AC 2011-1502: ELICITING MEXICAN HIGH SCHOOL STUDENTS' IMAGES OF ENGINEERING: WHAT DO ENGINEERS DO?

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Eliciting Mexican High School Students' Images of Engineering: What Do Engineers Do?

Abstract

The purpose of this study was to identify the perceptions held by Mexican high school students about engineering and the types of work engineers perform. A pilot study was conducted using a modified version of the *Draw an Engineer* (hereafter DAE) test. One large urban public high school from Ciudad del Carmen, in the state of Campeche, was selected to conduct the study; a total of 187 students (58% female) completed the modified DAE test. The drawings and open-ended responses were analyzed following an inductive data analysis approach. Four main categories emerged to describe the data: 1) engineers in action, 2) characteristics of an engineer, 3) gender, and 4) work context. Our findings indicate that the majority of participants in this study perceive engineers as male individuals that perform activities related to the construction and oil industries.

Introduction

In the 2009 results of the *Program for International Student Assessment* (PISA), Mexican students experienced a setback in the scientific literacy indicators, and even when a significant improvement in the mathematics scores can be celebrated, Mexico is one of the countries with the largest percentages of students performing below the baseline Proficiency Level 2 in mathematics and sciences among the *Organisation for Economic Co-operation and Development* (OECD) nations[1]. Given the crisis that Mexico faces in mathematics and science education in the P-12 levels, *Universidad de las Américas Puebla* started a research program to develop solutions to help overcome this situation. This investigation is part of a broader project funded by the *Consejo Estatal de Investigación Científica y Desarrollo Tecnológico de Campeche* (Campeche State Council for Science and Technology). Its goal is to promote an early approach to engineering and science among the student population at the upper elementary, middle and high school levels of the State of Campeche by creating high quality learning environments that promote interactive classrooms and contribute to a better understanding of science and mathematics while promoting careers in science, engineering and technology.

Previous work[2] on P-12 Mexican teachers' perceptions about engineers revealed that this population perceives engineers as "thinkers" rather than "doers." Given that teachers' ideas, knowledge and attitudes towards engineering and science might influence their students' perceptions toward these fields, it is necessary to explore the conceptions held by students to prevent (or correct) potential misconceptions. Addressing potential misconceptions is of critical importance since it has been established that student's negative images and stereotypes about engineers and engineering can influence their career choice, making them less likely to pursue a career in those fields[3].

In order to identify Mexican high school students' perceptions about engineering and engineers, the following sections describe a pilot study conducted in the state of Campeche using drawings and open-ended questions as the primary data collection tools.

Methods

Participants and setting

Ciudad del Carmen is a city in the Mexican southeastern state of Campeche –a state where oil extraction is an activity of high economic impact and a considerable proportion of the population is related in some way to this activity. One large urban public high school from Ciudad del Carmen was selected to conduct the study. The institution enrolls about 1500 students from 10th to 12th grades. A convenience sample of six groups (three from 10th grade and three from 12th grade) was selected to participate in the study. A total of 187 students (58% female) completed the modified DAE test; 62% of the participants were students from 10th grade.

Data collection

Data were collected using a modified DAE test (a copy of the test worksheet is provided in the Appendix). Students in each studied group were verbally prompted to draw an engineer on the blank side of the worksheet that was provided to them. The exact wording of the instructions given to the students was: "*Cierra los ojos e imagina a un ingeniero o a una ingeniera trabajando. Ahora dibuja lo que te imaginaste en la página que está en blanco.*" [Close your eyes and imagine a male or female engineer working. Now, draw what you imagined on the blank side of the sheet]. It is worth nothing that Spanish language places nouns into gender classes; therefore, the instructions mentioned both a male (*ingeniero*) and a female (*ingeniera*) engineer to ensure gender neutrality in the test directions.

After the drawings were completed (participants were given 10 minutes to complete this task), test facilitators prompted students to answer the questions written on the back of the worksheet: 1) Describe what the engineer is doing in your drawing. Write at least two sentences; 2) List at least three words/phrases that come to mind when you think of an engineer; and 3) From your perspective, what kind of activities you think are typical of an engineer? Fifteen minutes were given to the students to complete this part of the test. All written responses were transcribed verbatim into a spreadsheet.

Data analysis

Drawings and open-ended responses were analyzed by two researchers (i.e., the last author and a doctoral student, which is the first author). Following the procedure described by Oware *et al*.[4], an inductive data analysis approach was utilized to code the drawings and written responses. After reading and rereading the questionnaire responses and discussing their impressions of the entire data set, the researchers created a coding scheme that included four main categories to describe the data (see Table 1). Using this coding scheme both researchers coded each participant's response at the same time. This procedure allowed the researchers to resolve any discrepancies during the coding process.

Table 1. Coding scheme.

Category	Category description	Subcategories
Engineers in action	Types of work that engineers perform	a. Construction related activities b. Oil related activities c. Office related activities d. Other activities
Characteristics of an engineer	Features or traits attributed to an engineer	a. Intellectual attributes (e.g., intelligence, math skills, leadership, decision making) b. Appearance (i.e., special clothing such as jumpsuits, helmets, boots, safety glasses, and gloves)
Gender		a. Female engineer (*ingeniera*) b. Male engineer (*ingeniero*) c. Unknown-gender engineer
Work context	Places associated to specific kinds of engineering work	a. Indoors (e.g., classroom, office, lab) b. Outdoors (e.g., oil rigs, construction sites)

Results

Findings discussed in this section come from a preliminary analysis of the data; i.e., the drawings and the open-ended responses (see Table 2). While these findings are divided into four categories, the focus of this paper is placed on the types of work that students perceive engineers do, and the discernable gender associated to the persona drawn/described in the modified DAE test.

Engineers in action

As exhibited in Figure 1, a significant number of participants in this study perceive that engineers perform activities related to the construction and oil industries (35% and 27% of the total, respectively). Typical drawings/answers depicted engineers supervising the construction of a structure (see Figure 2), or working at oil rigs (see Figure 3). Male participants drew/mentioned construction and oil rigs related activities with almost the same frequency (38% and 35% of the time, respectively). Conversely, female participants placed less emphasis on the oil related occupations; one third (36) of the female participants associated engineers to construction work while only 19% (21) to oil related activities. Additionally, about one quarter of participants' responses suggested that engineers perform managerial tasks, often associated with office related work. Among the least frequently identified activities (coded as "other activities") are machinery operation (7%), and teaching/research (3%).

Table 2. Examples of students' responses to the open-ended questions.

Original quote	English translation
A. El ingeniero está dando la orden de lo que deben hacer.	The engineer is giving the order of what must be done.
B. Dirigiendo a los obreros en la construcción del puente y revisando el que lo hagan conforme a los planos en la mesa.	[The engineer is] leading the workers in the construction of the bridge, and revising they are constructing it according to the blueprints that are on the table.
C. El ingeniero está indicando hacia la plataforma para dar indicaciones del trabajo a realizar.	The [male] engineer is pointing to the oil rig to give indications about the work that has to been done.
D. La ingeniera está supervisando a las plataformas para obtener el crudo sin ninguna demora o problema.	The [female] engineer is supervising the rigs to obtain the oil without any delays or problems.
E. Está analizando los planos subterráneos estudiando el nivel de presión y las distintas rocas formadas por magma.	[The engineer] is analyzing the underground plans to study the pressure level and the different rocks formed by magma.
F. El ingeniero de mi dibujo está checando que los cimientos de la construcción estén correctos.	The [male] engineer in my drawing is checking the foundation of the building is correct.
G. Está corroborando que los materiales sean adecuados.	[The engineer] is confirming that the materials are appropriate.
H. La ingeniera está resolviendo unos problemas. La ingeniera está pensando cómo hacerlo.	The [female] engineer is solving problems. The [female] engineer is thinking about how to do it.

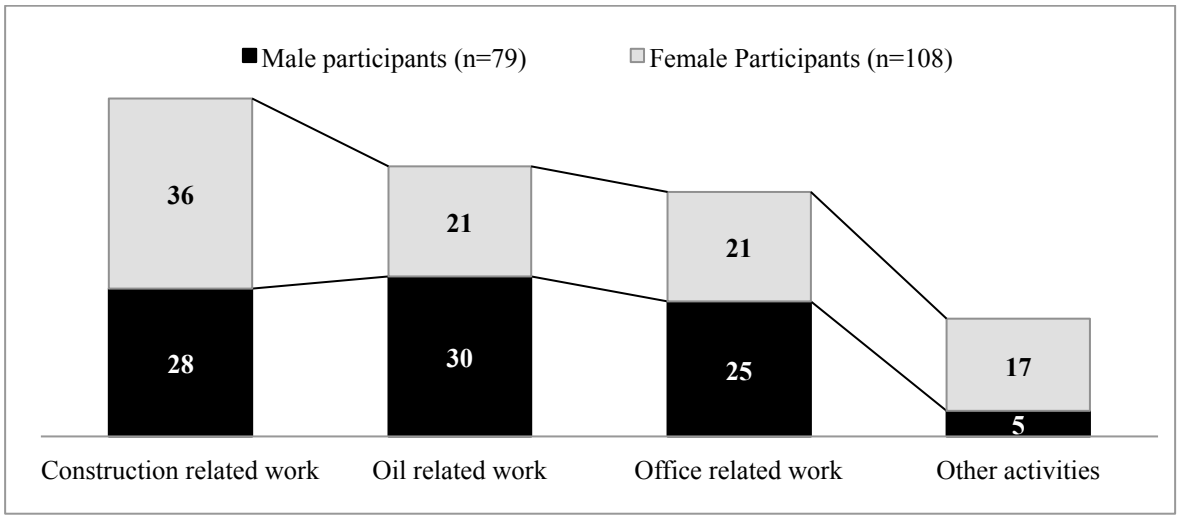

Figure 1. Total of participants that drew/described a specific type of work that engineers do.

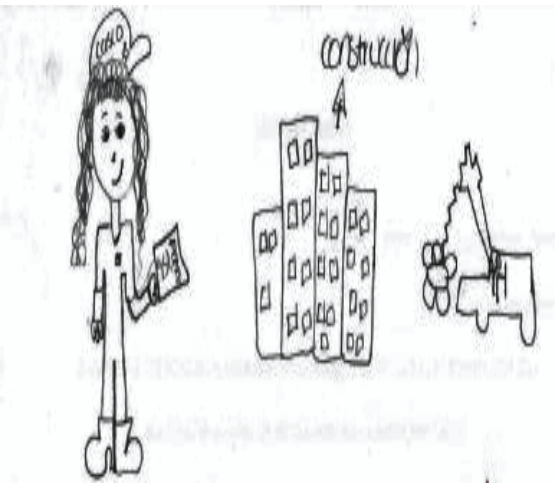

Figure 2. Female engineer directing construction work

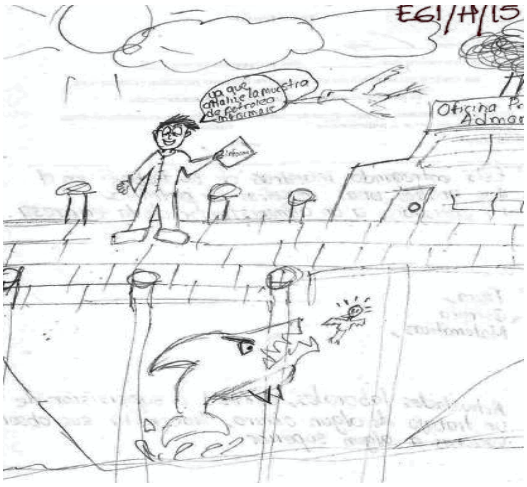

Figure 3. Male engineer working at an oil rig

Gender

Participants' responses were classified into one of three categories (i.e., female engineer, male engineer, or unknown-gender engineer) according to the characteristics depicted in the drawings/descriptions. Pictorial representations were categorized observing stereotypical features associated to a specific gender; for instance, long hair was associated to a female engineer (see Figure 2) and short hair to a male engineer (see Figure 3). Drawing descriptions also helped to figure out the characters' gender. Some participants made explicit the gender of their character using the nouns *ingeniera* (see Table 2, rows D and H) and *ingeniero* (see Table 2, rows A, C, and F) for a female engineer and a male engineer respectively. In those cases with no clear indication of a specific gender, characters were coded as unknown-gender engineers. As presented in Figure 4, the majority of the participants (63%) drew/described a male engineer, and only a small fraction (13%) portrayed a female engineer. Female participants displayed a stronger tendency to draw female or unknown-gender engineers (52%) than their male counterparts (15%). Both female and male participants were more likely to draw a male engineer than a female engineer (48% vs. 20%, and 85% vs. 4%, respectively).

Discussion

The majority of participants in this study perceive engineers as male individuals that perform activities related to the construction and oil industries. Perceiving science related fields as male-dominated arenas is the stereotypical image among the general population across borders[5] (including Latin American countries[6]). In the particular case of engineering, recent studies based on the DAE test[7-9] have shown that the male-dominated stereotype is the predominant view held by P-12 US students (see Table 3).

Results from this study confirm that cultural models to which students are exposed can contribute significantly to their mental schema, as suggested by Gardner[10]. Living in a city where the oil industry is the economic driver of the region, participants' drawings depicted what they see in their everyday life: oil rigs, orange jumpsuits, and construction sites. Children

stereotypical perceptions about engineering and engineers are derived from multiple sources that go beyond the media.

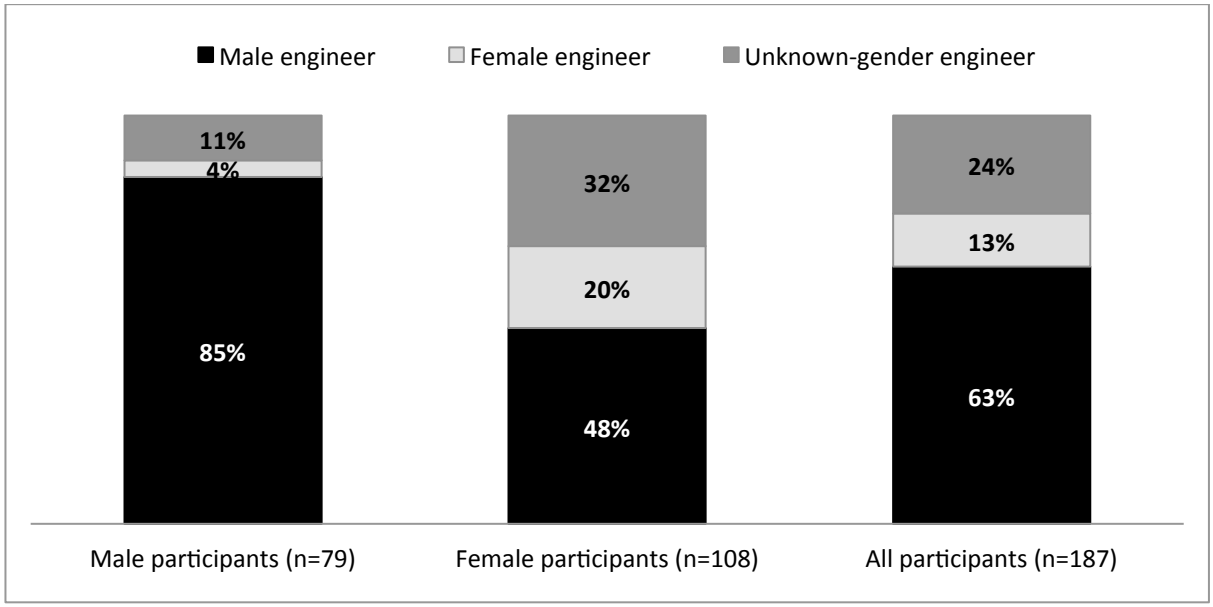

Figure 4. Percentage of participants that depicted a male, female, or unknown-gender engineer.

Table 3. Comparison of some studies exploring P-12 students' perceptions of engineers through the *Draw an Engineer* (DAE) test.

Study	Population school grade(s)	Total of drawings depicting personas	Percentage of drawings depicting gender specific personas		
			Male engineers	Female engineers	Unknown-gender engineers
Knight & Cunningham[9] (2004) [a]	3 – 12	189	21%	13% [b]	66%
Fralick *et al*.[7] (2009) [a]	3 – 8	526	69%	19%	12%
Karatas *et al*.[8] (2010)	6	20	65%	5%	30%
Current study	10 – 12	187	63%	13%	24%

[a] The total number of drawings depicting personas and the gender specific percentages were computed from the statistics reported by the authors.

[b] Authors report that the unusually high number of students drawing female engineers (from those containing discernable evidence of gender) is attributed to a visit of two female engineering students to some of the participant groups few months before the study was conducted.

Final remarks

The modified *Draw an Engineer* test used in this pilot study proved to be a useful tool to identify Mexican high school students' perceptions about engineering and engineers. However, the particular characteristics of the study context, the size sample, and some limitations related to the instrument utilized to collect the data[5], prevent us from making generalizations from our findings. In future studies, we will explore the suitability of the DAE checklist developed by Fralick *et al*.[7] and its flexibility to identify perceptions heavily based on a particular context.

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Appendix – *Draw an Engineer* Test Worksheet (In Spanish)

Género: hombre _____ mujer _____

Semestre actual: _____

LOS RESULTADOS DE LA ENCUESTA SE MANEJARAN DE FORMA AGREGADA Y CONFIDENCIAL.

DE ANTEMANO MUCHAS GRACIAS POR SU RETROALIMENTACIÓN

Ponga su nombre, teléfono y dirección de correo electrónico SOLAMENTE si desea participar de forma voluntaria en una entrevista posteriormente. Teléfono:

Nombre: e-mail:

1. Describe qué está haciendo el (la) ingeniero(a) de tu dibujo. Utiliza al menos dos frases

2. Enlista tres palabras o frases que vengan a tu mente cuando piensas en un(a) ingeniero(a)

3. Desde tu perspectiva, ¿qué tipo de actividades piensas que son propias de un(a) ingeniero(a)?