Spring 2014

Increasing Interest of Young Women in Engineering

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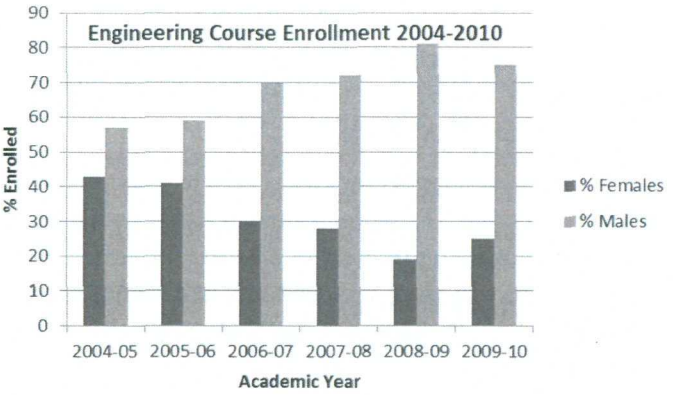
by Diane Hinterlong, Branson Lawrence & Purva DeVol, Ed.D.

INTRODUCTION

The internationally recognized Illinois Mathematics and Science Academy (IMSA) develops creative, ethical leaders in science, technology, engineering and mathematics. As a teaching and learning laboratory created by the State of Illinois, IMSA enrolls academically talented Illinois students in grades 10 through 12 in its advanced, residential college preparatory program. IMSA also serves thousands of educators and students in Illinois and beyond through innovative instructional programs that foster imagination and inquiry. IMSA also advances education through research, groundbreaking ventures and strategic partnerships.

Each year, IMSA enrolls approximately 225 students composed of nearly equal numbers of male and female students. Students are required to complete a core science program consisting of four courses in chemistry, physics, biology and scientific research during their sophomore year. Juniors and seniors must complete a minimum of four electives in science over the next two years. Students may elect to fulfill their elective requirements by completing any courses offered in the science program.

In the fall of 2004, engineering was first offered as a physics elective to upperclassmen. When the course was first offered, female and male student enrollment was approximately equal. Over the first few years that the course was offered, however, the percentage of female students enrolled in the course dropped significantly. Active recruitment of female students by IMSA instructors was the only factor preventing the course from becoming an all male course.



The growing disparity in enrollment of females and males in IMSA's engineering course prompted further inquiry, beginning with a review of relevant literature exploring trends in physics/engineering enrollment patterns. Following the literature review, a quantitative analysis was initiated to examine the assumption that the same trend of disparity in enrollment between females and males existed in other physics courses. Based on this data, information to provide insight into the reasons for the disparity was elicited through focus groups and surveys among IMSA students. Finally, action steps to proactively address the disparity were identified and implemented.

Quantitative Analysis: Examining Enrollment Trends for Five Physics Electives, 2003 – 2010

Enrollment in IMSA physics electives was analyzed for every student from the 2003-04 academic year through the

2009-10 academic year. Excluding Independent Study projects in physics, data from all "core" physics electives were analyzed: Advanced Physics, Modern Physics, Calculus-Based Physics, Engineering and Electronics. Of these courses, only Advanced Physics and Calculus-Based Physics are courses that span two semesters.

A. Gender Differences:

Female enrollment in four of IMSA's five physics electives was found to be significantly lower than male enrollment. The only exception was Advanced Physics, where the seven-year average is 54% female and 46% male enrollment. Table 1 details the gender differences for each elective for each academic year over the last seven years, followed by a bar representation of the 7-year average.

The lowest percentage of female enrollment occurred in engineering, where female students constituted 29% of the enrollment over the last six academic years.

Gender differences were then analyzed by ethnicity. Table 2 shows the female and male students who took physics electives prior to graduation, categorized by ethnicity.

Significantly fewer African-American females enrolled in electronics (7 out of 64, or 11%) compared to African American males (19 out of 33, 58%). The same is true for Latinas in calculus-based physics (4 of 34, 12%), compared to Latinos (12 of 33, 36%). Males of all ethnic groups took calculus-based physics at a greater number and percentage than their female peers, but the gap was significantly less for Asians. 45% (118 of 262) of Asian females took Calculus-Based Physics, compared with 70% of Asian males (175 of 251).

Table 1. Difference between female and male enrollment in physics electives

Physics Elective	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	Total	7-Year Average
Advanced Physics	60% F 40% M (60, 40)	59% F 41% M (51, 36)	60% F 40% M (43, 29)	47% F 53% M (49, 56)	53% F 47% M (69, 62)	51% F 49% M (32, 31)	50% F 50% M (39, 39)	343 F 293 M	54% F 46% M
Modern Physics	49% F 51% M (19, 20)	39% F 61% M (41, 63)	36% F 64% M (33, 59)	44% F 56% M (35, 44)	37% F 63% M (15, 26)	45% F 55% M (33, 40)	30% F 70% M (27, 62)	203 F 314 M	39% F 61% M
Calc-Based Physics	35% F 65% M (30, 55)	31% F 69% M (32, 71)	41% F 59% M (39, 56)	32% F 68% M (31, 65)	30% F 70% M (22, 51)	29% F 71% M (23, 57)	40% F 60% M (25, 37)	202 F 392 M	34% F 66% M
Electronics	30% F 70% M (21, 49)	40% F 60% M (23, 34)	34% F 66% M (12, 23)	31% F 69% M (11, 25)	36% F 64% M (13, 23)	32% F 68% M (12, 25)	32% F 68% M (11, 23)	103 F 202 M	34% F 66% M
Engineering	*	43% F 57% M (9, 12)	41% F 59% M (9, 13)	30% F 70% M (8, 19)	28% F 72% M (10, 26)	19% F 81% M (7, 29)	25% F 75% M (7, 21)	50 F 120 M	29% F 71% M

*Engineering was not offered until the 2004-05 academic year

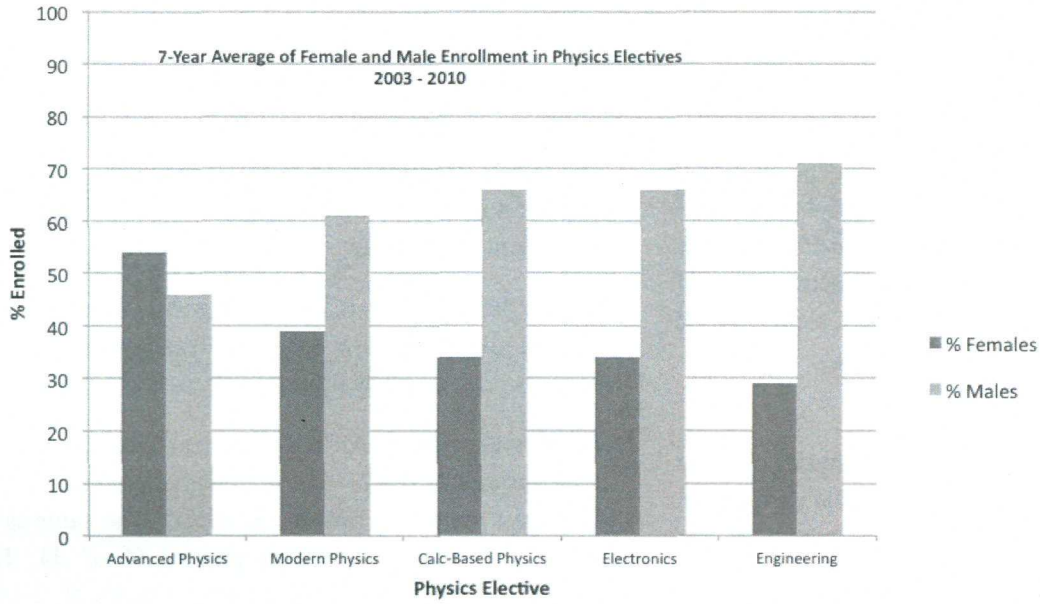


Table 2. Number, ethnicity and gender of IMSA graduates of 2004-2010 who took each physics elective

Ethnicity	Gender of 2004-2010 graduates	# who took Advanced Physics	# who took Modern Physics	# who took Calc-Based Physics	# who took Electronics	# who took Engineering
African-Americans	64 F 33 M	39 F 20 M	16 F 13 M	7 F 9 M	7 F 19 M	3 F 5 M
Asians	262 F 251 M	117 F 75 M	59 F 102 M	118 F 175 M	18 F 43 M	11 F 16 M
Latinos	34 F 33 M	14 F 28 M	13 F 12 M	4 F 12 M	11 F 15 M	4 F 13 M
Caucasians	302 F 312 M	147 F 146 M	103 F 166 M	72 F 216 M	58 F 109 M	29 F 77 M
Multiracial	38 F 25 M	18 F 16 M	10 F 13 M	5 F 12 M	7 F 13 M	3 F 5 M
Ethnicity not given	12 F 12 M	7 F 10 M	3 F 7 M	4 F 9 M	1 F 3 M	0 F 4 M

Table 3. Graduates from 2004-2010 who earned a C or lower in each physics elective, grouped by ethnicity

Physics Elective	African Americans with C or below	Latinos with C or below	Multiracial with C or below	Asians with C or below	Caucasians with C or below
Advanced Physics	15% (9/59)	19% (8/42)	*	6% (12/192)	9% (27/293)
Modern Physics	24% (7/29)	24% (6/25)	17% (4/23)	10% (16/161)	7% (19/269)
Calc-Based Physics	44% (7/16)	44% (7/16)	*	14% (41/293)	12% (34/288)
Electronics	15% (4/26)	23% (6/26)	20% (4/20)	*	8% (14/167)

*Not reported because fewer than 4 students of this ethnicity earned a C or lower in this class.
Engineering was excluded because fewer than 4 students of every ethnicity earned a C or below.

B. Grade Differences:

With differences in female and male enrollment for all ethnic groups, the next step was to examine the academic grades earned by the students in the physics electives. The percentage of students, by ethnicity, who earned a C or lower in each physics elective was determined. Table 3 presents the data for the last seven academic years. The only elective in which over 10% of students in each group earned a C was calculus-based physics. Of particular concern was that at least 19% of Latino students earned a C in each of the four electives (ranging from 19% in advanced physics to 44% of Latino students earning a C in calculus-based physics).

Qualitative Analysis: Focus Groups to Examine Students' Perceptions

The above analysis of data served as a basis for selection of questions and participants for small focus groups in the spring semester of 2009, conducted by Dr. Margery Osborne from the University of Illinois at Urbana-Champaign (UIUC). Although there were a small number of participants, 14, the focus groups revealed stark differences between males and females regarding their interest in physics.

Male students indicated that they like constructing physical models and problem solving and they were excited about projects. They were not worried about grades and saw physics as fun and connected to their life experiences. Male students further indicated that they like physics because it was not abstract. Interestingly, female students indicated just the opposite; they saw physics as abstract. Female students like physics because they felt they were good at it and earned good grades. Their reasons for liking physics, such as positive teacher relationships, were more personal than those provided by the male students. Table 4 below summarizes their responses:

Table 4. Why students like physics

Males	Females
Not Abstract	Abstract
Disregard Grades	Good Grades
Experiential Connections	Personal
Building	Good at it
Problem Solving	
Projects	
Fun	

The disparate viewpoints of the genders held regardless of the students' grade level, ethnicity and academic achievement in physics electives.

ACTION STEPS

The quantitative and qualitative data served as the foundation for creating action plans to reduce the disparities in enrollment and achievement as summarized below.

1. **Class Changes:** Advanced Physics has typically seen a decline in enrollment from first semester (Applied Mechanics) to the second semester (Sound and Light). Beginning the fall semester of 2010, the two semesters were switched so that the Advanced Physics: Sound and Light class was offered in the fall semester and the Advanced Physics: Mechanics class was offered in the spring semester. Since the introductory course, Scientific Inquiries: Physics, focused on mechanics, the goal of switching the sequence of the advanced courses was to offer new options in physics for students after completing the core rather than expanding knowledge of mechanics. In making this option of new topics available to students after completing the core, the hope was that students might be more inclined to stay enrolled in physics electives.

More recently, Applied Mechanics has been eliminated as a physics elective and students choosing to continue study of classical mechanics have been encouraged to enroll in Calculus-Based Physics: Mechanics. In addition, Sound and Light is now offered both semesters.

Other changes that occurred were in the physics class required for all sophomores, Scientific Inquiries: Physics. It is important to note that the changes to Scientific Inquiries: Physics were not a direct result of this research nor were they made to solely address differences in enrollment and achievement of females and underrepresented minorities. In 2009-10, the teachers of Scientific Inquiries: Physics made changes to the course focused on improved student learning. These changes included allowing students to make revisions on their assessments, reordering topics to promote increased student engagement, and paying attention to the grouping of students in these classes. As these changes benefit the learning of all students in physics, the expectation is that the gap in enrollment and academic achievement in physics electives will decrease for females and underrepresented minorities. The teachers of Scientific Inquiries: Physics incorporated changes to make the course proficiency-based and to allow more autonomy in working through concepts in order to support more personalization for students starting in the 2010-11 school year.

2. Alumni Connections: In the spring semester of 2010, a female alumni event was piloted to expose current students to successful female alumni currently working in STEM related fields. The goal was to increase interest of females to pursue STEM classes and careers. Six female IMSA alumni who had completed degrees in the physical sciences were invited to speak with IMSA students about their interest in STEM fields and their career choices and experiences. The event was created to allow for open dialogue with students in a casual setting. About 20 students attended the event, two of whom were male students. Approximately 45-50% of the students were African Americans. Although a small event, this may be replicated on a larger scale in future years.

3. Elective Choices: Students clearly influence one another's choices when selecting electives as affirmed through a survey eliciting student feedback on their elective choices. As the number of females enrolled in Engineering decreased, so did the number of females influencing peers to sign up for this physics elective. Several actions were taken to proactively inform students about the Engineering course. During a school elective fair, two videos were used to help inform students about the course. One video included interviews with two female students currently enrolled in the class; the other video captured some of the exciting projects students engaged in during the scope of the course.

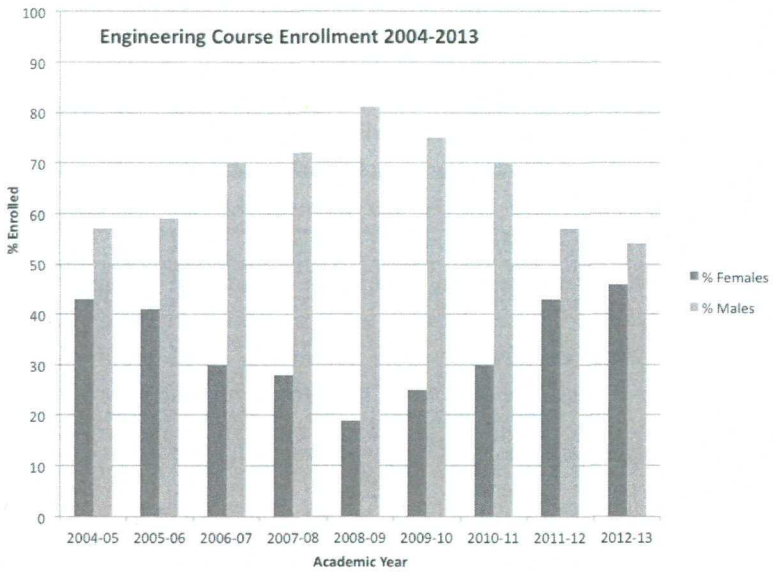
In addition, in the fall of semester of 2010, juniors and seniors enrolled in the course invited in teams of sophomores for an engineering competition. There were 6 teams in total that participated in the "Cardboard Boat Race" in September 2010. Each team was voluntarily formed and composed of two males and two females. With the assistance of junior and senior students enrolled in the fall 2010 semester of Engineering, the sophomore teams created boats from a fixed amount of cardboard, and then raced them across a campus pool for prizes. While learning engineering principles in a team setting, the goal was to excite more females and underrepresented students to enroll in Engineering as a junior or senior.

4. Project Choices: The mission of IMSA, the world's leading teaching and learning laboratory for imagination and inquiry, is to ignite and nurture creative, ethical, scientific minds that advance the human condition, through a system distinguished by profound questions, collaborative relationships, personalized experiential learning, global networking, generative use of technology and pioneering outreach. Each year, students enrolled in Engineering were required to propose an innovative project. Peer feedback on projects helped refine the projects and collaborative teams worked on projects selected to move from the idea phase into a prototype phase. In the first years the course was offered, students were given significant latitude in selecting a project. As the course evolved, more structure was embedded into the projects with a focus on energy-related projects one year followed by the current requirement to align projects with the IMSA mission, i.e., projects were required to "advance the human condition." Examples of student projects include keyboards for

individuals with limited use of hands or arms and swimming caps to aid blind swimmers. Based on survey feedback from students, alignment of projects to the mission was received positively especially by the female students. They were more excited and engaged by projects with this human factor embedded into the scope of the projects.

RESULTS/NEXT STEPS:

Although it is difficult to ascertain the influence of each individual action step, it is clear that something has made a difference. The downward trend in female enrollment in the Engineering course that originally sparked this investigation has not only stopped but female enrollment in the course has increased as noted in the chart below.



Moving forward, enrollment trends will continue to be monitored. The teachers of the introductory core course will evaluate the effectiveness of moving to a proficiency-based model in this course. In addition, the data presented here regarding grades, gender and ethnicity raise more questions to be considered in a future study.

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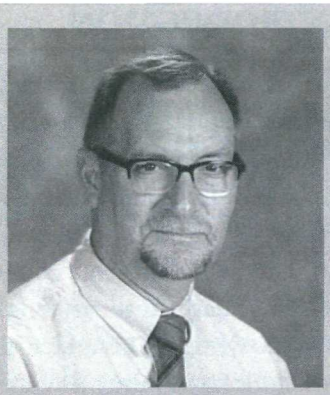

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