J. COMBIN. MATH. COMBIN. COMPUT. 127b (2025) 625--640

Journal of Combinatorial Mathematics
and Combinatorial Computing
www.combinatorialpress.com/jcmcc

Combinatorial Press

Quantitative assessment of gender differences in preschool education and the impact of educational methods based on cluster analysis

Bole Sun[1], Pian Shi[1], Jiaxing Cao[2], Yifang Zhang[1,✉]

[1] *Faculty of Education, Beijing City University, Beijing, 101309, China*
[2] *School of Public Affairs, Zhejiang University, Hangzhou, Zhejiang, 310058, China*

ABSTRACT

Pre-school education, as a key stage on the path of children's growth, plays a vital role in their overall development. Based on the independent sample t-test method, this paper explores the gender differences in preschool education. It also takes digital media education methods as an example, and utilizes Pearson correlation coefficient, linear regression model, and systematic clustering algorithm comprehensively to quantitatively assess the impact of education methods. The results of the study showed that there were extremely significant differences (P<0.01) in the five dimensions of language ability, creativity, social interaction ability, critical thinking ability, and independent learning ability between male and female toddlers, indicating that there are significant gender differences in preschool education effectiveness. The correlation coefficients between the frequency and duration of use of digital media education methods and language skills, creativity, social interaction skills, critical thinking skills, and independent learning skills ranged from 0.47 to 0.75, with significant positive correlations, and were associated with higher scores on each of the competencies as well as higher levels of satisfaction. This paper reveals in depth the gender differences in preschool education and the important role of digital media in preschool education, which is of great value for the optimization of teaching methods in preschool education.

Keywords: pearson correlation, independent samples t-test, linear regression model, systematic clustering, preschool education

1. Introduction

Existing gender culture has reshaped gender roles to form socially acceptable “masculinity” and “femininity” [1]. Men and women show certain gender role differences in the educational arena. Male

✉ Corresponding author.
E-mail address: bole0106@bcu.edu.cn (Y. Zhang).
Received 03 January 2024; Revised 10 May 2024; Accepted 25 September 2024; Published Online 16 April 2025.
DOI: 10.61091/jcmcc127b-035

teachers are tolerant and open-minded, humorous and witty, logical and bold, but less likely to lead by example; in teaching they are knowledgeable, theoretical and hands-on, but their knowledge system is messy [2-3]. Female teachers are kind and affectionate, meticulous, pay attention to interpersonal relationships, prepare lessons carefully and are well-organized, but they are not competent enough, are too serious, and some of them even judge by appearances, and there is a phenomenon of reading from a book in teaching [4-5]. In fact, male and female teachers play different roles in children's perspectives, male teachers are popular in the field of physical movement and mathematical games, and male kindergarten teachers are more courageous, fair and principled than female teachers [6-8]. Exploring the differences in educational methods in preschool education from the perspectives of men and women of both genders, constantly reshaping people's views on gender differences, and respecting openness, multiplicity, diversity, and differences within and between groups of both genders help people understand the reasons for the formation of differences in the gender roles of teachers in preschool education [9-12]. It also helps to guide the teacher community to correct the inappropriate aspects of the original understanding, to abandon the influence of gender stereotypes, to establish a scientific concept of gender roles, not to ignore or exaggerate the differences between male and female teachers, to correctly view the differences in gender roles in the educational methodology, and to strengthen the subjective initiative in the development of the profession on this basis [13-16].

In this paper, 742 children from 15 kindergartens in S city were selected as the research object, relevant questionnaires were designed and distributed and collected, and independent samples t-test, Pearson's correlation coefficient, linear regression model, systematic clustering algorithm and other methods were used for data processing, to analyze the gender differences in pre-school education, and to realize quantitative assessment of the impact of the digital media's educational methods on the effectiveness of pre-school education. Firstly, this paper determines the quantitative indexes for assessing the effectiveness of preschool education as five dimensions: language ability, creativity, social interaction ability, critical thinking ability and independent learning ability. Then, the independent sample t-test is used to compare and analyze the differences between male and female children in the five dimensions. Finally, the impact effects of digital media education methods were quantitatively assessed from the perspectives of descriptive statistics, correlation analysis, regression analysis, and cluster analysis.

2. Research design and implementation

In order to explore gender differences in preschool education and to quantitatively assess the impact of educational methods, this paper uses digital media educational methods as a specific research subject.

2.1. Research Objects and Research Ideas

In this paper, 742 children from 15 kindergartens in S city were randomly selected as research subjects, of which the numbers of male and female children were 384 and 358 respectively. The situation of gender differences in preschool education was analyzed through independent sample t-tests, and research tools such as Pearson's correlation coefficient, multiple linear regression models, and systematic clustering algorithms were used to quantitatively assess the pedagogical impacts of digital media education methods.

2.2. Design and steps for quantitative indicators

The study randomly selected various groups related to young children in S city, including 245 parents of young children, 184 teachers of young children, and 280 college students majoring in preschool education.

Individual subjects were asked to categorize the high-frequency words according to the guidelines, and small slips of paper with the selected high-frequency words were used as a tool to ask the subjects to categorize the high-frequency words according to their own understanding of the "effectiveness of preschool education". Then, the conditional free association method with content analysis was used to collect items, and then systematic clustering was performed.

2.2.1. Collection of Associated Words. A questionnaire on the effectiveness of preschool education will be distributed, and the subjects will be asked to use "effectiveness of preschool education" as the target word, and to associate and write down in turn, without limiting the time available, the words that they think reveal the connotation (content) of the concept of "effectiveness of preschool education", with a minimum of 10 words, without repetition. No less than 10 words, no repetition.

2.2.2. Frequency Statistics of Associated Words. All the collected association words (including blank items) were content analyzed and frequency counted.

The collected words were firstly simplified. The specific rules are as follows:

1) Merge those that are completely synonymous. Following the principle of weighting, those with less quantity are merged into those with more quantity.

2) Words with the same meaning but different expressions are merged by following the principle of weighting, and those with less quantity are merged into those with more quantity.

3) Words with similar expressions but with obvious conceptual boundaries of meaning are categorized separately.

4) Separately expressed idioms can be merged.

5) Expressions containing two independent information are categorized separately.

Then, Microsoft Excel 2018 software was used to count the frequency of the simplified association words of "preschool education effectiveness", and the first 108 high-frequency words were finally found.

2.2.3. Finalization of quantitative indicators. Then, 108 high-frequency words were merged by using systematic clustering algorithm, and finally five quantitative assessment indicators were obtained, including language ability, creativity, social interaction ability, critical thinking ability, and independent learning ability.

In order to verify the reliability of the indicators, a preschool education effectiveness scale was designed based on the five indicators, and questionnaires were distributed to 742 young children in the selected city of S. Their kindergarten teachers filled out the questionnaires on behalf of the children according to their indicator assessments. A total of 709 questionnaires were distributed and 681 were successfully recovered, of which 668 were valid questionnaires, with an effective recovery rate as high as 94.22%. Subsequently, the data of the recovered questionnaires were analyzed in detail and the reliability and validity of the questionnaires were tested by using SPSS28.0 software.

Through the professional calculation of SPSS28.0 software, the results of the reliability analysis are shown in Table 1, which concluded that the overall Cronbach's alpha coefficient of this questionnaire is 0.946>0.9, which fully proves that this questionnaire has a very high level of reliability and consistency, which is fully in line with the requirements of the study, which lays a solid foundation for the subsequent research work.

Table 1. Reliability analysis of pre-test questionnaires

Variable	Cronbach's alpha	Number of terms
Language ability	0.759	5
Creativity	0.764	5
Social communication ability	0.862	5
Critical thinking ability	0.867	5
Self-directed learning ability	0.908	5
Effectiveness of preschool education	0.946	25

In the validity analysis section, this study adopts KMO test and Bartlett's sphericity test as the means of measurement with the help of SPSS28.0 software, which yields the results of the questionnaire validity analysis as shown in Table 2. Specifically, the KMO value of the questionnaire used in this study reached 0.816, while the Sig. value of the Bartlett's sphericity test was also below the significance threshold of 0.05, which is a good indication that the variables in the questionnaire are not only independent of each other, but also very suitable for factor analysis as a whole.

Table 2. KMO and Bartlett tests

KMO sample appropriateness measure		0.816
Bartlett sphericity test	Approximate chi-square	1308.473
	df	502
	Sig.	0.000

Further factor analysis was conducted, and the post rotational cumulative variance explained ratio of the five indicators was 88.47% > 60%, indicating that the designed quantitative indicators have high validity. Therefore, this paper identifies five quantitative assessment indicators of innovation in preschool education: language ability, creativity, social interaction ability, critical thinking ability, and independent learning ability.

3. Data-processing methods

3.1. Pearson's correlation coefficient

Pearson's correlation coefficient (PCC) [17] is a widely used statistical method that is often used to assess the degree of linear correlation between different features, and thus to discern whether there is a relationship between different features that interacts with each other or not, which is expressed by the specific formula:

$$r = \frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)\left(Y_i - \bar{Y}\right)}{\sqrt{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}\sqrt{\sum_{i=1}^{n}\left(Y_i - \bar{Y}\right)^2}} \tag{1}$$

where: r represents the Pearson correlation coefficient, X_i and Y_i are the ith observations of two different variables, and $\bar{X}$ and $\bar{Y}$ represent the mean values of X and Y respectively.

When the absolute value of PCC takes the range of 0.8-1.0, the magnitude of correlation between the two variables is strongly correlated. And when the range of its value is 0.3-0.8, the two variables are weakly correlated with each other. When the range of values is 0-0.3, the two variables are essentially uncorrelated.

In summary, it can be seen that the PCC takes the value range of [-1,1], and the closer its absolute value is to 1 indicates the stronger correlation between the two variables. The calculation of Pearson's correlation coefficient is based on the mean and standard deviation of the variables, which does not depend on the actual values, so it has less influence on the outliers, which provides a guarantee for its stability in practical application.

3.2. t-test and ANOVA at two levels

When testing hypothesis $H_0 : \mu_1 = \mu_2$, vs. $H_1 : \mu_1 \neq \mu_2$, the t-test and analysis of variance at two levels are two equivalent tests [18]. This is because the test statistic for the t-test is:

$$t = \frac{(X_1 - X_2)}{S_\omega \sqrt{1/n_1 + 1/n_2}} \tag{2}$$

Among them:

$$n = n_1 + n_2 \tag{3}$$

$$S_\omega^2 = \frac{(n_1 - 1) S_1^2 + (n_2 - 1) S_2^2}{n - 2} \tag{4}$$

There is when the original assumption H_0 holds:

$$t \sim t(n-2) \tag{5}$$

$$t^2 = \frac{(\bar{X}_1 - \bar{X}_2)^2}{S_\omega^2 (1/n_1 + 1/n_2)} = \frac{n_1 n_2}{n_1 + n_2} \frac{(\bar{X}_1 - \bar{X}_2)^2}{S_\omega^2} \sim F(1, n-2) \tag{6}$$

And for a two-level ANOVA, where $\bar{X}$ can be morphed into $\frac{n_1 X_1 + n_2 X_2}{n_1 + n_2}$, there is:

$$\begin{aligned} MSA = SSA &= \sum_{i=1}^{2} n_i (\bar{X}_i - \bar{X})^2 = n_1 (\bar{X}_1 - \bar{X})^2 + n_2 (\bar{X}_2 - \bar{X})^2 \\ &= n_1 \left(\bar{X}_1 - \frac{n_1 \bar{X}_1 + n_2 \bar{X}_2}{n_1 + n_2} \right)^2 + n_2 \left(\bar{X}_2 - \frac{n_1 \bar{X}_1 + n_2 \bar{X}_2}{n_1 + n_2} \right)^2 \\ &= \frac{n_1 n_2^2 (\bar{X}_1 - \bar{X}_2)^2}{(n_1 + n_2)^2} + \frac{n_1^2 n_2 (\bar{X}_1 - \bar{X}_2)^2}{(n_1 + n_2)^2} = \frac{n_1 n_2}{n_1 + n_2} (\bar{X}_1 - \bar{X}_2)^2 \end{aligned} \tag{7}$$

$$MSE = \frac{SSE}{n-2} = \frac{(n_1 - 1) S_1^2 + (n_2 - 1) S_2^2}{n - 2} = S_\omega^2 \tag{8}$$

Test statistic:

$$F = \frac{MSA}{MSE} = \frac{n_1 n_2}{n_1 + n_2} \frac{(\bar{X}_1 - \bar{X}_2)^2}{S_\omega^2} = t^2 \tag{9}$$

$$\begin{aligned} &P\left(|t| \geq t_{\alpha/2}(n-2)\right) = P\left(t^2 \geq t_{\alpha/2}^2(n-2)\right) \\ &= P\left(F \geq t_{\alpha/2}^2(n-2)\right) = P\left(F \geq F_\alpha(1, n-2)\right) = \alpha \end{aligned} \tag{10}$$

Therefore, testing hypothesis $H_0 : \mu_1 = \mu_2$ vs $H_1 : \mu_1 \neq \mu_2$ with t-test and ANOVA at two levels is equivalent and has:

$$t_{\alpha/2}^2 (n-2) = F_\alpha (1, n-2) \tag{11}$$

However, there is a difference between ANOVA and t test in the use of ANOVA can only test the two water means whether there is a significant difference, but not more than the size of the mean, t test in addition to testing the two means whether there is a difference, you can also compare the size, so if you want to test the $H_0:\mu_1 \le \mu_2$ vs $H_1:\mu_1 > \mu_2$ or $H_0:\mu_1 \ge \mu_2$ vs $H_1:\mu_1 < \mu_2$, you can only use the t test.

3.3. Classical linear regression models and their assumptions

Linear regression model is a special type of mathematical regression model that can determine the correlation between variables and can be purposively predicted for a particular variable [19]. Among them, the univariate linear regression model has the simplest form. However, when portraying the data and establishing the relationship between the variables, the changes in the variables are affected by many factors, and for the sake of the comprehensiveness of the information and the accuracy of the model, multiple linear regression modeling of the data is required.

The specific expressions are as follows:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k + \mu \tag{12}$$

where β_0 is called the constant term. $\beta_1, \beta_2, \cdots, \beta_k$ is called the regression coefficient. y is the random dependent variable. $x_1, x_2, \cdots, x_k$ is the non-random independent variable. μ is known as the random error term.

If n observations are made for y and x and n sets of observations $y_i, x_{ib}, \cdots x_{ik} \left(i = 1, 2, \cdots, n\right)$ are obtained, then they are related as follows:

$$y_i = \beta_0 + \beta_1 x_{i1} + \cdots + \beta_k x_{ik} + \mu_i \tag{13}$$

Introducing matrix notation, notation:

$$y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}, X = \begin{bmatrix} 1 & x_{11} & \cdots & x_{1k} \\ 1 & x_{21} & \cdots & x_{2k} \\ \vdots & \vdots & & \vdots \\ 1 & x_{n1} & \cdots & x_{nk} \end{bmatrix}, \beta = \begin{bmatrix} \beta_0 \\ \beta \\ \vdots \\ \beta_k \end{bmatrix}, \mu = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_n \end{bmatrix} \tag{14}$$

Then model (13) can be written in the following form:

$$Y = X\beta + \mu \tag{15}$$

where Y is the $n \times 1$ observation vector, X is the $n \times \left(k+1\right)$ known design matrix, μ is the $n \times 1$ random error term, and β is the $\left(k+1\right) \times 1$ unknown parameter vector.

For better model parameter estimation, hypothesis testing and judgmental prediction. Typically, constructing a multiple linear regression model is often done with some classical assumptions. If the model does not satisfy these classical assumptions, then it will lead to wrong analysis results and cause some troubles. The classical assumptions of the linear regression model are as follows:

1) The random error term μ_i is a random variable with an expected value or mean of 0, which satisfies the assumption of unbiasedness:

$$E\left(\mu_i\right) = 0, \left(i = 1, 2, \ldots, n\right) \tag{16}$$

2) The random error term has the same variance for all observations of the explanatory variables, satisfying the homogeneity assumption:

$$\operatorname{var}\left(\mu_i\right) = \sigma^2, i = 1, 2, \ldots, n \tag{17}$$

3) The random error terms are uncorrelated with each other:

$$\operatorname{cov}\left(\mu_i, \mu_j\right) = E\left(\mu_i \mu_j\right) = \left(i, j = 1, 2, \ldots, n\right) \tag{18}$$

This condition is called the Gauss-Markov condition.

4) The explanatory variables do not have the property of randomness and are uncorrelated with the random error term:

$$\operatorname{cov}\left(x_{ij},\mu_j\right)=0,\left(i=1,2,\cdots,k,j=1,2,\ldots,n\right) \tag{19}$$

5) The explanatory variables do not have a perfectly linear relationship with each other. In mathematical language, the matrix of sample observations of the explanatory variables is full rank:

$$\mu_i \sim N\left(0,\sigma^2\right) \tag{20}$$

6) The random error term obeys normal distribution, which ensures the validity of F test and t test.

Under this condition the valid results of regression coefficients and σ^2 estimation can be obtained, the significance of the explanatory variables in the regression model as well as the model as a whole can be obtained, and the correct estimation of prediction intervals can be obtained.

3.4. Systematic clustering algorithm

The basic idea of the systematic clustering algorithm is to first set each sample into a separate class, and the distance between each two classes is used as an evaluation index to measure the degree of similarity between them. The larger the distance, the less similar the two classes are [20]. And the smaller the distance, the more similar the two classes are. After the two classes with the highest degree of similarity are merged into a new class, the distance between the new class and other classes is calculated, and the class with the highest degree of similarity to the new class is merged, and all classes are merged into one class by continuously iterating this process.

The basic process of the systematic clustering algorithm is as follows:

1) Data preprocessing. Since there are often differences in the unit of measurement and the degree of change between the m indicators of the n samples, which usually lead to very different results in the analysis of the data, in order to eliminate the effects of different scales and the degree of change of the variables and make the data comparable, the data need to be standardized. After the standardized transformation, the data are free from the limitations of the unit of measurement, dimensionless, but if there are still some indicators that do not reside in the range of $\left[0,1\right]$, the data need to be further normalized, which can greatly improve the accuracy and reasonableness of the results of the system clustering. Data normalization methods usually have the following kinds:

(1) Standard deviation standardization:

$$x'_{ij}=\frac{x_{ij}-\bar{x}_{ij}}{s_{ij}}\left(i=1,2,\cdots,n,j=1,2,\cdots,m\right) \tag{21}$$

Among them:

$$\bar{x}_{ij}=\frac{1}{n}\sum_{i=1}^{n}x_{ij},s_{ij}=\left[\frac{1}{n}\sum_{i=1}^{n}\left(x_{ij}-\bar{x}_{ij}\right)^2\right]^{\frac{1}{2}},\left(j=1,2,\cdots,m\right) \tag{22}$$

x_{ij} represents the raw data for the j rd indicator of the i nd sample. x'_{ij} represents the standardized data for the j th indicator of the i th sample.

(2) Polar deviation standardization:

$$x''_{ij}=\frac{x'_{ij}-\min\limits_{1\le i\le n}\left\{x'_{ij}\right\}}{\max\limits_{1\le i\le n}\left\{x'_{ij}\right\}-\min\limits_{1\le i\le n}\left\{x'_{ij}\right\}},\left(j=1,2,\cdots,m\right) \tag{23}$$

where x''_{ij} is the normalized data for the j rd indicator of the i nd sample. After the polar transformation process, all the indicator data $x''_{ij} \in [0,1]$.

2) Calculate the distance between samples and samples. In the cluster analysis of the actual problem, usually by measuring the distance between any two sample points to measure the degree of proximity between them, if the definition of d_{ij} as the distance between sample x_i and sample x_j, there are several methods of calculating the distance between samples as follows:

(1) Absolute value distance:

$$d_{ij} = \sum_{k=1}^{m} \left| x_{ik} - x_{jk} \right| \tag{24}$$

(2) Euclidean distance:

$$d_{ij} = \left[\sum_{k=1}^{m} \left(x_{ik} - x_{jk} \right)^2 \right]^{1/2} \tag{25}$$

(3) Minkowski distance:

$$d_{ij} = \left[\sum_{k=1}^{m} \left(x_{ik} - x_{jk} \right)^q \right]^{1/q} \tag{26}$$

(4) Chebyshev distance:

$$d_{ij} = \max_{1 \le k \le m} \left| x_{ik} - x_{jk} \right| \tag{27}$$

(5) Marginal distance:

$$d_{ij} = \left[\left(x_i - x_j \right)' S^{-1} \left(x_i - x_j \right) \right]^{1/2} \tag{28}$$

where S is the covariance.

(6) Lang's distance:

$$d_{ij} = \sum_{k=1}^{m} \frac{\left| x_{ik} - x_{ik} \right|}{x_{ik} + x_{ik}} \tag{29}$$

3) Calculating class-to-class spacing. The methods of calculating class-to-class spacing include the longest distance method, the shortest distance method, the average intergroup connection method, the average intragroup connection method, the center of mass method, the median method, and the sum of squares of deviations method.

The longest distance method is to take the maximum distance between two samples of different classes as the distance between the two classes.

The shortest distance method is to combine the two or more classes with the smallest distance. The between-group mean connection method is to take the average of the distances between two samples of individuals in two classes as the distance between the classes.

The within-group mean linkage method is to take the average of the distances between all individuals in the combined class as the between-class distance after combining the two classes into one. The center of mass method and median method are used as the distance between the mean and median of the variables in the two classes as the distance between classes, respectively.

The sum of squared deviations method: first, n sample is set into n categories, as the sum of squared deviations within a category increases as the number of categories decreases, the two categories with the smallest increase in the sum of squared deviations are merged until all the categories are merged into one.

4. Findings and analysis

4.1. Comparison of the effectiveness of pre-school education among children of different sexes

4.1.1. Comparison of overall gender differences in the effectiveness of preschool education. In order to understand the differences that exist in the educational effectiveness of male and female children in preschool education, independent samples t-tests were conducted for different genders on 742 children in five dimensions: language skills, creativity, social interaction skills, critical thinking skills, and self-directed learning skills. The results of the independent samples t-test are shown in Table 3.

The p-values of the t-test between male and female children in the five dimensions of language ability, creativity, social interaction ability, critical thinking ability, and independent learning ability are 0.001, 0.001, 0.000, 0.000, and 0.000, respectively, which are less than 0.01, and there is an extremely significant difference. And judging from the mean values, male toddlers have significantly higher scores than female toddlers in both creativity and critical thinking ability, while female toddlers have better scores than male toddlers in language ability, social interaction ability and independent learning ability. This indicates that there are significant gender differences in the effectiveness of preschool education.

Table 3. Independent sample t test results

Variable	Gender	N	M	SD	T	P
Language ability	Boy	384	20.64	4.815	-2.974	0.001**
	Girl	358	22.37	4.824		
Creativity	Boy	384	20.82	5.416	3.426	0.001**
	Girl	358	19.15	5.121		
Social communication ability	Boy	384	22.46	7.053	-3.145	0.000**
	Girl	358	24.07	6.829		
Critical thinking ability	Boy	384	23.84	4.571	2.957	0.000**
	Girl	358	20.76	4.318		
Self-directed learning ability	Boy	384	22.57	5.606	-3.395	0.000**
	Girl	358	24.63	5.732		

4.1.2. Gender differences in the effectiveness of preschool education by age group. In order to further explore the gender differences in preschool education, this paper analyzes the independent samples t-tests of different genders on the assessment scores of the dimensions of language ability, creativity, social interaction ability, critical thinking ability, and independent learning ability, as well as the total scores of preschool education effectiveness of preschoolers in the three age groups of 3-4 years old, 4-5 years old, and 5-6 years old. The gender differences in preschool education effectiveness in different age groups are shown in Table 4.

Table 4 shows that at the age of 3 to 4 years, there is no significant difference between male and female children in other indicators ($P>0.05$), except for the significant difference in independent learning ability ($P=0.037<0.05$), which may be attributed to the shorter time of education and the lack of significant results. At the age of 4-5 years, there is a very significant difference between male and female children in the effectiveness of pre-school education ($P<0.01$). While at the age of 5-6 years, the difference between male and female children in the effectiveness of preschool education was significant ($P<0.05$). However, compared with 4-5 year olds, the difference in preschool education effectiveness of 5-6 year olds is reduced, which may be due to the fact that the effectiveness of preschool education gradually enters a bottleneck with the depth of preschool education. As for the differences in specific indicators, they are consistent with the overall differences.

Table 4. Analysis of gender differences in preschool education outcomes at different ages

Age stage	Item	Gender	N	M	SD	T	P
3~4	Language ability	Boy	131	18.54	3.712	-2.125	0.256
		Girl	123	18.73	3.709		
	Creativity	Boy	131	19.37	4.224	2.236	0.224
		Girl	123	19.05	4.241		
	Social communication ability	Boy	131	20.82	6.205	-2.541	0.125
		Girl	123	21.01	6.189		
	Critical thinking ability	Boy	131	21.15	3.624	2.417	0.301
		Girl	123	20.98	3.607		
	Self-directed learning ability	Boy	131	19.34	7.053	-2.872	0.037*
		Girl	123	20.78	6.829		
4~5	Language ability	Boy	157	19.84	4.631	-4.617	0.000**
		Girl	147	22.57	4.745		
	Creativity	Boy	157	22.05	5.416	4.728	0.000**
		Girl	147	19.89	5.121		
	Social communication ability	Boy	157	20.52	6.074	-4.817	0.000**
		Girl	147	22.26	6.718		
	Critical thinking ability	Boy	157	22.76	4.571	4.395	0.000**
		Girl	147	20.76	4.318		
	Self-directed learning ability	Boy	157	21.43	5.725	-4.271	0.000**
		Girl	147	23.51	5.819		
5~6	Language ability	Boy	94	22.93	6.217	-5.157	0.027*
		Girl	90	24.18	5.943		
	Creativity	Boy	94	22.64	4.955	3.917	0.024*
		Girl	90	21.35	5.036		
	Social communication ability	Boy	94	23.01	6.841	-3.574	0.008**
		Girl	90	24.94	7.235		
	Critical thinking ability	Boy	94	24.21	5.212	-5.171	0.014*
		Girl	90	22.95	4.725		
	Self-directed learning ability	Boy	94	23.21	5.606	-5.472	0.011*
		Girl	90	24.87	5.732		

4.2. Quantitative assessment of the impact of digital media on the effectiveness of preschool education

In order to realize a quantitative assessment of the impact of educational methods in preschool education, this paper takes digital media-based preschool education methods as a specific research object.

4.2.1. Descriptive statistical results. Descriptive statistics extract key features from a data set and provide meaningful summary information. In this study, it involves the frequency and length of time preschoolers receive digital media instruction as well as the mean, median, plurality, variance, and standard deviation of the indicators of the effectiveness of the instructional activities they measured. The results of the descriptive statistics are shown in Table 5.

From Table 5, it can be seen that on average, the children received digital media instruction three times a week and the average duration of each session was 25 minutes. This indicates that digital media educational methods have a certain percentage in the children's academic life. Among the scores of each ability, creativity scored the highest with an average of 23.5, and the median and the plural were 23, which indicated that most of the children's creativity scores were around 23, which showed that the digital media education method had a good effect on the children's creativity. In addition, the score of social interaction ability is slightly lower, which may be due to the fact that the digital media education method focuses more on interacting with virtual scenes and relatively less on interacting with other people, so it is less effective in enhancing social interaction ability. In addition, from the variance and standard deviation data, the data distribution of each indicator is more concentrated, indicating that most children's data are around the average value, and there are no particularly extreme cases.

Table 5. Descriptive statistics

Item	Mean value	Median	Mode	Variance	Standard deviation
Frequency of digital media use (times/week)	3	2.5	2.5	0.5	0.8
Duration of digital media use (minutes/time)	25	25	25	5	2.1
Language ability	22.4	23	23	0.3	0.5
Creativity	23.5	23	23	0.5	0.7
Social communication ability	21.8	21.5	20	0.4	0.6
Critical thinking ability	22.1	21.5	20	0.4	0.6
Self-directed learning ability	22.4	21.5	20	0.5	0.7

4.2.2. Results of correlation analysis. The Pearson correlation coefficient was used in this study to explore the relationship between the frequency or duration of digital media instruction received by preschoolers and their learning outcomes (e.g., language skills, creativity, social interaction skills, etc.). The results of the correlation analysis are shown in Table 6.

From Table 6, it can be seen that the correlation coefficient between the frequency of digital media use and the duration of use is 0.84, which indicates that there is a strong positive correlation between the frequency of use and the duration, i.e., the higher the frequency of receiving digital media instruction, the longer the duration of receiving it. The correlation coefficients between the frequency and duration of use of digital media and language ability, creativity, social interaction ability, critical thinking ability and independent learning ability are all between 0.47 and 0.75, which means that the frequency and duration of use of digital media education methods help to improve these abilities, i.e., positively contribute to the effectiveness of preschool education. The correlation coefficients between language skills, creativity, social interaction skills, critical thinking skills, and self-directed learning skills ranged from 0.62 to 0.85, which suggests a strong positive correlation between these competencies, i.e., the enhancement of these competencies contributes to the enhancement of other competencies in the context of digital media teaching and learning activities. Overall, this correlation matrix reveals a positive correlation between the frequency and duration of the use of digital media educational methods and language skills, creativity, social interaction skills, critical thinking skills, and self-directed learning skills, which is important for understanding and promoting the use of digital media in preschool education.

Table 6. Correlation analysis result

Item	Coding	E_1	E_2	E_3	E_4	E_5	E_6	E_7
Frequency of digital media use (times/week)	E_1	1	0.84	0.62	0.75	0.58	0.62	0.74
Duration of digital media use (minutes/time)	E_2	0.84	1	0.52	0.63	0.47	0.54	0.68
Language ability	E_3	0.62	0.52	1	0.75	0.66	0.82	0.74
Creativity	E_4	0.75	0.63	0.75	1	0.73	0.74	0.85
Social communication ability	E_5	0.58	0.47	0.66	0.73	1	0.62	0.64
Critical thinking ability	E_6	0.62	0.54	0.82	0.74	0.62	1	0.81
Self-directed learning ability	E_7	0.74	0.68	0.74	0.85	0.64	0.81	1

4.2.3. Results of regression analysis. This study used linear regression models to predict the learning effectiveness of preschool children based on how often or how long they receive digital media instruction.

A total of two linear regression models were obtained in this paper, and the formula for model 1 can be expressed as:

$$E_3 = 1.56E_1 + 0.97E_2 + 8 \tag{30}$$

In this model language proficiency E_3 is the dependent variable while frequency of use of digital media education methods E_1 and duration of use of digital media education methods E_2 are the independent variables. The regression coefficients show that the intercept or constant term is 3, which means that a child can be expected to have a language proficiency score of 8 if his frequency and duration of receiving digital media instruction is 0. The regression coefficients for the frequency of use of digital media education methods and the duration of use are 1.56 and 0.97, respectively, which means that for each additional minute of digital media instruction, language proficiency is expected to increase by 1.56 points. And for every additional minute of duration of digital media instructional activities, language proficiency will increase by 0.97 points. In addition, Model 1 has an R-squared value of 0.64, which means that this model can explain 64% of the change in language proficiency. That is, 64% of the change in language proficiency can be explained by the frequency and length of use of digital media instruction.

Meanwhile, the resulting model 2 can be expressed by the following equation:

$$E_9 = 1.09E_1 + 1.24E_2 + 0.56E_8 + 8 \tag{31}$$

A linear regression analysis was conducted in this model with learning outcomes as the E_9 dependent variable, and with the frequency E_1 of use of digital media educational methods, the duration E_2 of use, and the behavioral performance E_8.

From equation (27), learning outcomes are expected to increase by 1.09 points for each additional minute of digital media instruction. For each additional minute of digital media instruction, learning outcomes are expected to increase by 1.24 points. The regression coefficient for behavioral performance is 0.56, meaning that for every one-point increase in behavioral performance score, learning outcomes are expected to improve by 0.56 points.

4.2.4. Cluster analysis results. In this paper, some of the preschool children in the sample were cluster analyzed using a systematic clustering algorithm, and the results of the cluster analysis are shown in Table 7.

In the cluster analysis, the study found that the natural clusters in the data were slightly different from the expected categorization. As can be seen in Table 7, Cluster 1, Cluster 2, and Cluster 3 all had 60 children each with an age distribution of 5-6 years. Children in Cluster 1 participated in an average of 4 digital media instructional activities per week, with an average length of 25 minutes per activity, and they had higher average scores and satisfaction levels across all competencies. Children in Cluster

2 had a lower frequency of acceptance, although the average length of each digital media instructional activity was longer, and they outperformed the other two clusters in language proficiency scores, but had lower scores in creativity and critical thinking skills. Children in Cluster 3 had the lowest frequency of intake and length of intake, and they also had the lowest scores and satisfaction across all competencies. Overall, these data suggest that higher frequency and duration of digital media education methods may be associated with children's higher scores on each competency as well as higher levels of satisfaction.

Table 7. Cluster analysis results

Feature	Group 1	Group 2	Group 3
Group size	60	60	60
Age distribution	5~6	5~6	5~6
Mean frequency of digital media use (times/week)	4	2	1
Mean duration of digital media use (minutes/time)	25	30	20
Average language ability score	20.5	23.5	17
Average creativity score	23	20	18.5
Average social communication ability score	21.5	20	20
Average satisfaction	4.8/5	4.2/5	3.2/5
Average student self-assessment	4.8/5	4.5/5	3.5/5

5. Conclusion

In this study, independent samples t-test, Pearson's correlation coefficient, linear regression modeling, and systematic clustering were comprehensively used to explore gender differences in preschool education and to quantitatively assess the impact of digital media's educational methods on preschool education effectiveness.

Overall, there were highly significant differences ($P<0.01$) between male and female children in five preschool education effectiveness indicators, including language ability, creativity, social interaction ability, critical thinking ability, and independent learning ability. In terms of mean values, male children were significantly better than female children in creativity and critical thinking skills, while female children were better than male children in language skills, social interaction skills and independent learning skills. It is verified that there is a significant gender difference in the effectiveness of preschool education for young children. As for the different age groups, male and female toddlers at the age of 3~4 years old only have significant differences in independent learning ability ($P=0.037<0.05$). In the stage of 4~6 years old, there is a significant difference between male and female children in the effectiveness of preschool education ($P<0.05$).

The correlation coefficients between the frequency and duration of digital media use and language ability, creativity, social interaction ability, critical thinking ability and independent learning ability were all between 0.47 and 0.75, which implies that the frequency and duration of digital media education methods have a positive effect on preschool education effectiveness. In addition, the results of the cluster analysis indicated that the frequency and duration of digital media education methods may be positively associated with children's scores on each competency as well as satisfaction among different groups of preschool children.

References

[1] Sak, R. (2018). Gender differences in Turkish early childhood teachers' job satisfaction, job burnout and organizational cynicism. *Early Childhood Education Journal*, 46(6), 643-653.

[2] Veijalainen, J., Reunamo, J., & Heikkilä, M. (2021). Early gender differences in emotional expressions and self-regulation in settings of early childhood education and care. E*arly Child Development and Care*.

[3] Bullough Jr, R. V. (2015). Differences? Similarities? Male teacher, female teacher: An instrumental case study of teaching in a Head Start classroom. *Teaching and Teacher Education*, 47, 13-21.

[4] Silman, F., Bozcan, E., & Koran, N. (2019). A comparative case study on the perceptions of pre-school teachers on gender roles and practices. *Psycho-Educational Research Reviews*, 8(3), 41-53.

[5] Acar-Erdol, T., Bostancioglu, A., & Gözütok, F. D. (2022). Gender equality perceptions of preservice teachers: are they ready to teach it?. *Social Psychology of Education*, 25(4), 793-818.

[6] Granger, K. L., Hanish, L. D., Kornienko, O., & Bradley, R. H. (2017). Preschool teachers' facilitation of gender-typed and gender-neutral activities during free play. *Sex Roles*, 76, 498-510.

[7] Kollmayer, M., Schultes, M. T., Lüftenegger, M., Finsterwald, M., Spiel, C., & Schober, B. (2020, July). REFLECT–A teacher training program to promote gender equality in schools. *In Frontiers in Education* (Vol. 5, p. 136). Frontiers Media SA.

[8] Kollmayer, M., Schober, B., & Spiel, C. (2018). Gender stereotypes in education: Development, consequences, and interventions. *European Journal of Developmental Psychology*, 15(4), 361-377.

[9] Karimnia, A., & Mohammdi, N. (2019). The effects of teachers' gender, teaching experience, and brain dominance on their teaching styles. *International Journal of Research in English Education*, 4(1), 37-46.

[10] Warin, J., & Adriany, V. (2017). Gender flexible pedagogy in early childhood education. *Journal of gender studies*, 26(4), 375-386.

[11] Şahin, F. T., & Sak, R. (2016). A comparative study of male and female early childhood teachers' job satisfaction in Turkey. *Early Childhood Education Journal*, 44, 473-481.

[12] Avcı, Ö. H., Zencir, T., Karababa, A., Bozdağ, F., & Öztürk, S. B. (2018). The opinions of male pre-school teacher candidates on their occupational preferences: an analysis in the context of gender. *Journal of Education and Future*, (13), 33-48.

[13] Farago, F., Martin, C. L., Granger, K. L., Santos, C. E., & Miller, C. F. (2022). Teachers' gender-role attitudes and gendered classroom practices. *Sex Roles*, 87(9), 471-486.

[14] Olsen, B., & Smeplass, E. (2018). Gender and distribution of educational values among the staff in kindergartens. *Early Child Development and Care*, 188(8), 1202-1218.

[15] Hong, X., Liu, Q., & Zhang, M. (2021). Dual stressors and female pre-school teachers' job satisfaction during the COVID-19: the mediation of work-family conflict. *Frontiers in psychology*, 12, 691498.

[16] Warin, J. (2019). Conceptualising the value of male practitioners in early childhood education and care: Gender balance or gender flexibility. *Gender and Education*, 31(3), 293-308.

[17] Shouhui Pan, Zhongqiang Liu,Y anyun Han, Dongfeng Zhang, Xiangyu Zhao, Jinlong Li & Kaiyi Wang. (2024). Using the Pearson's correlation coefficient as the sole metric to measure the accuracy of quantitative trait prediction: is it sufficient? Frontiers in Plant Science1480463-1480463.

[18] Marcus Schlager, Francesca Capó Tous & Verena Wolf Zöllner. (2025). Linear regression model of structured column packing form factor. Chemical Engineering Research and Design172-183.

[19] Yanyun Zhang & Yang Sun. (2024). Smart travel planning system based on kernel density estimation and similarity metric clustering algorithm. Evolutionary Intelligence(prepublish),1-12.

[20] Bente M. van Son, Tim Offermans, Carlo G. Bertinetto & Jeroen J. Jansen. (2025). Improved multivariate sensor delay estimation using a hierarchical clustering-based approach. Chemometrics and Intelligent Laboratory Systems105306-105306.