16)
- Feeling sad	- "I felt sad when my answer is wrong". – (Student 19). - "I am sad if my score is low" – (Student 10)
Self- efficacy	
- Being independent	- "I prefer to solve problems by my own". (Student 15) - "I can manage myself…" – (Student 6)
- Self- determination	- "Our teacher allows us to do what we want"- (Student 18) - "I prefer to set my own learning goals". (Student 25) - "I do research about the topic." – (Student 17)
- Self- confidence	- "During quiz, I am confident with my solutions…"- (Student 45) - "I think problem solving is easy… I am confident to pass the subject." – (Student 34)
Group Learning Activity	
- Group discussions	- "I learn a lot when we discuss our lessons with my classmates"- (Student 38) - "I easily understand the topic when we discuss it by groups."- (Student 44)
- Working with the Group	- "I enjoy solving mathematical problems specially when we work it by group" – (Student 40) - "Me and my classmates are working together to answer our assignments"- (Student 5)
Teacher-Student relationship	
- Teacher's Guidance	- "Our teacher guided us in our lessons…"- (Student 15) - "I love my teacher because she guided me…" –(Student 27) - "I need teacher's guidance for me to understand the lesson." –(Student 33)
- My teacher, my mother	- "My teacher is like my mother". –(Student 11) - "I like the way our teacher treat us, she treat us like her children… she care for us". – (Student 14) - "…easy to talk to, like my mother." – (Student 21)

In order to proceed with the analysis using Exploratory Factor Analytic technique, the following should be done as ad-hoc or assumptions (Hair Junior, Black, Babin, Anderson, & Tatham, 1998).

Table 4. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.820
Bartlett's Test of Sphericity	Approx. Chi-Square	4882.504
	Df	1596
	Sig.	.000

It can be gleaned from Table 4 that the Kaiser Meyer Olkin (KMO) and Bartlett's tests, measured the strength of the relationship among the variables. Kaiser recommended 0.5 (value for KMO) as minimum (barely accepted) (Kaiser, 1960).

Looking at the Table 4, the KMO Measure of Sampling Adequacy is .820, which is greater than 0.5 therefore, it can be barely accepted which means further that the responses given with the samples are "adequate" (Table 4).

Bartlett's Test is another indication of the strength of the relationship among variables. From Table 4, it was an evident that the Bartlett's Test of Sphericity was significant therefore, factor analysis was appropriate. Hence, it is not an identity matrix.

Table 5. Total Variance Explained

	Initial Eigenvalues		
Component	Total	% of Variance	Cumulative %
1	11.983	19.971	19.971
2	4.294	7.157	27.128
3	2.975	4.958	32.086
4	2.304	3.840	35.926
5	1.999	3.332	39.258
6	1.839	3.065	42.322
7	1.696	2.827	45.149
8	1.513	2.521	47.670
9	1.482	2.471	50.141
10	1.411	2.352	52.493
11	1.365	2.275	54.767
12	1.272	2.120	56.887
13	1.258	2.096	58.984
14	1.221	2.035	61.018
15	1.108	1.847	62.866
16	1.100	1.833	64.699
17	1.017	1.696	66.395

Notes: Eigenvalue reflects the number of extracted factors.

The data in Table 5 revealed that the Statistical Product and Service Solution (SPSS) extracted factors and the cumulative percentage was 66.395**.** These 17 factors explained 66.395% of the variance. All remaining factors were not significant. To further identify potential meaningful factors the scree plot was examined. Inspection of Cattell's scree test (see Figure 1) supported the appropriateness of rotating these seventeen factors, i.e. the bend in the elbow occurred after seventeen factors.

The scree plot is a graph of eigenvalues against all factors which determines the number of factors to be extracted. The point of interest is where the curve starts to flatten. It can be seen in Figure 1 that the curve begins to flatten between 18 and 19. It can be noted that factor 18 onwards have an eigenvalue of less than 1, hence, either sixteen or seventeen factors have to be retained.

Table 5 presents the rotated component matrix with variables in rows and components in columns which are considered as the key output of the principal components analysis. It contains estimates of the correlations between each of the variables and the estimated components. Table 5 displays that the variables i16, i31, i32, i33, i34, i35, i36, i37, i39 and i44, are loaded in *component 1*. Items 1, 3, 5, 6, 8, 14, and 18 are substantially loaded on *component 2*. The items loaded in *component 3* are i46, i47, i48, i49, i50, and i56. And all other variables loaded from *components 4 to 17* are shown in Table 5.

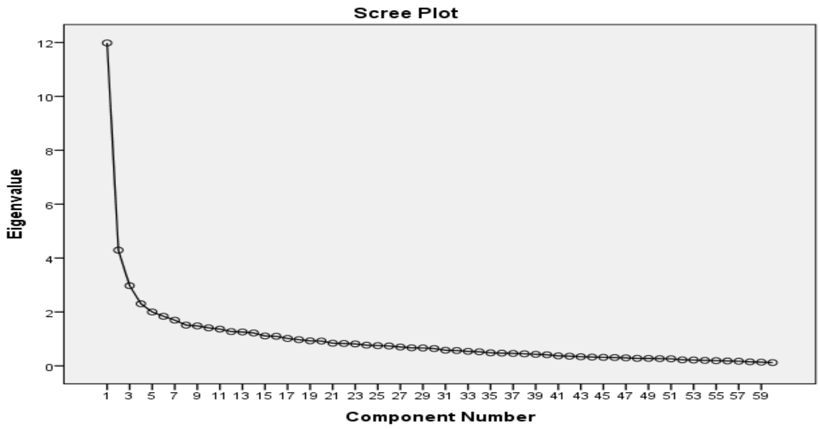

Figure 1. Scree Plot based on Principal Component Analysis (PCA) with 60 items.

The components loading were sort by size. The strongest factor loading on top was 0.739 and 0.410 was the weakest factor loading at the bottom (See Table 5).

	Component																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
i34	.739																
i36	.724																
i35	.719																
i31	.670																
i39	.667																
i32	.666										-.413						
i33	.654																
i37	.646																
i16	.547														.434		
i44	.538																
i6		.790															
i5		.767															
i1		.730															
i8		.649															
i18		.596															
i14		.422															
i3		-.411															
i50			.698														
i46			.689														
i56			.645														
i47			.583														
i49			.531														
i48			.448	.404													
i59				.605													
i58				.594													
i57				.591													
i55				.527	.462												
i54				.474			.445										
i26					.662												
i25					.595												
i27					.533												
i12					.530												
i24					.435												
i60						-.678											
i30						.669											
i28						.551											
i29						.496											
i20							.754										
i38							.723										
i53								.620									
i11								.510									
i52								.481									
i22									.744								
i23									.677								
i4										.735							
i7										.425							
i10											.587						
i19											-.436						
i17																	
i13												.820					
i21												.453					
i45													.750				
i40													.424				
i51																	
i41																	
i2														.746			
i42															-.786		
i15																.709	
i43																	.755
i9																	.410

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 22 iterations.

Figure 2. Rotated Component Matrix

Figure 2 shows that the variables i16, i31, i32, i33, i34, i35, i36, i37, i39 and i44 are loaded in *component 1*. Items 1, 3, 5, 6, 8, 14, and 18 are substantially loaded on *component 2*. The items loaded in *component 3* are i46, i47, i48, i49, i50, and i56. And all other variables loaded from *components 4 to 6*.

Rotated Component Matrix[a]

	Component					
	1	2	3	4	5	6
i34	.739					
i36	.724					
i35	.719					
i31	.670					
i39	.667					
i32	.666					
i33	.654					
i37	.646					
i16	.547					
i44	.538					
i6		.790				
i5		.767				
i1		.730				
i8		.649				
i18		.596				
i14		.422				
i3		-.411				
i50			.698			
i46			.689			
i56			.645			
i47			.583			
i49			.531			
i48			.448	.404		
i59				.605		
i58				.594		
i57				.591		
i55				.527	.462	
i54				.474		
i26					.662	
i25					.595	
i27					.533	
i12					.530	
i24					.435	
i60						-.678
i30						.669
i28						.551
i29						.496

Figure 3. Rotated Component Matrix having six factors

Meanwhile i32 is substantially loaded on component 1 and component 11 (cross-loading), i16 is loaded on component 1 and component 15 (cross-loading), i48 cross loaded to component 3 and 4, i54 and i55 are cross loaded to component 4 and 5 (see Figure 3).

After the rotation, we have to compare the item loading tables; the one with the "clearest" component structure (Figure 3) with few (only 1) item cross-loadings and no factors with fewer than three items (in fact there are 10, 7, 6, 6, 6 and 4 items for the 6 components, respectively), has the best fit to the data. Obviously the item loading Tables with six components (Figure 3) will be carried out (Osborne, Costello, & Kellow, 2014).

Based on the observations, the common thing about the items which belonged to Factor/Component 1 were named as theme 'Teacher-student relationship', Factor/Component 2 items were named as theme 'Emotions', items in Factor/Component 3 and 4 were commonly named as theme 'Self – efficacy' and all items in Factor/Component 5 and 6 were named as theme 'Group learning activity'. These six components initially accounted for 66.395% of the total variance in the correlation matrix (Table 5). Moreover, the percentage of total variance explained is crucial in determining factors and 66.395% serves as the acceptable minimum (Hinkin, Tracey, & Enz, 1997). Items that have cross loadings (i.e., items that load substantially on two or more factors) were deleted if the loadings were weak (< .40). Lastly, the factors were named based on the content of the factor items. In summary, an exploratory factor analysis of the 60 Likert-scale items produced an interpretable 4-factor simple structure.

CONCLUSION

Students preferred to learn to solve mathematics problems when their teacher guided them while they practiced by themselves. They need the guidance of the teacher to improve their mathematical performance. They are positively impacted when they know their teachers guide them during learning activities and considering their feelings and tailor education to fit their needs. Thus, the study exemplified that teacher- student interaction relationship during learning activities, which is a social factor, provides the highest correlated factor that influences the mathematical performance of the students.

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