Bartın University Journal of Faculty of Education
BUEFAD Volume 13, Issue 4
1045-1061
dergipark.org.tr/buefad
DOI: 10.14686/buefad.1367630

Constructivist Learning Environment: A Perfect Mediator for The Relationship of Students' Multiple Intelligences with Attitudes Towards and Achievement in STEM

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Research Article
Received: 27.09.2023
Revised: 10.11.2023
Accepted: 10.01.2024

Abstract

In STEM disciplines, it is crucial to design research studies clarifying the relationships between academic performance-related constructs and academic performance. This study aims at exploring whether middle school students' perceptions of constructivist learning environment (P-CLE) mediate the relationship between their perceptions of multiple intelligences (P-MI) and their attitude towards STEM disciplines (AtSTEM) and their achievement in STEM disciplines (AchSTEM). Because the relationships among middle school students' P-CLE, P-MI, and AtSTEM and AchSTEM are under investigation, this study is a correlational study. The sample consisted of 579 students from randomly selected 10 middle schools in Kayapınar, a district of Diyarbakır, Turkiye. The students' GPA scores in STEM-related courses were used to represent their achievement in STEM disciplines. In addition, the Attitude towards STEM Survey, Multiple Intelligences Inventory, and Constructivist Learning Environment Survey were used for the data collection. Lavaan, an R package, was used to conduct structural equation modeling for mediation analysis. The mediation analysis yielded that the P-CLE was a perfect mediator for the relationship between the P-MI and AtSTEM and AchSTEM. In consequence, this study emphasizes the importance of providing constructivist learning environments in STEM classes and encouraging students to think of intelligence as something malleable.

Keywords: STEM, achievement, multiple intelligences, constructivist learning environment.

Yapılandırmacı Öğrenme Ortamı: Öğrencilerin Çoklu Zekâ Alanlarının FeTeMM'e Yönelik Tutum ve Başarılarıyla İlişkisinde Mükemmel Bir Aracı

Öz

FeTeMM disiplinlerinde, akademik performansla ilgili yapılar ile akademik performans arasındaki ilişkileri açıklığa kavuşturan araştırmaların tasarlanması önem taşımaktadır. Bu çalışmanın amacı, ortaokul öğrencilerinin yapılandırmacı öğrenme ortamı algılarının (YÖOA), çoklu zekâ algıları (ÇZA) ile FeTeMM disiplinlerine yönelik tutum ve başarıları (FeTeMM-T, FeTeMM-B) arasındaki ilişkiye aracılık edip etmediğini araştırmaktır. Ortaokul öğrencilerinin çoklu zeka algıları, yapılandırmacı öğrenme ortamı algıları ve FeTeMM disiplinlerine yönelik tutum ve başarıları arasındaki ilişkiler araştırılmakta olduğundan, bu çalışma korelasyonel bir çalışmadır. Örneklem, Diyarbakır'ın Kayapınar ilçesinde rastgele seçilen 10 ortaokuldan 579 öğrenciden oluşmaktadır. Öğrencilerin FeTeMM ile ilgili derslerdeki not ortalamaları, FeTeMM disiplinlerindeki başarılarını temsil etmek için kullanılmıştır. Ayrıca, veri toplamak için FeTeMM'e Yönelik Tutum Anketi, Çoklu Zeka Envanteri ve Yapılandırmacı Öğrenme Ortamı Anketi kullanılmıştır. Aracılık analizi için yapısal eşitlik modellemesi yapmak üzere bir R paketi olan Lavaan kullanılmıştır. Arabuluculuk analizi, YÖOA'nın ÇZA ve FeTeMM-T ve FeTeMM-B arasındaki ilişki için mükemmel bir aracı olduğunu ortaya koymuştur. Sonuç olarak, bu çalışma FeTeMM sınıflarında yapılandırmacı öğrenme ortamları sağlamanın ve öğrencileri zekâyı şekillendirilebilir bir şey olarak düşünmeye teşvik etmenin önemini vurgulamaktadır.

Anahtar kelimeler: FeTeMM, başarı, çoklu zekâ, yapılandırmacı öğrenme ortamı.

To cite this article in APA Style:

Peşman, H., Güler, T., Arı, Ü. & Erdoğan, F. (2024). Constructivist Learning Environment: A Perfect Mediator for The Relationship of Students' Multiple Intelligences with Attitudes Towards and Achievement in STEM. *Bartın University Journal of Faculty of Education, 13*(4), 1045-1061. https://doi.org/10.14686/buefad.1367630

INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) movement, which first emerged in the 1990s in the United States (Martín-Páez et al., 2019), has started to become visible in the post-secondary education in the last fifteen years as well (Talanquer, 2014). Concurrently, the STEM movement began to spread all over the world after the success of establishing a "degree in STEM education" at the Virginia Tech University in 2005 (Martín-Páez et al., 2019). Apparently, there are some inter-related reasons for why STEM education has got such an international popularity. It is possible to categorize them as: (1) deficient competence in STEM disciplines (Martín-Páez et al., 2019), (2) lack of knowledge transfer (Martín-Páez et al., 2019; Roberts, 2012; Talanquer, 2014), and (3) growing demand for well-educated human resource in STEM disciplines with twenty-first century skills (Bybee, 2010; Corlu et al., 2014; Kelley & Knowles, 2016; Martín-Páez et al., 2019; Talanquer, 2014).

In spite of such a popularity, a cohesive definition or understanding for STEM education could not be presented (Kelley & Knowles, 2016; Martín-Páez et al., 2019). There are differing conceptions, from the fact that STEM education can be implemented in a single discipline to the fact that all disciplines must be integrated consistently. For most instructors and researchers, it means science and mathematics (Bybee, 2010; Corlu et al., 2014). For others, technology and engineering are so greatly in our daily life that it is not possible to make sense of everyday life contexts or socially and culturally relevant STEM contexts without approaching all those disciplines as whole entity - integrated STEM approach (Bybee, 2010; Kelley & Knowles, 2016; Martín-Páez et al., 2019; Roberts, 2012; Stohlmann et al., 2012; Talanquer, 2014). Moreover, the total or the whole entity is much more than the sum of the contents of those disciplines (Zollman, 2012 as cited in (Martín-Páez et al., 2019)).

As well as the non-cohesive conceptualization of STEM education, there is no a cohesive conceptualization about the implementation of integrated STEM education, either. The integrations are based on different combinations. Some researchers suggest "engineering" as a hinge to bring other disciplines together (i.e. (Brophy, Klein, Portsmore, & Rogers, 2008)) while some others suggest "mathematics" as a bridge for the integration (Kertil & Gurel, 2016). On the other hand, a coherent conceptualization about the teaching and learning methodologies accompanying the STEM education may be presented. Informal teaching, inquiry teaching, project- and problem-based teachings, which are "constructivist" or "student-centered" teaching methods in nature, have been supposed to contribute to STEM integrations (Martín-Páez et al., 2019; Roberts, 2012; Smith et al., 2009; Struyf et al., 2019).

Besides, there is persuasive evidence that constructivist learning approaches contribute to students' cognitive and attitudinal constructs better than the traditional approaches. Constructivist learning approach, which is defined as forming of new knowledge on the existing knowledge that individuals possess based on their experiences, has attracted attention in the twenty-first century in the globe (Fosnot, 2013; Tan, 2017). According to the constructivist view, knowledge is not something discovered. In other words, it is not something out there, in the outer world, to acquire (Gordon). Meanwhile, it is not something transmitted, or it is not formed in the brain as a sponge absorbs water (Roberts, 2012). It is constructed. In this context, as educators, our mission must be providing students with environments helping them construct their knowledge on their own. Constructivist learning environments, which are imaginative and integrative atmospheres, are key aspect of STEM education, and particularly, problem-, project-, context-, and inquiry-based learning have been proved to support the STEM education. Relation of the constructivist learning environments to STEM learning via positive attitude towards science is so clear that it is unavoidable to take it into account (Martín-Páez et al., 2019; Smith et al., 2009; Struyf et al., 2019).

In addition to constructivist learning environment, socio-psychological issues such as students' academic achievement related knowledge, beliefs, and perceptions have been shown to be positively related to academic performance in science and other disciplines. By the way, it is obviously crucial to make sense of how those relationships are in STEM disciplines (Talanquer, 2014). One of socio-psychological issues that possess an extensive literature in not only science education but also other disciplines is students' perceptions of multiple intelligences (P-MI).

Multiple intelligence theory was developed by Gardner (Armstrong, 2000) as a positive reaction against the limitations of intelligence questionnaires. He criticized the validity of such intelligence-scoring questionnaires through which individuals are asked for carrying out some unfamiliar tasks out of their natural learning environments. According to him, labeling individuals with an intelligence score would be unfair to combinations of multiple intelligences they possess and he at last proposed eight intelligences by categorizing capabilities people possess: (1) linguistic intelligence – the capability to use words effectively, whether orally or in writing, (2) logical-mathematical intelligence – the capability to use numbers effectively, (3) spatial intelligence – the capability to make sense of and use the virtual-spatial world accurately, (4) bodily-kinesthetic intelligence – the capability to use the whole or part of body to express ideas and feelings, (5) musical intelligence – the capability to perceive, transform, discriminate, and express musical form, (6) interpersonal intelligence – the capability to perceive and make distinction in the moods, intentions, motivations, and feelings of other people, (7) intrapersonal intelligence – the capability to use self-knowledge for acting adaptively, and (8) naturalist intelligence – the capability to recognize and classify of the numerous species in the environment (Armstrong, 2000).

That contemporary view of intelligence inspired many STEM education researchers like other researchers. As a result, it yielded an extensive literature, mainly in two categories: (1) experimental research aiming at exploring the effects of multiple intelligence-based interventions, and (2) associational research aiming at exploring the relation of P-MI to some educational constructs. The research on the effect of implementations based on the multiple intelligence theory has shown significant contribution to academic attitude to and achievement in STEM classes (Aina, 2018; Aydin, 2019; Baş, 2016; Batdı, 2017; Douglas et al., 2008; Gurcay & Ferah, 2017; Nasri et al., 2021; Okur & Kural, 2021; Pratiwi et al., 2018; Sánchez-Martín et al., 2017; Theobald et al., 2020). Similarly, research on association between P-MI and academic performance in STEM disciplines has also yielded in significant relationships (Ahvan & Pour, 2016; Baran & Maskan, 2011; Chan, 2006; Lillbacka, 2013; Pallrand & Seeber, 1984; Snyder, 1999; Träff et al., 2019)

Motivation and Purpose of the Study

A brief summary of the theoretical framework just aforementioned in the previous section and shedding light to this study can be summarized as follows:

1.There is huge amount of interest in student attitude towards and success in STEM fields in the related literature due to some reasons, such as, deficient competence in STEM disciplines, lack of knowledge transfer, and growing demand for well-educated human resource in STEM disciplines.

2.The related literature indicates that the teaching methods providing constructivist learning environments, such as, informal teaching, inquiry teaching, or problem-based learning, contribute to STEM education by means of positive student attitude.

3.Students' P-MI is positively related to the success in STEM disciplines.

In order to contribute to advances in STEM education, it is quite crucial to design research studies clarifying the relationships between academic performance related constructs and academic performance in STEM disciplines (Talanquer, 2014). In line with that recommendation and the related literature review, the main purpose of this study is to clarify the relations of middle school students' perceptions of multiple intelligences (P-MI) and constructivist learning environment (P-CLE) to their attitude towards STEM disciplines (AtSTEM) and achievement in STEM related disciplines (AchSTEM). In particular, the purpose is to investigate whether middle school students' P-MI mediates the relation of their P-CLE to their AtSTEM and AchSTEM, or vice versa. From this perspective, the study is indeed a mediation analysis. The related literature has already reported the significant and positive relations of the P-MI and the P-CLE to the AtSTEM and AchSTEM. What this study clarifies is that which one of those constructs mediates the relationship between the other construct and the AtSTEM and the AchSTEM. Furthermore, the study also reveals concretely what magnitude are the relationships among those educational constructs. Accordingly, the hypothesized model tested in this study is given in Figure 1.

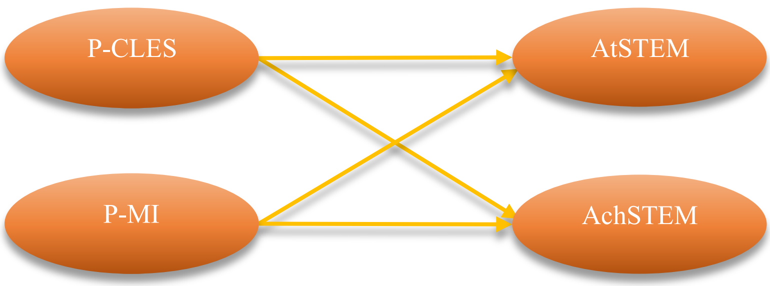

Figure 1. *The hypothesized model (P-CLE: Perceptions of constructivist learning environment; P-MI: Perceptions of multiple intelligences; AtSTEM: Attitude towards in STEM related disciplines; AchSTEM: Achievement in STEM related disciplines)*

Research Questions

This study aims at exploring whether middle school students' perceptions of multiple intelligences mediates the relationship between their perceptions of constructivist learning environment and their attitude towards and achievement in STEM related disciplines, or vice versa. In accordance, the specific research questions are as the following:

1.Is the individual relationship between middle school students' perceptions of multiple intelligences and their attitude towards and achievement in STEM related disciplines significant, if so, what is the magnitude of this relationship?

2.Is the individual relationship between middle school students' perceptions of constructivist learning environment and their attitude towards and achievement in STEM related disciplines significant, if so, what is the magnitude of this relationship?

3.Does middle school students' perceptions of multiple intelligences mediate the relationship between their perceptions of constructivist learning environment and their attitude towards and achievement in STEM related disciplines significant, or vice versa, and what are the magnitudes of these relationships?

Assumptions

The assumptions of the study are listed as follows:

1.The students' grade point averages (GPA) in STEM-related courses, which provide data for this study, are reliable indicators of their achievement in STEM.

2.The students gave candid and independent responses to the instruments administered in this study.

3.The students' scores on the Attitude towards STEM Survey represent their attitude towards STEM and 21st century skills.

4.The students' scores on the Multiple Intelligences Inventory represent their P-MI they possess.

5.The students' scores on the Constructivist Learning Environment Survey represent their perceptions about the level of constructivist learning environment provided to them.

METHOD

Because of the relationships among middle school students' P-MI, P-CLE, and AtSTEM and AchSTEM, which are continuous variables, are under investigation, this study is a correlational study, an example of associational research (Fraenkel et al., 2012, pp. 330-364).

Sample

All seventh-grade students, who are 12 or 13 years old, in Diyarbakır, constitute the study's target population. However, the accessible population is all the seventh-grade students in Kayapınar, a district of Diyarbakır, Turkiye. The sample is consisted of 579 students from randomly selected 10 middle schools. In other words, random selection of intact classes drawn the sample of this study (Fraenkel et al., 2012, pp. 90-109). The percentages of females and males are 59 and 41, respectively. In conclusion, the students could be assumed to represent many traits of the population, such as socio-economic status, gender, or other individual differences because the schools were randomly selected from the population.

Data Collection

STEM-related GPA scores of the students drawing the sample of the study were used as the observable variables to represent their achievement in STEM disciplines. Therefore, teacher-made assessment tools on the STEM related courses, which are explained in the next section, constitute an important part of the instruments that provided data for this study. On the other hand, the other instruments are Attitude towards STEM Survey, Multiple Intelligences Inventory, and Constructivist Learning Environment Survey.

GPA scores in STEM related courses

In this study, one of the educational constructs as a latent variable is middle school students' achievement in STEM disciplines. The observable variables related to this latent variable are the students' GPA scores in STEM-related courses. These courses are natural sciences, mathematics, information technologies and software, visual arts, and technology and design. The courses were assumed to be STEM-related courses according to their specific goals and content given to the students reported in the middle school curricula. Table 1 presents the specific goals of the STEM related courses which can be attributed to the 21st century skills based on relevant curricula developed by Ministry of National Education (MoNE).

Table 1. STEM Related Courses' Specific Goals Attributed to 21st Century Skills from the Related Curricula

Course Name	Related Specific Objectives
Natural Sciences	• To make students acquire fundamental knowledge on science and technology applications. • To make students be aware of interrelationships among individuals, environment, and society. • To enable students to use scientific knowledge and skills to overcome real-life problems. • To make students be aware of natural sciences related careers and to make them acquire entrepreneurial skills (MoNE, 2018b).
Mathematics	• To make students be able understand mathematical concepts and use them in real-life experiences. • To help students use mathematical terminology properly to communicate mathematical thinking. • To help students make sense of the relationships between human being and objects, and the relationships between objects and objects by means of the meaning and language of mathematics. • To make students articulate the concepts with multiple representations. • To make students develop skills about research and knowledge accumulation. • To make students realize the relationship of mathematics to arts and esthetics (MoNE, 2018d).
Information Technologies and Software	• To help students use information technologies properly and effectively. • To make students construct an overall understanding and technical accumulation in Computer Sciences. • To help students monitor and evaluate scientific reasoning. • To help students explore learning facilities on internet. • To make students execute studies in product design and management. • To help students develop innovative and exclusive projects to overcome real-life problems encountered. • To make students be aware of life-long learning (MoNE, 2018a).
Visual Arts	• To make students acquire fundamental knowledge, skills, and understanding in Visual Arts. • To make students follow current culture-and-art objects consciously. • To make students communicate effectively by utilizing knowledge, skills, materials, technique, and technology in visual arts in safety. • To help students integrate visual arts with other disciplines. • To make students be aware of visual arts related careers (MoNE, 2018c).
Technology and Design	• To make students acquire fundamental knowledge on development of technology. • To make students acquire fundamental knowledge on design process. • To make students use technology and design related knowledge and skills to overcome real-life problems. • To help students understand professional designers' problem identification and solution approaches. • To make students realize interrelationships among individuals, environment, society, and technology. • To help students develop skills of problem identification and solution (minds-on), and implementation (hands-on). • To make students be aware of technology and design related careers (MoNE, 2015).

Attitude towards STEM Survey

The Attitude towards STEM Survey (AtSTEM) was developed by Friday Institute for Educational Innovation (2012) with 37 5-point Likert type items (from Strongly agree to strongly disagree) and four dimensions (science, mathematics, engineering and technology, and 21st century). The dimensions include items to assess student attitudes to science, mathematics, engineering, technology, and 21st century skills (i.e., math is important for my life, I am sure of myself when I do science, I like to imagine creating new products, I am confident I can act responsibly). Friday Institute for Educational Innovation (2012) reports the AtSTEM as valid scale to collect reliable data with very high alpha reliability coefficients for each dimension, ranging from .89 to .92. Luo et al. (2019) conducted research supporting the validity of the scale from subtle aspects. They provided evidence not only related to internal structure validity but also related to criterion-related validity. Their measurement invariance results yielded that the AtSTEM can be utilized reliably in studies comparing groups or longitudinal research.

The Turkish version of the AtSTEM was adapted by Özcan and Koca (2019) in six phases: translation, reverse translation, language validation, pilot administration, final version, and main administration. They also reported the AtSTEM scores as a valid and reliable assessment of students' attitudes towards STEM with similar alpha reliability coefficients ranging from .89 to .91 for each dimension. In this study, the alpha reliability for the whole scale was .91 while they were ranging from .86 to .88 for each dimension. As a result, these findings support that the AtSTEM seems to be able to yield reliable attitude scores towards STEM.

Multiple Intelligences Inventory

The Multiple Intelligences Inventory (MII) was developed by Armstrong (2000) with eight dimensions and 80 items. Each dimension is associated with eight multiple intelligences: linguistic (i.e., Books are very important to me.), logical-mathematical (i.e., I can easily compute numbers in my head), spatial (i.e., I like to draw or doodle), bodily-kinesthetic (i.e., I find it difficult to sit still for long periods of time), musical (i.e., I have a pleasant singing voice), interpersonal (i.e., I have at least three close friends), intrapersonal (i.e., I consider myself to be strong willed or independent minded), and naturalist (i.e., I thrive on having animals around the house) to assess individuals' P-MI. The items in each dimension aims at assessing performance in some kind of tasks, activities, and experiences in the related intelligences. However, the tasks, activities, and experiences in these dimensions are quite limited with respect to the real spectrum of intelligence related abilities. Therefore, Armstrong (2000) emphasizes that this inventory could only partially assess multiple intelligences, too as any test cannot totally assess a person's intelligences. The scale was adapted to Turkish by Oral (2001) as a 5-point Likert scale (fits me very well, fits me well, fits me moderately, fits me a little, fits me little) and he reported the Turkish version provide with reliable assessment of multiple intelligences. The split-half reliability coefficient was calculated as .79 for the whole scale. The reliability coefficients for each dimension were calculated as the correlations between each dimension and the total scores, and they were ranging from .62 to .73. In this study, the Croanbach alpha reliability coefficients were calculated for evaluating whether reliable scores were collected. The alpha reliability coefficient for the whole scale was .94 while they were ranging from .55 to .74 for each dimension. As expected, the reliability coefficients for the dimensions may be smaller than .70, the acceptable critical value, because number of the items are limited with respect to the whole scale (Pallant, 2007). As a result, the MII scale could successfully yielded reliable scores of students' multiple intelligences.

Constructivist Learning Environment Survey

The Constructivist Learning Environment Survey (CLES) was developed by Taylor et al. (1997) to monitor what level of constructivist learning environment students are provided with in science courses so that teachers could monitor their development of constructivist approaches to teaching school science and mathematics. Following fine-grained analysis conducted for testing the validity and reliability of the scale, the CLES is a 30-item scale with 5-point Likert type frequency responses scale which involves the categories: almost always (5 points), often (4 points), sometimes (3 points), seldom (2 points), and almost never (1 points). The CLES has got five dimensions: personal relevance (i.e., I learn about the world outside of school), uncertainty (i.e., I learn that mathematics cannot provide perfect answers.), critical voice (i.e., It's OK to ask the teacher "why do we have to learn this?"), shared control (i.e., I help the teacher to plan what I'm going to learn.), and student negotiation (i.e., I get the chance to talk to other students.). The alpha reliability coefficients for each dimension, the researchers calculated, were greatly exceeding .70 apart from the dimension "uncertainty". In spite of the smallest reliability coefficient, .72, it was clearly indicated that the CLES could yield reasonably acceptable assessment of the level of constructivist learning environment the students were provided. Küçüközer et al. (2012) adapted the CLES into Turkish as a 25-item survey as a result of explanatory and confirmatory factor analysis, and the collected data demonstrated a good fit with the structure of the scale. The alpha reliability of the scale was calculated as .85 which means the CLES scores are quite reliable.

Procedure

After obtaining ethical and official permissions from the relevant ethics committee and the Directorate of National Education, booklets including all the instruments were administered to the participants under the supervision of one of the researchers. The students' GPA in natural sciences, mathematics, technology and design, visual arts, and information technologies and software courses in their last transcript received one semester ago were also requested in the booklet in order to represent their achievement in STEM. It took two lesson hours with a 15-minute break for the students to complete the booklet. Following the data collection, IBM SPSS Statistics (2016) was used for data entry, cleaning data, required computations, and descriptive analysis. Finally, lavaan – latent variable analysis (Version 0.5), an R package for structural equation modelling, (Rosseel, 2012) was used for the structural equation analysis.

Data Analysis

In accordance with the main purpose, whether middle school students' P-CLE mediated the relationship between their P-MI and their AtSTEM and AchSTEM was analyzed in this study. Mediation analysis took place in three steps: (1) whether relation of the independent variable to the mediator was significant, (2) whether relation of the independent variable to the dependent variable was significant, and (3) whether relations of both the independent variable and the mediator to the dependent variable were significant, were tested as Baron and Kenny (1986) suggested. If the relationships in the first two steps, and the relation of the mediator to the dependent variable in the third step are significant, then mediation is said to be established. As well as the significant relationship between the mediator and the dependent variable, if the significant relationship in the second step between the independent variable and the dependent variable disappears in the third step, the mediation is called perfect mediation (Baron & Kenny, 1986).

As aforementioned, an R package, lavaan, was used for the mediation analysis. Besides, maximum likelihood estimation and covariance matrix were used in the analysis. Whether the data collected demonstrated a good fit with the models tested was evaluated using several multiple indices; such as goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSE) (Schreiber et al., 2006). According to Schreiber et al. (2006), GFI and AGFI are expected to be larger than .95 while SRMR and RMSEA are expected to be less than .08 and .06, respectively, thus claiming a good fit between the models tested and the data collected. Moreover, the boundary values for standardized regression coefficients reported by Kline (2005) were used in order to make sense of the magnitudes of the relationships in the tested models. Accordingly, standardized regression coefficients less than .10 are small, coefficients around .30 are medium, and coefficients above .50 are large effect sizes.

Variables

The latent and observable variables used in this study with the variable names used in the statistical analysis are given in Table 2. All the variables are continuous in nature and more information about their assessment is given in the "instruments" section.

Table 2. The Latent and Observable Variables

Latent Variables	Observable Variables	Variable names of the variables in the statistical analysis
The Perception of Constructivist Learning Environment of the Students (CLES)*	Personal Relevance	Relev
	Uncertainty	Uncer
	Critical Voice	CriVoi
	Shared Control	ShrdCo
	Student Negotiation	Negot
The Perception of Multiple Intelligences of the Students (MII)*	Linguistic Intelligence	Ling
	Logical-Mathematical Intelligence	Logi
	Spatial Intelligence	Spat
	Musical Intelligence	Music
	Naturalist Intelligence	Natu
	Bodily-Kinesthetic Intelligence	Body
	Interpersonal Intelligence	Inter
	Intrapersonal Intelligence	Intra
Attitude towards STEM of the Students (AtSTEM)*	Attitude to mathematics	AtMat
	Attitude to science	AtSci
	Attitude to engineering and technology	AtEng
	Attitude to 21th century skills	At21
STEM related courses' GPA scores (AchSTEM)*	Science	Scie
	Mathematics	Math
	Information Technology	InfT
	Technology Design	TechD
	Visual Art	visual

*The letters in the parenthesis next to the latent variables are names of the variables in the statistical analysis.

Power Analysis

In this section, the minimum sample size for conducting the structural equation modelling, or for observing statistically significant regression coefficients when the null hypothesis is really false is evaluated. Although there are no exact rules for the minimum sample size in structural equation modelling, sample sizes smaller than 200s are not acceptable as a general rule (Barrett, 2007). A more specific rule for minimum sample size of one sample structural equation modelling analysis was reported by Schreiber et al. (2006) and they stated that 10 per estimated parameters seems to be a commonly accepted ratio. Accordingly, in this one-sample study, the final tested model includes 27 regression coefficients, 22 variances, and 6 covariances. Thus, there are 55 estimated parameters in total. The sample size is 579 and consequently an acceptable ratio of 10.53 participants per estimated parameters is the case for this study. In conclusion, the sample size of the study seems fairly enough for conducting a powerful structural equation modelling analysis.

Research Ethics

This study was approved by the Social and Human Sciences Research Ethics Committee, and the authors declare that there are no conflicts of interest of any kind.

FINDINGS

Assumptions and Descriptive Statistics

The assumptions for conducting structural equation modelling analysis are basically about sample size, normality, outliers, linearity, multicollinearity and singularity (Pallant, 2005; Tabachnick & Fidell, 2007). The sample size required for the analysis is explained in the previous section and it can be concluded that the assumption relevant to the sample size is not violated. In order to check the normality assumptions, the Q-Q plots were analyzed for each observed variable. The skewness and kurtosis values presented in Table 3 were also used to check the normality assumptions. Except from Information Technologies, Technology Design and Visual Arts, all the observed variables were normally distributed. The observed variables violating the normality assumption are the students' GPA scores in these courses, and it can be concluded that the GPA scores are stacked at high scores for these courses because the distributions are negatively skewed and the kurtosis values are quite large.

In order to check if there were outliers in the data, the boxplots were evaluated for each variable. However, as Pallant (2005) explains, the box plots were accompanied by five percent trimmed mean scores to evaluate possible outliers. The mean and five percent trimmed mean scores in the table appear fairly comparable to each other for each variable compared to the standard deviations. Therefore, it was concluded that there were no outliers in the data. The minimum and maximum values in the table indicates that there was no error in the data entry. Cronbach's alpha reliability coefficients for each observed variable appear generally acceptable. However, there are a few alpha values less than .70 attributable to small number of items. As Briggs and Cheek (1986) explains, mean inter item correlations (MIIC) may be used in such cases and an optimal MIIC value should be between .20 and .40. Although there are some MIIC values less than .20 in Table 3, the alpha values may be considered acceptable for these variables measured with small number of items.

Table 3. Descriptive Statistics and Cronbach's Alpha Coefficients of Observable Variables

Observed variable	n	M	5% trimmed M	SD	Minimum	Maximum	Skewness	Kurtosis	Cronbach's α	MIIC
1. Personal Relevance	579	3.39	3.32	.85	1.00	5.00	-.26	-.36	.69	.31
2. Uncertainty	579	3.63	3.67	.95	1.00	5.00	-.50	-.27	.79	.42
3. Critical Voice	579	3.04	3.05	1.05	1.00	5.00	.04	-.65	.70	.36
4. Shared Control	579	2.90	2.89	1.09	1.00	5.00	.11	-.45	.84	.48
5. Student Negotiation	579	3.61	3.67	1.03	1.00	5.00	-.47	-.43	.84	.50
6. Linguistic Intelligence	579	3.51	3.53	.67	1.20	5.00	-.18	-.18	.65	.16
7. Logical-Mathemat. Intelligen.	579	3.61	3.62	.71	1.60	5.00	-.17	-.42	.74	.21
8. Spatial Intelligence	579	3.53	3.54	.67	1.40	5.00	-.13	-.11	.60	.17
9. Musical Intelligence	579	3.35	3.37	.71	1.00	5.00	-.28	-.23	.65	.16
10. Naturalist Intelligence	579	3.55	3.56	.66	1.60	5.00	-.10	-.33	.65	.16
11. Bodily-Kinesthetic Intellige.	579	3.57	3.58	.67	1.00	5.00	-.27	-.25	.65	.16
12.Interpersonal Intelligence	579	3.44	3.44	.65	1.40	5.00	-.03	-.47	.55	.13
13. Intrapersonal Intelligence	579	3.39	3.39	.66	1.60	5.00	-.11	-.14	.59	.12
14. Attitude to mathematics	579	3.07	3.09	.54	1.00	5.00	-.38	1.08	.74	.27
15. Attitude to science	579	3.51	3.55	.77	1.00	5.00	-.61	.32	.85	.39
16. Attitude to engineer. and tech.	579	3.58	3.62	.95	1.00	5.00	-.57	-.18	.88	.43
17. Attitude to 21th century skills	579	3.70	3.76	.91	1.00	5.00	-.85	.43	.90	.47
18. Science	579	2.24	2.28	.76	0.0	5.0	-.61	.08	NA	NA
19. Mathematics	579	1.94	1.99	.98	0.0	3.0	-.57	-.73	NA	NA
20.Information Technology	579	2.75	2.83	.53	0.0	3.0	-2.43	6.27	NA	NA
21. Technology Design	579	2.78	2.87	.52	0.0	3.0	-2.76	7.82	NA	NA
22. Visual Art	579	2.83	2.91	.48	0.0	5.0	-3.20	13.82	NA	NA

MIIC = mean interitem correlation

In Table 4, the correlations among all the variables are given. The shadowed cells are intra-correlations among the dimensions of a scale while the other cells are inter-correlations between dimensions of a scale and the other dimensions. For the CLES scale, the intra-correlations are small in size, with the exception of moderate correlation between "personal relevance" and "uncertainty". The largest intra-correlations appear on the MII scale. Almost all of them are medium size. On the other hand, the intra-correlations for the AtSTEM and AchSTEM scales are usually of small size. For the AtSTEM scale, the intra-correlations among attitude towards science, attitude towards engineering and technology, and attitude towards 21st century skills are medium size. For the AchSTEM variable, only the intra-correlation between science and mathematics GPA scores is nearly large size. When the inter-correlations in the table are evaluated, most of them are small in size, with the exception of a few moderate ones. For an example, "student negotiation", a dimension of the CLES, demonstrates moderate correlations with dimensions of other scales such as "logical-mathematical intelligence", a dimension of the MII, and "attitude towards 21st century skills", a dimension of the AtSTEM.

Table 4. Correlation Matrix for Observed Variables

	Observed variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
CLES	1. Pers. Relevance	-																					
	2. Uncertainty	.54	-																				
	3. Critical Voice	.36	.36	-																			
	4. Shared Control	.34	.27	.42	-																		
	5. Student Negoti.	.38	.41	.34	.40	-																	
MII	6. Linguistic Intel.	.16	.21	.17	.28	.25	-																
	7. Log.-Math. Inte	.25	.30	.18	.23	.31	.67	-															
	8. Spatial Intelli.	.15	.20	.11	.18	.23	.63	.66	-														
	9. Musical Intelli.	.07	.13	.15	.19	.14	.56	.45	.59	-													
	10. Naturalist Int.	.23	.25	.12	.17	.23	.64	.63	.68	.55	-												
	11. Bod-Kines. Int	.18	.21	.14	.18	.25	.60	.65	.69	.54	.65	-											
	12.Interpers. Intel.	.23	.24	.13	.20	.26	.63	.60	.60	.50	.64	.61	-										
	13. Intraper Intel.	.11	.10	.11	.22	.21	.57	.54	.56	.55	.56	.57	.56	-									
AtSTEM	14. Atti. to math.	.13	.19	.06	.12	.15	.08	.14	.10	.05	.04	.07	.08	.01	-								
	15. Atti. to sci.	.23	.29	.18	.25	.31	.20	.23	.21	.13	.17	.17	.18	.15	.27	-							
	16. Atti. to engin. and tech.	.25	.31	.13	.23	.24	.12	.20	.12	.10	.15	.14	.14	.10	.27	.45	-						
	17. Att to 21th century skills	.27	.37	.15	.21	.34	.19	.21	.12	.14	.17	.13	.17	.15	.25	.50	.59	-					
AchSTEM	18. Science	.22	.30	.15	.15	.21	.07	.20	.09	.05	.06	.14	.09	.01	.22	.24	.06	.16	-				
	19. Mathematics	.16	.25	.16	.13	.21	.06	.19	.07	.01	-.01	.07	.06	.03	.22	.19	.07	.17	.68	-			
	20. Inform. Tech.	.08	.17	.11	.08	.10	.11	.09	.04	.06	.05	.05	.06	.01	.11	.09	.12	.13	.35	.31	-		
	21. Techn. Design	-.04	.08	.03	.09	.13	.09	.07	.06	.01	.03	.04	.03	-	.08	.07	.01	.13	.29	.25	.43	-	
	22. Visual Art	-.06	.02	.08	.06	.08	.10	.11	.10	.05	.05	.04	.03	.06	.10	.10	.10	.10	.15	.17	.26	.36	-

Measurement Models

Before the mediation analysis, measurement models to be included in the structural equations were tested. Four measurement models were tested for: (1) P-CLE, (2) P-MI, (3) AtSTEM, and (4) AchSTEM.

For the P-CLE, five observed indicators were hypothesized. When the measurement model was first tested, good fit indices could not be observed ($\chi^2(5, N = 579) = 51.039$, $p < .001$, GFI = .96, AGFI = .89, RMSEA = .13, SRMR = .05). After a covariance was added between "personal relevance" and "uncertainty" as a result of the suggested modifications, the tested measurement model resulted in good fit indices ($\chi^2(4, N = 579) = 18.292$, $p = .01$, GFI = .99, AGFI = .96, RMSEA = .07, SRMR = .03).

For the P-MI, eight observed indicators were hypothesized. When the model was first tested, although good fit indices could be observed ($\chi^2(20, N = 579) = 77.431$, $p < .001$, GFI = .97, AGFI = .94, RMSEA = .07, SRMR = .03), a covariance between "musical intelligence" and "logical mathematical intelligence" and a covariance between "logical mathematical intelligence" and "linguistic intelligence" were added. Thus, better fit indices appeared finally ($\chi^2(18, N = 579) = 40.577$, $p < .01$, GFI = .98, AGFI = .96, RMSEA = .05, SRMR = .02).

For the AtSTEM, there were four hypothesized indicators, and the tested measurement model directly resulted in good fit indices ($\chi^2(2, N = 579) = 4.156$, $p = .13$, GFI = .99, AGFI = .98, RMSEA = .04, SRMR = .02).

Finally, there were five hypothesized indicators for AchSTEM. The tested measurement model yielded in undesirable fit indices ($\chi^2(5, N = 579) = 132.201$, $p < .001$, GFI = .91, AGFI = .72, RMSEA = .21, SRMR = .11). After adding a covariance between "Science" and "Mathematics", and a covariance between "Technology Design" and "Visual Art", much better fit indices appeared at last ($\chi^2(3, N = 579) = 1.719$, $p = .63$, GFI = .99, AGFI = .99, RMSEA = .00, SRMR = .01).

Mediation Analysis

Mediation analysis was conducted as explained by Baron and Kenny (1986) to explore whether middle school students' constructivist learning environment perceptions mediated the relationship between their P-MI and their AtSTEM and AchSTEM using structural equation modelling by means of "lavaan". What steps mediation analysis has got was explained in the Data Analysis section. In accordance with the relevant explanations, first, the students' constructivist learning environment perceptions were regressed on their P-MI. Second, the students' AtSTEM and AchSTEM were regressed on their P-MI. Finally, in the third step, the students' AtSTEM and AchSTEM were regressed on both their P-MI and on their P-CLE.

When the students' constructivist learning environment perceptions were regressed on their P-MI, the structural equation modelling demonstrated a good fit to the data ($\chi^2 (61, N = 579) = 150.73$, $p < .001$, GFI = .96, AGFI = .94, RMSEA = .05, SRMR = .038) and a significant regression coefficient was observed with nearly large effect size (□=.41, z = 7.33, $p < .001$).

When the students' AtSTEM and AchSTEM are regressed on their P-MI, the structural equation modelling demonstrated a good fit to the data (χ^2 (112, N = 579) = 229.57, p < .001, GFI = .96, AGFI = .94, RMSEA = .043, SRMR = .043). The tested model with estimated parameters is shown in Figure 2. The students' P-MI had a non-significant direct small contribution to their AchSTEM (□=.06, z = 1.13, p = .26) but a significant direct moderate contribution to their AtSTEM (□=.28, z = 4.69, p < .001). The relationship between students' AtSTEM and AchSTEM was also significant with moderate effect size (□=.25, z = 3.57, p < .001). Indirect and total contributions of students' P-MI to their AchSTEM were significant as well (□=.07, z = 3.26, p = .001 and □=.13, z = 2.43, p = .02, respectively).

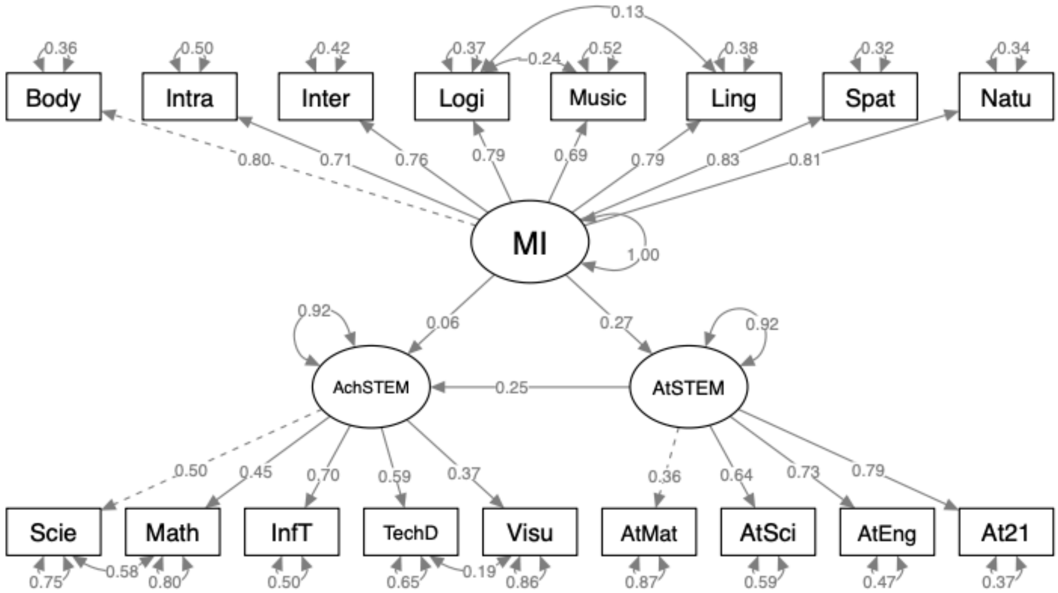

Figure 2. *The students' AtSTEM and AchSTEM are regressed on their P-MI.*

In the last step, the students' AtSTEM and AchSTEM were regressed on both their P-MI and on their P-CLE, and a good fit between the tested model and the data was also observed (χ^2 (198, N = 579) = 437.315, p < .001, GFI = .94, AGFI = .92, RMSEA = .046, SRMR = .049). The tested model with estimated parameters (standardized regression coefficients, covariances, and variances) is shown in Figure 3.

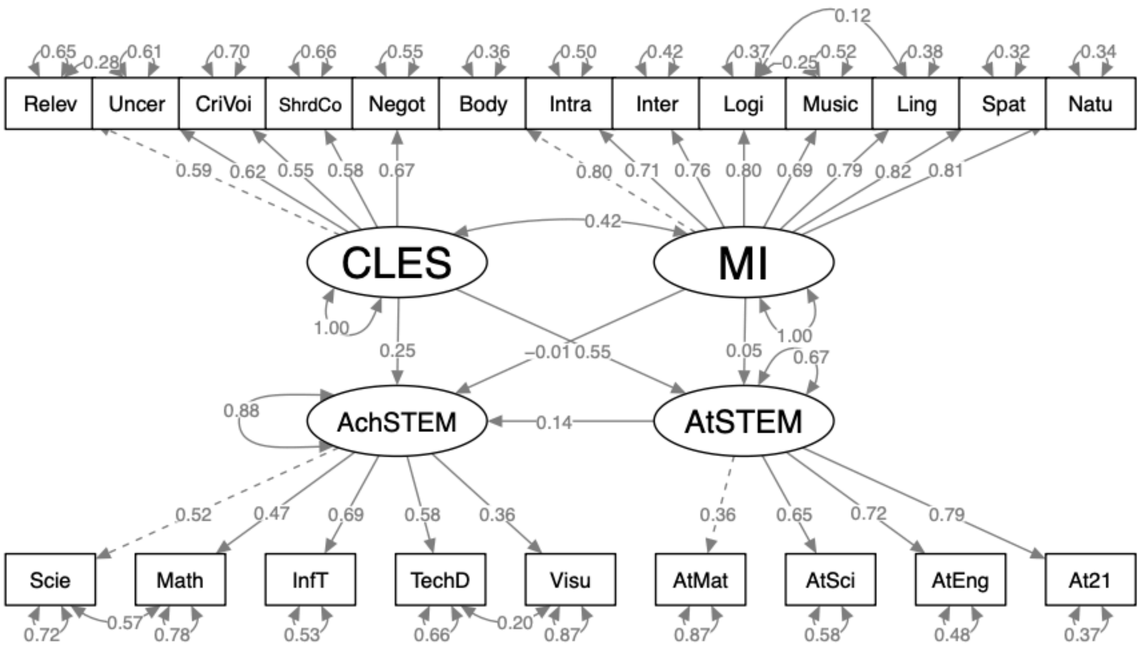

Figure 3. *The students' AtSTEM and AchSTEM are regressed on both their P-MI and P-CLE.*

In addition, Table 5 presents the direct, indirect, and total influences related to the tested model.

Table 5. Direct, Indirect, and Total Relations in Model Tested by means of Structural Equation Modeling

		Attitude towards STEM			STEM Related Courses' GPA Score		
Variable		Direct	Indirect	Total	Direct	Indirect	Total
Multiple Intelligences	*β*	0.05	-	0.05	-0.01	0.01	0.00
	SE	0.02		0.02	0.04	0.01	0.04
	z	0.88		0.88	-0.11	0.78	-0.00
Constructivist Learning Environment	*β*	0.55	-	0.55	0.25	0.08	0.33
	SE	0.04		0.04	0.07	0.03	0.06
	z	5.77		5.77	2.79	1.77	4.28
Attitude towards STEM	*β*	NA	NA	NA	0.14	-	0.14
	SE				0.16		0.16
	z				1.74		1.74

Note, χ^2 = 437.315, $p < .05$, goodness of fit index = .94, adjusted goodness of fit index = .92, root mean square error of approximation = .046; standardized root mean square residual = .049

Findings related to the tested model based on the figure and the table are as follows:

1.Students' AtSTEM had a non-significant small contribution to their AchSTEM (β=.14, z = 1.74, p = .08).

2.Direct influences of the students' P-CLE both on their AtSTEM and AchSTEM were significant (β=.55, z = 5.77, p < .001, and β=.25, z = 2.79, p < .01, respectively). The indirect influence on AchSTEM was non-significant and small (β=.08, z = 1.77, p = .08). However, the total influence was significant with medium size (β=.33, z = 4.28, p < .001).

3.Direct influence of the students' P-MI both on their AtSTEM and AchSTEM were non-significant (β=.05, z = 0.88, p = .38, and β=-.01, z = -0.11, p = .91, respectively). The indirect and total influence were also non-significant (β=.01, z = .78, p = .43; β=.00, z = -.003, p = .99, respectively).

In sum, respectively, 33 and 12 percent of the variances in student AtSTEM and AchSTEM were explained. Almost all these fractions were attributed to their constructivist learning environment perceptions, and the influences of multiple intelligences perceptions vanishes. This means that students' P-CLE seems like a perfect mediator for the relationship between their P-MI and AtSTEM and AchSTEM.

DISCUSSION & CONCLUSION

The main purpose of this study was to clarify the relations of middle school students' P-MI and P-CLE to their AtSTEM and AchSTEM. In particular, the purpose was to investigate whether middle school students' P-MI mediates the relation of their P-CLE to their AtSTEM and AchSTEM, or P-CLE does.

The mediation analysis carried out by means of structural equation modelling clearly demonstrated that middle school students' P-CLE perfectly mediated the relationship between their P-MI and their AtSTEM and AchSTEM. The indirect and total relationships of the P-MI to AchSTEM through AtSTEM were significant with small effect sizes. However, this may not mean that the relation of P-MI to AtSTEM and AchSTEM is small in reality because the MI items can cover only a small part of total spectrum of abilities in each intelligence category (Armstrong, 2000). Findings of associational research exploring the relationships between P-MI and academic performance in STEM disciplines also yield positive relationships (Ahvan & Pour, 2016; Baran & Maskan, 2011; Chan, 2006; Lillbacka, 2013; Pallrand & Seeber, 1984; Snyder, 1999; Träff et al., 2019). Although those studies reported relations of the dimensions of P-MI to academic achievement, they did not report how much variance in the achievement had been accounted for.

When the P-CLE entered the equation, the significant relation of P-MI vanishes and becomes zero. That is, a perfect mediation was the case, and the P-CLE perfectly mediate the relation of the P-MI to the AtSTEM and AchSTEM. It means that the students with high level of P-MI perceive the learning environment provided to them as more constructivist and positive; thus, they are more successful in STEM courses as well. In the Akdağ and Köksal (2022) study, the researchers also used the CLES to assess gifted students' P-CLE, and they observed that the gifted students had found the learning environments provided to them totally constructivist. That is, those students thought that they took more responsibility than their counterparts for learning new concepts, and they were active learners in the classroom. In another research, Rita and Martin-Dunlop (2011) compared 146 gifted and 115 non-gifted high school biology students' perceptions of learning environments. They reported that all the participants preferred more favorable learning environment than the one they were experiencing. However, the gifted students' perceptions of learning environments were more positive. Similar conclusions come from the Schijndel et al. (2018) study as well. They observed the primary school students with low intelligence perceptions had benefitted from inquiry-based instruction with higher quality of exploration except for the knowledge acquisition. In other words, they also observed that the students who perceived themselves as low intelligent had not been able to benefit from the inquiry-based instruction that provide a constructivist environment in terms of knowledge acquisition or academic performance.

Consequently, the students who perceive themselves as more intelligent tend to find the learning environments provided to them more constructivist in general. There is an extensive literature on the relationship between students' perception of learning environment and their achievement in STEM disciplines. Almost all studies found positive but small relationships between student perceptions of learning environment and AtSTEM and AchSTEM (Allen & Fraser, 2007; Aluri & Fraser, 2019; Boz et al., 2016; Chionh & Fraser, 2009; Fraser & Kahle, 2007; Goh & Fraser, 1998; Hafızoglu & Yerdelen, 2019; Ogbuehi & Fraser, 2007; Pamuk et al., 2017; Partin & Haney, 2012; Wolf & Fraser, 2008; Yang, 2015), except for few studies could not observe a significant relationship (e.g. den Brok et al., 2010). In constructivist learning environments, learners make sense of the world in relation to the knowledge they have already constructed and this process takes place by means of active negotiation with teacher and peers (Fraser, 1998; Taylor et al., 1997b). Obviously, this active participation should help students improve their academic performance; and thus, it may also help them feel smarter or more intelligent as well.

As providing students with constructivist learning environments may help them feel more intelligent, feeling themselves more intelligent may be helping them profiting more from the constructivist learning environments provided to them. Such a perspective is a natural result of associational research studies. That is say, perceptions of intelligence may be something expandible with some limitations. Dweck and her colleagues observed students to hold two types of views about intelligence: entity and incremental theories of intelligence (as cited in Aronson et al., 2002). They reported the students with the entity view of intelligence to possess "performance goals." They desire to show their intelligence and tend to prefer tasks which will verify that they are intelligent and capable. On the other hand, students with the view of incremental view of intelligence are reported to possess "learning goals." They tend to learn new concepts to improve their competence. When a challenging task is the case, the students with the entity theory demonstrate disengagement while the students with the incremental theory increase their engagement with less anxiety. That is to say, students perceive the constructivist learning environments to be more challenging as reported in the Shekhar et al. (2020) study because such environments require them to be more active and responsible. Therefore, students with the entity view of intelligence may become disengage in constructivist learning environments that are perceived as offering them more challenging tasks; and thus, they become less successful. If this is the case, even simply stating them intelligence is something malleable and can be improved may help them benefit more from the constructivist learning environments as Aronson et al. (2002), and Marchand and Taasoobshirazi (2013) did in their experimental research.

As a result of this study and the related literature, the following recommendations could be considered:

1.Because quantitative assessment of student aptitudes such as intelligence and skills may not reflect the true scores, researchers may conduct qualitative exploration of relationships between multiple intelligences, constructivist learning environment, and AtSTEM and AchSTEM so that a more realistic and deeper understanding about those relationships may be constructed.

2.Students may be provided with constructivist learning environments so that they become more successful, and thus, feel more intelligent.

3.Multiple intelligence theory laden interventions may help students more profit from the instructions and thus be more successful as well.

4.Students should be encouraged to think of intelligence as something malleable by guidance so that their perception of multiple intelligences may be improved; and thus, they may more benefit from constructivist learning environments.

5.Experimental research on reducing the stereotype threat should be conducted to test if simply encouraging students to think of intelligence as something malleable can improve their perceptions of multiple intelligences;

and thus, can improve their academic performance.This section may include the discussion of your findings, and conclusions with comparison to the literature, implications, and recommendations.

Statements of Publication Ethics

This study was approved by the Social and Human Sciences Research Ethics Committee, and the authors declare that there are no conflicts of interest of any kind.

Acknowledgment

This article is based on the master's thesis written by Güler (2019) and supervised by Haki Peşman.

Researchers' Contribution Rate

Haki Peşman: Supervision, Conceptualization, Project administration, Methodology, Software, Investigation, Writing- Reviewing and Editing **Tuba Güler:** Conceptualization, Methodology, Data curation, Writing- Original draft. **Üzeyir Arı:** Visualization, Investigation, Writing- Original draft. **Fatma Erdoğan:** Validation, Investigation, Writing- Reviewing and Editing.

Authors	Literature review	Method	Data Collection	Data Analysis	Results	Conclusion
Haki	☒	☒	☐	☒	☒	☒
Tuba	☐	☒	☒	☒	☐	☐
Üzeyir	☒	☐	☐	☒	☒	☒
Fatma	☒	☐	☐	☐	☒	☒

Conflict of Interest

The authors declare that there are no conflicts of interest of any kind.

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