AC 2011-353: EXPLODING STEREOTYPES: CARE AND COLLABORATION IN THE STEM SCIENCES

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Education-Engineering Collaborative Research Project
Exploding Stereotypes: Care and Collaboration in Engineering

Overview and Aims

Research has found that students in schools often hold stereotypes of STEM (Science, Technology, Engineering, and Mathematics) subjects and careers: they view them as male-dominated, individualistic[8] and uncaring. They are perceived to marginalize women.[6] These stereotypes are reinforced by mass media[9] and by curricula and in class activities that may not include girls' preferred learning styles,[3] which centre around collaboration and relationships[3]. Students hold views that scientists are men,[7] that males are better at STEM fields[8] and have negative notions of females in these fields.[1]

As students view STEM fields to not encompass collaboration, connection, and care,[2] a significant number of girls choose not to go into them for careers.[5] However, these conceptions are questionable as the STEM careers, for example the field of engineering, in fact require collaborative work, which is embedded in an ethic of care. The researchers conceptualize care as collaborating with others in the development of solutions to societal issues embedded in a framework of concern for the welfare of other people. Care is a necessary component of successful group work and is thus related to effective engineering design by the researchers, as engineering frequently depends on multi-disciplinary teams.

This paper presents the findings of a collaborative study that explored stereotypes and how these might be addressed. In particular**,** it discusses:

1) if previous research describing the presence of gender stereotypes among both male and female students about the engineering profession as non-caring and non-collaborative is supported in this study, with a particular focus on upper elementary school age children;
2) if male and female students have similar or varying views/stereotypes; and
3) whether stereotypes can be broken through engineering design activities that include elements of both care and community through in-class engineering design activities that included the participation of university engineering students.

Research Procedure & Findings

The researchers conducted their study in two grade six public elementary classrooms in British Columbia (BC), Canada as research evidence suggests that students begin to develop their perceptions of various careers at an early age.[4] A total of 53 students between the ages of 10 and 12 filled out the pre-assessments in two schools of varying socio-economic status. In the first school (A), students were of varied socio-economic backgrounds. Several students had blue-collar parents or relatives. At the second school, students were in a French Immersion program (B). Many had professional parents.

The research project involved three classroom visits conducted in January 2011. In the first brief visit of approximately 15 minutes, researchers conducted pre-assessments of students'

conceptions of engineers by having the students write and draw pictures of how they understood four careers (teacher, doctor, accountant and engineer) and then match a series of descriptors (including words such as caring, works with others etc.) to each career.

Discussion of Pre-assessments: Stereotypes about Careers

The pre-assessment activity identified stereotypes held by both male and female students at both schools towards engineering. Most commonly, male and female students drew similar pictures: an identifiable male engineer (7 males; 12 females), a person fixing a car (7 males; 9 females), and/or tools or working with one's hands (6 males; 7 females). Four males and two females drew a building or designer, and five males and two females drew other engineering-related activities (such as developing electricity systems). Only one female drew a picture of a female engineer. Two female students left their pictures blank. From their pictures, both male and female students held similar perceptions and understood engineering to be a predominantly male career, related to cars. They appear to have confused a car mechanic with an engineer. These pictures were in contrast to those of teachers and doctors, which were often drawn as identifiable females (see Appendix A, samples 1 and 2).

As well, both males and females choose similar words from a list of possible options to describe engineers:

Word chosen	Males	Females	Total
Hardworking	**13**	**19**	**31**
Mostly male	**12**	**11**	**22**
Intelligent	**7**	**8**	**15**
Good at Math	**7**	**5**	**13**
Makes our world better	5	3	8
Works alone	4	4	8
Helps people	1	6	7
Successful	1	6	7
Works with others	3	3	6
Kind	2	3	5
Boys and Girls	1	2	3
Caring	1	0	1

The most common words selected by both males and females were hardworking, mostly male, intelligent, and good at math (bolded in the table). Only one male, chose the word "caring," and only one male and two girls chose "boys and girls." Six students chose the word "works with others" and eight chose "makes our world better." Thus, both male and female students in this pre-assessment held similar stereotypes about engineering as a mostly male field that wasn't particularly related to caring. These answers were also illustrated in students' interview answers.

Student Interviews

Six (three males and three females) students from each class were interviewed about their answers. These students were selected randomly from the pile of parent consent and student assent forms in which permission to carry out the interviews had been given. Students were asked to explain why they drew their pictures in the manner they did and why they chose the particular descriptors they did. Other questions included: What do you think an engineer does? Do you think engineers work alone? Do you think engineers care about other people when they do their jobs?

Students stated that engineering jobs related to building, designing or fixing things, repairing cars, and helping others with/using math. One student confused university professors with engineers and another believed that engineers worked at places you could take your car to for an oil or transmission fluid change. Others (one male and three females) were not quite sure what engineers did. Students stated that engineers might work alone, but that they were more likely to work with other people, such as their partners or other engineers, in order to get their jobs completed more quickly. All participants believed that doctors and teachers should care about people when they do their jobs as their jobs related to helping others. If they didn't care, "they're not doing their job right" (student, interview). Many, but not all of those interviewed also thought engineers cared as they had to fix things, know about different oils, and do the job safely—which are more related to working carefully. One male student stated, however, "if they're working for the government, they just want money" (student, interview). Finally, most of the students thought that doctors, teachers, and accountants could be both male and female and that engineers were mostly males, as males are "more interested in learning about stuff like wires," they "work better with tools," it was a "dirtier job" and "girls don't like working…in building" (students, interviews).

In summary, both the pre-assessments and the interviews illustrated students at both schools to hold stereotypes about engineering as a mostly male field. Many confused the career with being a car mechanic. Some students did think that engineers worked together with other people and that they cared about other people as they did their jobs, although this was primarily related to working carefully. Others thought that engineers worked alone and that they didn't really care as they were "not really a people's worker" and they "work with objects" (students, interviews). Thus, stereotypes about engineering as a male field were strongly identified while those related to engineering as non-caring and non-collaborative were partly identified. Care, however, was generally understood as doing a job carefully and properly.

The Engineering Challenges

In the session following the pre-assessments, the researchers led the students in an interactive, engineering lesson that embedded elements of both care and collaboration. This activity took approximately 1.5 hours. It required students to collaborate in an engineering design challenge and to share their projects with their peers. The project engaged students in creating a "global village" for a community in need in Africa. Students were divided into groups of four to five students each (for a total of six groups). Each group had one or two university engineering students to assist them in its task and each group had a different challenge or problem to "solve"

through the creation of an object, each of which illustrated one of the engineering disciplines (civil, mechanical, and electrical): one group built a house, another a bridge, the third an irrigation system, the fourth a water filtration system, the fifth a power system using various fruits, and the last a communication system. Students were not told what each of the other groups was doing until after they had completed their individual group tasks. The engineering students were encouraged to use inquiry-based and student-focused learning strategies. They were also asked to encourage their group of students to work together in a caring and positive way to complete the activity.

Once each group had completed its task (approximately 20 minutes), the researchers brought the students together to create the "global village." The researchers and engineering students then led the students in a discussion on what they learned about what engineers do (through prompts and discussion in their individual groups as well as through whole class discussion on what each of the six groups created and the area of engineering it illustrated). The groups also shared how their creations would specifically help a village. The discussion continued by having the students consider how these activities illustrated the need for collaboration and care in the field of engineering. The latter element was further illustrated by having the university engineering students explain and describe the work of "Engineers Without Borders." Students were asked to discuss how the village they created illustrated care for other people, as well as collaboration. Gender stereotypes were addressed through having both male and female engineering students participate in the activities.

Discussion of the Activity: the Significance of Pedagogy

For centuries, philosophers have discussed the meaning and significance of education. Philosophers such as Plato, Rousseau, and Dewey have all considered the aims of education and the best methods of achieving these aims. Of these, Dewey's belief in the efficacy of experiential pedagogy resonates with many of today's educators and provided the philosophical basis for our study. Of particular relevance is Dewey's claim that the most effective learning comes from lessons that engage students in activities that illustrate the concepts being taught. This research project followed Dewey's approach by engaging students in hands-on and discussion-based lessons with the aim of changing stereotypes held by students about engineering.

During the activity, all students actively worked to complete the challenges in a hands-on manner. No behavioural problems were identified, and students were encouraged to work together collaboratively and to solve the challenges presented through their ideas and with prompting questions, rather than by being told the answers. All of the students were engaged in the challenges and genuinely seem to have enjoyed the activities. Gender did not appear to be an issue as both the male and female students eagerly participated and asked questions. All challenges were successfully completed, and students were respectful and actively participated in the subsequent sharing and discussion of each engineering challenge. They were able to identify which engineering discipline each illustrated. As a conclusion, engineering students presented a short PowerPoint presentation on Engineers without Borders, and explained why they had chosen to become engineers and how they wanted to make a difference in the world. Each group then shared with the class how their challenges illustrated care and collaboration. The post assessments demonstrate that this pedagogy was effective in addressing students' stereotypes.

Post-assessments

The project concluded with post-assessments that illustrated whether students' conceptions of engineers had changed. The post-assessments were conducted the day after the activity and involved administering the pre-assessment again: students were asked to re-draw their pictures of engineers and to select new words to explain the career.[1] They were also asked to make a list of the kinds of things engineers do. The post-assessments illustrated the exploding of stereotypes and the significance of experiential learning, with similar but slightly varying results at each school. At school A, the majority of students drew pictures of engineers building bridges and houses as well as developing electrical systems, irrigation systems, and water filtration systems. Most, that is, drew a picture of the challenge that they had personally been engaged in, or they drew pictures of all the challenges. Some labelled the challenges with the names of the three engineering disciplines (civil, mechanical, and electrical). Only one student drew a picture of a car mechanic. Students had clearly expanded their knowledge of what engineering is. Students at school B had also clearly expanded their knowledge of what engineering is and could describe more varied engineering fields. Similarly to school A, some students also drew the engineering challenges they had completed, and only one drew a picture of a car mechanic (one girl). However, the majority of these students, especially the girls (4 boys, and 9 girls out of a class of 26) chose to draw a picture of a person-- a smiling male person. It was almost as if the field of engineering had been "humanized" for these students, who had come to identify the field with the engineering student volunteers. The figures they drew were caring, but male. This may reflect a difference in the gender compositions of the volunteers. At school A, equal numbers of female and male engineering students participated in the challenges. At school B, the majority of the engineering student volunteers were male by more than 3:1. At both schools, the students had come to have a positive view of engineering, as one female wrote, "There are all sorts of engineers [,and] they make a lot of cool things" (student, post assessment). Further changes in perceptions were illustrated by the new words students chose to describe engineers. As school findings differed a little for these, the results are presented separately.

[1] The researchers conducted the post-assessments immediately afterwards due to paper submission deadlines. Gaining ethics approval to conduct the study in public schools was a slow process. In future studies, the researchers would like to conduct two post-assessments, one directly after the activity and the second a month later in order to explore how long term the changes were. Due to the nature of the change (stereotype-breaking), the researchers hypothesize that the changes were largely permanent. Some of the factual knowledge gained may have been forgotten but probably not the general idea learned.

School A

Word chosen	Males	Females	Total
Intelligent	**3**	**5**	**8**
Makes our world better	**3**	**5**	**8**
Hardworking	**3**	**4**	**7**
Helps people	**2**	**4**	**6**
Caring	3	2	5
Boys and Girls	2	3	5
Works with others	1	4	5
Successful	1	4	5
Good at Math			
Kind			
Works alone			
Mostly male			

A number of students changed their selection of words to state that both girls and boys could do the job. Also, more students chose "makes our world better" and "works well with others." Some chose caring and kind. Many viewed engineers as intelligent and successful. Girls, in particular, changed their perceptions of engineering to encompass more features of care. Significantly, no students chose the words "mostly male" or "works alone."

School B

Word chosen	Males	Females	Total
Intelligent	**7**	**9**	**16**
Makes our world better	**7**	**6**	**13**
Helps people	**6**	**6**	**12**
Hardworking	**3**	**8**	**11**
Good at Math	6	4	10
Caring	2	7	9
Boys and Girls	3	2	5
Mostly male	1	4	5
Successful	1	2	3
Works with others		1	1
Works alone			
Kind			

School B was similar to school A in that more students choose the categories of "making our world better," "helps people," and "caring." More students had come to see the fields of engineering as illustrating care. However, more students had answers that were consistent with the pre-assessments (hardworking, good at math and intelligent), thus illustrating more continuity in their conceptions of engineering. Possible reasons for this may include socio-economic or demographic factors, for school B students were a little older as a group than school A students implying that they had already developed their views of the career, and perhaps these

were harder to modify.[2] Further, and significantly for this study, while some students chose the words "both boys and girls," several females (not males) - as also illustrated in their pictures - continued to chose the words "mostly male." In short, students at both school A and school B increased their view of engineering as a caring profession that "makes our world better"; however fewer girls at school B came to see the profession as being for both males and females. This may be a consequence of the larger number of male engineering student volunteers who participated in school B. This would imply that actually seeing female engineers is effective in breaking gender stereotypes, and that this is particularly important for changing girls' perceptions.

Post Interviews

Five students in each class were interviewed again.[3] These were the same students who had been interviewed after the pre-assessments. These interviews demonstrated students' increased knowledge of as well as their changed perceptions of engineering fields. At both schools, students described the engineering activities they had completed to explain what an engineer does (such as builds houses, works on electrical and water systems) and sometimes mentioned the three fields of engineering. They all had more knowledge of engineering. As one student stated, "I learned a lot!" Further, they all mentioned that engineers care as they help to make the world "better for all people" (student, interview) and that this was "because they like people." One boy stated, "I really changed my thought" about whether engineers cared. Further, the majority believed that engineers worked with other people to get ideas and "get the job done faster" and "better" as the work was "too difficult" to do alone (students, interview). They stated that they had thought engineers were "mostly boys before" but now thought that engineers could be both males and females.[4] In summary, both the post-assessments and the interviews illustrated that students had changed their perceptions of engineering as a field that wasn't particularly caring to a view of engineering as illustrating elements of collaboration and care. The class that had more gender equal numbers of engineering students came to feel more strongly than the second class that engineering was a career for both males and females.

Future Work

This study presented several opportunities for future work. An interesting, related topic for future study presented itself through the breakdown of students responding to the invitation to participate in this study. Interestingly, while slightly under 90% of engineering students at the School of Engineering at the University of British Columbia's Okanagan campus are male, a significant number of our volunteers (more than 30%) were female. The researchers wonder what factors attracted a higher relative proportion of female engineering students to participate: was it the "caring" elements of the activity, or the desire to "serve" their fields?

[2] An interesting follow up to this study would be to conduct the study with students of different ages to see if stereotypes are harder to break at certain ages.
[3] One student at each school was either absent for the activity or for the post assessment.
[4] Only two females participated in interviews at school B. The answers of the girls interviewed on the question as to whether engineers were both females and males and those of some of their classmates were different.

Conclusion

This study explored how students' stereotypes towards STEM fields, and engineering in particular, can be exploded through experiential activities embedded in collaboration and care. Its findings are of significance to classroom teachers and to scholars interested in exploring how stereotypes can be broken through effective pedagogy. It found that: (1) stereotypical attitudes exist in students at this young age and (2) these views can be altered through a planned activity. These findings illustrate that pedagogy can be effective in breaking stereotypes which may be connected to negative social and media messages.[5] One question to emerge from this study is, if stereotypes are easy to break, then why aren't they broken? The answer is complex and may be embedded in power discourses about who makes choices about what is considered important to know. Perhaps this also relates to the difficult question of deciding, among all possible subjects of study, what should be studied. This study demonstrates that changes in perceptions can be made, and that continued advocacy on the part of engineers themselves is essential to success in changing elementary students' stereotypes of the profession. Perhaps, as illustrated in this study, the largely male demographic of engineering itself may both reflect as well as continue to perpetuate the perception and reality of engineering as a male career. A simple and effective first step to counter stereotypes of engineering as a male field appears to be, from this study, to work towards presenting equal numbers of male and female engineers to students.

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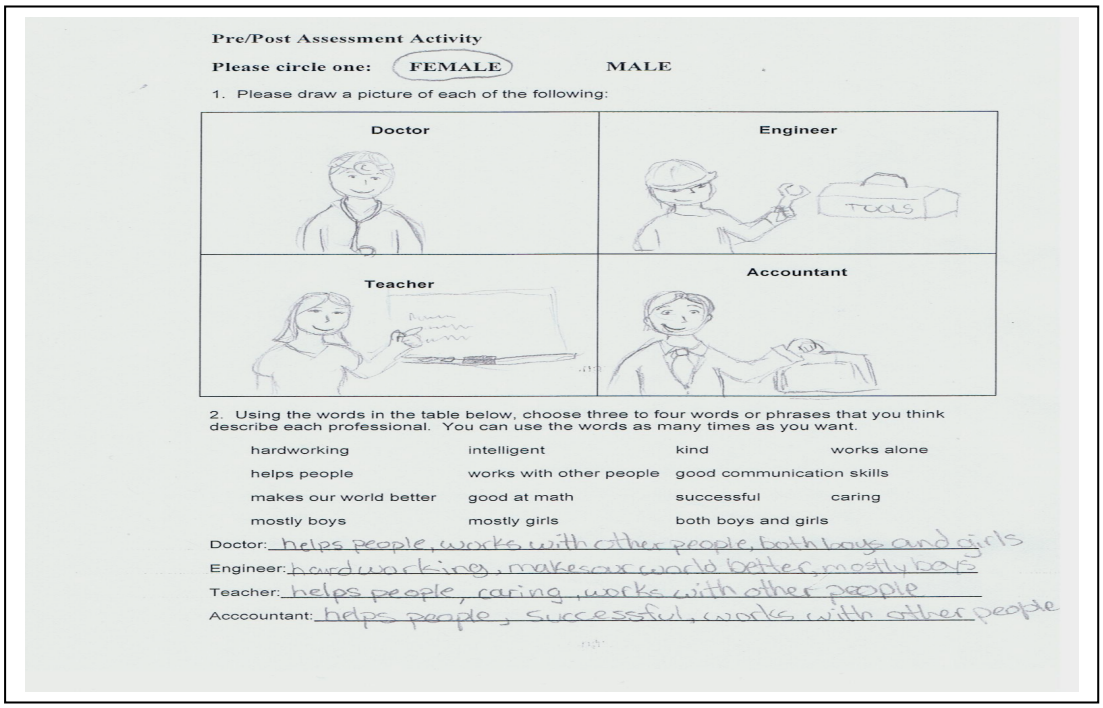
[5] A follow up study could also consider where students' perceptions/stereotypes of engineering arose, for example, by asking students, "have you ever seen an engineer on TV?"

APPENDIX A: Student Samples.

Student sample 1: Pre-assessment



Pre/Post Assessment Activity

Please circle one: FEMALE MALE

1. Please draw a picture of each of the following:

Doctor | Engineer (TOOLS) | Teacher | Accountant

2. Using the words in the table below, choose three to four words or phrases that you think describe each professional. You can use the words as many times as you want.

hardworking	intelligent	kind	works alone
helps people	works with other people	good communication skills	
makes our world better	good at math	successful	caring
mostly boys	mostly girls	both boys and girls	

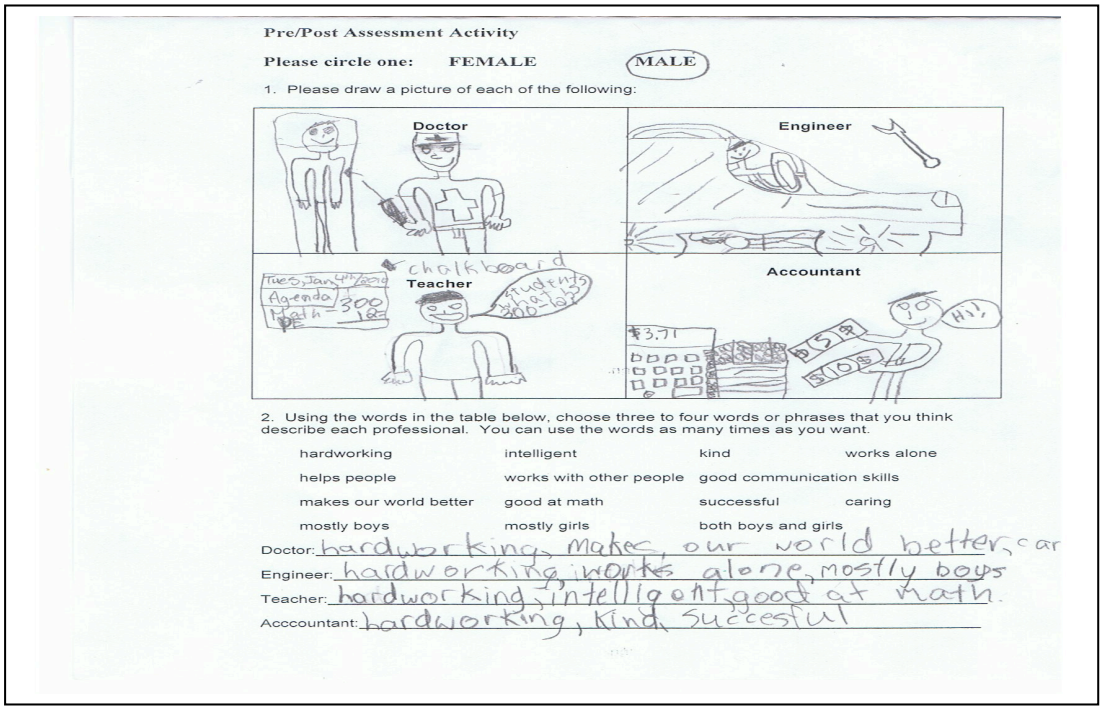
Doctor: helps people, works with other people, both boys and girls

Engineer: hardworking, makes our world better, mostly boys

Teacher: helps people, caring, works with other people

Acccountant: helps people, successful, works with other people

Student sample 2: Pre-assessment



Pre/Post Assessment Activity

Please circle one: FEMALE MALE

1. Please draw a picture of each of the following:

Doctor | Engineer | Teacher (chalkboard, Agenda, Math, PE) | Accountant ($3.71, Hi!)

2. Using the words in the table below, choose three to four words or phrases that you think describe each professional. You can use the words as many times as you want.

hardworking	intelligent	kind	works alone
helps people	works with other people	good communication skills	
makes our world better	good at math	successful	caring
mostly boys	mostly girls	both boys and girls	

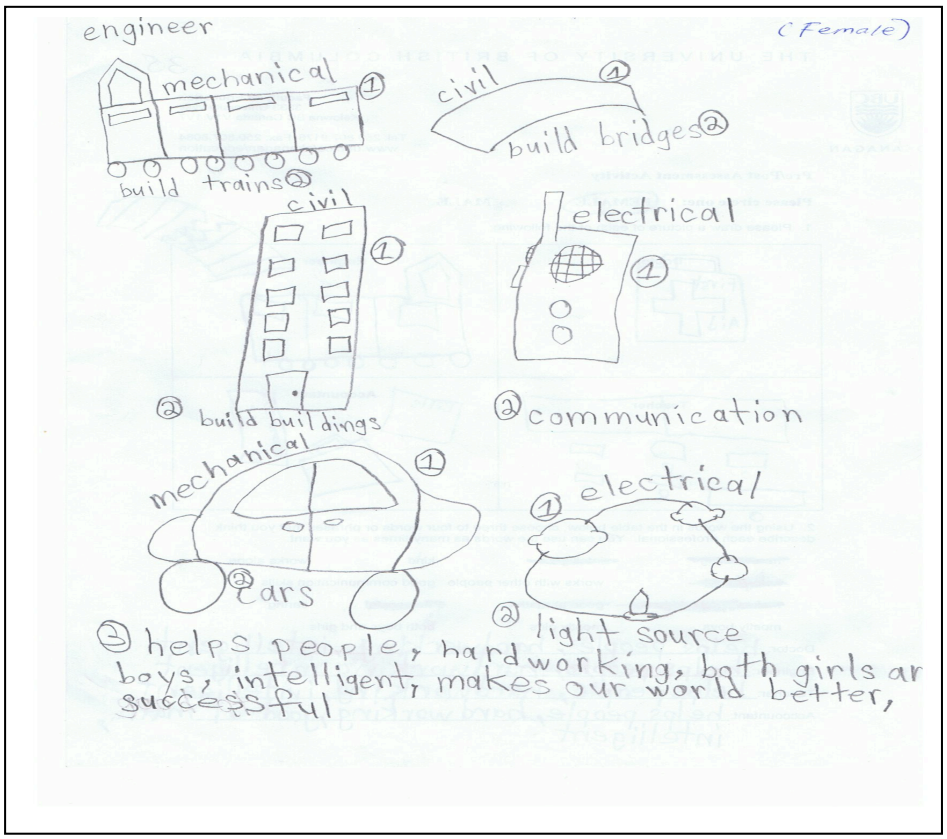
Doctor: hardworking, makes our world better, car

Engineer: hardworking, works alone, mostly boys

Teacher: hardworking, intelligent, good at math

Acccountant: hardworking, kind, successful

Student sample 3: Post-assessment



Student sample 4: Post-assessment