Empowering the Future: Integrating Invention and Intellectual Property Education in P-12 Engineering to Foster Innovation

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Marie is an alternate route teacher with an educational background in math, physics, chemical engineering and computer science. As the first girl in her family to go to college, and maybe to prove a point, she earned two bachelors degrees, one from Montclair State University and one from New Jersey Institute of Technology. After 26 years in industry an unexpected layoff came at a bad time, she was recently widowed. It was time for something completely different. She accepted a job teaching chemistry and physics at Bayonne High School. Since then she was able to write curriculum for a science research program and an engineering program. Now she teaches mostly pre-college engineering. She also brought in many new programs to her school including FIRST Tech Challenge, Lemelson InvenTeam, Technology Students Association, and Society for Science with a local science fair and ISEF.

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Abstract

Over the years, the U.S. Patent and Trademark Office (USPTO) has been engaging the P-12 Education Community and fostering relationships with prominent invention-focused organizations such as the Lemelson Foundation, Society for Science, and FIRST. In the last decade, momentum was gained with the Kids and Educators website featuring stories of inventors, young entrepreneurs with interesting patents, famous inventor trading cards, and games to teach Intellectual Property (IP). It debuted at the inaugural National Summer Teacher Institute (NSTI) in 2014. Fast forward to 2022, the USPTO established the Master Teachers of Invention and Intellectual Property (MTIP) program to reach a broader audience of teachers. Many teachers who were veterans of NSTI in past years joined the first cohort of teacher leaders. At the same time, the USPTO Kids and Educators website underwent a comprehensive transformation to include all their outreach programs and EquIP HQ, a new collection of curriculum and ready-made lesson plans, which is still evolving. This paper will broadly outline the efforts of the USPTO and specifically its effect on one teacher's engineering classroom. The educator has been in a longstanding relationship with the USPTO since 2008, integrating IP lessons into her curriculum. In 2014, she attended NSTI; in 2018, she advised a Lemelson InvenTeam and is now an MTIP participant. Aligned with the USPTO's goals, her engineering classes have been increasingly enriched in intellectual property, invention education, diversity and inclusion, and educational equity.

Introduction

Engineering Education, Invention, and Intellectual Property Education are not only compatible but necessary to each other. This paper documents the intertwined story of the United States Patent and Trademark Office's outreach into grades P-12 STEM education and one engineering educator's efforts to include Invention and Intellectual Property Education in a high school engineering curriculum that she was mandated to construct, and how the resulting relationship brought benefits to both.

The Story of the USPTO's Engagement with STEM Education

While the Patent and Trademark Office (USPTO) has been doing K-20 outreach since at least the early 1980's, the USPTO's U.S. Office of Education (OE) was not officially established till 2011. Its mission is to provide outreach and educational programs for teachers, students, and young inventors to dedicate specific IP and invention education to the K20 community. The Office of Education supports the mission of the USPTO by providing resources, professional development, student programming, and digital media to educators nationwide. One of its main goals is to tap into all children's creativity and passion by providing them opportunities to be innovative and to solve personally relevant problems. Solving problems through invention education empowers students to develop lifelong 21st-century critical thinking, creativity, collaboration, and communication skills.

In 2012 the U.S. Patent and Trademark Office (USPTO) released the first Inventor Trading cards. The trading card series features caricatures of inventors to showcase patent holders from diverse backgrounds. This creative endeavor is intended to foster inspiration and encourage upcoming generations of inventors and innovators, particularly those from varied and underrepresented groups. The USPTO periodically unveils new cards, distributing them at their booths during various education and outreach festivals and events. This initiative, conceptualized by the Office of Education and Outreach at the USPTO, is a vibrant and engaging means of celebrating inventors and promoting diversity in the invention community. Trading card lesson plans and digital media developed by OE provide resources for teachers and parents interested in advancing students' invention and intellectual property (IP) engagement.

On February 11, 2013, coinciding with the 165th birthday of the legendary Thomas Alva Edison, the "Science of Innovation" video series was launched as part of a collaborative project with the USPTO and the National Science Foundation (NSF). The series expanded in 2016, adding six additional videos. This series showcases how innovation can transform fundamental science and engineering concepts into impactful societal and economic outcomes. Access to the entire video collection is free, aligning seamlessly with state and national education standards. The Science of Innovation resonates with both educators and learners alike.

One of the goals of the USPTO Office of Education is to provide all students with opportunities to learn about intellectual property protection and invention, especially in STEM fields. Realizing that the most effective way to reach students would be through their teachers, the OE started its flagship professional development program, the National Summer Teacher Institute (NSTI), in 2014. The NSTI offers a weeklong immersive professional development experience. NSTI is tailored to elevate elementary, middle, and high school teachers' understanding of making, inventing, and intellectual property (IP) creation and protection. Creating IP becomes an inspirational force motivating student achievement across science, technology, engineering, and mathematics (STEM) disciplines, computer science, and fields like innovation and entrepreneurship. Renowned speakers and workshop instructors at NSTI include experts from the USPTO, scientists and engineers, entrepreneurs, and representatives from federal government agencies. Attendees participate in engaging sessions and hands-on workshops designed to provide teacher-friendly materials, enhancing student learning, and igniting the passion for innovation, IP, and problem-solving.

At the inaugural NSTI in 2014, the first version of the “Kids and Educators” [3] section of the USPTO website was debuted. It included the Inventor Trading Cards, the “Science of Innovation” video collection, IP games, and inspiring young inventor and entrepreneur stories and videos ready-made for classroom use, all in one place.

During the 2022-23 school year, the USPTO Office of Education initiated the inaugural year of the Master Teacher of Invention and Intellectual Property Education Program (MTIP). The MTIP program is a dynamic train-the-trainer initiative championed by the U.S. Patent and Trademark Office (USPTO) and STEMisED [13]. Seasoned educators passionate about invention or intellectual property (IP) education step into the spotlight as teacher leaders, offering their peers a wealth of professional development opportunities. They create a robust network of

teacher-leaders who, in turn, will empower educators nationwide to infuse their classrooms with the spark of invention and IP education. In their first year, these teachers have provided professional development for over 2000 educators nationwide and have reached a broader community through educational websites, including Edutopia [12] and the74million.org [14].

Along with the MTIP program rollout, the MTIP teachers became the first to try out a whole new release of the USPTO's "Kids and Educators" [3] website. A significant new resource called EquIP HQ [3] was introduced. It features extensive lesson plans, games and activities, and inspirational and educational videos designed for all grade levels. Students can walk through the invention, patent, and trademark design processes in various activities that simulate the real thing. This release also enhanced the Inventor Trading cards section with games and lessons featuring some inventors' stories. One is Rory Cooper, engineering professor, inventor, veteran, Paralympic athlete, and National Inventor's Hall of Fame inductee.

As part of their training as teacher leaders the Master Teachers of Invention and Intellectual Property were invited to participate with the USPTO and STEMisED in the 2022 InventEd Convening at their first gathering. This group meets about every 18 months and forms what they call an "eco-system" of cooperative support for anyone involved in STEM and Invention Education, though not exclusively for STEM, because through Invention Ed they create a convergence point for all other educational disciplines, even the fine arts. For MTIP teachers, an already dynamic group, this represented a goldmine of new networking and reconnections with many already worked with, such as Society for Science, FIRST, and National Science Foundation, providing new resources for their students and fellow teachers. The MTIP teachers meet virtually as small "teams" with those in the same geographical area supported by STEMisED, to share ideas and update each other on progress. STEMisED also helps them with new materials for their presentations. All the original group of 22 MTIP teachers have opted on to a second year with the program and continue to reach out to the education community in new ways, even helping USPTO employees to be presenters with them.

In essence, the Office of Education at the United States Patent and Trademark Office is a catalyst for unlocking the boundless potential within every child. The OE commitment extends beyond providing resources and is about igniting the spark of innovation and instilling the belief that each child possesses the capacity for extraordinary achievements. By nurturing creativity and leveraging the power of invention, the USPTO Office of Education envisions a future where students recognize and embrace their potential, becoming lifelong innovators destined to shape the world. The Office of Education now operates as part of the USPTO's larger Office of Public Engagement extending its possibilities even further.

The Engineering Teacher's Story of Creating a Curriculum Including IP and Invention

In late 2007, four teachers were asked to "imagine an engineering academy for high school." The notes from that morning meeting became the draft outline for "Intro to Engineering," which debuted in the 2008-09 school year, followed by a second-year portfolio-based course called Engineering. There were a few restrictions for the teacher chosen to bring these courses to life. The new courses had to be homegrown, as there was no budget to buy an existing program. As electives in the science department, they could not place any requirement on another department,

such as math prerequisites. At that time, there were no pre-college engineering textbooks and no budget to buy them. Faced with this start, the teacher decided to prepare an engineering program as applied science, based on her experience with college programs and in industry. The NextGen Science Standards [1] and the Framework for P-12 Engineering Learning [2] later validated this decision. The courses soon grew in richness and became popular at the school. With mentorship from the Research Experience for Teachers program at the New Jersey Institute of Technology, the teacher was able to present the program and curriculum to the ASEE national conference in 2015 [4].

The lack of a textbook was not a handicap because it left the teacher free to pull resources from various sources, including the USPTO website. From her experience of engineering in industry, it seemed necessary for her to include awareness of the patent process. When teaching the steps of Engineering Design in-depth, the product is the invention of a new technology, [8] which lends itself naturally to a discussion of intellectual property, IP, and entrepreneurship. Before the "Kids and Educators" [3] site existed, there was a four-page document on the USPTO website called "General Information Concerning Patents". It was an excellent summary of USPTO information, including patents, trademarks, service marks, and copyright. Access dates show it was added to the engineering curriculum in March 2009, along with some teacher-made PowerPoint class notes made from information on other parts of the USPTO website on the process of getting a patent. These original notes were not very exciting and mainly consisted of "file some paperwork, pay a fee, file more paperwork, hire a lawyer and pay more fees, then the patent is either accepted or rejected, and the rejection can be appealed." This original document and teacher notes were later replaced by a 36-page 2014 PDF document also called "General Information Concerning Patents." This second document was also superseded by a new series of guides and tutorials to help walk prospective inventors through the process. By this time, however, the teacher was invited to the inaugural National Summer Teacher Institute in 2014 and much more classroom-ready material was available, taking IP education for this teacher in a new direction and beginning a new relationship with the USPTO.

In those early days of the course, in 2009-10, the teacher shared her experience of searching for good examples of IP with a college professor colleague. She suggested a collection of about a dozen mid-twentieth-century patents in the estate of her late uncle, Gustav Klein, who worked for the Caloric Stove Company, because they were written in plain English and very easy to read. She noted this because they both had experience with patents that were not easy to read and were not good examples for classroom use. She emailed the teacher the patent numbers. The discovery of the "FreePatentsOnline" [9] website made finding copies of those patents easy. They became the first entries in a sample patents collection used ever since for Intro to Engineering. The students found them easy to read, and the patent drawings were easy to understand. One patent, US2560959, from 1951 for an improved gas stove top referenced several earlier patents, including one, US1159896, from 1915 on an early gas stove design, and led to an entire lesson on how invention led to the development of modern kitchen appliances, highlighting the contributions of mechanical, industrial, and manufacturing engineering.

While these early steps to include IP evolved ad hoc and organically, the giant leap forward came, as previously mentioned, when the teacher attended the NSTI in 2014. Instead of simply using the USPTO website as a resource for lessons, the teacher now had a much more interactive

relationship with the USPTO informally sharing ideas and resources. The new "Kids and Educators" [3] section of the USPTO website provided the teacher with several new lessons using the "Science of Innovation" videos, young entrepreneur videos, and Inventor Trading cards. The teacher could show pictures of herself with some inventors in the videos she met at NSTI. It also built a stronger connection between the teacher's lessons on IP and entrepreneurship. In her students' entrepreneur projects they had to propose an idea for a new business and pitch it. The teacher could now show how the inventors in the "Science of Innovation" videos formed new companies to sell the technology in their patents, adding enrichment to the students' experience. It also added several new patents to the sample patents class collection, including the paper airplane US4377052, which became a novelty for engineering presentations during National Engineers Week, with attendees trying to read and fold it. Copies of the patents from the Inventor Videos were also added because students could relate to them, having seen the inventor's story.

The quality of the students' experience working with patents also subtly improved. One example is from their final project. Students must watch an episode of the series "How it's Made" and present a 5–10-minute slide show describing how the video addressed five topics from the year's lessons: engineering design and systems, economics, intellectual property, ethics and sustainability, and entrepreneurship. Early on, there was only one standout presentation using IP where the student's slides on electric guitars were almost entirely pictures, including several shots of early patent drawings leading up to the Les Paul 1955 Gibson patent. With updated lessons on IP, this section of the students' final projects improved with more substantial examples of patents on equipment similar to the machines used in the videos. One good example came from a girl who watched the "How Crayons are Made" episode. The video mentioned a "secret ingredient" in the crayon recipe so she could have just cited a trade secret. Instead, she also added some patent numbers for crayon recipes, and speculated that the secret ingredient in the video might be a plasticizer because it was listed in one of the recipes. She was also an English language learner. In another example, two girls chose to prepare a display for a Tech Expo event on the "Evolution of the Toothbrush" to highlight the importance of everyday technology and cited that they found over 3000 patents related to toothbrushes.

More significant projects for engineering students began to include Intellectual Property Research. The first was a Lemelson MIT InvenTeam [11] project in 2017-18. It was inspired by a 2016-17 STEAM Tank™ Challenge [10] project that had just won local awards, and the students wanted to take it to the next level. When researching background for science fair projects, students researched patents to see if their idea could be done. In early 2020, one of her students won the local Regeneron ISEF-affiliated science fair and filed a patent for her project. During COVID-19 in the 2020-21 season, when our FIRST Tech Challenge robotics teams worked remotely, FTC was allowed to do the Innovation Project [6], usually only for FIRST Lego League. Three girls worked entirely on Zoom to propose a digital version of the high school's service-learning program, which was not only all paper-based but used old-style "carbon copy" forms. In recent years, students also did patent research when submitting entries to the Samsung "Solve for Tomorrow" [15] competition; a few were state finalists. Most recently, January 2024, the teacher's senior engineering class presented a design for The High School Challenge: Lincoln and Holland Tunnel Robotics of the Port Authority of NY and NJ.

Their design for the Holland Tunnel: “Holland Helper” featured a little “TM” on the name and logo they designed to suggest that they should be trademarked.

The teacher’s experience and knowledge of patents also improved at every turn. She was able to teach students better how to identify the parts of a patent, the kinds of patents, utility, design, or plant, and show how the format of patents evolved over the years. She could explain why patents referenced other patents and how the claims distinguished them. More patents of interest were added to the collection used by the course, including an early patent on a beehive, US9300, from October 5, 1852, because the school’s mascot was a bee. Even her lessons on the mechanics of toys included their patents, for example, yoyos, US4332102 and US3953936, Slinky US2415012, Jenga US5611544, and Legos US9821245 B2.

The teacher’s participation in the Master Teacher of Invention and Intellectual Property program, MTIP, in 2022 to the present, added even more to the student's experience of Intellectual Property and to the other teachers in her department as she was able to offer it to them as professional development. She used new materials such as the “Two Patents and an Invention” project, where students or teachers in professional development sessions pick two random patents from a collection. They then follow a five-step “sprint” process using the two patents to imagine a new invention. They brainstorm, sketch, and design it as if they would patent it, design its “branding” for a trademark in any form, and then pitch it as if for a “shark tank.” When the teacher added this process to her entrepreneurship lesson, the students’ entrepreneurship projects went to a new level. Instead of just a few adding a logo or trademark for their business plan almost all of them had trademarks with creative logos. The “elevator speech” team presentations were more animated. The teamwork in the projects improved as well because the new format gave more structure to brainstorming activities encouraging more participation with more of them actively participating in the “pitch”.

Lastly, the teacher’s participation in MTIP and the InventEd Convening brought home resources for STEM education that she could share not just with her own school district but with her state and beyond.

Common goals – Diversity Equity and Inclusion, DEI, and IP in Engineering Education

When teaching engineering in a school with a diverse student body, it’s beneficial to see inventor role models who “look like you.” The state of New Jersey educational standards also includes several diversity requirements for all subject areas. In efforts to include DEI in STEM, all the teacher’s experiences with the USPTO and the Invention Community over the years have brought a benefit in some way to her engineering classes that are in sync with the USPTO’s own goals. In teaching Engineering Design the teacher found that she had to also teach proper “brainstorming” methods[4] to help students approach engineering problems in an organized fashion. In one exercise students make a prioritized list of questions they need to answer for a set of poorly defined but interesting scenarios. In one scenario students are told that they work for a sports equipment company that will be sponsoring the Paralympics, and they need to brainstorm ways their sponsorship could benefit the athletes. After asking the obvious questions like, “What’s our budget? Where is it held? Can I go there? The students realize that they must get to know the athletes they are sponsoring. Sometimes there are even students who are unfamiliar

with this event. The new Inventor Trading Card for Rory Cooper offers a perfect segway for the teacher. Just a few years ago, and shortly after this lesson, the teacher questioned a student who appeared to be wearing a small knee brace, if he had a sports injury. He explained that it was for his prosthetic leg. The teacher immediately apologized for not noticing sooner, saying he wore it so naturally. The student responded with a quick grin "thanks for doing the Paralympics".

One of her lessons presents the many engineering professional societies and their contributions to society. This is normally a great way to show inclusion and diversity, especially with societies like the Society of Hispanic Professional Engineers, SHPE, the National Society of Black Engineers, NSBE, the Society of Women Engineers, SWE, and many others representing engineering disciplines. SWE now includes a list of members who receive patents in their annual awards. This lesson also includes a tour of the National Academy of Engineering's fourteen Grand Challenges [5] for the future and the National Hall of Fame [7] for history. Although the teacher already had a good collection of engineers and inventors of color from several sources for black history month, adding more from the National Inventors Hall of Fame with patent numbers brought it to a new level. For the school's Black History Month classroom door decorating contest, hers featured 200 years of National Inventors Hall of Fame inventors from Norbert Rillieux to Marian Croak, featuring some on their Inventor Trading Cards.

In their sharing sessions, some MTIP teachers have found diversity to be a driver of innovation leading to multidisciplinary lessons with students solving local problems through inventions. This approach has even drawn "at risk" students to improve their math and writing skills so they can follow through on properly creating their inventions. In collecting and assessing the numbers of students they reach the teachers have also found that the "qualitative data", telling the students' stories of discovery, to be just as valuable for inspiring other students and teachers.

Reflecting on how the inclusion of IP and Invention education has added value to her engineering curriculum and classroom lessons the teacher could see the value it brought to the applied science engineering woven into NGSS [1]. While presenting to her colleagues in her role as MTIP teacher, the teacher felt she could offer something to each of their different areas of science. After presenting Intellectual Property and Invention to teacher at the NJ Science Teachers Convention in October 2023, a group of elementary teachers came forward to explain that their students' STEAM Tank™ Challenge [10] project had won a local award, and they were advised to look into getting a patent on it. The teacher was able to provide them with contacts at the USPTO's Office of Education that could help them. Several other MTIP teachers have had similar experiences helping teachers and some could even speak from their own journeys to help students patent an invention.

The impact of the latest releases of USPTO educational tools, especially the EquIP HQ [3] package, is only beginning to be felt in science and engineering classrooms. As pre-college engineering programs begin to step beyond being an extension of NGSS into their own realm IP and Invention education will play an integral role.

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