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Elementary Students' Perceived Images of Engineers

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Abstract: The number of students choosing science, technology, engineering, and mathematics (STEM) related careers are declining. Thus it became a worldwide challenge in the 21st century. As public images of the engineers are unfavorable and inaccurate, misconceptions and stereotypes about engineers are prevailing. The purpose of this study was to investigate elementary school students' perceived mental and pictorial images of engineers and the nature of engineering work. This study involved 512 fifth and sixth grade students (Boys: 287 and Girls: 225) from four elementary schools at one of metropolitans in South Korea. The Draw An Engineer-Korean version (DAE-K) was developed based on Draw an Engineer (DAE) and Draw a Scientist (DAS), and Song and Kim (1999)'s instruments. A pilot-tested was conducted with 33 elementary students prior to the main study. The students were asked to answer how they think the engineers would be, to draw an engineer at work, and to write the engineer's personal information and the job description. Engineers were perceived as a person fixing, building, manufacturing, working outdoors in labors' clothes such as a robe. Engineers were shown with building tools, robots, airplanes, machines, conveyor belt, etc. Moreover, compared to the scientists, engineers were perceived as less intelligent, less imaginative, and less accurate. The results of this study revealed that elementary school students had a lack of accurate images of engineers. Students' current perceived images of engineers could help educators find the baselines for the future engineering education in elementary schools. In addition, the findings of this study could also contribute to the development of engineering education in terms of gender issues, STEM career choice, and even cultural diversity.

Keywords: scientist, engineer, drawing, image, perception, STEM education, career

Introduction

The number of students choosing science, technology, engineering, and mathematics (STEM) related careers are declining (Oware, 2008; Thompson and Lyons, 2005). Public image of the engineers is unfavorable and inaccurate so that many elementary and secondary students hold misconceptions and stereotypes about engineers (Fralick et al., 2009; Oware, 2008; Pearson and Young, 2002).

Research has showed that the perceptions children hold about STEM impact their learning and future career decision (Buldu, 2006; Knight and Cunningham, 2004; Losh et al., 2008; Newton and Newton 1998; Oware, 2008; Thompson and Lyons, 2008). Looking at the research on images of scientists, the images of scientists that students hold are formed at very early years of elementary school; moreover, those images remain stable through high school and college (Jung et al., 2012; Lyons and Thompson, 2006; Newton and Newton, 1992, 1998; Rahm and Charbonneau, 1997). Chambers (1983) stated that the stereotypical images of a scientist should already be apparent at the second grade. Jenkins (2006) noted that some STEM related major students decided their career choice based on the decision made when they were 12 years old.

Many authors pointed out that there has not been much research conducted regarding students' perceived images of engineers, whereas students' perceptions of scientists have been well documented (Knight and Cunningham, 2004; Oware, 2008). Oware (2008) noted that "more research on children's perceptions of

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engineers is needed to allow researchers to better understand how children who decide to enroll in engineering programs learn about and develop an interest in engineering" (p. 7). In addition, there have been few studies reporting the images of the engineers in non-western countries while the images of the engineers in Western countries have a rich history. As Vygotsky (1978) noted, culture influences students' thought and speech. Korean cultural beliefs about engineers and the nature of engineers could exert an impact on how Korean students perceive engineers at work. Therefore, this study could also help address cultural diversity in terms of students' perceptions of engineers.

The purpose of this study is to investigate elementary school students' perceived images of engineers and the nature of engineering work. Two research questions guiding this study are:

(1) What are the elementary school students' perceived mental images of the engineers compared to the scientists? Is there a statistically significant difference on students' perceived mental images of the engineers by gender and future career choice?

(2) What are the elementary school students' perceived pictorial images of the engineers? Is there a statistically significant difference on students' perceived pictorial images of the engineers by gender and future career choice?

To answer those research questions, students were asked to answer how they think the engineers would be, to draw an engineer at work, and to write the engineer's personal information and the job description.

Children's Drawing

Children's drawing has been used as one of the most important means to investigate the perceptions and understandings of their inner worlds (Farver et al., 2000; Losh et al., 2008). Drawing is a comfortable and age-appropriate language for children. Children can express their emotion and personality in a personally meaningful way (Oware, 2008; Thompson and Lyons, 2008). According to Smith et al. (2003), "children's drawings provide a more complete and expressive representation of their experiences than might be obtained through more traditional verbal interview methods or paper and pencil tests. They disclose children's preferences, attitudes, and biases (p. 132). White and Gunstone (2000) stated that drawing is "very open, with few limits on how the student may respond…they allow the teacher to see, and the student to reveal, qualities of understanding that are hidden from other procedures (p. 98). MacPhail and Kinchin (2004) stated the benefits of using drawings;

- Being fun and an attractive universal activity of children,
- Being a quick and efficient way to elicit a large amount of accurate information as no training or practice is required,
- Allowing children to freely choose what they want to include and not being prompted by adult's or the researcher's frame of reference,
- Allowing those unwilling, unable or too upset to express themselves verbally, or through literacy skills, an opportunity to express their viewing.
- Being an opportunity for children to provide more of their own retrieval cues, i.e., drawing one item may cue retrieval of others related (to them) aspects they wish to include in their drawing (p. 91).

Di Leo (1970) stated that "once we begin to understand the language of the child's graphic expression, we are impressed by how much the child is telling about himself through his drawings, and how worthy they are of our attention, and how revealing they may be of the child's attitudes, feelings, and intellect" (pp. 122-123). Finson (2002) also noted that "some have indicated that the perceptions of scientist held by students (or others) are related in some way to their attitudes toward science, locus of control, and self-efficacy (p. 335)."

Drawing and Thought

The theoretical framework for thought and drawing derived from Vygotsky's theory (1962, 1978). Vygotsky (1978) stated that children "can draw not only objects but also speech" (p. 118). Vygotsky (1962) suggests conveying of thought and experience requires a mediating system. Speech was the primary mediating tool and symbols, algebraic system, art, drawing, writing, and diagrams were also mediating tools. Also, Brooks (2009) noted that drawing is a salient mediation tool for thinking and for meaning making.

Luquet (2001) noted that children use an internal model in their mind to draw, namely they draw what they know and not what they see. He stated that "drawing is an activity in which children can and do make choices about what is important to them and what they would like to reveal in a drawing" (Oware, 2008, p. 30). Di Leo (1970) stated that "once we begin to understand the language of the child's graphic expression, we are impressed by how much the child is telling about himself through his drawing, and how worthy they are of our attention, and how revealing they may be of the child's attitudes, feelings, and intellect" (pp. 122-123). Wadsworth (1996) noted that "mental images are internal representations (symbols) of objects and past perceptual experiences, although they are not accurate copies of those experiences. Images are not copies of perceptions stored in the mind. As drawings bear a resemblance to what they represent, so too mental image are imitations of perceptions and necessarily bear a similarity to the perceptions themselves. In this sense, images are thought to be symbols" (p. 59-60).

In this study, drawing as Brooks (2003) stated was utilized as a mediating tool, a meaning-making tool and a cultural tool facilitate the acquisition of higher mental functions (Brooks, 2003, 2009).

Studies Related Draw-an-Engineer (DAE)

The Draw-a-Scientist-Test (DAST) has been well known tool to measure student perceptions of scientists and science, and has been valued as a valid and reliable tool for assessing students' perceptions of science and scientists (Chambers, 1983; Chiang and Guo, 1996; Finson, 2002; Finson et al., 1995; Losh et al., 2008; Newton and Newton, 1992; Newton and Newton, 1998; Song and Kim, 1999; Thompson and Lyons, 2008).

The same effort to develop the similar tool to measure students' perceptions of engineering and engineers developed the Draw-an-Engineer Checklist (Yap et al., 2003), Draw-an-Engineering-Test (DAET) (Knight and Cunningham, 2004), Draw-an-Engineer (DAE) (Thompson and Lyons, 2005), and DAET Scoring Guide (Lyons and Thompson, 2006). Yap et al. (2003) developed the Draw-an-Engineer Checklist. Knight and Cunningham (2004) used DAET for students to describe their knowledge about engineers and engineering through written descriptions and drawings. They found that students perceived engineering works as repair-type activities which were representative of blue-collar work. Thompson and Lyon (2005) developed a Draw-an-Engineer instrument to capture 3rd, 4th, and 5th grade students' perceptions of engineers and engineering. They found that students generally held the incomplete perception that engineers are primarily builders rather than a more accurate perception of an engineer as a designer or problem solver. Lyons and Thompson (2006) used DAE Scoring Guide and interviews to measure sixth graders' perceptions about engineers and engineering. Thompson and Lyons (2008) investigated 6th grade African-American student perceptions of engineering. They used DAET Scoring Guide which is a numerical coding system to measure perceptions of engineering.

Oware et al. (2007) conducted the qualitative study using a constructivist theoretical framework to investigate 3rd and 4th grade the gifted education resource institute (GERI) students' perceptions of engineers. They found that students held common misconceptions about engineers while other were knowledgeable about what engineers do. Oware (2008) measured 3rd through 6th grade gifted and talented students' perceptions of engineers using the questionnaires, interviews, and drawings. Fralick et al. (2009) investigated middle school students' perceptions of engineers and scientists through drawings and written responses. They found that the students perceived scientists as working indoors conducting experiments while they perceived engineers as working outdoors in manual labor. They found that the students portray engineers mainly outside with many civil structures, building tools, and vehicles. The things engineers are doing involve primarily lower level mental functions and physical actions (operating and making) rather than higher level mental functions (explaining and experimenting). Many studies suggested that most of students have inaccurate perceptions or the lack of perceptions.

Methods

Participants

This study involved 512 fifth and sixth grade students (Boys: 287 and Girls: 225) from four elementary schools at one of metropolitans in South Korea. Table 1 presents the participants of this study.

Table 1. Participants of this study

	5^{th} grader (Born 1999-1998)	6^{th} grader (Born 1997)	Total
Boys	168	119	287
Girls	128	97	225
Total	296	216	512

Instrument

The Draw an Engineer-Korean version (DAE-K) was developed based on DAE (Fralick et al., 2009; Thompson and Lyons, 2008; Yap et al., 2003), DAS (Chambers, 1983; Finson et al., 1995; Fralick et al., 2009; Mead and Metraux, 1957), and Song and Kim (1999)'s instruments. DAE-K consists of two domains of students' perceived images of engineers. The first section was designed to explore a mental images of engineers compared to scientists. Students were asked to answer the questions "How do you think the engineer/scientist would be" with five five-point items (1: close to negative images; 5: close to positive images). They circled an appropriate number for each item. This instrument was originally developed by Song and Kim (1999) in order to measure students' mental images of scientists and, was modified for this study. In this study, the following definitions of engineering and engineer were used to evaluate whether students' drawing is accurate or not.

> Engineering is a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants (National Research Council, 2012, p. 202).

> An engineer is a professional practitioner of engineering, concerned with applying scientific knowledge, mathematics, and ingenuity to develop solutions for technical, societal and commercial problems. Engineers design materials, structures, and systems while considering the limitations imposed by practicality, regulation, safety, and cost (Wikipedia, 2014).

Students' mental images of engineers were evaluated by compared to the images of scientists (e.g., stupid-intelligent, lazy-industrious, unimaginative-imaginative etc.). The second section was designed to explore the pictorial images of engineers. Students were asked to draw a picture of an engineer working and described their engineer concerning personal information and job description. The Draw an Engineer-Korean version (DAE-K) was pilot-tested with about 33 elementary school students prior to the main study in order to test and refine the instrument.

Procedures

Students were provided with a piece of DAE-K worksheet, pencils, erasers, and coloring supplies (crayons and markers). They were instructed to "How do you think the engineer would be" (circle an appropriate number for each item)" and "Draw a picture of an engineer working and describe your engineer (personal information and job description)", given 40 minutes as a classroom activity to complete their answers and drawings. The students were asked to present their images of the engineers compared to the scientist on the instrument investing the mental images of engineers.

Coding Drawings

Our coding began by referring DAE and DAS (Finson et al., 1995; Yap et al., 2003) checklist as a base to code the children's drawings. Two post-doctoral researchers in STEM education field developed our coding checklist in a naturalistic manner as

Fralick et al. (2009) conducted. Throughout examining 512 drawings, the coding checklists of the gender of the engineers, the objects drawn with engineers, and physical attributes of the engineers were developed. The specific features coded in students' drawing fall into four categories: 1. Gender; 2. Physical attributes of the engineers (overalls laborer's clothing, hard hat); 3. Objects drawn with engineers; and 4. Inferences of Actions. In order to ensure the inter-rater reliability (IRR) of coding, 30 drawings were randomly selected and coded by two researchers. Across the two coders, the IRR was slightly greater than 92% which was considered as an acceptable criteria for all types of situations (Cooper and Hedges, 1994; Fralick et al., 2009).

Results

The purpose of this study was to investigate the elementary school students' perceived images of engineers and the nature of engineering work. Research question one investigated how elementary school students perceived mentally engineers compared to the scientist. Their images were investigated if there were statistically significant differences by gender and future career choices. Table 2 indicates students mental images of engineers compared to the images of scientists.

As shown in Table 2, looking at the means of mental image of engineers, students answered 4.03 (industrious), 3.94 (intelligent), 3.79 (imaginative), and 3.33 (open minded), and 3.17 (exciting). On the other hand, looking at the means of mental image of scientists, students showed a little more positive perceptions (4.50: imaginative, 4.49: intelligent, 4.17: industrious, 3.47: open minded, and 3.37: exciting). Overall, students assessed engineers (mean: 3.65) less positively than scientists (mean: 4.00). Not surprisingly, students seemed to recognize the scientists more positive compared to engineers. In particular, students saw engineers (mean: 3.94) are less intelligent than scientist (mean: 4.49) and scientists (mean: 4.50) are

Table 2. Students' mental images of engineers compared to the images of scientists

Items of mental image	Engineers		Scientists		*t*-value	p
	Mean	SD	Mean	SD		
(1) Stupid-intelligent	3.94	0.94	4.49	0.89	-11.47**	.000
(2) Lazy-industrious	4.03	0.95	4.17	0.95	-2.99**	.003
(3) Unimaginative-imaginative	3.79	1.10	4.50	0.78	-13.59**	.000
(4) Closed minded-open minded	3.33	0.93	3.47	0.99	-2.81**	.005
(5) Boring-exciting	3.17	1.14	3.37	1.15	-3.00**	.003
Mean	3.65		4.00			

**p< .05

Table 3. Students' mental images of engineers by gender

Items of mental image	Gender	N	Mean	SD	*t*-value
(1) Stupid-intelligent	Boys	287	3.90	0.97	-1.30
	Girls	225	4.00	0.90	
(2) Lazy-industrious	Boys	287	3.95	0.97	-2.07**
	Girls	225	4.12	0.91	
(3) Unimaginative-imaginative	Boys	287	3.74	1.14	-1.30
	Girls	225	3.86	1.05	
(4) Closed minded-open minded	Boys	287	3.32	0.94	-0.11
	Girls	225	3.33	0.92	
(5) Boring-exciting	Boys	287	3.16	1.19	-0.31
	Girls	225	3.19	1.08	

**p< .05

Table 4. Mental image of engineers by future career choice

Items of mental image	Career Choice	N	Mean	SD	t-value
(1) Stupid-intelligent	Non-STEM	375	3.94	0.94	-0.29
	STEM related	137	3.96	0.94	
(2) Lazy-industrious	Non-STEM	375	4.06	0.96	1.36
	STEM related	137	3.93	0.93	
(3) Unimaginative-imaginative	Non-STEM	375	3.77	1.11	-0.71
	STEM related	137	3.85	1.06	
(4) Closed minded-open minded	Non-STEM	375	3.32	0.91	-0.31
	STEM related	137	3.35	0.99	
(5) Boring-exciting	Non-STEM	375	3.10	1.14	-2.33**
	STEM related	137	3.36	1.12	

**p< .05

more imaginative than engineers (mean: 3.79). But, they seem to consider both engineers and scientist as persons not exciting.

Table 3 presents students' mental images of engineers by gender. Male students seem to have a little bit negative mental images of engineers compared to the female students. Female students represents 4.00 (intelligent), industrious (4.12), imaginative (3.86), open minded (3.33), and exciting (3.19). Male students represents 3.90 (intelligent), 3.95 (industrious), 3.74 (imaginative), 3.32 (open minded), and 3.19 (exciting). Overall, both male and female students perceive that engineers are persons who are intelligent, industrious, and imaginative, but not exciting jobs.

Table 4 shows how students mentally perceive engineers by their future career choice. Students' future career choices were investigated and their answers were divided into STEM related areas and Non-STEM related areas. STEM related careers include scientist, engineer, math teacher, doctor, dentist, technician, and so on while Non-STEM related careers include artist, musician, writer, and so forth. 137 (26.76%) students considered pursuing STEM related future careers while 375 (73.24%) in Non-STEM related future careers. As presented in Table 4, students considering STEM related future careers shows 3.96 (intelligent), 3.85 (imaginative), 3.35 (open-minded), and 3.36 (exciting). Regarding students considering STEM related future careers, the result indicates that there is no statistically significant difference in the mental image of boring and exciting. They might want to pursue careers in STEM related fields since they see engineers' work excited and fun.

Table 5. The gender of the engineers in the drawings

Gender of the engineer	Boy	Girl	Subtotal
Male Engineer	238	165	403
Female Engineer	15	49	64
Not identified	34	11	45
Total			512

Research question two investigated how elementary school students' perceived pictorial images of the engineers. Students were asked to draw a picture of an engineer working and described their engineer concerning personal information and job description. The specific features coded in students' drawing fall into four categories.

1. Gender
2. Physical attributes of the engineers (overalls (laborer's clothing), hard hat)
3. Objects drawn with engineers
4. Inferences of Actions

Table 5 shows the gender of the engineers in the students' drawings. 79% of male engineers (403 out of 512 drawings) and 12.5% of female engineers (64 out of 512 drawings) were drawn. Interestingly, only 6% of female engineers were drawn by boys while 23% of girls drew the female engineers. About 80% of boys seem to consider engineers as a male career.

Table 6. The physical attributes of the engineers in the drawings

Physical attributes of engineers	Gender	
	Boy	Girl
Glasses/Goggles	30	23
Lab Coat	30	32
Overalls (Laborer's clothing)	78	89
Hard Hat (Safety Helmet)	2	2

Table 7. The objects drawn with engineers

Objects	gender		Number of objects (%)
	Boy	Girl	
Robot	31	21	52 (8.8)
Computer	35	20	55 (9.3)
Car	120	98	21 (37.0)
Train	3	1	4 (0.7)
Construction Vehicle	6	4	10 (1.7)
Bridge, Building	15	8	23 (3.9)
Rocket, Space vehicles	16	6	22 (3.7)
Screw Driver, Hammer, Wrench	114	91	205 (34.8)
Total			589 (100)

After reviewing 512 drawings, the physical attributes of the engineers were identified. Most likely, students seemed to draw a technician working at outdoor situation. The engineers in their drawings wear the overalls (laborer's clothing) as the results of Frallick et al. (2009)'s study. It seems that students consider their engineers in drawings as outdoor workers. Table 6 presents the physical attributes of the engineers in the drawings. Interestingly enough, students who have non-STEM future career choice drew engineers more likely as a technician who wears laborer's clothing. Overalls were drawn by more girls and lab coat less drawn than lab coat. Moreover goggles were easily shown in their pictures. Carefully assuming, students pursuing STEM related future career choice perceive engineers accurate.

Table 7 shows the objects drawn with the engineers. After reviewing 512 drawings, the objects drawn with the engineers were investigated. Most likely, the car (37.0%) was frequently observed and tools (34.8%) such as screw driver, hammer, and a wrench were often drawn. Besides, bridge and building (3.9%), computer (9.3%), and robot (8.8%) were recurrently sketched.

Table 8. The inferred actions of the engineers in the drawings

Inferred actions	Gender	
	Boy	Girl
Making/fixing/working with hands	222	183
Operating/driving machines or vehicles	23	11
Designing/inventing/creating products	8	11
Experimenting	11	5
Teaching	7	8
Observing	8	12
No action	3	3

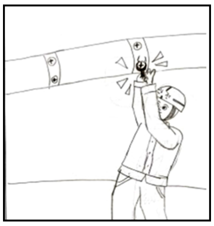
As Fralick et al. (2009) conducted, each drawing was viewed as a whole in order to infer what the engineer was doing. As the same manner, "the inferred actions were coded into the following seven categories: (1) making/fixing/working with hands, (2) operating/driving machines & vehicles, (3) designing/inventing/creating products, (4) experimenting/testing/creating knowledge, (5) explaining/teaching, (6) observing, and (7) no action" (Fralick et al., 2009, p. 63). Table 8 presents the inferred actions of the engineers in the drawings. Making, fixing and working with hands were mostly inferred actions in students' engineers.

Table 9 presents the examples of students' drawings of engineers. Ahn, 5th grade female student, drew the female engineer working with a conveyor belt. She seemed to see the engineer do a manual labor at an industrial unit. Also, Kim, 6th grade female student, portrayed a female technician fixing a car and wearing a dirty overall. On the other hand, both Jeong, 5th male student, and Min, 6th grade male student drew the male technicians welding in a factory and fixing an industrial pipe in overalls with safety helmets.

Concusions and Implications

This study aimed at investigating elementary school students' perceived mental and pictorial images of engineers and the nature of engineering work. It is significant to note that little research has been documented to present the elementary students' images of engineers rather than scientists.

Table 9. Examples of students' drawings of engineers

Surname/Gender/ Grade	Drawing of the engineer	Description of Drawing
Ahn/Female/5th		Working with a conveyor belt Safety mask
Kim/Female/6th		Fixing a car. Overall
Jeong/Male/5th		Welding in a factory Safety helmet Overall
Min/Male/6th		Showing fixing a pipe Safety helmet Overall

Looking at the elementary school students' mental images of engineers, engineers were perceived as less intelligent, imaginative, and accurate compared to the scientists and their pictorial images of engineers were perceived as a person fixing, building, manufacturing, and working outdoors on labors' clothes such as a robe. In addition, engineers were shown with building tools, robots, airplanes, machines, conveyor belt and so on. Stereotypical images of engineers could be summarized as follows.

• Less intelligent and accurate than scientists

• Outdoor works: fixing, building, manufacturing, and so on

• Overalls with safety helmets

These results echoed the findings of previous studies (Fralick et al., 2009; Oware et al., 2007). That is, elementary school students still had a lack of accurate images of engineers. As Buldu (2006) noted, students' perceptions of engineers and their interest in engineering-related careers are highly related. Fralick et al. (2009) noted "students have inaccurate perceptions of engineering. By focusing on these patterns a powerful image of engineers and engineering is revealed. It is not accurate and is probably a factor in students choosing not to pursue engineering as a career choice (p. 67). Namely, the relationship between the children's perception of engineers and their future career choice are evident (Chiang and Guo, 1996; Cunningham et al., 2006; Fralick et al., 2009; Oware, 2008). Therefore, in an effort to encourage more students to pursue STEM related jobs, especially earth and space science related works and careers, the results of this study may give teachers and educators in elementary education some clue to facilitate elementary students to build up accurate images of the engineers.

We carefully suggest that children's earlier exposure to engineering could support them to develop positive images of engineers, understand their works, and to influence on their perceptions of other science related careers (Choi, 2011; Jang and Nam, 2012). Based on the findings, further research and educational practice in STEM education focused on engineering education are needed. As Buldu (2006) noted, once teachers know what perceptions about engineers students posses, they could alter their instructional strategy and Oware (2008) noted that educators should know the students' existing perceptions of engineers as an opening to discussions about the various roles of engineers. Cunningham and Hester (2007) also stated that learning about engineering could facilitate students' accurate awareness and positive attitude toward engineers and the nature of engineering. Students' perceived present images of engineers could help give direction to the future development of curriculum in elementary schools. Also, an examination of perceived images of engineers might guide and resolve some of the current challenge attracting students into engineering field. Educational programs needs to be developed to increase students' positive images of engineers. We hope that the findings from this study can be used by teachers, educators, curriculum developers and policy makers to help them develop engineering program in elementary schools.

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References

Buldu, M., 2006, Young children's perceptions of scientists: A preliminary study. Educational Research, 48, 121-132.

Brooks, M., 2003, Drawing, thinking, meaning: Retrieved from http://www.lboro.ac.uk/departments/ac/tracey/thin/brooks.html (October 6th 2009).

Brooks, M., 2009, What Vygotsky can teach us about young children drawing. International Art in Early Childhood Research Journal, 1, 1-13.

Chambers, D.W., 1983, Stereotypic images of the scientist: The draw-a-scientist test. Science Education, 67, 255-265.

Chiang, C. and Guo, C., 1996, A study of the images of the scientist for elementary school children (ERIC Document Reproduction Service No. ED 399 148).

Choi, H., 2011, Inservice elementary teachers' perceptions of teaching skills and educational settings in implementing a problem based learning approach. Journal of the Korean Earth Science Society. 32, 334-345. (in Korean)

Cooper, H. and Hedges, L.V. (Eds.), 1994, The handbook of research synthesis. Russell Sage Foundation, New York, USA, 573 p.

Cunningham, C. and Hester, K., 2007, Engineering is elementary: An engineering and technology curriculum for children. Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education, San Antonio, TX, USA, AC 2007-8: 1-18.

Cunningham, C., Lachapelle, C., and Lindgren-Streicher, A., 2006, Elementary teachers' understandings of engineering and technology. Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education, Chicago, IL, USA, 2006-350: 1-15.

Di Leo, J.H., 1970, Young children and their drawings. Brunner/Mazel Publishers, New York, USA, 386 p.

Farver, J.A.M., Ghosh, C., and Garcia, C., 2000, Children's perceptions of their neighborhoods. Journal of Applied Developmental Psychology, 21, 139-163.

Finson, K.D., 2002, Drawing a scientist: What we do and do not know after fifty years of drawings. School Science and Mathematics, 102, 335-345.

Finson, K.D., Beaver, J.B., and Crammond, B.L., 1995, Development and field test of a checklist for the draw-a-scientist test. School Science and Mathematics, 95, 195-205.

Fralick, B., Kearn, J., and Thompson, S., 2009, How middle schoolers draw engineers and scientists. Journal of Science Education and Technology, 18, 60-73.

Jang, M. and Nam, Y., 2012, Pre-service elementary teachers' conceptions on the relative sizes of celestial bodies. Journal of the Korean Earth Science Society, 33, 645-657. (in Korean)

Jenkins, E.W., 2006, Student opinion in England about science and technology. Research in Science & Technological Education, 24, 59-68.

Jung, J., Lee, H., Go, S., and Oh, Y., 2012, Gifted elementary students' understandings about Earth systems and environmental problems. Journal of the Korean Earth Science Society, 33, 672-682. (in Korean)

Knight, M. and Cunningham, C., 2004, Draw an Engineer Test (DAET): Development of a tool to investigate students' ideas about engineering and technology. Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education, Salt Lake City, UT, USA, Session 2530: 1-11.

Losh, S.C., Wilke, R., and Pop, M., 2008, Some methodological issues with "Draw a Scientist Tests" among young children. International Journal of Science Education, 30, 773-792.

Luquet, G.H., 2001, Children's drawings. Free Association Books, London, UK, 192 p.

Lyons, J. and Thompson, S., 2006, Investigating the long-term impact of an engineering-based GK-12 program on students' perceptions of engineering. Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education, Chicago, IL, USA, 2006-1981: 1-15.

MacPhail, A. and Kinchin, G., 2004, The use of drawings as an evaluative tool: Students' experiences of sport education. Physical Education and Sport Pedagogy, 9, 87-108.

Mead, M. and Metraux, R., 1957, Image of the scientist among high school students: A pilot study. Science, 26, 284-390.

National Research Council, 2012, A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. The National Academies Press, Washington, D.C., USA, 400 p.

Newton, D.P. and Newton, L.D., 1992, Young children's perceptions of science and the scientist. International Journal of science Education, 14, 331-348.

Newton, L.D. and Newton, D.P., 1998, Primary children's conceptions of science and the scientist: is the impact of a national Curriculum breaking down the stereotype? International Journal of Science Education, 20, 1137-1149.

Oware, E., Capobianco, B., and Diefes-Dux, H., 2007, Young children's perceptions of engineers before and after a Summer engineering outreach course. Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education, Milwaukee, WI, USA, S2B: 1-18.

Oware, E., 2008, Examining elementary students' perceptions of engineers. Unpublished Ph.D. dissertation, Purdue University, Lafayette, IN, USA, 254 p.

Pearson, G. and Young, T., 2002, Technically speaking: Why all Americans need to know more about technology. National Academy Press, Washington, D.C., USA, 159 p.

Rahm, J. and Charbonneau, P., 1997, Probing stereotypes through students' drawings of scientists. American Association of Physics Teachers, 65, 774-778.

Smith, M.H., Meehan, C.L., and Castori, P.S., 2003, Children's drawings: An alternative assessment strategy. Environmental education on the internet: Received from http://naaee.org/conferences/alaska/proceedings_2003.pdf (October 7th 2009).

Song, J. and Kim, K., 1999, How Korean students see scientists: The images of the scientist. International Journal of Science Education, 21, 957-977.

Thompson, S. and Lyons, J., 2005, A study examining change in underrepresented student views of engineering as a result of working with engineers in the elementary classroom. Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education, Portland, OR, USA, 1-14.

Thompson, S. and Lyons, J., 2008, Engineers in the classroom: Their influence on African-American students' perceptions of engineering. School Science and Mathematics, 108, 197-210.

Wadsworth, B.J., 1996, Piaget's theory of cognitive and affective development (5th ed.). Longman, New York, USA, 163 p.

White, R. and Gunstone, R., 2000, Probing understanding. Falmer Press, London, UK, 196 p.

Wikipedia, 2014, Engineer, Wikepedia Corp. http://en.wikipedia.org/wiki/Engineer (August 11st 2014)

Yap, C., Ebert, C., and Lyons, J., 2003, Assessing students' perception of the engineering profession. Proceedings of the South Carolina Education for the Practical Use of Research Annual Conference, South Carolina Education for the Practical Use of Research, Columbia, SC, USA, 60-73.

Vygotsky, L., 1962, Thought and language. Harvard University Press, Cambridge, MA, USA, 287 p.

Vygotsky, L., 1978, Mind in society: The development of higher psychological processes. Harvard University Press, Cambridge, MA, USA, 159 p.

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