My interest in engineering is relatively recent. Like many of my peers, I had only vague ideas about majors and careers after high school. On the recommendation of my guidance counselor, I listed "engineering - undecided" on my college applications. I did well in, and enjoyed, math and science, but the same could be said for most of my classes. After choosing to enroll at the University of Delaware, I declared chemical engineering mostly for the strong reputation of Delaware's program. By the time my freshman year was over, however, my interest in engineering began to wane. To my knowledge, none of my engineering peers had the spontaneous dorm-room conversations that, according to university marketing departments, are endemic amongst budding political science, anthropology, and even quantum physics students. My failure to appreciate the necessity of the fundamentals left me disappointed in engineering as an exciting profession.

As college progressed, however, I slowly began to see my chosen discipline in a new light. Through undergraduate research, in particular, I came to relish the excitement of turning ideas to reality. My research revolved around a novel application of thermoelectric materials, which have long held promise as a critical piece of the sustainable-energy puzzle. The benefits of thermoelectric power are numerous: they capture energy from waste heat (such as that of industrial processes and automobile exhaust) and naturally-occurring thermal gradients (such as geothermal energy), have a small size, degrade slowly, generally consist of nontoxic materials, and operate silently. However, their widespread adaptation has been limited by their low power outputs and efficiencies. Although a large number of thermoelectric applications have been considered, investigated, and commercialized, the thermal driving force remains the same in each: a steady-state, spatial temperature gradient, such as that between automobile exhaust and ambient air. My project, advised primarily by Dr. Joshua Zide as well as by Dr. Ajay Prasad, aimed to model and build devices that convert periodic variations in temperature into spatial temperature gradients for thermoelectric power generation. This type of power is ideal for sensors and other low-power electronics.

Over the past three years, my problem-solving capabilities and personal and professional development dramatically accelerated as a direct result of research. For example, we were interested in adding a simple solar simulator to our experimental apparatus to quantify the effect of solar radiation on our devices, but commercial options ran for sums well outside our research budget. The simulator had to match the frequency, intensity, and spectrum profiles of the sun; simply sinusoidally adjusting the power to the bulb would skew the radiation spectrum. Over the course of two weeks, I designed a pulse-width modulation program with a sinusoidally-varying duty cycle in LabVIEW and connected it to a LabJack and a halogen lightbulb; the result was a suitable solar simulator at a fraction of the cost. Experiences like these spurred my passion for hands-on engineering and problem solving. Additionally, through both numerical and experimental simulations, I have developed a sense of the process of engineering design—tweaking rod configurations, fine-tuning truncation distances, and toying with degrees of oxidation to wring every last milliwatt of power from each device. Rather than being tedious or daunting, however, the process of iterating to convergence was a game scored by cost and elegance. Some of the components of the experimental devices include fortune-telling crystal balls and fabric from the local arts-and-crafts store. As the only student returning to the project for a second summer, I experienced the satisfaction of guiding the direction of research, lobbying for and then designing an experimental approach to our project. I also learned to communicate my results to both technical and nontechnical audiences. My research has contributed to three publications in technical journals [1,2,3], and I have presented at domestic and international technical conferences. However, I most relish explaining my research to nontechnical audiences, comparing my research to analogous phenomena in everyday heat transfer.

Additional experience contributed to this reversal. Coursework, particularly design projects, demonstrated the power and subtlety of making assumptions with limited information. Can we assume the demand for propylene glycol in 2020 increases proportionally with projected natural gas demand, and what are the consequences if we overdesign the manufacturing facility? Can we assume our oil pipeline will not be targeted by drunken caribou hunters, as the Trans-Alaska Pipeline was in 2001, and what are the implications if we are wrong? Additionally, interning with DuPont has illustrated the challenges of good design when squeezed by both shareholder demands for quarterly profits and a public commitment to safety, health, and the environment, especially in an industry traditionally viewed as callously indifferent to these concerns. Is swapping a carcinogenic coolant with a known global warming agent a good tradeoff? At what capital cost does implementing a nontoxic, environmental coolant become unreasonable? For me, these questions represent philosophy with numbers, as quantifying safety, environmental, and geopolitical attributes reflects our judgment of their value.

Formal study in engineering ethics expanded my appreciation for a less exposed side of the discipline. In the spring of my sophomore year, I enrolled in Environmental Ethics, taught by Dr. Thomas Powers, to eliminate a breadth requirement. However, the philosophical approach to problem solving – defining principles and frameworks for making decisions – contrasted sharply with the empirical approach espoused by the engineering curriculum but seemed necessary for consistency in the "gray areas" outside the engineering domain. For example, when risk assessments are laden with uncertainty, the "precautionary principle" neatly characterizes appropriate liability levels. My term paper, published in *Science and Engineering Ethics* [4], attempted to define an appropriate environmental ethic for decision-makers to assess the potential environmental costs of nanotechnology. These challenges sparked a desire to engage policymakers and participate in technical policy discussions as a professional engineer.

Finally, I began to recognize engineering as a tool for social progress through my interactions with Dr. Ismat Shah, a materials science and engineering professor at UD. In many ways, we are quite different - he is a Muslim quinquagenarian immigrant, while I am a second-generation Egyptian-American college student - yet his life exemplifies my career ambitions. His work as a scientist is profoundly humanitarian, as his research in solar cells and water purification directly improves the lives of people worldwide, particularly in Pakistan. I studied introductory materials science with him in Marseilles for a winter term; this past spring break, he invited me and Dr. Powers to present at a nanotechnology and ethics conference in Pakistan, where livelihoods – and, to an extent, American national security – are deeply rooted in the success of engineering solutions. While I desire a career applying engineering skills outside of academia, Dr. Shah epitomizes the "citizen-scientist" ideal, reminding me of engineering's power, and responsibility, as a force for good.

My current enthusiasm for engineering has compelled me to give back to the profession. In my second summer of undergraduate research, I mentored an underrepresented high school student who was interning in our lab, assigning him meaningful contributions to my project and encouraging his growing interest in engineering. That same summer, I led a workshop with my lab for a summer camp demonstrating how thermoelectric materials and a campfire could charge a smartphone, illustrating key concepts in energy and power. Beginning my junior year, I also began tutoring math and chemistry both for pay through the University of Delaware and not-for-pay through UrbanPromise, a small high school in Wilmington, DE serving students who struggled in the public education system. I am both inspired and challenged by the proportion of students at UrbanPromise who want to build electric automobiles, design video games, and fix cars yet do not have access to chemistry labs or SAT preparation books. Additionally, I currently serve as the treasurer of Delaware’s chapter of Tao Beta Pi, where our leadership team promotes professional development of its members and facilitates interactions with industry.

I plan to be an engineer developing technologies that dramatically improve peoples' lives, such as increasing access to fresh water and clean energy. I refer to "developing" in the traditional R&D sense of bringing proven research to market; my work will likely be performed in either an industrial laboratory or a start-up setting. To this end, graduate studies in materials science and engineering will immerse me in a fascinating interdisciplinary field primarily focused on applied research. I am convinced that many of this century's greatest innovations in energy and water access will come from the field of materials science, including distributed energy, localized structural materials, and passive water treatment. I believe electrochemistry is the key to enabling advances in renewable energy, as intermittent power sources such as solar and wind cannot be integrated into the grid without dynamic and cost-effective storage systems to distribute supply. I hope to work under Dr. Fikile Brushett at MIT, who researches total organic redox flow batteries – a novel approach that could both improve performance and reduce the cost of grid-scale energy storage systems. I plan on developing deep expertise in the fundamentals of battery design and then apply this experience towards scale-up and commercialization of promising battery technologies and other materials science innovations. An NSF Graduate Research Fellowship would enable my career to advance the electrochemical field and improve both America’s standard of living and interest in applied science.

[1] CC Bomberger, **PM Attia**, AK Prasad, and JMO Zide. *Appl Therm Eng*, 56, 1-2, 152 (2013).

[2] P Dongmo, Y Zhong, **P Attia**, *et al*. *J Appl Phys* 112, 093710 (2012).

[3] **PM Attia**, MR Lewis, CC Bomberger, AK Prasad, and JMO Zide. *Energy*, 60, 432 (2013).

[4] **P Attia**. *Sci Eng Ethics*, 19, 3, 1007 (2013).