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META-ANALYSIS ON THE EFFECTIVENESS OF INVENTION EDUCATION IN SOUTH KOREA: CREATIVITY, ATTITUDE, AND TENDENCY FOR PROBLEM SOLVING

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Abstract. *This study aims to synthesize the research findings on the effects of K-12 invention education regarding creativity, attitudes toward invention, attitudes toward science, and tendency for technological problem solving in South Korea. Meta-analyses were conducted by calculating the effect size of 37 studies, including theses and journal papers associated with the implementation of invention education, published in South Korea. The overall effect size was medium (0.694), and invention education was found to have an effect on education. The effect sizes determined by the dependent variables and the categorical variables indicated that invention education had a positive impact. In other words, invention programs have helped improve K-12 students' creativity, attitudes toward science, and tendency for technological problem solving. However, the number of program sessions and participants in invention programs did not have an impact on the benefits of invention education. Considering the effects of invention education on the students' perspectives, this study could be helpful to both K-12 educational researchers and practitioners in the fields of science and technology education. Further studies are needed to develop the concrete instructional strategies of invention education for K-12 science and technology classrooms.*

Key words: *invention education, meta-analysis, science education, South Korea, technology education.*

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Introduction

Inventions are the driving force behind the convenient lives that people enjoy today. As a result, the importance of invention is increasing. As intellectual property rights obtained for inventions determine national competitiveness, many countries around the world are competing to secure more intellectual properties. As the phrase "patent war" suggests, different countries are in a fierce battle for invention. The only way to win this battle is to create high added value by fostering a workforce that can quickly grasp new social contexts and creatively solve problems.

For that reason, attempts have been made to teach invention to K-12 (K-12 is a shortening of kindergarten through twelfth grade) students. In the early days of invention education, experts debated whether it was possible to teach invention to students. Shlesinger (1980, p. 572) argued, "If people including children could be taught, for example, how to play a musical instrument, why couldn't they be taught to invent?"

Through the invention education program, students experience hands-on activities (McCormack, 1984; Plucker & Gorman, 1999; Saxon, Treffinger, Young, & Wittig, 2003) and team-based problem-solving strategies (Gorman & Robinson, 1998; Gorman, Richards, Scherer, & Kagiwada, 1995; Plucker & Gorman, 1999; Saxon et al., 2003). These invention activities positively affect students' inventing ability (Carlson & Gorman, 1990; Plucker, 2002; Rule, Baldwin, & Schell, 2009; Westberg, 1996; Wongkraso, Sitti, & Piyakun, 2015), creativity (Kuehn & Krockover, 1986; McCormack, 1984; Rule et al., 2009; Saxon et al., 2003; Wongkraso et al., 2015), attitude or interest toward particular subjects (Kuehn, 1985; Kuehn & Krockover, 1986; Rule et al., 2009; Shlesinger, 1982), and motivation to learn particular subjects (Gorman, Plucker, & Callahan, 1998; Shlesinger, 1982).

Despite the positive effect of invention education, few studies related to invention education have been published in international journals. Westberg (1996) noted, "Although educators, psychologists, and inventors believe in the value of instruction in inventing for students and society, research investigations of this topic have been infrequent and limited" (p. 256). Plucker and Gorman (1999) stated that "published research on efforts to improve children's inventive skills, especially at the secondary level, is almost nonexistent" (p. 141). In another recent study, Wongkraso et al. (2015) observed that "these studies have been researched very little among secondary school students for teaching invention" (p. 523). Throughout the world, teaching invention to K-12 students is uncommon.

In contrast to the lack of research on invention education around the world, in South Korea, studies on the topic have been actively conducted and published in Korean journals. According to Lee (2015), there were only 12 studies (8.7%) on invention education for infants and K-12 students between 1992 and 2004, but the number increased to 61 (44.2%) between 2005 and 2009 and to 138 (65.4%) between 2010 and 2014. The active research on invention education in South Korea can be explained by the fact that invention became part of the national middle school curriculum in 2010 and has been included in the national primary school curriculum since 2014 (National Curriculum Institute Center, 2015). Invention has become an important learning content of the national curriculum in South Korea.

Readers who are not familiar with the concept of invention education may ask what educational effects it has on K-12 students. This can be a difficult question to answer, considering the insufficient amount of research on the subject in international journals. However, in South Korea, many studies and measurements related to invention education have already been conducted; these can help answer the question above. This study aims to verify the effect of invention education in South Korea by using meta-analysis. Meta-analysis methods have been widely used to synthesize findings of prior studies and draw an objective conclusion on the effectiveness of an intervention (Borenstein, Hedges, Higgins, & Rothastein, 2009).

Lee (2015) described the trends of invention education in South Korea based on prior studies, while Kwon and Lee (2014) identified the effects of invention education on students' creativity. However, these studies merely reviewed previous studies and did not include a comprehensive discussion on the effects of invention education.

Therefore, this study aims to synthesize the effects of invention education for K-12 students in South Korea through meta-analysis. This study is an attempt to synthesize findings of previous research on invention education to measure the overall effect size and compare the effects of variables that can influence the effects of invention education. Prior studies have indicated that invention is an important educational topic in science and technology subjects (Plucker & Gorman, 1999; Rule et al., 2009; Westberg, 1996). Therefore, this study will provide confirmed evidence on valuable effects of invention education for researchers and science or technology teachers who wish to design or implement effective invention education programs in the future.

This study focuses on the following research questions:

1. What is the overall effect size of invention education?
2. What is the effect size of invention education according to categorical variables (creativity, attitude toward invention, attitude toward science, technological problem solving, activities, grade, class type, subject, publication)?
3. What is the effect size of invention education according to continuous variables (number of sessions, number of students)?

Theoretical Background

Invention Education for K-12

It is vital to understand that world history is based on invention (Kuehn & Krockover, 1986). If students can understand the importance of invention, they can also better understand human history and predict the future more reliably. For this reason, diverse attempts have been made to enable K-12 students to access invention.

Saxon et al. (2003) introduced Camp Invention® for students to experience invention in a camp. Camp Invention® is a large event in which over 400 students across the nation participate and perform interesting invention activities by combining science, history, mathematics, art, and other subjects in U.S. These activities help students understand academic subjects and develop teamwork.

Invention competitions also provide students with a good opportunity to access invention. In the 1980s, Japan produced more creative patents than the United States as a result of the "Exhibition of the Contests on

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School Children's Inventions," which began in 1941 (Sakamoto, 1989). Students were motivated to engage in creative activities while preparing for and participating in this competition, and the motivation later led to numerous patents in Japan (Sakamoto, 1989). Smaller invention competitions have also been introduced. Yoon (2008) organized invention contests at the end of each semester so that students would review what they had learned during the semester in U.S. These contests were thought to enable students to experience the process of invention and develop their ideas further. Some invention competitions were based on simple machines. Hadi-Tabassum (1997) suggested that Goldberg machine competitions can help students develop a sense of cooperation or high level problem-solving skills.

In addition to camps and competitions, other attempts have been made to teach invention to students. Shlesinger (1982) proposed a step-by-step program for teaching invention to students. Teachers reported increased interest in science and history among students who participated in the program. McCormack (1984) recommended an instructional model for teaching invention. In his quasi-experimental study among primary school students, he found that creativity, problem-solving skills, and attitude toward science positively increased in the experimental group. Kuehn and Krockover (1986) investigated that inventing instruction affected creativity skills and attitudes toward science in primary school students. They found no significant difference in attitudes toward science and creativity skills between the experimental group and control group but a significant difference in the measure of inventiveness. Westberg (1996) found that classes that induce interest in invention at the beginning motivated students to invent. She reported that her program increased the number of inventions made by the students but did not improve the quality of inventions. Rule et al. (2009) conducted inventing activities based on animal analogies and the SCAMPER (Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Reverse) technique. They checked the invention content score and creativity score each week; these scores were higher in the experimental group than in the comparison group. Wongkraso et al. (2015) conducted classes based on an invention learning approach for secondary students who chose a science course. The results showed a significant increase in the students' inventing ability.

These studies imply that invention education for students can be conducted as part of school education as well as in other forms. According to previous research, variables that can be influenced by invention education for K-12 students include inventing ability, creativity, and motivation or attitude toward academic subjects.

Science-Technology Curriculum and Invention Education in South Korea

In South Korea, the same national curriculum is applied to all students from the first grade to the ninth grade. During these years, students are required to complete certain courses. One of the most significant recent changes in the Korean curriculum was the inclusion of invention in the national science-technology cluster curriculum. Since 2010, seventh-grade students have been learning invention as part of their school education. The curriculum includes invention under topics such as "Meaning and Value of Invention," "The Procedure from Invention to Patent," "Understanding Various Inventing Techniques," and "Specifying Ideas for Invention." The revised curriculum further emphasizes the subject of invention and includes it in the regular curriculum not only for middle school education but also for primary and high school education. Based on the revised curriculum, invention is now taught to primary students under topics such as "Relationship between Technology and Invention," "Inventing Techniques and Ideas," and "Make Creative Household Goods." Invention is also taught to middle school students under topics such as "Producing and Materializing Ideas," "Divergent Thinking Skills," and "Convergent Thinking," as well as to high school students under topics such as "Technological Innovation and Invention" and "Patent" (National Curriculum Information Center, 2015).

As the importance of invention becomes increasingly recognized in South Korea, research on invention education has also increased. In South Korea, 211 studies related to invention in preschool, primary, and secondary education were published between 1992 and 2014, 199 studies (94.3%) of which were conducted in the last 10 years (Lee, 2015). Moreover, 64 studies (30.3%) of these studies are related to the science-technology curriculum, whereas 159 studies (75.4%) did not specify specific subjects.

Researchers in South Korea have also used meta-analysis to examine the effects of invention education. Kwon and Lee (2014) performed a meta-analysis on the effects of invention education on creativity. Their results showed that the overall effect size of invention education on creativity was .652, which is a medium effect size.

The literature review suggests that invention education is being actively researched in South Korea. Some studies investigated part of the effects of invention education, while others looked into the overall trends in invention education. However, there is no comprehensive research on the effects of invention education on specific variables; therefore, it is necessary to investigate the subject.

Methododology of Research

Subjects

In this study, theses and academic journal articles on invention education published between 2002 and 2015 in South Korea were used as subjects for a meta-analysis of the effect size of invention education. The data were collected using the National Assembly Digital Library (http://www.dlibrary.go.kr), Research Information Sharing Service (http://www.riss.kr), and DBpia (http://www.dbpia.co.kr), among other tools. A total of 2,380 theses and 2,163 journal articles were found by searching "invention," 84 theses and 158 journal articles were found by searching "TRIZ," and 14,089 theses and 20,983 journal articles were found by searching "innovation." From the search results, this study selected 127 theses and 218 journal articles related to invention education for primary and secondary schools. From these studies, this study excluded those that were irrelevant to verifying the effects, such as qualitative research, correlation research, and comparative studies, and finally selected 37 papers for meta-analysis. Studies that proposed multiple results from different levels of school were analyzed to separate results. For the theses that were also published in academic journals, this study selected only the journal article versions.

Analysis

This study reviewed 37 papers and identified meaningful categories for coding. Gender was excluded because gender was mixed in all the studies. This study finalized key categories such as dependent variables, activity type, grade, class type, giftedness, publication, number of sessions, and number of students. These variables were coded by two experts of invention education and one meta-analysis expert. When they disagreed on the analysis, the experts discussed and decided on the code together.

The effect size was measured using the standardized mean difference effect size (*d*) proposed by Borenstein et al. (2009). In meta-analysis, studies that include more cases are assumed to be more accurate than those with fewer cases. In this study, weight was applied according to the method proposed by Hedge and Olkin (1985). The effect size found in the meta-analysis results was interpreted according to the criteria presented in Table 1, which is the interpretation criteria proposed by Cohen (1977).

Table 1. Interpretation of Effect Size.

Small effect size	Medium effect size	Large effect size
≤.20	.20 ~ .80	≥ .80

Homogeneity Test

A homogeneity test was performed using the test formula proposed by Borenstein et al. (2009), based on the assumption that individual findings used for analysis were collected from the same population. As shown in Table 2, the effect sizes obtained from the subjects were heterogeneous (Q = 156.776, p < .05, I^2 = 66.194). Therefore, in this study, the random-effects model was used to compare the effect sizes. The data were processed using Comprehensive Meta-Analysis 2. Meta-ANOVA was conducted to examine the effect sizes according to sub-factors, and meta-regression was used to look into the linear relation with variables.

Table 2. The result of homogeneity test(Q).

Q-value	*df(Q)*	*p-value*	I^2
156.776	53	0.000	66.194

Publication Bias Test

To secure the internal validity of the meta-analysis results, this study conducted a publication bias test, which can be analyzed in various ways. First, when using rank correlation as proposed by Begg and Mazumdar (1994), there was no significant correlation (tau = 0.36, $p > .05$). Second, a degree of left-right symmetry was found when this study examined the distribution of effect sizes based on the funnel plot. Based on these results, this study could not find a publication bias in the subjects of this study.

Results of Research

Overall Effect Size

Table 3 shows the results of meta-analysis on the educational effects of invention education. This study included a total of 37 papers and 54 effect sizes. The overall effect size was 0.694, and the 95% confidence interval was between 0.588 and 0.801. According to the effect size interpretation criteria proposed by Cohen (1977), the overall effect size was medium.

Table 3. The result of meta-analysis on the educational effects.

Number Studies	*Q*-value	*p*-value	E.S.	95% CI	Standard Error
54	156.776	<.05	0.694	0.588 ~ 0.801	0.033

Effect Size According to Categorical Variables

Table 4 shows the effect sizes according to the dependent variables. The effect size for creativity (0.743) was the largest, followed by attitudes toward invention (0.689), attitudes toward science (0.686), and tendency for technological problem solving (0.444). According to the effect size interpretation criteria proposed by Cohen (1977), invention education had a medium effect size on all the dependent variables.

Table 4. Effect size by dependent variables.

Outcomes	Number Studies	Q-value	p-value	E.S.	95% CI	Standard Error
Creativity	32	112.749	<.05	0.743	0.591 ~ 0.895	0.055
Attitudes toward invention	15	26.466	<.05	0.689	0.522 ~ 0.856	0.041
Attitudes toward science	2	1.686	<.05	0.686	0.213 ~ 1.158	0.167
Technological problem-solving	5	10.166	<.05	0.444	0.147 ~ 0.741	0.081

Table 5 shows the effect size according to the categorical variables. The effect size according to the activity type was largest in non-hands-on (0.703) and hands-on (0.691) activities, while the effect size according to the school level was largest in primary school (0.723), followed by high school (0.709) and middle school (0.530). According to class type, the effect size was largest in the regular class (0.836), followed by the discretion class (0.698) and camp (0.610). The effect size according to subjects was larger among general students (0.703) than among gifted students (0.635). The effect size according to publication was larger in theses (0.734) than in academic journals (0.667). According to Cohen's (1977) effect size interpretation criteria, the effect size on all the variables was medium.

Table 5. Effect size by categorical variables.

Category	Sub-Category	Number Studies	Q-value	p-value	E.S.	95% CI	Standard Error
Activity type	Non hand-on	17	40.516	<.05	0.703	0.523 ~ 0.884	0.051
	Hand-on	37	115.042	<.05	0.691	0.559 ~ 0.823	0.043
School grade	Primary school	45	146.826	<.05	0.723	0.598 ~ 0.848	0.072
	High school	2	0.398	<.05	0.709	0.395 ~ 1.022	0.035
	Middle school	7	7.915	<.05	0.53	0.347 ~ 0.714	0.043
Class type	Regular class	13	19.615	<.05	0.836	0.642 ~ 1.030	0.051
	Discretion class	21	48.424	<.05	0.698	0.537 ~ 0.859	0.044
	Camp	20	76.385	<.05	0.61	0.431 ~ 0.789	0.06
Subject	General students	48	141.134	<.05	0.703	0.586 ~ 0.821	0.036
	Gifted students	6	13.246	<.05	0.635	0.360 ~ 0.910	0.076
Publication	These	23	46.881	<.05	0.734	0.580 ~ 0.888	0.042
	Academic journals	31	105.756	<.05	0.667	0.524 ~ 0.810	0.047

Effect Size According to Continuous Variables

Meta-regression was performed to examine linear relationship with the number of sessions and students. The results are shown in Table 6.

Table 6. Effect size by continuous variables.

Category	Covariate	Coefficient	Standard Error	z-value	p-value
Number of sessions	intercept	0.8828	0.1194	7.39	0
	slope	-0.0119	0.0067	-1.77	0.0762
Number of students	intercept	0.7687	0.093	8.26	0
	slope	-0.0016	0.0016	-0.98	0.3272

The gradient according to the number of sessions in the program was –0.0119 ($p > .05$), while the gradient according to the number of students was –0.0016 ($p > .05$). Neither of the gradients was statistically significant.

Discussion

This study provided a comprehensive and systematic analysis of research related to invention education in South Korea, and it attempted to suggest the ways in which invention education impacts the educational experience of students. Meta-analysis was performed based on the standardized mean difference effect size. This section presents a discussion of the findings.

First, the overall effect size of invention education was medium (0.694) in South Korea. This indicates that the

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findings of this study are consistent with those of prior studies in that invention education affects creativity (Kuehn, 1985; Kuehn & Krockover, 1986; McCormack, 1984), attitudes towards, or interest in a subject (Plucker & Gorman, 1999; Rule et al., 2009; Westberg, 1996), as well as the students' inventing ability (Shlesinger, 1980; Westberg, 1996; Wongkraso et al., 2015). Invention education can be a powerful approach for improving students' creativity and attitudes toward science and technology. Educational policymakers or curriculum designers should include invention education content or processes in their educational agenda by considering the benefits of invention education in the areas of science and technology education.

Second, the effect size based on dependent variables was greatest for creativity (0.743), followed by attitudes toward invention (0.689), attitudes toward science (0.686), and tendency for technological problem solving (0.444). The effect size of invention education based on dependent variables was medium. Most invention education programs are believed to have a positive effect on creativity, as they are implemented with diverse thinking skills, problem-solving activities, and hands-on experiences to create new solutions or strategies. The results of this study support those of Kwon and Lee (2014), whose meta-analysis showed that invention education has a positive educational effect on creativity. In addition, attitudes towards invention or science had a medium effect size. Positive attitudes toward science and invention may have been formed as students used scientific knowledge to solve the problems they were assigned in invention education. However, only two effect sizes were used to analyze the attitudes toward science.

Third, with respect to the effect size based on categorical variables, non-hands-on activities (0.703) had a slightly larger effect size than hands-on activities (0.691). Although hands-on activities are generally believed to improve inventing ability, this study found that invention programs based on reading, writing, and thinking techniques also have similar educational effects. The majority of research focuses on hands-on activities; therefore, further research needs to be conducted on non-hands-on activities. The effect size based on the school level was largest in primary school (0.723), followed by high school (0.709) and middle school (0.530). As suggested by the number of cases in the meta-analysis, most of the studies focused on primary school education. For years, researchers have been investigating the various invention education methods used in primary schools, and the accumulated knowledge is likely to improve the educational effects of invention education. While the effect size was also relatively large in high school, it is important to note that only two cases were involved in the interpretation. Although invention is included in the middle school curriculum, only seven cases were found in middle school, and the effect size was small. Further research needs to be conducted on effective ways to teach invention in middle schools. The effect size according to the class type was largest in the regular class (0.836), followed by the discretion class (0.698) and camp (0.610). This finding suggests that invention can be taught more effectively when combined with other academic subjects than when it is taught separately. South Korea promotes convergence education as a policy, and integrating invention into various academic subjects is expected to have a positive effect on different subjects. Moreover, the sections related to invention that were included in the science-technology curriculum in South Korea can create synergy in secondary education. In terms of educational subjects, the effect size was larger among general students (0.703) than among gifted students (0.635). The results of this study showed that invention education had a slightly stronger educational effect on general students who previously did not have access to invention programs. This finding supports the results of a study conducted by Choi (2014) who argued that anyone who has an interest in and passion for invention can develop their inventing ability through education and training, and that invention is not exclusive to those who have a special talent for it. Hence, invention is a subject that can be embraced by all K-12 students, and invention education must be expanded and globally implemented. The effect size based on type of publication was larger in theses (0.734) than in academic journals (0.667). This finding contradicts that of Ragosta (2010), who suggested that academic journal articles generally have a larger effect size than theses. Further research is needed in order to investigate the reason for this contradiction.

Fourth, in terms the continuous variables, the number of sessions and students in the programs did not have a significant impact on the effect size. Prior studies reported that there was no clear correlation between the effect size and the number of program sessions (Bellini, Peters, Benner, & Hopf, 2007; Ekers, Richars, & Gilbody, 2008). This finding suggests that the selection of programs in invention education is more important than the duration of those programs. However, invention programs should be implemented with the smallest number of participants as possible because they rely on hands-on and/or design activities (Kroesbergen & Van Luit, 2003).

Conclusions

This study confirmed the effects of invention education for primary and secondary students using meta-analyses. In particular, invention education was found to have an educational effect on students' creativity, attitudes toward invention, attitudes toward science, and tendency for technological problem solving. Based on these findings, the educational community in STEM education fields should pay careful attention to invention education. Globally, science education researchers have conducted initial studies related to invention education (Kuehn & Krockover, 1986; McCormick, 19984; Shlesinger, 1982), but, until recently these types of studies have been rare in this field (Wongkraso et al., 2015).

This study proposes several topics for future research. First, while this study confirmed the benefits of invention education regarding K-12 students' perspectives, further studies are needed to address practical considerations for practitioners and policymakers. Second, in this study, the meta-analysis was conducted using the standardized mean difference effect size, assuming that the variables are mutually independent. Because the variables could possibly influence one another, multilevel meta-analysis should be conducted by controlling the levels of influence that different variables could exert.

References[1]

*Ahn, J. B., Kim, D. J., Park, S. Y., Lee, J. B., Yoon, H. B., Park, K. T. (2009). Effects of invention-related reading activities in creative abilities and creative personalities of elementary third grade students. *Korean Journal of Teacher Education, 25* (1), 226-241.

*Bae, J. E. (2011). *Effect of task-based instant challenge on the primary learners' creative thinking abilities and scientific attitude* (Unpublished master's thesis), Seoul National University of Education, Seoul, Korea.

Begg, C. B., & Mazumdar, M. (1994). Operating characteristics of a rank correlation test for publication bias. *Biometrics*, 1088-1101.

Bellini, S., Peters, J. K., Benner, L., & Hopf, A. (2007). A meta-analysis of school-based social skills interventions for children with autism spectrum disorders. *Remedial and Special Education*, *28* (3), 153-162.

Borenstein, M., Hedges, L. V., Higgins, J.P., & Rothastein, H.R. (2009). *Introduction to meta-analysis*. West Sussex, UK: John Wiley & Sons.

*Byeon, S. H. (2010). *Development and application of invention educational program for students' creativity* (Unpublished master's thesis), Seoul National University of Education, Seoul, Korea.

Carlson, W. B., & Gorman, M. E. (1990). Understanding invention as a cognitive process: The case of Thomas Edison and early motion pictures, 1888-91. *Social Studies of Science, 20* (3), 387-430.

*Cho, D. H. & Jung, J. H. (2009). Effect of invention education in practical arts on child creativity. *Journal of Elementary Education, 25* (1), 137-164.

*Choi, E. H. (2012). *Development and application of idea generating education program using synectics technique* (Unpublished master's thesis), Seoul National University of Education, Seoul, Korea.

*Choi, K. E., Jung, J. H., Kang, J. P., Kwak, H. R., & Jung, M. K. (2014). The effect on the invention attitude and the emotional factors of children through invention experience activity. *Journal of Korean Practical Arts Education, 20* (2), 145-164.

*Choi, M. H. (2004). *Effect of invention education on creativity and scientific attitudes of elementary school students* (Unpublished master's thesis), Cheongju National University of Education, Cheongju, Korea.

*Choi, Y. H. (2007). The effect of invention education program on technological problem solving styles and invention attitudes of the elementary, middle and high school students. *The Journal of Practical Arts Education Research, 13* (3), 271-288.

Choi, Y. H. (2014). *Invention education educational research*. Seoul: Hyungseol Press.

*Choi, Y. H., Moon, D. Y., Kim, Y. I., Lee, H. G., Lee, J. W., Kang, K. K., … & Kim, D. H. (2007). The analysis of effect and development of education program for junior invention leader. *Journal of Korean Practical Arts Education, 20* (4), 171-193.

*Chung, M. K., Choi, K. E., Kang, J. P., Kwak, H. R., & Jung, J. H. (2013). The effect on invention attitude and satisfaction of invention activity program based on life. *Journal of Korean Practical Arts Education, 26* (4), 233-248.

Cohen, J. (1977). *Statistical power analysis for the behavioral sciences*. New York: Academic Press.

Ekers, D., Richards, D., & Gilbody, S. (2008). A meta-analysis of randomized trials of behavioural treatment of depression. *Psychological medicine*, *38* (05), 611-623.

Gorman, M. E., & Robinson, J. K. (1998). Using history to teach invention and design: The case of the telephone. *Science and Education, 7*(2), 173–201.

Gorman, M. E., Plucker, J. A., & Callahan, C. M. (1998). Turning students into inventors: Active learning modules for secondary students. *Phi Delta Kappan, 79* (7), 530-535.

Gorman, M. E., Richards, L. G., Scherer, W. T., & Kagiwada, J. K. (1995). Teaching invention and design: multi-disciplinary learning modules. *Journal of Engineering Education, 84* (2), 175-185.

1 References marked with an asterisk indicate studies included in the meta-analysis.

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Hadi-Tabassum, S. (1997). The invention convention: mind meets simple machines. *Science & Children, 34*(7), 24.

Hedge, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis*. New York: Academic Press.

*Heo, H. R. (2006). *Effect of inventive education, using internet information, for the enlargement of creative and inventive recognition of elementary school students* (Unpublished master's thesis), Yeungnam University, Gyeongsan, Korea.

*Huh, O. J. (2002). *Study on the effect of invention education based on invention techniqued upon primary school students' creativity progress* (Unpublished master's thesis), Seoul National University of Education, Seoul, Korea.

*In, J. B. (2005). *Effects of reading activity related to invention in creative ability and creative personality of elementary third grade students* (Unpublished master's thesis), Korea National University of Education, Cheongju, Korea.

*Jang, J. K. & Jung, J. H. (2014). The effect of invention attitude and mental health of children through invention education in elementary school. *Journal of Korean Practical Arts Education, 27* (4), 61-75.

*Kim, E. H. (2008). *A study on the effect of invention education on the improvement of creativity* (Unpublished master's thesis), Yeungnam University, Gyeongsan, Korea.

*Kim, G. Y. (2003). *Effects of the invention program for improving the creativity of the youth* (Unpublished doctoral dissertation), Myoungji University, Seoul, Korea.

*Kim, G. Y. & Moon, S. H. (2013). Effect of invention education program using traditional technology on elementary school children's image of traditional technology and interest in the invention. *Journal of Korean Practical Arts Education, 19* (4), 251-270

*Kim, H. P., Nam, S. K., Lee, H. K., Kye, G. S., Lee, J. H., Yim, B. Y., … & Jung, S. J. (2007). Development and effects of the invention education program applied with TRIZ to enhance elementary school students' creativity. *Journal of Korean Practical Arts Education, 20* (2), 1-20.

*Kim, J. H. & Moon, S. H. (2009). Development of practical arts education program for the improvement of elementary school children's interest in the invention Using TRIZ method. *Journal of Korean Practical Arts Education, 22* (1), 93-114.

*Kim, K. O. (2011). *The effect of wiki basd creative problem solving model on improvement of elementary student's creativity in invention education* (Unpublished master's thesis), Korea National University of Education, Cheongju, Korea.

*Kim, K. Y., Ham, H. I., Kim, H. J., Kim, Y. M., & Kim, K. S. (2013). The development and effectiveness of the invention education program with the inventions of great inventors as materials. *The Korean Journal of Technology Education, 13* (3), 47-69.

*Kim, S. C. (2006). *Effect of TRIZ-based invention education on the elementary school students' creativity progress* (Unpublished master's thesis), Inha University, Incheon, Korea.

*Kim, S. C. (2011). *Effect of invention-idea exchange activities on students' invention attitude* (Unpublished master's thesis), Seoul National University of Education, Seoul, Korea.

*Kim, S. J. (2014). *Effect of invention education program by using recycling products based on SCAMPER technique on creativity of elementary school students* (Unpublished master's thesis), Seoul National University of Education, Seoul, Korea.

*Kim, Y. J. (2014). *Development and application of musical instruments invention education program using SCAMPER technique* (Unpublished master's thesis), Seoul National University of Education, Seoul, Korea.

*Kim, Y. S. (2000). *Fabrication and study education of invention program development and creative mind* (Unpublished master's thesis), Kyungsung University, Pusan, Korea.

Kuehn, C. (1985). *An analysis of fifth and sixth grade students' acquisition of the process of inventing*. Dissertation Abstracts International, *46*, 3672-A. (University Microfilms No. DA8529295)

Kroesbergen, E. H., & Van Luit, J. E. (2003). Mathematics interventions for children with special educational needs a meta-analysis. *Remedial and Special Education*, *24* (2), 97-114.

Kuehn, C., & Krockover, G. H. (1986). *An analysis of fifth- and sixth-grade students' acquisition of the inventing process*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco. (ERIC Document Reproduction Service No. ED 276 618.)

Kwon, H. S., & Lee, D. K. (2014). The effects of invention education on students' creativity: A meta-analysis. *The Journal of Practical Arts Education Research, 20* (3), 145-163.

Lee, E. S. (2015). Research trends and issues of invention education in early childhood, elementary and secondary education : focussing on journals in Korea. *Korean Journal of Teacher Education, 31* (3), 331-354.

*Lee, K. H. (2015). *A study on the effect of development and application of the plane production activity oriented elementary science invention program for gifted pupils* (Unpublished master's thesis), Daegu National University of Education, Daegu, Korea.

*Lee, K. H., & Park, C. S. (2013). The effects of mission invention program of team project on the primary students' creativity and satisfaction. *The Journal of Creativity Education, 13* (3), 71-90.

*Lee, K. H., & Tae, J. M. (2013). Development and application effects of creative problem-solving invention program of focusing on team project. *Journal of Gifted/Talented Education, 12* (3), 95-116.

McCormack, A. J. (1984). Teaching inventiveness. *Childhood Education, 60* (4), 249-255.

*Moon, H. J., & Moon, D. Y. (2013). The effect of creative instant challenge activities on the inventively gifted elementary school students' creative personality. *Journal of Korean Practical Arts Education, 26* (1), 179-194.

*Moon, S. H. & Kim, O. B. (2011). The development of an invention education program using the wise life textbook for children's creativity. *Journal of Research in Curriculum Instruction, 15* (2), 333-351.

*Nam, S. K., & Choi, W. S. (2006). Effects of TRIZ`s 40 inventive principles application on the improvement of learners` creativity. *Journal of the Korean Institute of Industrial Educators, 31* (2), 203-232.

National Curriculum Information Center. (2015). *Permalink national curriculum of korea.* Retrieved August 15, 2015, from http://ncic.go.kr/english.index.do

*Park, S. W., & Yu, Y. K. (2012). The effect of invention gifted education program(IGEP) based on inventors. Journal of Korean Practical Arts Education. *Journal of Korean Practical Arts Education, 25* (4), 243-264.

Plucker, J. A. (2002). What's in a name? Young adolescents' implicit conceptions of invention. *Science Education, 86* (2), 149-160.

Plucker, J. A., & Gorman, M. E. (1999). Invention is in the mind of the adolescent: effects of a summer course one year later. *Creativity Research Journal, 12* (2), 141–150.

Ragosta, P. (2010). *The effectiveness of intervention programs to help college students acquire self-regulated learning strategies: A meta-analysis*. (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database.

Rule, A. C., Baldwin, S., & Schell, R. (2009). Trick-or-treat candy-getters and hornet scare devices: second graders make creative inventions related to animal adaptations. *The Journal of Creative Behavior*, *43* (3), 149-168.

Sakamoto, T. (1989). Promotion of school children's invention in Japan. *Journal of Science Education in Japan*, *13* (2), 95-101.

Saxon, J. A., Treffinger, D. J., Young, G. C., & Wittig, C. V. (2003). Camp invention®: A creative, inquiry-based summer enrichment program for elementary students. *The Journal of Creative Behavior, 37* (1), 64-74.

*Seo, S. J. (2003). *Study on the effect of invention education on improvement of creativity* (Unpublished master's thesis), The University of Suwon, Hwaseong, Korea.

Shlesinger Jr, B. E. (1980). I teach children to be inventors. *Educational Leadership, 37* (7), 572-573.

Shlesinger Jr, B. E. (1982). An untapped resource of inventors: gifted and talented children. *Elementary School Journal*, *82* (3), 215-220.

*Wang, Y. J. (2014). The effect of creative invention education program on the gifted elementary students' creative personality. *Journal of Korean Practical Arts Education, 27* (3), 189-203.

Westberg, K. L. (1996). The effects of teaching students how to invent. *The Journal of Creative Behavior, 30* (4), 249-267.

Wongkraso, P., Sitti, S., & Piyakun, A. (2015). Effects of using invention learning approach on inventive abilities: A mixed method study. *Educational Research and Reviews, 10* (5), 523-530.

*Yang, J. G. (2012). *Development and application of TRIZ-based elementary invention education which utilize recyclable materials* (Unpublished master's thesis), Seoul National University of Education, Seoul, Korea.

Yoon, J. (2008). Invention: contest. science activities: *Classroom Projects and Curriculum Ideas, 45* (3), 3-10.

*Yoon, T. H., & Moon, S. H. (2014). Development and application of an invention educational activities using fairy tales for elementary school student`s creativity. *The Journal of Korea Elementary Education, 25* (1), 335-350.

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