Development of a Pressure-Sensing, Battery-Powered Air Purifier Respirator System

(Technical Paper)

Examination of Intellectual Property and University-Industry Relations amid a Global Crisis

(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

The Coronavirus Disease (COVID-19) pandemic was declared on March 11, 2020 by the World Health Organization (WHO) and is a global emergency resulting in over 1.2 million deaths worldwide as of November 5, 2020 (Ferreira et al., 2020). It is obvious that the pandemic will have lasting social, economic, and political impacts, and will reinvent classic innovation models as global emergencies have in the past (Viale et al., 2020). Accelerated innovation has occurred in the months since the pandemic began, from the rapid development process of the COVID-19 vaccine to creative solutions for manufacturing personal protective equipment (PPE), a technology vital to halting the community spread of COVID-19 when social distancing is not possible. The need to wear face coverings in order to protect transmission between individuals, often asymptomatic, of COVID-19 virus particles, coupled with increased outdoor activity to combat months of quarantine and lockdowns, presents a problem as individuals exercising in populated areas may find it uncomfortable to wear fabric face masks when breathing at elevated rates. Therefore, the objective of my technical research is to determine an alternative to fabric masks in the form of a Powered Air Purifying Respirator (PAPR) that will provide a circulating, purified air flow to exercisers during the COVID-19 pandemic.

The development of a PPE technology in the technical research is one example of the accelerated innovation occurring during the pandemic as corporations, universities, and individuals sprang to action to develop technologies that would prevent the spread of COVID-19, treat individuals with the virus, and more. In my research, I hope to explore how the innovation process in a pandemic differs from the standard, and how this global emergency will shape innovation models going forward. I also want to examine the role of patenting policies and other government regulations under the scope of the New Political Sociology of Science (NPSS)

framework and how these regulations may be inhibiting innovation, especially during an emergency where collaboration is required.

Technical Topic

According to the Centers for Disease Control and Prevention (CDC) and the Journal of the American Medical Association (JAMA) (2020), cloth face masks were declared a vital tool in preventing the spread of COVID-19, especially if adopted universally by communities. From the CDC's Morbidity and Mortality Weekly Report (MMWR), it was reported that 75% of adult Americans had adopted the mask recommendations set forth by the CDC. The social groups that do not follow these guidelines may have health conditions that lead to troubled breathing, or may feel that the cloth masks are uncomfortable. Therefore, this technical research is focused on creating an alternative to masks that will provide a constant circulation of purified air within an enclosed space around the wearer's face. This alternative device is known as a PAPR.

PAPR devices that predated the COVID-19 pandemic were utilized in environments with chemical or biological contaminants, and supply the wearer with air purified of the hazardous aerosols. However, these devices do not filter the output air, a design feature that has become increasingly important during the COVID-19 pandemic as particles can be spread by aerosols in exhaled air from asymptomatic individuals. Therefore, existing PAPRs are not viable in preventing the spread of COVID-19.

Despite the CDC guidelines of wearing a mask in public when unable to socially distance, it may be uncomfortable for individuals exercising at elevated breathing rates to abide by these recommendations of wearing a fabric mask as their air flow is interrupted. In particular, runners pass many people on routes in populated areas, which presents a heightened risk due to

the increased rate of exhalation and therefore increased projection of aerosols that may be contaminated with virus particles. Blocken, Malizia, van Druenen, and Marchal (2020) performed a study with engineering simulation software that determined that the risk of virus spread is elevated in the area surrounding runners without masks, as a slip-stream is created behind a runner that allows for virus particles to spread up to 10 meters, opposed to 1.5 meters when an individual is stationary. Therefore, the objective of this technical research is to construct a comfortable PAPR device for long distance runners to wear that filters both inhaled and exhaled air, and is lightweight, durable for high-impact activity, and low-cost to manufacture, under the guidance of Professor Gavin Garner of the Department of Mechanical and Aerospace Engineering at the University of Virginia.

First, it was imperative that the PAPR device meet requirements outlined by the CDC in the document, "Concept for Industrial Powered Air-Purifying Respirator Standard" (CDC, 2005). The article establishes the following required components: respiratory inlet covering, filter units, harness assembly, blower, breathing tubes, battery indicator, and operation switch. The device designed in this technical research will include all of these units, with exception of the battery indicator as the device has a fail-safe mechanism in the form of breathable material that will allow for air flow in the event of a dead battery. The document also establishes the requirement that a positive pressure gradient must be maintained and provides minimum flow ratings for the circulating air. In addition, according to a document by the University of Texas at Austin Environmental Health and Safety Department (2007) detailing safe operating procedures, it is important that the filter material must be incorporated in the device such that it can be replaced, especially after high-impact activity where sweat is present. To meet the requirements, fit tests at multiple stages in the iterative design process will be implemented to ensure the

positive pressure gradient is maintained, and a computational fluid dynamic analysis will be performed to ensure that the minimum breathing rate is met.

In addition to the regulations outlined by the CDC for existing PAPR devices, other design requirements for the PAPR device intended for distance runners include minimizing the weight of the device, minimizing manufacturing costs, and maintaining a proper fit and pressure gradient. In order to minimize the bulkiness of the device, the fan-filter assemblies were directly integrated into the head harness assembly to eliminate the need for excess tubing. To maximize comfort, the PAPR enclosure was incorporated into a baseball cap, a lightweight accessory typically worn by athletes during exercise. In order to reduce the cost of the device to make it a reasonable alternative to disposable or cloth masks, 3-D printing techniques were utilized to cheaply and quickly prototype parts. Future steps include installing a diaphragm and phototransistor system to monitor the breathing rate of the user, which will ensure that the fans are circulating air at a comfortable rate and that the positive pressure gradient is maintained. My role is to develop the code that will control the speed of the fans proportional to the user's breathing rate for maximum comfort. The aforementioned design considerations will be implemented in the PAPR to ensure its functionality and comfortability, resulting in an alternative to fabric masks for distance runners that will effectively filter COVID-19 particles during the pandemic.

STS Topic

The technology developed in the technical portion of this research is capable of improving public health and safety in the midst of a pandemic if the aforementioned design requirements are met. Additional examples of rapid innovation occurring during this global crisis include contact tracing mobile applications that operate via Bluetooth technology, personal

protective equipment produced by additive manufacturing, and robots that utilize UV light to sterilize surfaces. The accelerated development of these technologies in response to an emergency requires an examination, framed by the New Political Sociology of Science (NPSS) theory, of intellectual property and the relationships of the three institutions—government, business, and university—that make up the triple helix model of innovation, especially with respect to technology transfer offices.

The triple helix model of innovation emerged from World War II, with the collaborative development of mission-oriented technologies such as radar to support the war effort. According to Leydesdorff and Etzkowitz (1998), "a seamless web of technology transfer and feedback loops" between the government, industry, and academia was sustained during this era. The triple helix model also addresses transformation within the aforementioned groups, for instance the increasing demand for academic research in universities (Leydesdorff & Etzkowitz, 2000). Viale, Etzkowitz, and Fornaci (2020) suggest that global crises, such as the COVID-19 pandemic, reshape the triple helix model through evolutionary innovative leaps. The triple helix model relates to the NPSS theory and the examination of the three main spheres of influence and their collaboration in order to support or impede technological advancements (Razak & White, 2015). NPSS as a framework explores the political nature of knowledge production institutions and "the dynamics of resistance and accommodation" (Frickel & Moore, 2006, p. 5) associated with this power, and will be applied to this topic of the complexities of the university-industry relationship.

The technology transfer between universities and industries is of interest as the state-funded academic research is commercially-driven and has the capacity to influence private-sector markets (Leydesdorff & Ivanova, 2016). The technology transfer office serves as the

bilateral relation between the academic and industry sectors. Its mission revolves around prioritizing commercial objectives in academic research environments by way of patents, licenses, and other commercial avenues of transfer (Sanders & Miller, 2010). As academic institutions transform to have more industry-oriented objectives and vice versa, private intellectual property is emphasized and "leads to a re-interpretation and reframing of norms" (p. 691) in both directions, such as industrial goals incorporating traditional academic values of serving the public good. Technical transfer offices aim to rebrand academic research and development such that it is most appealing to the industrial sector, while simultaneously aligning the goals of each institution and maintaining boundaries. The role of technical transfer offices relates directly to the NPSS framework and how the technical transfer offices influence the objectives of two of the three institutions within the triple helix model in order to promote entrepreneurship and serve public interest towards a collective shared need.

Patents are one avenue in which technical transfer offices emphasize commercial interests in academic settings. As rapidly developing technology becomes increasingly political in contemporary societies, preexisting intellectual property policies and structures are challenged and deemed inadequate by actors from all spheres of the triple helix model (Hilgartner, 2009). According to Hilgartner, the new politics of intellectual property "centers on concerns about who governs technology and in pursuit of what goals" (p. 207). This statement is of interest as it relates to the NPSS framework and how powerful institutions—such as regulatory bodies determining patenting and intellectual property policies—have the capacity to infringe on citizens' ability to participate in the innovation process. This is particularly relevant during the COVID-19 pandemic and how citizens with entrepreneurial mindsets sprang into action to innovate at accelerated rates for public good.

Through the analysis of the influence of technical transfer offices and intellectual property regulations on innovation, I hope to determine whether innovation can be considered a collective good or simply a technological change, and the degree to which the three spheres of influence inhibit or encourage innovation according to the NPSS framework. This analysis will largely be performed through reviewing academic articles and legal literature relating to the transformation of intellectual property and patenting policies over time. As the University of Virginia is a public research institution, I will obtain anecdotal evidence from engineering professors and research associates surrounding their experiences with technical transfer and I will examine the extent to which their work is influenced by commercial objectives. Important questions to consider in this analysis going forward include: What role do patents play in the balance of power between academic, industrial, and government institutions? What role do patents play in a global crisis, when innovation is accelerated and should not be inhibited? How is the innovation process altered in a global emergency? What improvements need to be made to the intellectual property framework as innovations become increasingly political in nature? To what extent are researchers in academia influenced by commercial objectives, and is this influence direct or simply profit-driven?

Next Steps

In the following thesis, I will examine the transformation of specific intellectual property and patent regulations over time in order to determine if the policies are adequate in maintaining the balance of power in technological invention processes. In addition, I will examine the effect of technical transfer between academia and industry at the University of Virginia and identify how technical transfer offices both align objectives of the two sectors while maintaining their boundaries. This anecdotal information will be used to verify the findings presented in the case

study by Sanders and Miller (2010). I plan to focus my research on the surge in innovation related to COVID-19, as the accelerated rate of technological development due to the global crisis is of particular importance at this time.

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