Asian Women
September 2017, Vol. 33, No. 3, pp. 41-64

Girls' and Boys' Science Choices and Learning in Upper-Secondary Schools in Taiwan

Hsiao-chin Hsieh
National Tsing Hua University, Taiwan
Pei-ying Chen
National Taiwan Normal University, Taiwan
Ta-sen Lin
Fo Guang University, Taiwan

Abstract

This study explores differences in how high school girls and boys in upper-secondary schools in Taiwan choose courses and learn science. The Actor-Network Theory (ANT) is adopted as the analytical approach. Two upper-secondary schools, LL Senior High School and MM Vocational High School, were selected due to their emphasis on science and technology education. Student surveys were conducted to investigate how students chose between courses and majors; two chemistry lab classes, one led by a male teacher and the other by a female teacher, in LL Senior High School, and one chemical-engineering lab class of MM Vocational High School were observed multiple times. Lab class teachers from both schools were interviewed. The survey data showed clear gender segregation in both schools, but only part of the students considered gender to be an important factor influencing their selection of courses and major fields. Observations of the relatively gender-balanced chemistry laboratories revealed that equipment and instrumentation were sufficient and equally accessible to all, that girls and boys behaved differently in the lab, and that patterns of teacher-student interaction varied by teacher's gender, which might result in differences in laboratory learning between boys and girls. The concept of embodied pedagogical insight of female teachers, which may specifically benefit girls' learning, is discussed.

Key words

gender, science choice, laboratory learning, upper-secondary school

Introduction

Low participation rates of women in science, technology, engineering, and mathematics fields (hereafter STEM) is a world-wide phenomenon. Looking upwards along the academic ladder, the steep decline in female participation rate is referred to as the leaky pipeline in STEM (Blickenstaff, 2005; Rees, 2001; Xie & Shauman, 2003). This not only limits girls and women's access to learning in these fields but may further impinge on their opportunities in the job market. Moreover, it will have a tremendous impact on the capacity for science and engineering in connection with social economic development. Research investigating the phenomenon and proactive measures promoting girls and women's participation in STEM are thus in demand.

Taiwan is no exception. Although already popularized in Taiwan, upper-secondary education shows apparent gender segregation due to educational tracking and curricular differentiation into high schools and vocational high schools. High school curriculum is divided into science and social science programs from 11th grade onwards, and it is apparent that boys concentrate more on natural science programs and girls on social science programs. Vocational high schools consist of a wide variety of specialized departments from grade 10 to grade 12; in these schools boys tend to focus on industry related departments, while female students tend to focus on business related and home economics departments.

Under Taiwan's college entrance exam system, upper-secondary education streaming profoundly affects students' choice of field and major in higher education. As higher education rapidly expands in Taiwan, girls and boys are gradually enjoying equal access to university. At the same time, however, their choices of field remain grounded in gender stereotypes, with the common belief that boys study science and engineering; girls study humanities. Even more so, in recent years, the male to female student ratio in humanities has gradually narrowed from 1 to 2 at the undergraduate level to 1 to 1 at the doctorate level. But in science and technology fields, the male-female gap grows wider from 7 to 3 at the undergraduate level to 8 to 2 at the doctorate level.

Because streaming and differentiation begin in upper-secondary education in Taiwan, it makes this stage a key factor in students' science and technology education as well as future career opportunities. Therefore, there arises a need to gain a deeper understanding of girls' and boys' science and technology choice and learning in this critical phase of education. This study attempts to answer the following two questions: 1) How do senior high school girls and boys of equivalent general academic achievement make decisions with regard to selecting science and technology related courses or majors? And, 2) once they have taken a science and technology related course, in this case, the chemistry laboratory class, what actually happens in the lab? More specifically, how do girls and boys behave and how do teachers interact with students in these lab activities? These findings may help formulate strategies to create a gender-friendly environment for science and technology learning in upper-secondary education.

Literature Review

Why So Few? Girls and Women's Low Participation in STEM

The phenomenon of girls and women's under representation in STEM majors and careers has attracted scholarly attention since the 1970s. Factors contributing to the phenomenon are complex. In her highly cited article, "Women and science careers: Leaky pipeline or gender filter?" Blickenstaff (2005, pp. 371-372) reviewed research literature on factors that kept women from studying science or working as scientists and found the following explanations put forth in the literature:

1. Biological differences between men and women.
2. Girls' lack of academic preparation for a science major/career.
3. Girls' poor attitude toward science and lack of positive experiences with science in childhood.
4. The absence of female scientists/engineers as role models.
5. Science curricula are irrelevant to many girls.
6. The pedagogy of science classes favors male students.
7. A 'chilly climate' exists for girls/women in science classes.
8. Cultural pressure on girls/women to conform to traditional gender roles.
9. An inherent masculine worldview in scientific epistemology.

Blickenstaff (2005) argued that explanations targeting girls as the root of the problem possessed little merit and that efforts should be focusing on making the school a more friendly and encouraging learning environment in order to attract women to science, to support women already in science, and to change science to be more inclusive of women. Initiatives such as *Women in Science and Engineering* (WISE) in the U.S. and *Girls into Science and Technology* (GIST) in the U.K. were established in early 1980s to encourage more girls and women to participate in fields of science and technology.

According to a UNESCO report, similar efforts in many countries increased the enrollment of women in these areas slightly in the 1980s and 1990s, from around 10–15% to 20–25%. Since 2000, however, this progress seems to have declined again, down to 10 percent in some countries, along with declining enrollment of men in many countries (Huyer & Westholm, 2007), indicating the gender issues in STEM remain complex and challenging. Time and again publications, such as *Why so few? Women in science, technology, engineering, and mathematics* by the American Association of University Women (hereafter AAUW) (Hill, Corbett, & St Rose, 2010), and *A complex formula: Girls and women in science, technology, engineering, and mathematics in Asia* edited by UNESCO Bangkok Office and Korean Women's Development Institute (UNESCO, 2015), offer additional research-based evidence on how social, cultural, educational, and organizational factors contribute to the persistently low participation of girls and women in STEM, attempting to provide solutions to improve the situation. For the purpose of this study, we shall concentrate our discussion on high school related literature with special reference to research in Taiwan where applicable.

Girls' Non-Choice of Science in High School

Traditional gender ideology tends to fuel males' preference of math and science fields and females' preference of language, humanities, and social science. In the socialization process, parents and teachers often play the role of cultural gatekeepers; therefore reinforcing traditional gender roles and values. However, there are other significant factors involved in student career choice, which strongly influence students' tendency to choose majors that fit traditional gender values (Acker & Oatley, 1993; Stromquist, 1991).

As mentioned previously, gender differences in STEM fields begin as young as 15 years old, when schools in some countries permit student to select from elective courses, or when curriculum track systems are applied in other countries. The fact that secondary school courses are optional creates a filter that blocks entry into science related subjects as girls tend to elect fewer advanced math and science courses than boys (Burkam, Lee, & Smerdon, 1997; Oakes, 1990; UNESCO, 2015). A number of studies in the U.S. show that, for girls, their high school math grade is a critical filter in deciding whether or not to choose a science or engineering major (Oakes, 1990; Peng & Jaffe, 1979; Sells, 1980; Stromquist, 1991). However, many studies have shown that the gap in math achievement between girls and boys has narrowed significantly in recent years and that even if they have good math grades, girls may not necessarily choose a traditionally male major (Ayalon, 2003; Hill et al., 2010; UNESCO, 2015; Xie & Shauman, 2003). A similar phenomenon is also found in Taiwan. Chien and Jen (2011) analyzed data from 8,812 Taiwanese students' responses in the 2006 OECD Program for International Student Assessment (PISA) to investigate gender differences in Science-related Career Choice Intentions (SCCI). They found not only that boys' SCCI, science self-efficacy, outcome expectation, and science interest were significantly higher than girls' but also that *gender* exerts a direct effect on SCCI and indirect effects mediated through science self-efficacy, outcome expectation, and science interest.

The Importance of Science Choice in High School

In addition to math achievement, the structure of curricular tracking also generates differences in Taiwanese girls' and boys' curricular program choice. Kuo and Sheu (2011) use panel data from the Taiwan Education Panel Survey (TEPS) to investigate the potential influence of a student's past math achievement on senior high school girls' and boys' choices of major. They found that while math achievement was the most important factor among all variables in determining the choice of major, the impact of math was not consistent across gender—family backgrounds accounted for only 16–21% of the overall gender gap, suggesting that a considerable portion of the gender gap could not be explained. In another study, Chen (2013), also analyzing TEPS data, found that previous test scores had a significant impact on senior high students' curricular track choice. She also found that among 9th graders who believed the statement that it would be better fit if boys choose to study natural science rather than girls, boys were more likely to choose natural science program later at the senior-high-school stage and, in contrast, girls tended to choose the social science program, controlling for previous test scores. The results suggest that the dual-track curriculum system in Taiwan's senior high schools, together with students' gender role beliefs, could play a role in fortifying stereotypically gendered choice of major.

The Importance of Laboratory Activities in Science Education

Among suggestions to make science courses more attractive to students in general, and to girls in particular, hands-on experiences in laboratory activities are often proposed. (Hill et al., 2010; Huyer & Westholm, 2007; UNESCO, 2015)

The laboratory has been given a central and distinctive role in science education, and science educators have suggested that rich benefits in learning accrue from participating in laboratory activities. In their reviews of research literature on laboratory activity in science education, Hofstein and Lunetta (1982, 2004) concluded that laboratory experiences improved student attitudes and interest in science and that the school laboratory offered important opportunities for interaction between students and their teacher and among peers that could be conducive to meaningful inquiry and collaborative learning that resulted in desired cognitive growth.

The U.S. National Research Council (2006) also recognizes the value of laboratory activities, stating that:

[t]he science learning goals of laboratory experiences include enhancing mastery of science subject matter, developing scientific reasoning abilities, increasing understanding of the complexity and ambiguity of empirical work, developing practical skills, increasing understanding of the nature of science, cultivating interest in science and science learning, and improving teamwork abilities. (National Research Council, 2006, p. 75).

Research results have indicated that hands-on laboratory activities stimulated girls' interest and performance in STEM related subjects. Burkam et al. (1997) used data from NELS: 88, a large and nationally representative longitudinal database from the U.S., to identify important factors related to gender differences in 10th grade science performance. They found that male high school sophomores were moderately advantaged, compared to their female counterparts, in learning both physical and life sciences, that hands-on science instruction increased girls' confidence, performance, and interest in science, and that time spent doing hands-on lab work was related to a reduced gender gap in physical science learning. The authors therefore highlighted the importance of the active involvement of students in the science classroom as a means to promote gender equity. Freedman (2002) investigated the use of a hands-on laboratory program to improve science attitudes and achievement among 9th grade students in a physical science course in a large urban high school in the U.S. Using the same course content, he compared the final examination performance of two groups: the treatment group received regular, weekly lab activities as part of their physical science course, whereas the control group received traditional, teacher-centered instruction without lab experience during the school year. The research findings showed that students with lab instruction scored significantly higher on achievement in science knowledge than those without lab experience, that girls with regular laboratory instruction scored significantly higher than those without laboratory instruction, and that girls and boys within the treatment group did not differ significantly. Freedman (2002) concluded that it was reasonable to assume that a hands-on laboratory program appeared to mitigate the gender gap in science achievement.

Studies in Asian countries also reveal that the provision and use of science labs have a positive impact on student participation and interest in science, and can also help overcome biases against girls' science abilities. Increased resources for experiments are recommended as effective means to help stimulate interest in science among female students. (UNESCO, 2015)

The Importance of Female Science Teachers as Role Models

Nearly all the research literature mentioned above assert the importance of female teachers in STEM-related subjects, as these teachers serve as role models to inspire young girls to learn. Some studies revealed that teacher gender may have a differential impact on girls' and boys' learning. Analyzing Taiwan's TEPS panel data, Chen (2013) found that, with previous test scores controlled, girls who had been taught by a female math teacher at some point during junior high school were more likely to select the natural science program in senior high school. In contrast, when math teachers were predominantly male, boys were less likely to choose the social science program.

In Scandinavia, Elltad and Turmo (2009) conducted a survey of 798 students from seven high schools in Oslo, Norway. They found that certain findings supported the theory that when teachers and students share the same gender, better learning results were achieved. They also found that the key to these results was whether the teacher was consciously aware that students of different genders required different methods of interaction as well as how those interactions might affect them. This study further emphasized the importance of meaningful reciprocal trust. When students interact with a science teacher they highly trust, they gain more and better experiences from studying under that teacher. Generally speaking, it is easier for female teachers to build such mutual trust with female students. In their recent reports on women in STEM, both AAUW and UNICEF suggest that exposing girls to successful female role models can help counter negative stereotypes in math and science learning and attract them to the field (Hill et al., 2010; UNICEF, 2015).

In studying the importance of laboratory practice to girls' science learning, Burkam et al. (1997) did not find teacher gender to be a factor in students' learning and felt this non-finding noteworthy. In Freedman's (2002) study, teacher gender was not a factor under concern. This raises a question about the impact of teacher gender on student's learning in science labs. Laboratory activities involve networking between people and the experimental equipment and materials. We found that the Actor-Network Theory (ANT) provides a useful perspective from which to observe laboratory activities. The ANT treats human and non-human (e.g., artifacts, organization structures) in a functioning network as equally powerful agent. By so doing, one gains a detailed description of how the human and non-human act to hold the network together. In their pioneering book, *Laboratory Life: The Construction of Scientific Facts*, Latour and Woolgar's (1979) presents an ethnographic study of a scientific laboratory at the Salk Institute, giving detailed descriptions of the routine practices performed by scientists in scientific knowledge production, and other elements of laboratory life. It has inspired some studies in college laboratories in Taiwan (Han, 2012), but little has been done on high school laboratory classes. Mulcahy (2011) used the perspective of ANT to examine the process of becoming a teacher in Australia. The author thinks that teaching not only involves the meeting and interaction of people or the process of transferring knowledge and skills, that is, the representation aspect of teaching, but also entails the process of a series of highly heterogeneous interaction of bodies (referring to individuals with professional habits and routines), contextual and institutional codes (professional standards, images required in the profession), and non-human materials (course materials, technological tools that facilitate teaching, classroom spatial arrangements, campus environment, etc.), which is the performative aspect of teaching. Adopting Mulcahy's (2011) study as an example, we could use the ANT perspective to observe the performative aspect of student learning and, especially, the performative aspect of teaching and teacher-student interactions in laboratory classes.

Methodology and Research Design

Considering the literature discussed above, this study attempts to answer the following two questions: 1) How do senior high school girls and boys of equivalent general academic achievement make decisions with regard to selecting science and technology related courses or majors? And, 2) once they have chosen a science course or major, which in this study is the chemistry laboratory class, how do girls and boys behave and how do teachers interact with students in the lab class? Student learning experiences in the senior high schools is assumed to be different from that in the vocational high schools in Taiwan. The general academic achievement of students in the same upper-secondary high school are relatively equivalent since they have gone through the entrance examination screening process. The school's level of emphasis on science and engineering education and level of sufficiency of the laboratory facilities impacts how lab class is conducted. With these in characteristics mind, we selected one senior high school and one vocational high school that value science education, lab skills, and internships and have comprehensive lab facilities as sites of study.

Located in northern Taiwan, LL Public Senior High School was founded as a science high school. From grades 10 to 12, each grade has nine regular classes plus one advanced math and science class and one advanced physical education class. Altogether there are 33 classes across three grades and approximately 1,000 students in the entire school. The school implements a school-based curriculum in grades 10 and 11, 3 hours per week. There are 18 weeks in each semester. The first 5 weeks of the first semester of grade 10 are devoted to basic inquiry methodology courses, and for these courses, students are assigned randomly to 13 non-home-based classes.

Although the 5-week basic inquiry course was founded on a common scheme, each of the 13 classes were conducted somewhat differently because the teachers possess different specialties. Over the next 13 weeks, students had two trial rounds of topic research classes, ranging from Chinese literature or English to chemistry, physics, or computer sciences, depending on the student's own choice. Then, students would remain in the same topic research class for the second semester of grade 10 and the entire grade 11 school year.

The other school, MM, is a well-reputed public vocational high school located in central Taiwan. It has 12 departments ranging from agricultural to industrial fields, as well as practical skill evening classes and vocational skill classes for students with special needs. The school has approximately 2,000 students. The school shows good performance as it encourages, or requires, students to take at least Class C technician license tests and to participate in regional and national craftsmanship competitions. MM has quite a few teachers who are actively involved in competitive curriculum research and development projects.

To answer question one—how do girls and boys of equivalent general academic achievements make decisions with regard to selecting science and technology related courses or majors?—we conducted simple questionnaire surveys on all the grade 11 students of LL High School and all the grade 10 students of MM Vocational High in the fall of 2013. At LL High School, all students have enrolled in their elective topic research class by grade 11. We received a list of students in each topic research class from the school. A questionnaire consisting of ten items was developed. The questions asked about the student's gender, current grade, that is, grade 11, elective topic research class, and the basic inquiry class that he or she was assigned to in grade 10. In addition, the questionnaire asked, "Are the following factors important in your decision in electing the topic research class?" The possible factors included: One's academic achievement or ability in the subject, suggestions by a significant other, one's interest, experience from the basic inquiry course, and usefulness for college matriculation. Each factor was measured by a 5-point likert scale ranging from very important (5) to not important at all (1). Simple frequency analyses were conducted.

For the MM Vocational High, in addition to student's department and gender, a similar question to the one in the LL questionnaire was asked: "Are the following factors important in choosing your department?" Those possible factors included: suitability of your gender for the department, parent's suggestion, academic ability, your own interest, and job concern. Each factor was measured by a 5-point likert scale ranging from very important (5) to not important at all (1). Frequency and crosstabulation analyses were conducted.

Our second research question is: Having taken a science course, how do students behave in laboratory class? This can be further divided into the following: Do girls and boys behave differently? Does the teacher interact differently with girls and boys? If she or he does, in what way? Does the teacher's pattern of interaction with the students differ by gender? If it does, what would be the implication for promoting girls' participation in science courses? To answer these questions, we chose to observe two grade 10 first semester trial elective chemistry lab classes in LL High School, in which gender distribution was more balanced. One of these classes was taught by a female teacher; the other, by a male teacher. At MM Vocational High, a grade 10 chemistry lab class instructed by two teachers, one male and the other female, from the chemical engineering department was observed. Eight to ten observations were made in each school during the 2013-2014 academic year. With permission from the school principals and class teachers, photographs and video documentation was collected during the observations at both schools. In-depth interviews of the class teachers were recorded, and those audio-recordings were transcribed.

Findings

In this section, we shall first present findings from the survey data of LL High School and MM Vocational High to answer the first research question. Then we will follow-up those findings with a report on the observations from the chemistry lab classes in both schools.

Students' Choices of Study

In 2014, there were a total of 272 Grade 11 students in LL Public Senior High School, with 174 males and 97 females, plus 1 student who identified as a non-binary gender of *other*. LL High School had almost twice as many male students emphasize science education as female students. In addition, gender segregation was obvious through the choice of topic research.

According to Table 1, almost one-third of the male students chose math, 13% in physics and 11% in chemistry. In contrast, the most popular topic for girls was English (18.6%), followed by 14.4% in geography, and 13.4% in Civics. The gender ratios were relatively balanced in Chinese, chemistry, and biology.

Table 1.
Grade 11 Students in LL Public Senior High School - By Topic Research Class and Gender

Topic Research Class	Gender		
	Male	Female	Subtotal
Chinese	11(6.3%)	7(7.2%)	18(6.5%)
English	8(4.6%)	18(18.6%)	26(9.4%)
History	13(7.5%)	10(10.3%)	24(8.8%)*
Geography	11(6.3%)	14(14.4%)	25(9.1%)
Civics	8(4.6%)	13(13.4%)	21(7.7%)
Math	50(28.7%)	6(6.2%)	56(20.5%)
Physics	23(13.2%)	4(4.1%)	27(9.9%)
Chemistry	19(10.9%)	12(12.4%)	31(11.3%)
Biology	7(4%)	4(4.1%)	11(4%)
Earth Science	10(5.7%)	3(3.1%)	13(4.7%)
Computer Science	14(8%)	6(6.2%)	20(7.3%)
Subtotal	174(100%)	97(100%)	272*

Unit: person
Note. 1 student in history identified own gender as “other.”

A closer look at the flow of topic choice reveals more interesting clues related to the interaction of gender and topic election. For the purpose of analysis, we grouped the 11 topic classes into three categories according to the three tracks in the university entrance examination, that is, HSS (humanities and social sciences, or Category one), MPE (math, physics, and earth science, or Category two), and CBC (chemistry, biology, computer science,[1] or Category three).

[1] The computer science elective is more for application than for programing and is not a subject tested in the entrance examination. It is grouped into category three for the convenience of analysis.

Table 2.
Cross-tabulation Analysis of Grade 10 Basic Inquiry Class & Grade 11 Topic Research Class, SY 2013-2014

Grade 10 Basic Inquiry	Grade 11 Topic Research			
	HSS*	MPE**	CBC***	Subtotal
HSS*	46(22/23)	26(24/2)	31(24/7)	103(60/32)
MPE**	41(16/25)	49(41/8)	17(12/5)	107(69/38)
CBC***	27(13/14)	20(17/3)	23(13/10)	70(43/27)
Subtotal	114(51/62)	95(82/13)	71(39/22)	270(172/97)

Unit: person (male/ female)
Note. *HSS (Humanities and social science) including Chinese, English, history, geography, and civics.
**MPE including math, physics, and earth science.
***CBC including chemistry, biology, and computer science.

Table 2 shows results of cross-tabulation analysis identifying the relationship between students' Grade 10 Basic Inquiry class and Grade 11 Topic class. There were 103 students assigned to Grade 10 HSS basic inquiry classes in 2012. Forty-six of them (44%) remained in the HSS research topic at Grade 11, with almost equal number of boys and girls. Twenty-six of the 103 students changed their research topic to MPE—a majority of those were male (24 boys and only 2 girls). Another 31 students changed their research topic to CBC, including 24 boys and only 7 girls.

One hundred seven students were assigned to the grade 10 MPE basic inquiry classes in 2012. By grade 11, 41 of them, 16 boys and 25 girls, changed their research topic to HSS. Forty-nine of them, 41 boys and 8 girls, approximately 45%, remained in MPE classes; 17 shifted to CBC classes, and boys still outnumbered girls. Finally, of the 70 students assigned to grade 10 CBC basic inquiry classes, by grade 11, 27 chose HSS topic research classes, 20 (17 boys and only 3 girls) chose the MPE class, and 23 remained in CBC classes.

It is noteworthy that the gender ratio of each category in the grade 10 basic inquiry classes more or less reflected the gender ratio of the student population. Then, uneven gender flows in topic research classes resulted in gender segregation by grade 11, with only about one third of the boys choosing HSS topic research classes and one third of the girls choosing MPE and CBC topic research classes. How did they make these choices? Students identified their own interest (81%) and the basic inquiry class experience (75%) as the two most important influencing factors.

How about the situation in MM Vocational High? As previously mentioned, a highly differentiated curriculum is available in vocational high schools in Taiwan based on department specialties, and students have to choose a department upon entering the school at grade 10. At MM Vocational High, there are six industry related departments and six agriculture related departments as shown in Table 3.

Table 3.
Gender and Choice of Department of 10th graders in MM Public Vocational High School, SY 2013-2014

Department	(female %)	In choosing department, is "if the departmental suits your gender" an important concern?					
		Important			Not important		
		male	female	%	male	female	%
Mechanical Engineering	80(4%)	42	1	54%	35	2	46%
Electrical Engineering	77(5%)	26	1	35%	47	3	65%
Refrigeration & Air-Conditioning	75(8%)	33	2	47%	36	4	53%
Bio-industrial Mechatronics	37(19%)	15	2	46%	15	5	54%
Sheet Metalworking	69(20%)	29	3	46%	26	11	54%
Forestry	42(40%)	7	8	36%	18	9	64%
Chemical Engineering	40(40%)	9	7	40%	15	9	60%
Fowl and Livestock Health Care	37(51%)	13	12	68%	5	7	32%
Farm Management	43(53%)	4	9	30%	16	14	70%
Food Processing	40(55%)	7	9	40%	11	13	60%
Horticulture	41(63%)	6	12	44%	9	14	56%
Home Economics	44(91%)	1	21	50%	3	19	50%
Total	625(40%)	279		45%	346		55%

Table 3 indicates that, among 625 grade 10 students in MM Vocational High School, the vast majority of students in industry related departments (including mechanical engineering, electrical engineering, refrigeration and air-conditioning, bio-industrial mechatronics, and sheet metalworking) were male, except for the department of chemical engineering where gender distribution was relatively balanced. Students in agriculture related departments (including fowl and livestock health care, farm management and horticulture) were relatively gender balanced, except for department of home economics with a majority of female students.

Seventy percent of boys and eighty-one percent of girls considered *one's own interest* to be important factor in choosing their department; 67% boys and 77% girls thought academic ability was important, and job concerns influenced 70% boys and 77% girls. When asked whether if the department suits your gender was an important consideration in their choice of department, 45% students answered yes and 55% said no. While 68% students of the department of fowl and livestock health care considered gender to be an important factor, at least 60% students in the departments of chemical engineering, forestry, food processing, and farm management did not consider gender important in choosing departmental major. It was also determined that, in the process of choosing a department, students who considered gender to be an important factor tended to consider his or her own interest and future job concern to be important factors as well.

Survey data from both LL High School and MM Vocational High showed, not surprisingly, that even in schools emphasizing science and industry education, girls' participation in science and engineering related courses or departments was still minimal. While interest and academic ability were considered to be the most important factors influencing their choice, a considerable percentage of the students did recognize gender as a concern.

Girls, Boys, and Teachers in Grade 10 Chemistry Lab Classes

In LL High School. LL High School was founded upon science education. Its chemistry laboratories have comprehensive equipment, providing easy access to mixing chemicals and measuring instruments for all students in class. By grade 10, certain students were already very familiar with laboratory processes.

Chemistry topics class was an elective and relatively gender-balanced science class. The 2013 first round trial elective class of chemistry was divided into two classes with a total of 32 students. One class was taught by a senior male teacher C and the other a junior female teacher ZH. Interestingly, teacher C's students were predominately boys (11 boys and 3 females), while teacher ZH had more girls (11 girls and 8 boys). We noticed that boys often moved around in other groups to discuss the experiments in the classroom, showing more initiative, while girls often stayed around their station and rarely interacted with members of other groups.

Male teacher C said, because LL is a science high school, boys have outnumbered girls since the school started over 10 years ago, and curriculum designs almost never took gender into consideration. In his laboratory class, C seldom walked around, so if students had any question they had to walk up to talk to him. According to teacher C, all-boy groups often bantered and bonded well, whereas all-girl groups got along like sisters when everything was well, but needed the teacher to intervene and console when disputes arose. In mixed-gender groups, often a boy would be appointed as the leader and a girl as the supervisor. C noted that often boys are free to stay as late as they want to do lab, but girls had to leave before a certain time for safety concerns.

In one instance, students were required to choose their own experiment topic for lab class one day. Six all-boy groups chose: Prank candles that cannot be extinguished, slime toy (polymer), small DIY volcano, paper banknote that cannot be burned, chemical rainbow in a test tube, and chemical fragrance. The boys were having a blast. The only all-girl group chose to use dye yam with colorful leaves. They quietly gathered around the station and boiled the leaves; when the process did not seem to go well they did not seek help nor did the teacher go over to assist them. C said, "I wouldn't tell you exactly what you should do. You have to come and ask me [⋯] you must think for yourself. I want them to discover the answer on their own, because what they learned they would never forget [⋯]"

On the other hand, female teacher ZH often approached her students actively and closely observed and instructed students in their experiments. ZH mentioned that in addition to being encouraged by her father to take up science, she had a female science teacher as her tutor in junior high school. She liked the tutor a lot, and thus preferred learning science even more. Coming to LL High School, at first ZH would use her spare time to take student inquiries. Early on, she allowed students to freely pick their group and topics, but later changed to a more structured guiding method because she realized she could not accurately track how students were doing. She noticed that boys would adopt a trial-and-error approach, while girls often stayed in whatever situation they got themselves in. Girls were better at organizing information, jotting notes, and writing up reports, while boys showed better execution skills. ZH mentioned that because she was more junior, she chose to observe and instruct students closely in class and lab times. She was also closer to students so that they could both learn from and observe each other.

Taking the final assessment in the chemistry lab as an example, ZH asked the students to pick their own teammates and form a group of two to three members. Each team had to choose an experiment topic for the following semester and, meanwhile, had to complete a series of five assigned tasks. The five assignments were: Weigh different chemical materials, make solutions, extract solutions, use Microsoft Excel program to process and explain data, and explain usages of various lab instruments. As each team proceeded, ZH carefully observed them and gave them pointers about key matters. “If my students can’t even handle basic methods, I’d feel embarrassed,” she said. In addition, based on their interactions, it appeared that ZH’s students seemed to trust her a lot; ZH said girls would even seek her advice on personal matters.

In MM Vocational High School. We observed grade 10 chemistry lab classes from the chemical engineering department, which is well equipped and designated as a governmental skill evaluation and technician license tests site.

Grade 10’s Introduction to Chemistry Lab class in the chemical engineering department was allocated 4 hours per week and was co-instructed by a senior male teacher and a relatively junior female teacher. However, most of the time only the female teacher W was in charge of student instruction. The class covered very basic topics from glass processing, separation and manufacturing (separating salt and sand), melting point tests, crystallization, density and energy tests, and essence and soap production. Students were paired off according to their respective student number. Most of them were unfamiliar with lab work. During the first week, Teacher W spent the whole time introducing lab equipment and explaining and stressing safety codes in the lab. Over the first few weeks, glass test tubes were frequently broken; though, this became quite rare in subsequent weeks.

Teacher W noticed differences between girls and boys while conducting experiments. Boys were faster and enjoyed trial-and-error; whereas girls typically studied the procedures thoroughly before carrying out the experiment step-by-step. In the essence production class, W asked the students to bring their own materials. Girls brought pretty flower petals, whereas boys brought mainly tangerine or pomelo peel or roadside grass. When dealing with heavier equipment, teacher W noticed that the male teacher often jumped in to the rescue when the girls did not have enough physical strength; however, she stated that she would handle it differently.

> For some of our equipment students need to set up instruments that have valves or are made of iron […] sometimes the screws could be too tight or even a bit rusty […] or the gas needed more effort to turn on because it needed more lubrication. The boys would solve the problem by themselves. […] They can tackle the problems better […] but they would have higher rate of breaking instruments nearby. As for the girls, if they encountered these problems, they would usually just stand there, then call out to the teacher and tell us they can't turn something on. […] I don't jump in immediately. […] I'd look at them and say, just give it a shot. Or I might say, why not try to use the towel or some other way to make it work […] I know what could help. Yes! I'd ask them to try, but if they really can't make it work, then I'll step in […]

Teacher W said that many of the chemical engineering equipment and installations from her own school days were obsolete. Those older equipment models were from industrial factories and were really heavy and clumsy, particularly for girls to handle. There has been much progress in equipment for school labs—often tailored specifically for student needs and capabilities. She showed us how she handled a large-scale engineering installation in another lab.

> It's because I'm a female too […] I think if you are in the chemical engineering department you are bound to have to use these instruments. […] You have to think for yourself if there are any other ways to go around them. I might give you suggestions, such as trying this or that, or where to find new replacements. Yes! When you have tried everything, you could and still can't solve the problem, then I will help you take a look and see what to do best.

In the chemistry lab classes we observed at both LL High School and

MM Vocational High, we found that girls and boys did behave quite differently and that teachers' interaction with students also differed by gender—which we shall discuss further in the next section.

Summary and Discussion

Upper-secondary education is a critical phase for girls' participation in science education because during this educational phase—in many countries—curriculum differentiation takes place. This study explores differences in how high school girls and boys in upper-secondary schools in Taiwan choose courses and learn science. Two upper-secondary schools, LL Senior High School and MM Vocational High School, were selected due to their emphasis on science and technology education. Student surveys were conducted, and two chemistry lab classes, one led by a male teacher and the other by a female teacher, at LL High School, and one chemical-engineering lab class at MM Vocational High School, taught by both a male and female teacher, were observed multiple times.

Results from quantitative studies show that, in high schools that emphasize science and technology, male students significantly outnumbered female students and gender segregation in elective topic research classes and vocational departments persists. At LL High School, grade 11 students considered their own interest to be the most important factor influencing their choice of topic research class, while at MM Vocational High, although the gender distributions of many departments were highly unbalanced, less than half the students responded that *whether or not the department suits his or her gender* was an important concern in choosing the department. These quantitative findings suggest that the majority of students might not be aware of the effect that gender has on their choice of study. Given how ingrained these gender stereotypes are, how would boys and girls learn in a relatively gender-balanced chemistry lab class?

Results from our qualitative studies are revealing. In general, both schools we observed placed emphasis on the laboratory, where students had to learn how to use laboratory devices and factory equipment correctly. All of the students had an opportunity to operate instruments and equipment. The general instruments and supplies in the science labs showed no apparent gender difference.

At the same time, while students chose their elective topic research classes or their departments, there are still observable differences based on gender in the lab at LL High School's two chemistry topic electives, notably, the students' gender highly correlated with teachers' gender (the male teacher had more male students, while the female teacher had more female students). The male teacher C encouraged students to explore and experiment on their own, and his male students were active, while his female students were more introverted, behaving more conservatively. In the session where students could choose their own experimental subject, gender difference was also observed. The female teacher ZH placed emphasis on basic lab skills. She interacted with both male and female students closely and gave them guidance on their experiments; with ZH as a teacher, there was little difference observed in the performance of both genders. At MM Vocational High, boys were more active and girls were much quieter while conducting lab experiments. The female teacher W paid close attention to and gave detailed instruction on students' handling of equipment and experiment materials.

From the perspective of ANT, we noticed that science and technology learning entails not only knowledge acquisition but also familiarity and control of objects and operation procedures in a lab, involving equipment (lab station, measuring instruments, etc.), lab articles (beakers, flasks, alcohol burners, etc.) and other various items (chemicals, raw materials, lab notebooks, etc.). We were surprised to find strikingly similar patterns of teacher-student interaction in both schools. In the classes observed, female and male teachers' science experiments and hands-on teaching methods differed in style and seemed to influence the students' learning differently.

Teaching with a more free and open style, male teachers valued active learning, which was advantageous to male students who were adventurous, but less helpful to those who were shy and quiet. Meanwhile, female teachers preferred frequent and close interactions with students and valued basic details and skills in instrument operation and experiment execution. The training offered by female teachers was effective for students of both genders. Female teachers had personal experiences figuring out how to handle heavy or dangerous equipment, and, thus, could relate and better understand the girls' mentality with respect to certain learning and physical limitations. The female teachers demonstrated, for the girls, how to handle the equipment, helping them refine their skills and nurturing their knowledge of and familiarity with lab equipment and instruments. This further boosted the students' confidence in conducting hands-on tasks and substantiated their sense of security and efficiency in learning.

No matter whether the female teachers were aware of this or not, their embodied pedagogical insights, that is, bodily experiences gained from past hands-on learning that enabled them to better assist the female students, are characteristics unique to their gender and, therefore, generally speaking, such insights are difficult for male teachers to develop or implement. Perhaps this also explains why female science teachers can attract more girls to the science field than their male counterparts.

What factors influence girls' and boys' learning in high school laboratory classes? What is entailed in the concept of a female teacher as a role model? Drawn from observations of two schools, this study contributes to the existing knowledge by identifying the *embodied pedagogical insight* unique to female science teachers. Based on this study, when asked how we can attract and encourage more girls and women to participate in STEM? We suggest: Include more hands-on lab activities in science education and bring in more female science teachers into high schools.

References

Acker, S., & Oatley, K. (1993). Gender issues in education for science and technology: Current situation and prospects for change. *Canadian Journal of Education*, *18*, 255–272.

Ayalon, H. (2003). Women and men go to university: Mathematical background and gender differences in choice of field in higher education. *Sex Roles, 8*(5/6), 277–290.

Blickenstaff, J. C. (2005). Women and science careers: Leaky pipeline or gender filter? *Gender and Education*, *17*(4), 369–386.

Burkam, D. T., Lee, V. E., & Smerdon, B. A. (1997). Gender and science learning early in high school: Subject matter and laboratory experiences. *American Educational Research Journal, 34*(2), 297–331.

Chen, W-C. (2013). Causes and consequences of high school curriculum-track selection: Gender, belief, teacher's gender, and cognitive development. *Taiwanese Journal of Sociology, 25*, 89–123. (In Chinese)

Chien, C-L., & Jen, T-H. (2011). Investigating the impact of secondary school students' gender on science-related career choice intentions in Taiwan: The case in PISA 2006. *Chinese Journal of Science Education*, *19*(5), 461–481. (In Chinese)

Elltad, E., & Turmo, A. (2009). The influence of the teacher's sex on high school students' engagement and achievement in science. *International Journal of Gender, Science and Technology*, *1*(1), 83–104.

Freedman, M. P. (2002). The influence of laboratory instruction on science achievement and attitude toward science across gender differences. *Journal of Women and Minorities in Science and Engineering*, *8*(2), 191–200.

Han, T-Y. (2012). The masculinization of an engineering laboratory. *Taiwanese Journal for Studies of Science, Technology and Medicine, 14*, 9–66. (In Chinese)

Hofstein, A., & Lunetta, V. N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. *Review of Educational Research, 52*(2), 201–217.

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*(1), 28–54.

Hill, C., Corbett, C., & St Rose, A. (2010). *Why so few? Women in science, technology, engineering, and mathematics*. Washington, DC: American Association of University Women.

Huyer, S., & Westholm, G. (2007). *Gender indicators in science, engineering and technology: an information toolkit*. France: UNESCO. Retrieved September 8, 2017, from http://unesdoc.unesco.org/images/0015/001504/150434e.pdf

Kuo, Y-C., & Sheu, S-J. (2011). The impact of mathematics background and gender on the choice of major in Taiwan's senior high school. *Taiwan Economics Review December*, *39*(4), 541–591. (In Chinese)

Latour, B. & Woolgar, S. (1979). *Laboratory life: The construction of scientific facts*. Beverly Hills: Sage.

Mulcahy, D. (2011) Teacher professional becoming: A practice-based, actor-network theory perspective. In L. Scanlon (Ed.), *"Becoming" a professional: an interdisciplinary analysis of professional learning* (pp. 219–244). Heidelberg: Springer Science and Business Media B.V.

National Research Council. (2006). Laboratory experiences and student learning. In S. Singer, M. Hilton, & H. Scheingruber (Eds.), *America's lab report: Investigations in high school science* (pp. 75–115). Washington: National Academies Press.

Oakes, J. (1990). Opportunities, achievement and choice: Women and minority students in science and mathematics. *Review of Researcher in Education*, *16*, 153–222.

Peng, S., & Jaffe, J. (1979). Women who enter male-dominated fields of study in higher education. *American Educational Research Journal, 16*(3), 285–293.

Rees, T. (2001). Mainstreaming gender equality in science in the European Union: The ETAN report. *Gender and Education*, *13*(3), 243–260.

Sells, L. W. (1980). The mathematics filter and the education of women and minorities. In L. H. Fox, L. Brody, & D. Tobin (Eds.), *Women and the mathematic mystique* (pp. 66–75). Baltimore: Johns Hopkins University Press.

Stromquist, N. P. (1991). *Daring to be different: The choice of nonconventional fields of study by international women students*. New York: Institute of International Education.

UNESCO. (2015). A complex formula: girls and women in science, technology, engineering and mathematics in Asia. Retrieved September 8, 2017, from http://unesdoc.unesco.org/images/0023/002315/231519e.pdf

UNICEF. (2015). The investment case for education and equity. Retrieved September 18, 2017, from https://www.unicef.org/publications/index_78727.html

Xie, Y., & Shauman, K. A. (2003). *Women in science: Career processes and outcome*. Cambridge, MA: Harvard University Press.

Biographical Note: **Hsiao-chin Hsieh** is a professor in Center for General Education and Institute of Learning Sciences and Technology at National Tsing Hua University, Taiwan. Her research interests include sociology of education, gender education, higher education and science, technology and society. E-mail: hhc@mx.nthu.edu.tw

Biographical Note: **Ta-sen Lin** is a professor in the department of Sociology at Fo Guang University, Taiwan. His research interests include sociology of education, social stratification, quantitative methodology and labor market study. E-mail: tslin@mail.fgu.edu.tw

Biographical Note: **Pei-ying Chen** is an Associate Professor in the Department of Education & Graduate Institute of Policy & Administration at National Taiwan Normal University. She specialises in research on school improvement, school leadership, professional learning communities, and gender & education. Email: pychen@ntnu.edu.tw