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The Relationship Between 7th Grade Students' Spatial Abilities and The Geometric Habits of Mind

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Abstract

The aim of this study is to determine the relationship between the geometric habits of mind and spatial relations which is one of the spatial visualization abilities of 7th grade students. The sample of the research designed in the relational model is composed of 98 students randomly selected among 7th grade students studying in a state secondary school. "Spatial Relations Test" and "Fostering Geometric Thinking Test" are used as data collection tool in the research. In order to analysis the data, simple linear correlation analysis and simple regression analysis were performed in SPSS 20.00 statistical program. As a result of the data analysis, it was found that the average points for geometric habits of mind and the points attained out of the spatial relations test were on an average level. A positive low-level relationship was reached between the geometric habits of mind and the spatial relations. The findings that there is a positively significant correlation between the spatial relations and geometric habits of mind, and mathematics achievement; and that the spatial relations predict the geometric habits of mind at a certain level were obtained. Suggestions were made in line with the findings.

Keywords: *Spatial relations, spatial ability, geometric habits of mind, geometry education.*

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7.Sınıf Öğrencilerinin Uzamsal Yetenekleri ile Zihnin Geometrik Alışkanlıkları Arasındaki İlişki

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Öz

Bu araştırmanın amacı 7.sınıf öğrencilerinin zihnin geometrik alışkanlıkları ile uzamsal görselleştirme becerilerinden biri olan uzamsal ilişkiler arasındaki ilişkiyi belirlemektir. İlişkisel modelde tasarımlanan araştırmanın örneklemini bir devlet ortaokulunda öğrenim görmekte olan 7. sınıf öğrencileri arasından rastgele seçilen 98 öğrenci oluşturmaktadır. Araştırmada veri toplama aracı olarak "Uzamsal İlişkiler Testi" ve "Geometrik Düşünmeyi Teşvik Etme Testi" kullanılmıştır. Verileri analiz etmek için SPSS 20.00 istatistik programında basit doğrusal korelasyon analizi ve basit regresyon analizi yapılmıştır. Veri analizi sonucu zihnin geometrik alışkanlıkları ortalama puanları ve uzamsal ilişkiler testinden alınan puanların orta düzeyde olduğu bulgusu elde edilmiştir. Zihnin geometrik alışkanlıkları ile uzamsal ilişkiler arasında pozitif yönlü düşük düzeyde bir ilişkiye ulaşılmıştır. Uzamsal ilişkiler ve zihnin geometrik alışkanlıkları ile matematik başarıları arasında pozitif yönde anlamlı bir ilişki olduğu; uzamsal ilişkilerin zihnin geometrik alışkanlıklarını belli düzeyde yordadığı bulgusu elde edilmiştir. Araştırma sonucunda ulaşılan bulgular doğrultusunda önerilerde bulunulmuştur.

Anahtar Kelimeler: *Uzamsal ilişkiler, uzamsal yetenek, zihnin geometrik alışkanlıkları, geometri eğitimi*

Introduction

Knowledge of geometry is utilized in many areas of our daily life. For instance; geometry knowledge is applied in many situations such as building a wardrobe, placing a piece of furniture in the room, building an inclined stair or drawing a picture about the subject of perspective. In such situations, individuals make use of the characteristics of geometric concepts with or without any awareness. As from very small ages, a new-born child is keen on discovering his/her environment with a sense of curiosity and interest. Without discouraging the enthusiasm of the child, he/she should be shown which characteristics of geometry we apply to the things we see in nature and the activities in our lives. In this way, it is possible for children to witness that the things they learn in the classroom are not just composed of pieces of information. The individuals, as in the examples given above, need to use the capacity to bear in mind the potential positions of an object after its movement. This capacity is called "spatial ability" in literature. In respect to the concept of spatial ability; the expressions such as spatial visualization, visual-spatial ability, spatial perception ability and three dimensional visualizations are all used interchangeably in the body of literature. The following expressions can be given as an example to the definitions used within the frame of spatial ability: Stockdale and Possin (1998) defined spatial ability as one's capacity to perceive the spatial relationship between oneself and the environment or among the objects except themselves, whereas Olkun (2003) defined it as the capacity to be able to use the abilities related to space as well as the properties of geometrical form and perform mind games. The instability on the concept of spatial ability, therefore, has caused various subcomponents to be identified.

Being an important component of spatial ability, spatial relations, according to Lohman (1979, p.188), are defined as "the ability to solve problems quickly by using mental rotation"; whereas, according to Olkun and Altun (2003, p.2), the same concept is defined as "the students' ability to turn over two and three dimensional geometric forms in their minds as a whole and recognize them in various positions". Different tests were developed by researchers for the purpose of measuring the ability of spatial relations. Different researches were conducted with the developed tests. Some of these are the following: extensive research was done by administering the Purdue

Spatial Visualization Test, which was developed by Guay in 1976, to high school and university students, (Turgut, Yenilmez & Balbağ, 2017; Uygan, 2016); research was carried out by administering the Primary Mental Abilities Test and research was carried out by using the Cube Comparison Test, which was developed by Ekstrom, French, Harman and Derman in 1976, on high school and university students (Kayhan, 2005; Tekin, 2007; Turğut & Yılmaz, 2012). The relationship between the concept of spatial ability and the fields such as mathematics achievement, geometry learning, art, gender, dynamic software's and engineering education was analysed. Studies related to the subject of spatial ability and its components in mathematics education can be encountered in the literature (Guay and McDaniels, 1977; Naraine, 1989; Pittalis and Christou, 2010; Tso and Liang, 2002; Turğut and Yılmaz, 2012). Clements and Battista (1992) stated that due to the strong relationship between geometry and spatial ability, topics related to spatial ability should be incorporated into the curriculum and activities that would develop such abilities of the students should be increased. In order for such abilities to develop, the curriculum should be designed in a way to provide students with opportunities to think in different ways and make interpretations. Individuals need to be able to develop their habits in order to realize the effective thinking process. In case of a problem, one's ability to act intellectually, such as reasoning, perseverance, creativity and mastery, is expressed as mental habit (Köse and Tanışlı, 2014). The geometric habits of the mind described in the discipline of geometry serve as a framework for the development of students' geometric thinking. Depending on the development of the geometric habits of the mind, individuals can think effectively and make comments on geometry problems by establishing a relationship between geometric shapes. Here, it is seen that the geometric habits of the mind and spatial ability aim to solve geometry problems by performing similar functions as concepts. At this point both are important for teaching geometry. National Council of Teachers of Mathematics (NCTM) (2000) gave place to the importance of the process of solving geometry problems in curriculum standards. According to NCTM (2000), it was stated that all students from preschool education to twelfth grade must be able to recognize the spatial relations and the fact that the students make use of their spatial abilities in the process of solving geometry problems would contribute to the permanence of education. Depending on the individual's spatial relati-

ons, the mental rotation of two or three dimensional figures, the condition of rotating the figures in various forms can be related to the capacity to use the geometric habits of mind. In this respect, it is anticipated that the more one uses the spatial relations, the more one uses the geometric habits of mind. The concept of geometric habits of mind is the child's capacity to use the existing strategies when solving a geometry problem. The concept of geometric habits of mind asserted by Driscoll, DiMatteo, Nikula and Egan (2007) consists of four components. These are; the component of reasoning with relationships, the component of generalizing geometric ideas, the component of investigating the invariants and finally the component of exploration and reflection. When solving a geometry problem, the individual can utilize one or several of these components. And while using these components, the individual should be able to visualize the two and three dimensional positions of the figure. When the studies carried out in relation to geometric thinking are analysed, the studies in which the framework of Geometric Habits of Mind is used are quite a few in number (Bülbül, 2016; Bülbül and Güven, 2019; Bülbül and Güven, 2020; Driscoll et al., 2008; Erşen, 2017; Köse and Tanışlı, 2014; Özen, 2015; Sezer, 2019; Tolga, 2017; Uygan, 2016).

As mentioned above, the geometric habits of the mind can be stated as productive ways of thinking that support the application and learning of geometric concepts. In this respect, the geometric habits of the mind are very important as they will affect the development of students' geometric thinking. Spatial skills play an important role among the geometry thinking skills. In this study, we aimed to investigate how spatial ability and geometric habits of the mind affect each other. For this purpose, the following research problems are investigated in this study:

1. What level are the 7th grade students' geometric habits of minds?
2. What level are the 7th grade students' spatial abilities?
3. What kind of correlation is there between the 7th grade students' geometric habits of mind and spatial relations?
4. Are spatial relations a meaningful predictor of geometric habit of mind?
5. Is there a correlation between 7th grade students' geometric habits of mind and mathematics achievement?
6. Is there a correlation between 7th grade students' spatial relations and mathematics achievement?

Method

Research Model

Correlational survey model was used since the study aimed to determine the correlation between the spatial relations and geometric habits of mind of 7th grade students. Correlational survey model is one of general survey models. The correlational survey model; is a research model that aims to determine the existence of co-change between two or more variables (Karasar, 2013).

Participants

The study was conducted with the participation of a total of 98 secondary school students, 51 being female and 47 being male, at 7th grade during the 2018-2019 school year. The reason behind selecting grade 7 is the fact that the geometric topics such as lines and angles, polygons, circumference and circle, positions of objects from different perspectives had been taught.

Data Collection Tools

"Fostering Geometric Thinking Test" and "Spatial Relations Test" were used as data collection tools for the study. The information regarding the assessment instruments is given below in sub-headings. In this study, the test consisting of multiple-choice questions developed by Dokumacı Sütçü and Oral (2018) was used for the data about spatial relations. The test is both appropriate for seventh grade students and functions as an extensive assessment instrument testing the two and three dimensional spatial relations abilities using different question types in the same test.

Fostering Geometric Thinking Test

Fostering Geometric Thinking Test was administered in order to determine the geometric habits of mind of 7th grade secondary school students. The test includes 10 open-ended geometry questions. The 1st problem constitutes the topic of the area of parallelogram which requires the use of habits such as

reasoning with relationships and balancing exploration and reflection. Aiming at students using the properties of area calculation of quadrilaterals, the 2nd problem sets into practice the use of reasoning with relationships and exploration and reflection habits for a problem with the help of supplementary construction during the concluding phase. The 3rd problem involves the use of the habit of reasoning with relationships in order to find the relationship between the circumference of circle and pi for the solution. The 4th problem is a problem that requires the use of the component of reasoning with relationships and generalizing geometric ideas as it involves arriving at general rules relevant to the properties of polygons. The 5th problem involves the use of the component of reasoning with relationships. Aiming at the use of the relationships among the area, perimeter and height of rectangle and parallelogram out of the quadrilaterals, the 6th question anticipates the use of the component of reasoning with relationships, determination of variants or invariants, investigating the invariants and exploration and reflection. The 7th problem, dictating the construction of a figure consisting of unit cubes from different viewpoints, requires the use of exploration and reflection habit by way of a supplementary construction/conveyance of the figure to the analytical plane. The problem also requires the use of the habit of reasoning with relationships by establishing relationships among the areas. In the 8th problem, the students are expected to use the component of reasoning with relationships as they are asked to find out the height of the rectangular prism. The 9th problem, consisting of the topics of triangles and quadrilaterals, firstly requires a supplementary construction in order to be able to recognize the relationships among the areas which accordingly requires the use of the habit of exploration and reflection and the determination of the relationship among the areas requires the component of reasoning with relationships. The last problem consisting of the problem of area of four-sided aims at the use of reasoning with relationships by establishing relationship among the areas. In an attempt to ensure the validity of geometric thinking habits test, a preliminary pilot study was carried out in concern with the problem of whether the problems in the assessment instrument represent the acquisitions to be assessed. 10 students who were not included in the actual research process were made to solve the problems in the test and in-depth interviews were made on how they solved the problems. In this way, it was examined whether or not the problems were in

accordance with the indicators of geometric thinking habits determined by the researcher. Subsequently, the language, level and content validity of the test of geometric habits of minds consisting of open-ended problems was ensured in consultation with two expert mathematics educators and four secondary school mathematics teachers. Graded scoring scale, developed by Bülbül (2016) was utilized for the scoring of each question for the sake of the reliability of the test of geometric habits of mind; the points that the students got out of each question were indicated. The Cronbach's Alpha value of the test was estimated as 0.74.

Spatial Relations Test

Dokumacı Sütçü & Oral (2018) developed a multiple-choice test on the spatial relations ability, one of the primary components of spatial ability, which is both appropriate for seventh grade and can measure the two and three dimensional mental rotation and cube comparison skills by means of the same test. The 21-item spatial ability test developed for this purpose was presented through a study conducted on a total of 303 seventh grade students. After having consulted with expert opinion for content and face validity, exploratory factor analysis was performed by way of tetra choric correlation matrix and item 8 and 18 were removed from the test and thus a two-factor structure, "two dimensional spatial relations" and "three dimensional spatial relations", was obtained. Item analysis was performed for item 21; and the test was found to be of moderate difficulty and high in distinctiveness consisting of items with different difficulty levels and high distinctiveness. KR-20 internal consistency coefficient was calculated as 0.79 for the first factor, 0.73 for the second factor and 0.74 for the overall test.

Analysis of Data

In the research, the study conducted by Bülbül (2016) was taken as reference for the scoring of geometric thinking habits of 7th grade students; 0 point was given if no thinking habit was used, 1 point if one habit was used but no solution achieved, 2 points if more than one habit was used but no solution achieved and 3 points were given if more than one geometric habit was used and a solution was achieved. Simple linear correlation analysis (Pear-

son correlation coefficients) was used in an attempt to determine the correlation between the geometric thinking habits and spatial abilities of the students and simple regression analysis was performed in order to demonstrate the predictor capacity of spatial ability on geometric thinking habits. The data obtained through the research was analysed using SPPS 20.00 software package.

Findings and Commentaries

The findings obtained as a result of the analysis of data collected throughout the research are presented below in tables.
Descriptive statistics of the 7th grade secondary school students' scores on Fostering Geometric Thinking Test are given in Table 1.

Table 1. Descriptive analysis of the scores on Fostering Geometric Thinking Test

Variable	N	Lowest	Highest	Average	Standard deviation –sd
Geometric Habits of Mind	98	3	28	14.43	5.797

When the data in Table 1 is analyzed, it is seen that the average score of the students on Fostering Geometric Thinking Test scale is 14.43 ($\bar{X}$=14.43). It can be asserted that the students' achievement of geometric thinking habits is on an average level. Descriptive statistics regarding the scores on each problem in Fostering Geometric Thinking Test are presented in Table 2.

Table 2. Descriptive analysis of the points scores individual problems in Fostering Geometric Thinking Test

Problems	Points							
	0 point		1 point		2 points		3 points	
	F	%	F	%	f	%	F	%
1st problem	19	19.4	3	3.1	0	0	76	77.6
2nd problem	56	57.1	6	6.1	0	0	35	35.7
3rdproblem	32	32.7	11	11.2	4	4.1	51	52.0
4thproblem	25	25.5	31	31.6	5	5.1	37	37.8
5thproblem	24	24.5	4	4.1	1	1.0	69	70.4
6thproblem	77	78.6	5	5.1	3	3.1	13	13.3
7thproblem	53	54.1	6	6.1	5	5.1	34	34.7
8thproblem	19	19.4	8	8.2	4	4.1	67	68.4
9thproblem	51	52.0	9	9.2	8	8.2	30	30.6
10thproblem	76	77.6	14	14.3	3	3.1	5	5.1

In accordance with Table 2, while approximately 19% of the students failed to use any thinking habits for the 1st question; approximately 3% of the students used one thinking habit but could not arrive at the solution; nearly 76% made use of the reasoning with relationships habit as well as the habit of generalizing geometric ideas and arrived at the correct solution. For the 2nd problem, while approximately 57% of the students used no thinking habits; an approximate 6% used one thinking habit but could not finalize the solution; nearly 36% made use of the reasoning with relationships habit as well as the habit of exploration and reflection and arrived at the correct solution. For the 3rd problem, while an approximate 33% of the students used no thinking habits, 11% used one thinking habit but could not arrive at the solution. Although a 4% used more than one thinking habit, no solution was reached; 52% arrived at the solution by using the components of reasoning with relationships and generalization. For the 4th problem, while approximately 25% of the students used no thinking habits; an approximate 32% used one thinking habit but could not finalize the solution. Even though a 5% used more than one thinking habit, they couldn't finalize the solution; whereas, 38% arrived at the solution by using the components of reasoning with relationships and generalizing ideas. For the 5th problem, 25% of the students used no thinking habit whereas; an approximate 4% used one thinking habit but couldn't achieve the solution. Although 1% used more than one thinking habit yet could not arrive at the solution; 70% of the students arrived at the correct solution by using both reasoning with relationships and exploration and reflection thinking habits. For the 6th problem, while approximately 79% of the students used no thinking habits; %5 scored 1 points; %3 scored 2 points; 13% scored 3 points by using the habit of reasoning with relationships as well as the balancing the exploration and reflection habit. For the 7th problem, nearly 35% of the students arrived at the correct solution using more than one thinking habits. In problem 8, 68% of the students arrived at the solution using the components of reasoning with relationships and generalization. For the 9th problem, 51% of the students used no thinking habit whereas, approximately 9% used one thinking habit but couldn't finalize the solution and 8% used more than one thinking habit yet couldn't achieve the solution; 30% arrived at the solution using the reasoning with relationships and generalization components. For the 10th problem, while 77% of the students used no thinking habits; an app-

roximate 14% used on thinking habit but could not finalize the solution; although 3% used more than one thinking habit, yet they couldn't achieve the solution; 5% arrived at the solution by using the reasoning with relationships and generalization components.

Descriptive statistics of the 7th grade secondary school students' scores on Spatial Relations Test are given in Table 3.

Table 3. Descriptive analysis of the scores on spatial relations test

Variable	N	Lowest	Highest	Average	Standard Deviation
Spatial Relations	98	0	19	7.79	4.330

When the data in Table 3 is analysed, it is seen that the average score of the students on Spatial Relations Test scale is 7.79 ($\bar{X} = 7.79$). From this point of view, it can be asserted that the students' achievement of spatial relation skill, a component of spatial ability, is close to average level.

Table 4. The Analysis Results of Pearson Product-Moment Correlation between Geometric Habits of Mind and Spatial Relations of 7th Grade Students

Dependent Variables		Spatial Relations
Geometric Habits of Mind	R	.256
	P	.011
	N	98

As can be seen in Table 4, the results of Pearson product-moment correlation analysis conducted in relation to the assessment of the correlation between "Fostering Geometric Thinking Test" and "Spatial Relations Test" are presented. In line with these results, it was determined that there is a positive, low-level correlation between "Fostering Geometric Thinking Test" and "Spatial Relations Test" (r=.256) and that this correlation is statistically significant (p<.05).

Simple regression analysis was applied to reveal the predictive power of spatial relations, which is a component of spatial ability, on geometric thinking habits. The results of the regression analysis made are given in Table 5.

Table 5. Simple regression to predict geometric thinking habits

Independent variable	B	Standard error	T	F	R	R^2
				6.725	.256	.065
Constant	11.761	1.175	10.006			
Spatial Relations	.343	.132	2.593			

In accordance with the results of the analysis, 6% of the geometric habits of mind are predicted by spatial relations.

Pearson Product-Moment Correlation Analysis was conducted in order to analyse the correlation between spatial relations and geometric habits of mind with mathematics achievement of 7th grade students. The results of the analysis are given in Table 6.

Table 6. The Correlation between spatial relations and geometric habits of mind with mathematics achievement of 7th grade students

Grade	Component	N	Coefficient– r
7th grade	Geometric habits of mind - Mathematics achievement	98	.669
7th grade	Spatial Relations–Mathematics Achievement	98	.235

In line with the analysis results in Table 6, there is a moderate and positively significant correlation between geometric habits of mind and mathematics achievement ($r= .669$, $p < .05$). Whereas, there is a low-level and positively significant correlation between spatial relations and mathematics achievement ($r= .235$, $p < .05$).

Conclusion and Discussion

In this study, the correlation between the spatial relations and geometric habits of mind of 7th grade students are investigated. As a result of the analysis of research data, it is seen that the scores on the tests of spatial relations and geometric thinking habits are on an average level. The fact that the average scores of the 7th students related to geometric habits of the mind are on average level is similar to the finding obtained as a result of the study conducted by Erşen (2017). The fact that the average scores of the students related to spatial ability are on average level is similar to the finding obtained as a result of the study conducted by Gürbüz, Erdem and Gülburnu (2018). It can be said that the students' middle scores are due to their new transition from the developmental period to the abstract process period.

In view of the literature, studies were carried out on the subject of spatial ability and its sub-skills. There are, although limited in number, also studies conducted on the subject of Geometric Habits of Mind both within our country and abroad. Looking at the studies in the literature, there are studies

investigating the relationship between the development of the geometric habits of the mind and the attitude of the geometric habits of the mind towards the geometry in the problem-centered learning environment of the geometric habits of the mind, the dynamic geometry software.

However, no study investigating the spatial ability in tandem with geometric habits of mind was encountered. In view of the theoretical frameworks in geometry, there are studies in which the correlation between Van-Hiele levels of geometric thinking and spatial ability was investigated (Idris, 1998; July, 2001). Positive correlations were found between the variables as a result of these studies. In this research, the relationship between the geometric habits of the mind and the spatial ability of the theories about teaching geometry was investigated. Likewise, as a result of the analysis of the data obtained in our study, a positive and low-level correlation was found between the scores of the test of geometric habits of mind and those of the test of spatial relations. This result comes to mean that the positive development of geometric habits of mind indicates a positive development of spatial relations just as in the correlation between geometric thinking levels and spatial ability. Achieving a conclusion in the literature shows that teaching environments should be provided for the development of the geometric habits of the mind from a young age.

Considering whether or not spatial relations predict the geometric habits of mind, spatial relations predict the geometric habits of mind at the rate of 6%. This result, as required by the definition of the concept of spatial relations, can be explained by the fact that the ability to rotate two and three dimensional forms of the figures in the mind is likely to be connected with the geometric habits of mind.

Similar to this research, Erşen (2017) investigated the correlation between geometric habits of mind and geometry attitudes of 10th grade science high school students. The results attained as a result of the research demonstrated that geometry attitudes are a predictor of geometric thinking habits.

Accordingly, apart from affective factors, spatial abilities can also be utilized in predicting the geometric habits of mind. It is expected that certain skills will be developed in order to increase the academic achievement of the students. For this, teaching must be effective. In addition, 7th grade students' positive attitude towards geometry will increase their success. Sezgin Mem-

nun and Akkaya (2010) showed that most of the 7th grade students like to learn through games and activities.

A moderate, low-level and significant correlation was found between the spatial relations and mathematics achievements of 7th grade students. The studies conducted by Kayhan (2005) and Turğut and Yılmaz (2012) differ in that as a result of their study, it was found that there is a moderate and positively significant correlation between spatial relations and mathematics achievement of the students. The reason behind the emergence of a low-level correlation in the study might be due to the lack of activities aiming at the development of spatial relation abilities.

A moderate and positively significant correlation was found between the geometric habits of mind and mathematics achievement of 7th grade students. Geometric habits of mind are components that improve problem solving ability. This finding suggests that the mathematics achievement of the child can very well be enhanced by the use of geometric habit of mind during the problem solving process. In the literature, the study investigating the relationship between the geometric habits of the mind and the success of mathematics could not be reached, and the fact that a positive relationship was found successfully shows the importance of the geometric habits of the mind.

The study carried out by Bülbül and Güven in the literature supports the finding. Bülbül and Güven, in the study, the mathematics up to the fourth grade with the points obtained by the preservice teachers' geometric thinking habits achievement test. He investigated the relationship between the points he got from his lessons. As a result of the research, prospective teachers geometric thinking habits with scores from mathematics lessons a high level, positive and significant relationship was found between the scores. This result is for preservice teachers they states that they use the geometric habits of the mind to overcome the problems he encounters.

Suggestions

Several suggestions have been made to the researchers and teachers in accordance with the findings attained as a result of the study.

- The reasons behind the findings of the research conducted here can be analysed and revealed in more details by means of qualitative research.

- Similar studies aimed at analysing the correlation between spatial ability and geometric habits of mind can be conducted at different grade levels on greater number of samples.
- Studies can be conducted in accordance with experimental research design in an attempt to investigate the impact of different teaching methods on spatial ability and geometric habits of mind.
- Studies can be conducted on to what extent the development of spatial visualization abilities, geometric habits of mind and spatial relations can affect achievement in mathematics and other lessons.
- According to the relationship between the geometric habits of the mind and the mathematical success of spatial ability, studies can be conducted to develop these components and the relationship between them can be investigated.

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