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META-ANALYSIS APPROACH TO DETECT THE EFFECT OF STUDENT ENGAGEMENT ON ACADEMIC ACHIEVEMENT

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Abstract. *Numerous studies have indicated that student engagement is an important factor to promote the quality of education. Previous studies have shown a lot of related results in this topic; however, limited studies have demonstrated directly their integration in terms of comparing different findings and determining related influenced factors among these studies. This study examined the relationship between student engagement and academic achievement in related studies through comprehensive meta-analysis (CMA). The result reveals: (1) there is a close relationship existing between student engagement and academic achievement, and specifically, the correlations between behavioral, emotional, cognitive engagement and academic achievement are .299 ($p < .001$), .232 ($p < .001$), and .238 ($p < .001$) respectively; (2) in different levels of education, it has shown moderating effect on behavioral engagement and academic achievement; (3) there is moderating effect of education levels on the relationship between the three dimensions of student engagement and academic achievement. The findings may further enrich the knowledge of this field.*

Keywords: Academic achievement, Student engagement, Comprehensive meta-analysis (CMA), Student learning, Knowledge discovery

1. **Introduction.** Most researchers have proposed that student engagement is the key to academic success [1-3]. Previous studies have indicated that education quality can be improved through student engagement and that student engagement should include assessment indices of student learning success and failure. However, the field of education currently disregards the importance of these indices [4]. Student engagement is the degree to which students are engaged in learning in the formal education process and refers to the time, effort, and energy they commit to educational learning tasks, such as school-related learning activities and coursework [5]. Previously, the definition of *student engagement* was neither uniform nor unambiguous. In addition, because student engagement encompasses several facets of the learning process, it was regarded as multidimensional, and various methods were developed to classify these dimensions. Among these methods, the classification of the dimensions of emotional engagement as behavioral, emotional, and cognitive was relatively clear. Thus, most researchers have adopted this categorization [1,2,6,7]. Academic achievement indicators are defined according to scores on achievement

tests or the grade point average (GPA) for each school year or semester. However, overall performance in learning is a fundamental indicator; thus, an overall score for student learning assigned by teachers can be used as an indicator of academic achievement [8]. We defined academic achievement as achievement test scores in languages, mathematics, or science, year-end or semester GPA, or the score assigned by teachers to students regarding overall performance in learning.

Some studies have determined a correlation between student engagement and academic achievement. However, whether this correlation exists at different levels of education is unclear. This study conducted comprehensive meta analysis (CMA) to discover the knowledge covered in previous related studies. The primary contribution of this study is to examine the correlation between student engagement and academic achievement, but we also considered whether this relationship is affected by education levels. On the basis of the objective, this study proposed the following questions. (a) What are the results of a meta-analysis of the correlation between student engagement and academic achievement? (b) Is there a difference in the relationship between student engagement and academic achievement at different levels of education? In this paper, the discussion includes the methods related to CMA, results, and conclusions.

2. Method.

2.1. Research targets. This study examined research on student engagement and academic achievement by searching the ERIC and EBSCO host databases. These databases focus on literature in the fields of education and educational psychology. We performed searches using the keywords "student engagement" and "academic achievement" in the title or abstract fields. The participants of the studies had to be students in elementary school, junior or high school, or college. We found that most studies have used samples of students in the United States. To avoid cultural differences affecting the study results, we included only those studies that have focused on American students. Finally, considering when the student engagement concept gained prominence, we limited our searches to articles published between 1990 and 2014. Finally, we included 58 articles on student engagement and academic achievement.

2.2. Models for meta-analysis. In this study, a meta-analysis of the relationship between each of the three dimensions of engagement (i.e., behavioral, emotional, and cognitive) and academic achievement was performed. Subsequently, Hedges' one-way analysis of variance (ANOVA) was employed to test the moderating effects of education levels on academic achievement. Finally, meta-analysis was again performed to determine the overall correlation between student engagement and academic achievement. This study used the effect size (r) research method and set cognitive engagement, emotional engagement, and behavioral engagement as the research variables. The effect size in each correlation analysis was calculated and analyzed using CMA. During the meta-analysis, each study was compared to determine whether its results were homogeneous before the effect size was combined. Our criteria for selecting a model are as follows.

A homogenous effect size of a study indicates that the variability in the study results was caused by a sampling error. These effect sizes can be combined to determine an average effect size. We accepted the fixed effect, and calculated using CMA, for further testing.

An effect size that did not pass the homogeneity test indicates that the variability in the study results was not caused solely by a sampling error and may have been affected by moderators. Heterogeneity may likely have included a random variation effect in addition to a sampling error. In this case, we accepted the random effect calculated using CMA.

2.2.1. *Fixed effects model.* To determine moderators that may have caused heterogeneity in the study results, an analysis and exploration of the moderators should be included. Based on the self-process model of student learning, numerous moderators of student engagement and academic achievement are worth investigating. However, we restricted our investigation to education levels and achievement types because of limitations imposed by the data provided by the collected studies and our focus on the research questions to obtain meaningful results. Education levels were categorized as higher education, secondary education, and primary education.

One-way ANOVA was used to determine the Q value in the homogeneity tests and to determine whether to accept or reject the fit of the fixed effects model. An explanation of equations used in combining effect sizes and homogeneity tests is as follows [9]:

- Use Equation (1) to calculate Fisher's Z_r value, using the original r value provided by studies or a converted r value;
- Use Equation (2) to calculate the variation in Fisher's Z_r value;
- Use Equation (3) to determine the weighted average Fisher's $\bar{z}_r$ value after combining effect sizes;
- Use Equation (4) to determine the variation in weighted average Fisher's $\bar{z}_r$ value;
- Use Equation (5) to calculate the Q_{fix} value of the homogeneity test. Compare the Q_{fix} value with the p value. Determine whether p was significant ($p < .05$). When $p > .05$, it means the effect size was homogeneous.

$$Z_{ri} = \frac{1}{2} \ln \left[\frac{1+r}{1-r} \right] \tag{1}$$

$$v_i = \frac{1}{n_i - 3} = \frac{1}{w_i} \quad (n_i \text{ is the sample size of the } i\text{th study}) \tag{2}$$

$$\bar{z}_r = \frac{\sum_{i=1}^{k} w_i Z_{ri}}{\sum_{i=1}^{k} w_i} \quad (k \text{ is the sum of combined effect sizes}) \tag{3}$$

$$v_. = \frac{1}{\sum_{i=1}^{k} w_i} \tag{4}$$

$$Q = \sum_{i=1}^{k} w_i \left(z_{ri} - \bar{z}_r \right)^2 \tag{5}$$

In this study, Q was used to determine whether homogenous or not judged by $p > .05$ or $p < .05$. If p was higher than .05, then the study result was deemed homogeneous, and the fixed effect calculated using CMA was accepted. If p was less than .05, then the study result was deemed heterogeneous and required moderator analysis. However, the Q value determines only whether homogeneity exists, but I^2 can be used to indicate the degree of variation in effect size. The standards for I^2 are as follows: 25% represents low heterogeneity, 50% represents moderate heterogeneity, and 75% represents high heterogeneity [10]. When heterogeneity is high, the fixed effects model is not a good fit for the data [11,12].

If the fixed effects model was used, the r value could be found to give the weighted average Fisher's $\bar{z}_r$ value by consulting a reference table or by reverse engineering using Equation (1). The calculated r value represented the combined effect size and was used in significance testing. If the p value was less than .05, then a correlation existed between the research variables. Equation (6) can be used to calculate the 95% confidence interval of the weighted average combined effect size r.

$$\bar{z}_r \pm 1.96\sqrt{v_.} \tag{6}$$

2.2.2. *Random effects model.* If the random effects model was used, then the variation of weighted average Fisher's $\bar{z}_r$ value was calculated using Equation (7). In Equation (3) and Equation (5), which are used to calculate the weighted average Fisher's $\bar{z}_r$ value and Q value, respectively, w_i^* is used instead of w_i. To calculate the 95% confidence interval, $v_\cdot^*$ is used instead of $v_\cdot$.

$$v_\cdot^* = \sum_{i=1}^{k} w_i^* = \sum_{i=1}^{k} \frac{1}{v_i + \hat{\tau}^2}$$
$$\text{where } \hat{\tau}^2 = \left[\begin{array}{ll} \frac{Q_{\text{fix}} - (k-1)}{\sum_{i=1}^{k} w_i - \sum_{i=1}^{k} w_i^2 / \sum_{i=1}^{k} w_i} & \text{if } Q_{\text{fix}} \geq k-1 \\ 0 & \text{if } Q_{\text{fix}} < k-1 \end{array} \right] \qquad (7)$$

The random effects model was used when the effect size of a study was heterogeneous and required an exploration of relevant moderators. All characteristic variables of the sample in this study were categorical variables; therefore, categorical variables were used in the discussion of moderators. First, using a method similar to one-way ANOVA, we separated the Q_{fix} variable in the homogeneity test into Q_B, representing the between-group variation, and Q_W, representing the residual variation. If the results showed that in-group variation was homogeneous but between-group variation was heterogeneous, then this categorical variable had a moderating effect on the research variables. This is one reason that the Q_{fix} variable in the homogeneity test is the determinant of heterogeneity.

2.2.3. *Mixed effects model.* If Q_W and Q_B both reached the significance level of .05, then whether this category of variables contains moderators cannot be determined. In these instances, we employed the mixed effects model. The mixed effects model considers variability in study results produced by moderators. The mixed effects model includes a random variation in addition to sampling error [13]. In addition, effect size was defined according to the r value standards proposed by Cohen [14], where $r = .1$ is a small effect, $r = .3$ is a medium effect, and $r = .5$ is a large effect.

2.3. **Testing for publication bias.** To test for publication bias, we used the fail-safe number suggested by Rosenthal [15]. The fail-safe number in this study refers to the number of studies without significant results, unpublished studies, or studies with null results that would nullify the results of the meta-analysis when the significance level is .05. If the fail-safe number was higher than the tolerance level, or $5k + 10$, where k is the number of studies included in the meta-analysis, then the meta-analysis results were not affected by excluded studies.

3. **Results.** Table 1 presents the meta-analysis results of the effect of the three dimensions of student engagement on academic achievement. All of the Q_{fix} values of behavioral engagement, emotional engagement, and cognitive engagement, representing each dimension's effect size on academic achievement, reached significance levels of .001, indicating that the variation was much larger than the sampling error. The effect sizes were not homogenous, and I^2 values showed high heterogeneity. The CMA showed the correlations between the three dimensions of student engagement and academic achievement from low to moderate, when the fixed effects model and random effects model were used. Because the effect sizes were heterogeneous, the moderators with heterogeneous effects had to be examined. In addition, the fail-safe numbers ($p < .05$) of academic achievement and behavioral engagement, emotional engagement, and cognitive engagement were 50,293, 9,540, and 7,639, respectively, which were all significantly higher than the tolerance levels of 300, 200, and 175, respectively. This result indicated a high reliability and that a high number of studies without significant results must be included to overturn the results of the meta-analysis; therefore, studies not included did not affect the results of the meta-analysis.

Table 1. The results of the effect of the three dimensions of student engagement on academic achievement by meta-analysis

Student engagement	No. of effect sizes	Model	Average of effect size	95% confidence interval		$Q_{\text{fix (df)}}$	I^2	Fail-safe number (.05)
				lower	upper			
Behavioral	58	Fixed effects	.290***	.284	.296	$2328.026_{(57)}$***	97.552	50,293
		Random effects	.299***	.255	.343			
Emotional	42	Fixed effects	.150***	.140	.160	$519.264_{(41)}$***	92.104	9,540
		Random effects	.232***	.192	.272			
Cognitive	33	Fixed effects	.166***	.156	.176	$545.315_{(32)}$***	94.132	7,639
		Random effects	.238***	.191	.284			

*$p < .05$; **$p < .01$; ***$p < .001$

3.1. **Effect of education levels.** A significant correlation was observed between each of the three dimensions of student engagement and academic achievement. However, the effect size analysis showed heterogeneity, which required relevant moderators to be investigated. In this study, we analyzed the education levels. The fixed effects model homogeneity test was performed to analyze the three levels of education moderators: higher education, secondary education, and primary education. Table 2 shows that the Q_{fix} values of most of the moderators achieved significant levels of .001. The residual variation (Q_W) and the variation of the education level variable (Q_B) reached statistical significance, indicating that a variability caused by random variation may still exist in the three dimensions of student engagement. Thus, the mixed effects model, instead of the fixed effects model, should be adopted to fit the data.

Table 2. Results of the meta-analysis of the relationship between student engagement and academic achievement moderated by education levels

Student engagement	Education level	No. of effect sizes	Fixed effects model			Mixed effects model			
			$Q_{\text{fix (df)}}$	$Q_{w\text{ (df)}}$	$Q_{B\text{ (df)}}$	Avg (r)	95% confidence interval		$Q_{B\text{ (df)}}$
							Lower	upper	
Behavioral	University	10	$73.748_{(9)}$***	$2139.252_{(55)}$***	$188.774_{(2)}$***	.208	.115	.297	$10.071_{(2)}$**
	High school	36	$1893.813_{(35)}$***			.350	.289	.408	
	Elementary school	12	$171.692_{(11)}$***			.224	.153	.292	
Emotional	University	5	$23.915_{(4)}$***	$432.848_{(39)}$***	$86.416_{(2)}$***	.213	.085	.333	$0.464_{(2)}$
	High school	31	$348.495_{(30)}$***			.227	.183	.271	
	Elementary school	6	$60.438_{(5)}$***			.264	.153	.368	
Cognitive	University	5	$24.310_{(4)}$***	$529.500_{(30)}$***	$15.815_{(2)}$***	.168	.069	.264	$5.557_{(2)}$
	High school	26	$504.564_{(25)}$***			.259	.202	.314	
	Elementary school	2	$0.626_{(1)}$			.178	.135	.220	

*$p < .05$; **$p < .01$; ***$p < .001$

Table 2 shows the results of the mixed effects model analysis of the moderating effect of education levels on the relationship between the three dimensions of student engagement and academic achievement. As shown in the table, the average effect size r of the three dimensions of student engagement moderated by education levels reached statistical significance. A homogeneity test was performed on education levels and the three dimensions of student engagement, and only the Q_B value of behavioral engagement reached a significance level of .001. Heterogeneity existed in the effect size of each education level. Thus, the moderating effect of education levels on the correlation between the three dimensions of student engagement and academic achievement affected only the behavioral engagement dimension.

4. **Conclusions.** The results show that student engagement and academic achievement yielded a significant average effect size r and that they were correlated, which was verified using comprehensive meta-analysis. Using the random effects model, the correlation between academic achievement and behavioral engagement, emotional engagement, and cognitive engagement was respectively .299 ($p < .001$), .232 ($p < .001$), and .238 ($p < .001$), indicating low to moderate correlations.

The meta-analysis performed in this study revealed that education levels exerted a moderating effect on only the relationship between behavioral engagement and academic achievement. The effect of secondary education was significantly higher than that of primary education or higher education, indicating that, in secondary schools, high behavioral engagement among students results in high academic achievement.

This study has examined the relationship between student engagement and academic achievement in related studies through CMA. Comprehensive meta-analysis has also demonstrated it is a useful tool for synthesizing the previous studies to make it more succinctly. Furthermore, the findings may enrich the knowledge of the field and the results may be applied to educational practices. For further studies, the researchers can apply this model to test research topics in other fields.

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