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NOBEL LAUREATES AS HEROES IN SCIENCE

A Qualitative and Quantitative Analysis

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DEPARTMENT OF PSYCHOLOGY

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Abstract

To conceptualize what makes a scientific hero, this study draws on three areas of literature – the social psychology of science, empirical estimates of scientific productivity, and theories of heroism. We qualitatively explore whether the stages of becoming a scientific hero correspond to Campbell's stages of heroism. Through quantitative analyses, we determine for whom a scientist becomes a hero, in terms of popularity among immediate peers as well as the larger general public. Using a mixed method approach, we understand whether the establishment of a scientific hero is characterized by their scientific achievements, their popular representations, or both. Implications are discussed.

Keywords: bibliometrics; citation analysis; heroism; Nobel Prize; hero's journey; monomyth

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1. Introduction

Eminent scientists typically represent creative geniuses, who through their persistence and originality, contribute to ongoing scientific and academic progress (Simonton 1992, 2000, 2008, 2013). The term "genius" has been commonly applied to scientists, as scientific genius is associated with scientific creativity (Simonton 2004, 2018). However, this paper builds upon the "genius" conception of scientists and analyses numerous factors that affect the creation and propagation of a scientist as a "hero." Research (Abir-Am 1982; Felt 1993; Charney 2003) suggests that a combination of multiple factors (such as winning the Nobel prize) influences how scientists are perceived by the public as well as their peers. This paper seeks to examines the process through which certain scientists become heroes for their peers as well as the public by looking at when, how, and why they attain heroic status, over and above their existing genius status.

Data, Citations, and Publications

Myers (1970) highlighted that major award recipients in psychology typically have higher citation metrics, indicating that winning an award has a positive after-effect on a researcher's popularity. Cole and Cole (1967) found the same, showing that only 1.08% of nearly a quarter million scientists had the same number of citations as Nobel Laureates, indicating that citations are a common measure of significance within the scientific community. Upadhye, Kalyane, Kumar, and Prakasan (2004) discussed productivity levels of Nobel Laureates, before and after they received the award in terms of publications. They found that higher citation data by the Institute for Scientific Information (ISI) are often successfully deployed to forecast Nobel Prize winners. Casadevall and Fang's (2013) results further strengthened the argument that while the prize recognizes important contributions to the field, most recipients have already received plenty of recognition by the time they are nominated. Merton (1968) famously termed such a phenomenon the 'Matthew Effect' in science and empathized the role of psychosocial mechanisms that increase the visibility of eminent scientists.

Scientists in the Media

While the Nobel Prize is associated with citation data, it also draws the attention of the media each year, making it an important contributing factor to attaining heroism in science. Narrative construction of scientists, public's perception, and their acceptance are influenced by media (Felt 1993; Charney 2003; Kim 2009). Charney (2003) emphasized the relationship between journalists and the scientific community, and the information flow between the two domains: one between the domain of science and media, and one between the media and the public sphere. Public perception raises social stakes for scientists as the benefits of acceptance and public support are essential to the field. Jacobi and Schiele (1989), and Osborne, Simon, and Collins (2003) suggest that it is popular media and effective science education, respectively, that turns scientists into heroes in order to make the field of science more appealing. The media's tendency to equate the scientist with their work aids the construction of scientific success stories, i.e., puts the worker in with the work (Felt 1993). The narratives regarding scientific work also influence public perception of the findings and the dissemination of the hero-like image of a scientist (Kim 2009).

Allchin (2003) highlighted the role media has in weaving a compelling story that typically involves a pattern of suppressing facts and propagating narrative inaccuracies meant to enhance story-telling. These can be viewed as feeding into conflicts between society and scientists, with the latter being inherently held up as elite competing with the former for attention. Goethals and Allison (2012) also stated that this storytelling pattern involves creating a sense of drama, and often more so than historical fact. These historical 'reconstructions' of scientific work, moulded to fit a set narrative, results in the construction of the 'mythic architecture,' which, according to Allchin (2003), perpetuates a scientist-hero image as being virtuous and flawless. This myth serves to explain and justify the authority of science and subsequently, the scientist (Allchin 2003). Thus, as a result, a scientist may be elevated to heroic status. For example, 'The Theory of Everything' (Bevan et al. 2014), documents the journey of Stephen Hawking, a non-Laureate who overcomes significant health issues to become a path-breaking astrophysicist. In much of the film, Hawking is portrayed as one in dogged scientific pursuit, at the cost of family and personal well-being.

Simultaneously, economic and political context are key in the construction of scientific success stories (Felt 1993). Abir-Am (1982) highlighted the relevance of such contexts in how media coverage of a scientist's work can subsequently popularise it. Popular media may choose to portray socio-politically acceptable outcomes of a scientific achievement, thereby creating a one-sided narrative of the heroic scientist, despite the existence of others who may have been equally accomplished (Abir-Am 1982). For instance, in the "war of the currents" waged between Thomas Edison and Nikola Tesla, the former often publicly demonstrated the presumably hazardous nature of alternating currents, oftentimes using media outlets (like the Daily Graphic and the New York Times) to dominate this discourse (Allerhand 2017). Thus, with different environments, the same work may or may not have gained momentum and consequently, projected a heroic image of the scientist.

Heroism in Science

Conceptualised as a social activity, heroic behaviors are directed toward the public good, engaged in voluntarily after appreciating associated risks, and involve some degree of self-sacrifice without obvious external gains (Franco et al. 2011). Goethals and Allison (2012) described a traditional hero as an individual who is moral and pursues nobility, and is seen as competent and exceptional at achieving their goals. The traditional hero is also described in relation to Joseph

Campbell's (2004) widespread monomyth theory. Citing examples like Buddha, Jesus, Moses, and other classical characters from mythology, Campbell described a fundamental structure that chronicled a hero's journey. He listed 17 stages that began with the call to adventure and concluded with the freedom to live. Some other stages included entering the belly of the whale (5[1]- separation from hero's world, and willingness to undergo change), meeting with the goddess (7- hero gains things for help in the future), woman as a temptress (8- hero faces temptations that either lead or stray from their goal), apotheosis (10- the hero becomes more knowledgeable and is armed for a more difficult journey ahead), the ultimate boon (11- achievement of the goal), rescue from without (14- powerful guide who aids the hero).

Broome and Pierce (1997) described the hero's journey as an exercise in transcending boundaries, with a factual external journey, and a mental or existential inner journey. This serves as support for the application of a hero's journey across various profiles, including those in science. Further, Franco, Blau, and Zimbardo (2011) characterized scientific heroes as a heroic subtype who took risks that involved social sacrifices by defying limits of the known world and exploring unknown areas of science using novel methods for societal benefit.

Oreskes (1996) noted how this image of the hero, as a scientist, fits and contrasts with community norms and expectations in science. She suggested that narratives of heroism in science contradicts the objectivity science demands and its storytelling requires less standardization, and more adventure and uncertainty. Oreskes also provides support for characteristics described by Goethals and Allison (2012), associated with Campbell's traditional hero. While the element of danger may appear to undermine scientific credibility, it is viewed as an essential aspect of the heroic image (Oreskes 1996). Jacobi and Schiele (1989) further illustrated the archetypes

[1] The numbers represent Campbell's chronological sequencing of the stages of the monomyth/hero's journey. For a complete explanation of each of the 17 stages, the reader is referred to Campbell (2004).

associated with scientists - the 'mad' scientist, the human/ordinary scientist, and the scientist-teacher. Haynes (2003) describes the primary stereotypical images to include, the evil, the mad, the adventurous, and the noble scientist, especially prominent in Western culture. These descriptions support the images purported in studies regarding the scientist-hero image (Broome and Peirce 1997; Allchin 2003; Goethals and Allison 2012). From a functional perspective, Kinsella et al. (2015a) suggested that the chief functions of heroes were to enhance our lives, promote morality, and protect us. Epistemic functions (such as garnering wisdom) were additional purposes of heroic storylines (Allison and Goethals 2014), particularly pertinent to scientific heroes. Kinsella, Ritchie and Igou (2015b) identified 13 central traits (such as conviction, determination, inspiration, courage, among others) and 13 peripheral traits (risk-taking, intelligence, exceptional, talented, and others), which are commonly ascribed to scientists, qualifying them as unconventional heroes (Kafashan et al. 2016).

Traditionally, heroism has been denied to the vast majority of women, and is almost always associated with men (Allison et al. 2017). Characteristics like paternalism and inherently masculine traits are attributes that constitute a scientific hero (Abir-Am 1982; Oreskes 1996) as the predominant view in the scientific community was that women in science tend to do research in a less objective, less detached, and more contextualized manner (Oreskes 1996). These are viewed as being opposite to the characteristics possessed by the scientific hero; such characteristics often allude to professional aspects of male scientists, whereas for females, their efforts are never discussed in isolation of their personal lives (Abir-Am 1982).

Researchers (Flicker 2003; Whitelegg et al. 2008; Tintori 2017) have examined the association between gendered representations of scientists and mass media. Tintori (2017) stated that stereotypes propagated by the media also keep women outside science, engineering, technology, and mathematics (STEM) fields, as well as create a glass ceiling at a low position in the scientific hierarchy. The lack of role models or representation also discourages women from pursuing a career in the field (Blickenstaff 2005). When represented, films perpetuate disparaging images of female scientists categorized as old maids, male woman, the naive expert, the evil plotter, the daughter or assistant, and the lonely heroine (Flicker 2003). As these images of women in science do not overlap with the stereotypical images of the male scientist hero, it suggests that women might experience a different journey to heroism (Oreskes 1996; Flicker 2003). While women portraying characters in STEM fields, in movies and television, are gaining popularity in modern times, until recently, women have been represented in less than one-fifth of characters in media (Tintori 2017).

Numerous *Draw A Scientist* studies conducted with children and students over the years (Song and Kim 1999; Finson 2002; Buldu 2006; Samaras et al. 2012) have demonstrated the pervasiveness of common stereotypes about scientists. They indicate the influence of mass media on the image and perception of a scientist as the images children present, match the archetypes and characteristics discussed previously. The studies reviewed also provide support for the shift in the stereotypes or associations attributed to scientists, from that of the 'mad scientist,' to that of a hero and warrior of science.

The Present Studies

Against this background of diverse, yet related, literature on heroism in science, the studies presented here seek to fill a gap in the past work by analysing for whom and when a scientific figure becomes a hero through a mixed-methods approach. Study 1 explored different aspects of heroism in science and qualitatively investigated paths to becoming a hero using the conceptual framework of Campbell's journey of a hero. Given that this journey, delineated through 17 stages, are relatively universal (Goethals and Allison 2012), they served as a loose framework through which three very different scientists could be systematically compared.

Analysing these classic scientists through a case-study approach, similar to Simonton's (2004, 2018) method of documenting what makes a scientific genius, was complemented by quantitative data on contemporary laureates in Study 2. Study 1 therefore sought to examine and reconcile the various stages that three well-renowned scientists go through with that of mythical heroes. Study 2 extended this framework to empirically assess whether the career path of Nobel laureates in science validates their status as scientific heroes. Notably, the two studies presented here compare scientists from different eras in an attempt to examine if paths to scientific heroism has remained constant over time.

Therefore, the present work explores the relationship between scientists, their peers, popular media, the Nobel prize, and the rise in popularity or heroic status. The current work also seeks to establish a framework for the emergence of heroes in science and provide an empirical overview of the importance of their work to other scientists as well as their recognition in popular media. Life trajectories of popular scientists are compared and analysed using the framework of Campbell's journey of a hero, and experiences leading up to, creating, and establishing a scientific hero are explored. Further, this research adds to the literature regarding the reward system in science and its effect on one's popularity.

Thus, the following research questions were posed:

RQ1: Do the stages of becoming a scientific hero correspond to Campbell's theory of heroism?

RQ2:What makes a scientific hero? For whom does this individual become a hero – the scientific community or the general public?

RQ3: Are scientific heroes a product of impact moments or years of conscious toiling?

Study 1

The first study used qualitative means to assess whether the stages encapsulated in becoming a scientific hero corresponded with Campbell's monomyth theory (RQ1); this study also addressed whether scientific heroes are a result of unique contributions to their field or arise from continuous periods of less impactful, though salient work.

Method

In a pilot attempt to generate a pool of recognizable and eminent scientists, a recognition test (*N* = 45) was conducted via an online questionnaire that was posted on various social media platforms. This only served as a means for selecting scientists to further examine the journey of a scientific hero. Participants were presented with photographic portraits of 20 scientists (16 male, four female) and asked to identify their names. The scientists were chosen to include those regularly appearing in popular media today (e.g., Neil DeGrasse Tyson), as well as Nobel laureates (e.g., Wilhelm Rontgen), and female scientists (e.g., Barbara McClintock). The six most accurately recognized scientists in this pilot questionnaire were (percentage of correct identification in parentheses): Stephen Hawking (98%), Albert Einstein (93%); Neil deGrasse Tyson (82%); Marie Curie (76%), Nikola Tesla, and Charles Darwin (both 62%).

Among the most accurately recognized, three scientists–Albert Einstein, Marie Curie, and Nikola Tesla were chosen,[2] first, because they were contemporaries, working towards scientific inquiry in the last two decades of the 19th century and consequently finding success and prominence within the scientific community in the first two decades of the 20th century. Second, all three scientists were pioneers and major contributors to the second scientific revolution, having left indelible marks in scientific history. Tesla revolutionized electricity; Einstein's theory of relativity reformed theoretical physics and challenged Newtonian laws that were considered

[2] It is likely that Hawking, Tyson, and Darwin were highly recognized as well owing to their distinct physical characteristics or general popularity.

biblical truth; and Curie, often regarded as the first female scientist, discovered two new elements radium and polonium. Third, the trajectory of their fame is vastly varied, and analysing the same would help understand not only what factors create a scientific hero, but also what contributes to sustaining that role. Fourth, although Tesla had over 200 patents to his name, and was rumoured to be a strong contender for the Nobel, he never won the coveted prize. Einstein and Curie, both have won the Nobel, and the latter twice. Studying Tesla's journey along with that of two laureates will also help understand the role that the Nobel prize possibly plays in popularizing scientists and creating scientific heroes.

Once the three scientists were selected, information on their lives was collected through documentaries, and historical accuracy was checked for by referencing various biographical texts (Pasachoff 1996; Rockwell 2003; Kaku 2018), including Tesla's autobiography (Tesla, 1919/2013). Biographical information for Curie and Einstein was also available on the official Nobel Prize website. Documentaries were available through various online broadcasters like National Geographic (Genius–Einstein, 2017), British Broadcasting Corporation (The genius of Marie Curie, 2013), and Public Broadcasting Service (Tesla, 2016). These varied sources served as data for comparison.

The research design for this study was based on the principles of consensus methodology, specifically the nominal group technique (NGT; Fink et al. 1984), which was used to code scientists' life events into Campbell's stages that functioned as themes for the study. The NGT was adapted to the present study, wherein three reviewers independently watched the documentaries and coded life events to the stages, as defined by Campbell, before the responses were collated together. Reviewers were well-versed with the existing research on heroism and Campbell's model. To avoid any forceful superimposition of life events into a stage, reviewers were permitted to input a 'not applicable' code, if as per their discretion, a scientist's life event did not correspond to any particular stage. The cut-off for consensus was predetermined by the researchers at 66% (i.e. 2 out of the 3 reviewers had to agree on the same life event to a stage). Once collated and consensus was achieved (see Appendix A in supplementary materials), stages and life events were analyzed for any larger patterns, linearity, gendered experiences, and pivotal moments (obstacles, failures, recognition).

Results

The lives of the three scientists were compared using Campbell's stages from the aforementioned sources. For instance, Stage 7- Road of trials - was independently coded (at least 2 of 3 coders assigned the same life event for a given stage) for Tesla as living in poverty and digging ditches for sustenance; for Einstein as working at the patent office in Bern before his manuscripts were accepted; and for Curie this stage was coded as including the years she spent attempting to isolate her new elements and subsequently coining 'radium' and 'polonium.' Once coded, inferences were drawn and notably Tesla's life events were the most linear and chronologically followed the stages outlined by Campbell. In comparison, life events assigned to stages for both Curie and Einstein were non-linear; both had more instances than Tesla's where more than one life event could be applied to a particular stage. Curie and Einstein also had more events in their lifetime that could be viewed as pivotal moments than Tesla. For instance, Curie's acquaintance with her husband Pierre Curie, her historic Nobel win in the second year since the Prize's introduction (meeting with the goddess), [3] her affair with Langevin that momentarily tainted her name in the public sphere (woman as a temptress), retracting from public eye, focusing her efforts in establishing the Radium Institute, and encountering Marie Meloney were influential in shaping her life (rescue from without). Similarly, for Einstein – meeting Mileva Marić (meeting with the goddess), formulating the theory of relativity in 1904, divorcing Mileva, marrying Elsa

[3] Campbell's stage of a hero's journey that corresponds to the scientist's life event.

Löwenthal (woman as a temptress), and toiling relentlessly to prove the theory up until in 1919 when Arthur Stanley Eddington provided photographic support for it (the ultimate boon)– all influenced his image as a scientist today. Tesla's only impactful moments seemed to be his conflict with Edison (entering belly of the whale), securing funding from Westinghouse (meeting with the goddess), introducing the Tesla coil and alternating current motor at the Columbia Exposition in 1893 (apotheosis).

A striking differentiation among the three scientists was that while aspects of Einstein's and Curie's personal lives impacted and sometimes enriched their professional lives, not much is known about Tesla's private life. Einstein's marriage to Marić and then to Elsa aided his professional life. Though hotly debated, Marić is thought to have contributed to Einstein's *Annus Mirabilis* papers. Elsa, with her supposed business acumen, helped Einstein manoeuvre through the social circles of the scientific community. The Curies famously worked together and jointly won the Nobel prize in 1903. Tesla's private life, on the other hand, did not receive much attention. He was known to be someone who enjoyed solitude, experimenting with current all his waking hours.

However, there are gender differences in the kind of attention that their personal lives received. News of Einstein's affair with his cousin Elsa did not receive the scorn and ridicule that Curie's faced. While Curie's personal life became a matter of public outrage, Einstein's misdemeanours were not associated to his professional life. Curie's affair was inopportune and her integrity as a scientist was questioned in 1911.

Although in terms of overall consensus of assigning life events into stages was highest for Curie, followed by Tesla and Einstein, interestingly, hers also had least consensus for the first few stages. These first few stages chronicle the beginnings of a hero's life. Events leading up to Curie establishing herself as a scientist were met with more obstacles than that for Einstein and Tesla. While both Tesla and Einstein faced obstacles on their path to success largely due to their iconoclastic ideas, Curie's sex itself posed an inherent obstacle. She was not allowed to pursue higher education and struggled to find a job as a researcher.

Additionally, their scientific pursuits varied vastly, in that Curie's area of research was largely marginalized by the scientific community until she was finally able to isolate radium. Works of Einstein and Tesla were contentious from the very beginning. Tesla's ideas were repeatedly turned down by Edison; similarly, Einstein's ideas were rubbished continually by Lenard and other physicists, till Planck extended support for it.

The type and trajectories of their successes was also varied. While Tesla's success was commercial, Einstein's and Curie's were more academic, at least at the beginning. Tesla's life did not end on a high note; rather his name dissipated into oblivion. He lived his final years as a recluse with grandiose ideas and in poverty. Curie and Einstein, on the other hand, continued being active within and outside the scientific community. Curie regained public support with her efforts during World War I, while Einstein famously engaged in diplomatic efforts with the United States of America (USA) during World War II. Despite having more than 200 patents to his name, and inventions such as the radio and remote control to his credit, Tesla's fame waned, unlike that of Curie's or Einstein's. Their involvement beyond scientific efforts popularized them outside the scientific community. Although all three pursued science because of their passion for scientific inquiry, Tesla's inability to extend his efforts beyond science inadvertently contributed to his waning popularity.

Curie and Einstein were able to maintain their popularity, partly because of certain figures in their lives, namely Marie Meloney and Elsa Löwenthal, respectively. Meloney, a journalist, helped Curie acquire funds for her institute by traveling to the USA and arranged for Curie to lecture at various esteemed universities. She ensured that Curie's visits received extensive media coverage. Similarly, Elsa managed her husband's interaction with the media, especially during his support for the Zionist movement during their trip to the USA in 1921. Unlike the other two, Tesla had no helping hand in carefully manufacturing his image outside the scientific community while also pursuing the scientific cause. Tesla made no attempts to appeal to those outside of the scientific community, and this also made it more difficult for him to get investors.

The confluence of their personal and professional lives impacted their creation as heroes, and presented them as 'holistic images/packages,' more compelling than Tesla. Additionally, it seems that scientists making attempts to connect with masses outside the scientific community can have enduring consequences on their popularity. Both Curie's and Einstein's engagement in political affairs magnified their scientific works. Media's coverage of their scientific and political efforts bolstered their image and also perpetuated the scientist hero myth.

Discussion

Study 1 aimed to apply Campbell's stages to real-life figures and help in understanding their journey to becoming a scientific hero. It was found that the stages do not necessarily correspond in a linear manner to well-renowned scientists' life journeys (RQ1). Furthermore, there was little consensus among raters on assigning early-life stages of the hero's journey, suggesting that entry into science is not a clearly distinguishable moment in the lives of scientific heroes. Campbell based his stages on mythological characters; however, lives of scientists are composite, and do not necessarily fit neatly into 17 stages. Incorporating their life events into Campbell's stages was insightful for understanding how complexities made their lives more riveting for storytelling, which possibly contributes to maintaining their popularity. A feature common to the three scientists was behaving in a self-sacrificing manner, incurring significant physical risks, and using unproven methods of research in the service of humanity - all characteristics of social scientific heroes (Franco et al. 2011). Traditional mythic heroes are inspirational because they were often the underdogs, drawn into a journey rife with unique challenges and ultimately emerging victorious (Allison and Goethals 2014), akin to the three scientists compared here.

Using Campbell's framework also highlighted some gender differences in the pathway toward becoming a scientific hero. For instance, the mad scientist myth and image, does not apply to female scientists who are held by entirely different standards (Ganetz 2015). Female scientists are often emphasised as mother-figures, adopting secondary roles to a man in research and often viewed as asexual (Flicker 2003). This image of a female scientist held by both academicians and the public probably explains why Curie was vilified and condemned for allegedly having an affair, while Einstein was largely spared.

The study also explored whether the creation of the image of scientist hero is a result of certain impactful moments, or continuous years of effort and struggle (RQ3). Marie Curie is most known for her work on radium. Although there is some disagreement on whether Einstein's general theory of relativity was his most critical work in theoretical physics, the confirmation of the theory is widely considered to be crucial to Einstein's subsequent scientific contributions and fame (Claes and de Ceuster 2013). Their life trajectory demonstrated that the creation of a scientist as a hero, even only within the scientific community took a few years. While Einstein was a well-known nonconformist in the academic community, he was only truly heralded as a scientific hero in 1919, after evidence for his theory was furnished, taking him approximately 14 years since the publication of his papers in *Annus Mirabilis* to establish and prove his worth within and outside the scientific community.

Though the time frame for Curie's work to receive recognition was much shorter (approximately 4 years), it was no less arduous and met with resistance. In spite of having worked on isolating radium, much on her own, Marie was at first not even considered for the prize because of her gender. The trajectory of her fame was more askew than that of Einstein's. Winning the

Nobel prize did not make Curie a household name, much less secure an academic position. News of her affair with a colleague overshadowed her second Nobel win. This disparity is reflective of the extra effort women must make in order to gain and maintain their recognition both within and outside the scientific community.

The recognition given to scientists as heroes who risk their lives for the advancement of knowledge is still only emerging (Csikszentmihalyi, M., Condren and Lebuda 2016). Hence, Study 1 applied Campbell's stages of heroism to the life journeys of three classic scientists. In order to extend these findings empirically with contemporary scientists, the motivation for Study 2 was established.

Study 2

Using quantitative means, Study 2 aimed at answering the second and third research questions, pertaining to the audience for whom scientists become heroes (the general public or their peers), and whether the heroic status accorded to scientists is a result of continuous efforts or one big, impactful work.

Bibliometric and Demographic Data

Data on Nobel laureates in Physics, Chemistry, Medicine, and Economics between 2000 and 2020 were collated. Demographic details included year of award, name, discipline and sub-disciplines, year of birth, and year they received their PhD (to signify the year in which their career as scientists began). Bibliometric data compiled for each laureate included the number of citations before and after being awarded the Nobel Prize; the title of their most cited work; and the citations of the most cited work. The number of citations before the award were computed by aggregating citations of preceding years, excluding the year of the award. Similarly, the number of citations post the award were computed up to 2020, excluding the year of the award. For economics laureates, this data was collated from Google Scholar (www.scholar.google.com/citations) and Citec (www.citec.repec.org). For the remaining sciences, data were compiled from Semantic Scholar (www.semanticscholar.org).

Representation in Popular Media

We collected data on representation in media using Google searches for each laureate, including the year of their earliest mention in popular culture. Popular culture here included books (excluding reference books) – written by them or written about them, movies in which they were featured, television shows and interviews they gave. In some cases the only popular culture media presence recorded was a speech given at a public forum or meeting.

Results

Descriptive statistics on demographic and bibliometric data are presented in Table 1. The total number of laureates was 204, and irretrievable data were tagged as missing in the analyses. The most common type of popular media was interviews (46%), followed by articles (24%) and books (13%) across disciplines. The other kinds of popular media coded included biographies, lectures, magazine features, movies, profiles, speeches/talks, TV appearances, and videos (each less than 5%). The average age at which Nobel laureates started their careers (received their PhDs) was consistent across disciplines, *Ms* = 26.89 to 28.30 years. The average experience level (measured as the number of years between obtaining a PhD and winning the Nobel, *M* = 39.37 years) at which the Nobel was awarded did not differ significantly across disciplines. Furthermore, correlations suggest that this was not significantly associated with the number of citations received before and after the award (r_{before} = -0.034, r_{after} = -0.04; n.s.).

Table 1

Bibliometric and Demographic Data for Nobel Laureates Across Disciplines (2000-2020)

Area	Year of PhD	Year of Media Release	Peers	Public	Pre-Nobel Citations	Post-Nobel Citations	Citations of most cited Work
Physics	1969	2004	40.80	35.35	17424.71	1383.30	3220.09
	15.37	12.74	15.26	16.66	24114.76	4037.47	5518.71
	46	56	46	46	55	46	55
Chemistry	1971	2009	40.07	37.64	34444.52	719.09	2881.90
	12.53	8.30	10.99	12.80	35252.93	3326.74	3436.74
	42	53	42	42	52	47	52
Medicine	1974	2010	36.86	36.26	65151.87	28636.41	6157.58
	10.49	5.46	10.44	10.43	62494.49	51183.90	9961.56
	42	53	42	42	53	46	52
Economics	1970	2000	39.65	30.62	46735.02	34902.84	11873.76
	10.56	19.82	8.54	14.97	43005.74	57736.59	11866.14
	37	42	37	37	42	37	41
Total	1971	2006	39.37	35.11	40422.74	15375.62	5669.91
	12.55	12.83	11.75	14.06	46720.02	40031.40	8758.26
	167	204	167	167	202	176	200

Note. Means, standard deviations, and *Ns* are represented in rows.

Two additional variables were computed to answer RQs posed: (a) PEERS, which was the difference between the year they received the Nobel and the year they completed their PhD; and (b) PUBLIC, which was the difference between the year of release of popular media where they were featured and the year they completed their PhD. The variable PEERS elucidated how much time elapsed between the start of their academic career (PhD) and the peak of their career

(Nobel) and thus their recognition as scientific heroes by their peers. The variable PUBLIC represented when they were featured in a public-facing, non-academic platform after starting their academic career, and thus their prominence in the public sphere.

To determine for whom a scientist becomes a hero (RQ1), comparisons were made using t-tests between the variables PEERS and PUBLIC to illustrate which audience recognized a scientist's work faster. Across disciplines, it was found that academic peers recognized the contributions of a laureate much later than the general public, $t(166) = -4.43$, $p < .001$, $d = .34$. However, there was no statistically significant difference noted for Chemistry, $t(41) = -1.42$, $p = .08$ or Medicine, $t(41) = -0.48$, $p = .31$. For Physics, academic peers recognized the importance of a scientist's work slower than the general public, $t(45) = -2.79$, $p = .004$, $d = .41$; similarly, for Economics, the general public recognized the achievements of scientists through popular media representations sooner than their peers, $t(36) = -3.56$, $p < .001$, $d = .59$. There was also a significant association between Peers and Public variables, $r = .55$, $p < .001$, indicative of an overlap in academic and general recognition.

Within academic peers, we sought to explore whether bibliometric data was indicative of scientific heroism by way of a change in citations for an awardee's work. Across the four disciplines, there were significantly more citations prior to receiving the Nobel versus after the award, $t(174) = 8.13$, $p < .001$, $d = .61$. Similarly, this trend held true for awardees in each of the four disciplines as well: Physics, $t(44) = 4.59$, $p < .001$, $d = 0.69$; Chemistry, $t(46) = 7.03$, $p < .001$, $d = 1.03$; Medicine, $t(45) = 4.28$, $p < .001$, $d = 63$; and Economics, $t(46) = 1.83$, $p = .07$, $d = .30$.

Further analyses explored whether scientific heroism was attributable to impact moments or continuous toiling over the course of one's scientific career (RQ2). The proportion of citations for the most cited work was averaged, and it was found that laureates in Physics, $M = .23$ were most likely to have one very impactful research contribution. On the other hand, Economics awardees, *M* = .19, Chemistry and Medicine laureates, both *M* = .13, were relatively less likely to have a very significant, single contribution.

Discussion

Bibliometric data of Nobel Prize winners in the fields of Physics, Chemistry, Medicine, and Economics were analysed to understand how diverse factors contributed to creating and maintaining a scientific hero. Results confirmed that citations, awards, and media coverage, all influence the creation of a scientific hero. Specific variables relating to the recognition of scientists among their peers or the public further helped understand the trajectory of a scientist's success (RQ2). The interest displayed by scientific colleagues and the popular media served as gatekeepers to the popularization of their work and subsequent elevation to a heroic status (Abir-Am 1982).

Contrary to what was expected, academic peers recognised scientific work slower than the general public, especially in the disciplines of Physics and Economics where scientific work was recognised by the public much faster through popular and social media. This contradicts past evidence (Chan, et al., 2014), which indicates that receipt of scholarly awards, an indication of peer recognition, intensifies in the periods leading up to the award of a Nobel, and declines afterward. In each of the four disciplines studied, the number of citations prior to receiving a Nobel was greater than after receiving the prize.

The average time in an individual's career when they win the Nobel is similar across disciplines and was not significantly correlated with their citations before or after the award. This is especially interesting as it would suggest that the laureates were already recognized widely enough to have been nominated, and that winning the prize did not have any particular bearing on increasing their acceptance within the scientific community.

General Discussion

The goal of the present work was to explore whether the academic trajectories of scientists compare with that of a mythical hero (Campbell 2004; Goethals and Allison 2012). Qualitative case studies undertaken in Study 1 found that the lives of the most famous scientists do not linearly fit with that of the stages of heroism (RQ1). However, the empirical counterpart in Study 2 found that this varied by disciplines. For example, in chemistry and physics there was considerable overlap between recognition of work by peers and the public, but for medical scientists and economists there was no such correspondence (RQ2). Most work receives recognition in public only after it has stirred up some furore within the academic and research community. Acceptance of a researcher's work can therefore further influence its dissemination to the public. Across all disciplines, except economics, peers recognized works faster than the general public. The exceptional result for economics can be explained by previous findings that fame in the discipline is not merely a function of academic achievements (Claes and de Ceuster 2013). Though winning the Nobel would imply ground-breaking research in any discipline, the findings and implications of those from the natural and physical sciences seem to elude the general public at first (Tintori 2017). This initial inability of the public's understanding of a laureate's work and its applications can influence when laureates receive public recognition. Applicability and implications of findings from economic sciences seem to be more urgent to 'problems of the day' and get subsumed into public policy and behavioural business models (Stigler 1983), explaining the relatively speedier recognition of its laureates even before the Nobel win. However, winning the Nobel prize does have a significant impact in increasing a scientist's recognition in public, although only momentarily (Baram-Tsabari and Segev 2015). Our results extend support to that of Bagrow, Rozenfeld, Bollt, and Ben-Avraham's (2004), which stated that scientists are primarily famous within their own scientific communities, and enjoy limited public fame.

Three of Campbell's stages overlay with Study 2's empirical observations well: Crossing of the first threshold corresponds to the year in which scientists received their PhD; the ultimate boon is suggestive of the year in which scientists received the Nobel Prize; and master of the two worlds is when scientists receive public and peer recognition, associated with the year when they appeared in the popular media for the first time. Thus, in Study 1, the fact that there were documentaries on the three scientists' lives also highlights the role of the media in enabling public recognition of a scientist's work, therefore helping them become scientific heroes. In the cases of Einstein, Curie, and Tesla, stories of their work (and personal lives as well) dominated popular discourse on their personas. However, for those who do enjoy public fame, even momentarily, the media plays a major role in motivating people to search for information on Nobel laureates (Bagrow et al. 2004; Ganetz 2015; Baram-Tsabari and Segev 2015). Media's portrayal of scientists can have enduring impacts on the public's perception of them, especially endorsing or questioning the scientist archetype (Jacobi and Schiele 1989; Nisbet and Dudo 2013). Ganetz (2015) further stated that a very specific type of "celebrity" has resulted from the media's positive representation of scientists, which is most often of a white male who attained their fame through much hard work and competition. The most recurrent archetype of scientists is that of a 'mad scientist'– one who works in isolation, and is an eccentric anti-social geek (Nisbet and Dudo 2013). Audio-visual interviews, which is the most common medium of disseminating information on male scientists, perpetuates this scientist archetype by using strategic imagery techniques such as presenting the scientists in white lab coats, in their laboratory, and with equipment in the background to lend credibility to the images (Jacobi and Schiele 1989). These images make scientists come alive and result in heroic figures (RQ2).

The proportion of citations for the most cited work suggested that Chemistry and Physics laureates tended to have one very impactful contribution, unlike those for Medicine and

Economics (RQ3; Study 2). This mirrors the findings from case studies, which suggest that both Curie and Einstein had specific impactful scientific works that boosted their recognition and acceptance among peers (RQ3; Study 1). However, the confluence of professional and personal life events amounts to complexity and serve to add to the dramatic themes in the scientist's life. Allchin (2003) stated that the dramatic nature and storytelling of a scientist's life allows them to be popularized. This also explains why Tesla's relatively tame life events could have contributed to a decline of his popularity, despite his feats. Although a popular scientist, getting recognition has been a difficult process for Tesla (2018). Furthermore, research (Jacobi and Schiele 1989; Charney 2003; Osborne et al. 2003; Kim 2009) suggested that popular narratives, and the relatable portrayal of scientific work, as opposed to a purely academic one influences the degree to which a scientist appears appealing and heroic. Scientists extending their efforts beyond scientific pursuit, can have enduring implications for their popularity (Claes and de Ceuster 2013).

The news of a Nobel win is limited in its ability to popularise a scientist. If the Nobel alone could elevate a scientist into heroic status for the general public, there would be an increasing number of popular scientists every year. This indicates that many other factors affect the formation and maintenance of a scientific hero. The complex portrayal of scientists in mass media, their life events, and their own efforts outside the scientific realm, all together appear to influence the popularity of a scientist and thereby propel them to a heroic status.

Limitations and Future Directions

Despite being one of the first investigations of scientific heroism through a mixed-methods lens, this study was not without its limitations. Bibliometric data could not be sourced for all Nobel laureates since 2000, yielding missing values and a truncated sample size. Only the Nobel prize was considered as the entry point into scientific heroism; future research can redirect attention to similarly prestigious awards across disciplines, such as recipients of the Fields Medal in

Mathematics and the Turing Award in Computing. Layperson perceptions of scientific heroes as well as awareness of their contributions in the general public can lend further data on the extent to which scientists are able to penetrate the public psyche and stay memorable. For instance, scientists like Stephen Hawking have made conscious attempts of connecting with the masses through media and social networking, and hence, perhaps winning the highest award in their discipline is not a prerequisite to becoming a scientific hero. Moreover, other work can focus on investigating the gender disparities in science, particularly in the reward structure of science, which is associated inevitably with the making of a scientific hero.

To conclude, the research questions posed at the start of this article do not have simple or easy answers: First, both the scientific community and the general public make a scientific hero; moreover, an individual scientist may achieve heroic status at different times for different audiences, dependent on numerous factors, one of which is their scientific discipline. Further, the role of popular media representations in the making of a scientific hero cannot be understated. Second, all scientific heroes do not traverse all of Campbell's stages in a linear fashion. Last, heroes in science are born from a combination of years of toiling and impactful output, which again differs by discipline.

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