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HOW TO FOSTER SCIENTISTS' CREATIVITY

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Scientific progress can be credited to creative scientists, who constantly ideate new theories and experiments. I explore how the three central positions in philosophy of science – scientific realism, scientific pessimism, and instrumentalism – are related to the practical issue of how scientists' creativity can be fostered. I argue that realism encourages scientists to entertain new theories and experiments, pessimism discourages them from doing so, and instrumentalism falls in between realism and pessimism in terms of its effects on scientists' creativity. Therefore, scientists should accept realism and reject both pessimism and instrumentalism for the sake of scientific creativity and progress.

Keywords: empirical creativity, empirical progress, instrumentalism, scientific pessimism, scientific realism, theoretical creativity, theoretical progress.

* I thank anonymous referees of this journal for useful comments.

Introduction

There are diverse philosophical positions in philosophy of science. The present paper concerns only three of such positions: scientific realism, scientific pessimism and instrumentalism. I have chosen these three positions because they are central to the realism debate, and any discourse about other positions can be extrapolated from the discourse about the three. This paper adjudicates among the three positions in terms of their effects on scientists' creativity. Specifically, I argue that realism is the best means of fostering scientists' creativity. This topic is important because scientific creativity makes scientific progress possible.

This paper is structured as follows. In the next section I flesh out realism, pessimism, and instrumentalism and the prominent arguments for each position. In the following section, I make explicit what it means for science to make progress, what it means for scientists to be creative and how scientific progress and creativity are related to each other. In the subsequent

section, I argue that with regard to scientists' creativity, realism has a positive impact, pessimism has a negative impact and instrumentalism falls in between realism and pessimism. Therefore, scientists should accept realism and reject both pessimism and instrumentalism to be creative and make scientific progress.

This paper is distinct from other papers in philosophy of science in that it explores how realism, pessimism, and instrumentalism are connected with the practical issue of how scientists' creativity can be nurtured for scientific progress; other papers have only focused on whether realism, pessimism, and instrumentalism are tenable or untenable independently of the practical issue. Consequently, this paper should be of interest to both philosophers of science and creativity scholars.

Realism, pessimism, and instrumentalism

Realism, pessimism, and instrumentalism are different views about successful scientific theories, such as the oxygen theory of combustion, the special theory of relativity, the kinetic theory of heat, and the germ theory of diseases. A theory is successful when "it has functioned in a variety of explanatory contexts, has led to confirmed predictions and has been of broad explanatory scope" (Laudan 1981: 23). Thus, the aforementioned theories explain and predict a lot of phenomena. Realism, pessimism, and instrumentalism hold, respectively, that successful theories are (approximately) true, false, and useful.

These three different perspectives can be illustrated through an example. The special theory of relativity claims the following: the speed of light is invariant across different frames of reference, nothing can go faster than light, and $E = mc^2$. Note that the theory makes claims about unobservables, as do other scientific theories. Also, it is successful in that it explains and predicts various phenomena. For example, it makes the true prediction that an atomic clock will slow down if it is carried on a fast-moving jet.

Realists, pessimists, and instrumentalists adopt different epistemic attitudes towards the special theory of relativity. Realists believe that it is true and successful. Therefore, they maintain, for example, that the speed of light is invariant across different frames of reference and that atomic clocks will slow down if they are carried on a fast-moving jet. Pessimists, in contrast, believe that the special theory of relativity will follow the unfortunate path of past theories, such as the ether theory of light. Thus, pessimists do not maintain, for example, that the speed of light is invariant across different frames of reference. It is debatable whether they are entitled to believe or not that the prediction of the special theory of relativity is true, as will become clear in a later section. Instrumentalists, by contrast, do not believe that the special

theory of relativity purports to describe unobservables. Instead, they hold that this theory is a useful instrument for making predictions. Therefore, they do not believe, for example, that the speed of light is invariant across different frames of reference, but they believe that atomic clocks will slow down if they are carried on a fast-moving jet.

Why should we accept realism? In philosophy of science, the best argument for realism is reputed to be the no-miracles argument (Putnam 1975: 73; Psillos 1999). It holds that it would be a miracle for a false theory to be empirically confirmed. On this account, a theory passes strict tests because it is true, and it would not pass them if it were false. Thus, realism best explains why a theory is successful. For example, the special theory of relativity predicts that atomic clocks carried on a fast-moving jet will slow down. An experiment was performed in the early 1971 that confirmed the special theory of relativity (Hafele, Keating 1972). The no-miracles argument asserts that it would have been a miracle if the special theory of relativity was false and yet agreed with the experimental outcome. The theory passed the empirical test because it was true. In short, the realist hypothesis that it was true best explains why it passed the test.

Why should we accept pessimism? Pessimists argue that successful past theories, such as the phlogiston theory of combustion, the ether theory of light, the caloric theory of heat, and the miasma theory of diseases, have turned out to be false, so successful present theories, such as the oxygen theory of combustion, the special theory of relativity, the kinetic theory of heat, and the germ theory of diseases, will also eventually be disproven. This argument is called the pessimistic induction in the philosophy of science literature. John Worrall (1989: 99), Philip Kitcher (1993: 136), Stathis Psillos (1999), and K. Brad Wray (2013: 4321) claim that the pessimistic induction is the strongest argument against realism.

It is a historical fact that the aforementioned past theories passed strict empirical tests, which was why they were considered to be successful. For example, the phlogiston theory of combustion explained why a burning object became lighter. The explanation was that an object contains an invisible substance called phlogiston, and when the object burns, phlogiston is released from it. All the other aforementioned past theories were successful, just as the phlogiston theory of combustion was, and yet they were all later proven to be false. We should keep in mind that successful theories can, indeed, be false.

Who advocate the pessimistic induction in the philosophy of science literature? Its chief exponent is Henri Poincaré (1952: 160). He eloquently expresses the pessimistic induction as follows:

> "The ephemeral nature of scientific theories takes by surprise the man of the world. Their brief period of prosperity ended, he sees them abandoned one after the other; he sees ruins piled upon ruins; he predicts that the theories in fashion today will in a short time succumb in their turn, and he concludes that they are absolutely in vain" (Poincaré 1952: 160).

The pessimistic induction has been advocated not only by Poincaré but also by Ernst Mach (1911: 17), Larry Laudan (1977: 126), Hilary Putnam (1978: 25), Kyle Stanford (2006: 19–20), and Wray (2010: 311, 2013: 4327). If these thinkers are right, successful present theories are false and unwarranted, just like successful past theories.

Let me now turn to instrumentalism. Different thinkers have espoused instrumentalism with regard to various theories for slightly different reasons (Park 2016: 75–76). To summarise, Andreas Osiander (1498–1552) advocated instrumentalism about the Copernican theory (Kuhn 1957: 187). He refused to accept the theory's claims about unobservables because they clashed with his cherished metaphysical belief. Pierre Duhem (1861–1916) defended instrumentalism concerning physical theories (Duhem 1982: 19). He refused to accept any physical theory's assertion about unobservables because it cannot be confirmed or disconfirmed by observations. Stanford (2006: 197) embraces instrumentalism regarding all scientific theories on the grounds that past theories were superseded by present theories. All instrumentalists concur that their target scientific theories are not proved to be true beyond a reasonable doubt; that is, scientists' arguments in support of their target scientific theories are weak. Thus, epistemological worry grounds instrumentalism.

The current paper does not aim at defending or attacking the aforementioned arguments for and against realism, pessimism, and instrumentalism. Rather, it seeks to show that realism is a better means than pessimism and instrumentalism for nurturing scientific creativity and ensuring scientific progress; therefore, if scientists want to be creative and make progress, they should accept realism and reject both pessimism and instrumentalism. In order to defend this thesis, I first clarify the concept of scientific progress, the concept of scientific creativity, and the relationship between them in the following section.

Scientific progress and creativity

What does it mean to say that science makes progress? There are two sorts of scientific progress. They are theoretical progress and empirical progress. Theoretical progress is made when theories get closer to truths. Empirical progress is made when theories become more successful. Theoretical progress can be made when a true theoretical claim is added to an

existing theory or when an old theory is replaced with a new one that is closer to the truth. Empirical progress can be made when an existing theory is successfully applied to new observables or when an old theory is replaced with a new theory that explains and predicts more phenomena.

The replacement of old theories with new ones is important for theoretical progress and empirical progress, so let me elaborate on this with an example. Consider the replacement of the Ptolemaic theory with the Copernican theory. According to the former, Earth is at the centre of the universe, and the celestial bodies, such as the Sun, the Moon, Mercury, Venus, Mars, Jupiter, and Saturn, move around Earth once a day. In contrast, the latter posits that the Sun is at the centre of the universe, and Mercury, Venus, Earth, Mars, Jupiter, and Saturn move around the Sun. Galileo Galilei (1564–1642) reasoned that if Earth moved around the Sun, and if the orbit of Venus were between the Sun and Earth, the phases of Venus should be observable. Galileo made a telescope and observed the phases of Venus, thereby confirming the Copernican theory and disconfirming the Ptolemaic theory. Now, strictly speaking, the Copernican theory is false. The Sun is not at the centre of the universe. It is clear, however, that the Copernican theory was closer to the truth than the Ptolemaic theory. That is, theoretical progress was made. Also, the Copernican theory explained and predicted more phenomena than the Ptolemaic theory. For example, the Copernican theory, unlike the Ptolemaic theory, predicted and explained why Venus went through phases. Thus, the Copernican theory was more successful than the Ptolemaic theory, and in this way, empirical progress was made.

This historical example is intended to illustrate the following five general claims. First, new theories are closer to truths than old theories. Second, new theories are more successful than old theories. Third, the replacement of old theories with new theories is an important source of scientific progress. Theories get closer to truths and become more successful largely because scientific revolutions occur. Fourth, scientific creativity makes scientific progress possible. Old theories were replaced with new theories in the history of science because scientists ideated new theories and observations. For example, if Nicolaus Copernicus had not been creative, the heliocentric theory would not have occurred to him. Similarly, if Galileo had not been creative, the notion of the phases of Venus would not have occurred to him. Fifth, scientific creativity can be classified into theoretical creativity and empirical creativity. Theoretical creativity is the ability to conceive a new theoretical claim that can be added to an existing theory or a new theory that can replace an old theory. Empirical creativity is the ability to initiate a new observation that would obtain, if a theory is true or to conduct a new experiment to confirm or disconfirm a theory. Copernicus was theoretically creative because he

formulated the heliocentric system, whereas Galileo was empirically creative because he forwarded the idea of the phases of Venus. Theoretical creativity and empirical creativity drive scientific progress. It is thanks to these creativities that our theories get closer to truths and become more successful.

Adjudication

In previous sections, I introduced realism, pessimism, and instrumentalism, and I shed light on how scientific creativity is related to scientific progress. Which is the best philosophical doctrine for nurturing scientific creativity? In other words, should scientists be realists, pessimists, or instrumentalists in order to devise new theories and observations? This section aims to answer this question through the discussion of a historical episode.

Let me summarise a historical episode recounted in detail by Carl Gustav Hempel (1966: 3–6). A puzzling and distressing phenomenon occurred in the Vienna General Hospital in 1846. The hospital had two maternity divisions. Approximately 10% and 2% of the women who gave birth in the first division and in the second division died of child fever, respectively. Ignaz Semmelweis (1818–1865), a Hungarian physician, investigated the cause of the high mortality rate of the first division, testing six hypotheses one by one. Put briefly, the first hypothesis held that miasma travelled to the first division via the air; the second stated that the first division was overcrowded; the third held that medical students treated the women in the first division roughly; the fourth claimed that a priest and his attendant had a terrifying psychological impact on the women in the first division; the fifth contended that the women in the first division lay on their backs during labour; and the sixth held that medical students did not wash their hands after performing autopsies and before helping the women who were in labour in the first division. Semmelweis hit upon the idea that cadaverous material on the students' hands was killing the women in the first division. After he instituted a hand-washing policy, the mortality rate dropped from approximately 10% to approximately 2%. In short, he arrived at a true and successful hypothesis after eliminating five false and unsuccessful hypotheses.

What would have happened, if Semmelweis had been a pessimist? Imagine that he tested the fifth hypothesis and realised that it was false and unsuccessful. He would have reasoned, as a pessimist, that the next hypothesis would be false and unsuccessful as the five previous hypotheses were, thereby presuming that it was pointless to devise further hypotheses and test them. Thus, he would not have been motivated at all to be theoretically and empirically creative, and as a result, he would not have been able to reduce the high mortality rate of the

first division. In general, pessimists believe that the trial and error process is repetitive and futile (Park Forthcoming).

What would have happened, had Semmelweis been a realist? Imagine again that he tested the fifth hypothesis and realised that it was false and unsuccessful. He would have thought, as a realist, that the next hypothesis might be true and successful, although the five previous hypotheses were false and unsuccessful. If the next hypothesis had passed the test, he would have thought that it was true, although the five previous hypotheses were false. Thus, he would have been motivated to adopt a theoretically and empirically creative approach in order to determine the cause of the high mortality rate and lower it. In general, realists believe that the trial and error method can lead to breakthroughs and it is therefore worthwhile to entertain further hypotheses and experiments.

What would have happened, if Semmelweis had been an instrumentalist? As noted previously, instrumentalists believe that a theory does not even purport to describe unobservables; only the theory's success is important. Imagine that Semmelweis tested the fifth hypothesis and realised that it was unsuccessful. He would have thought, as an instrumentalist, that the next hypothesis might be successful, although the five previous hypotheses were unsuccessful. As a result, he would have thought that it was worthwhile to construct further hypotheses and test them. In general, instrumentalists believe that achievements might come about after trial and error, and that it is therefore worthwhile to devise further hypotheses and experiments; however, they hold that the achievements are only empirical progress.

A similarity and a difference exist between pessimism and instrumentalism, which can both be illustrated through the example of Semmelweis. The similarity is that if Semmelweis were a pessimist or an instrumentalist, he would not have thought that the sixth hypothesis would be true. As a pessimist, he would have concluded that it was false. As an instrumentalist, he would have thought that it did not have a truth-value. The difference is that if he were a pessimist, he would have predicted that the sixth hypothesis was false and unsuccessful. By contrast, if he were an instrumentalist, he would have thought that it might be successful, although the five previous hypotheses were unsuccessful. Thus, pessimism would have discouraged him whereas instrumentalism would have encouraged him to formulate further hypotheses and experiments.

A similarity and a difference also exist between realism and instrumentalism, which, again, can be demonstrated through the case of Semmelweis. The similarity is that if Semmelweis were a realist or an instrumentalist, he would have thought that achievements might come about as a result of trial and error; therefore, he would have been motivated to

devise new hypotheses and experiments. The difference is that if he were a realist, he would have expected that the sixth hypothesis would be true and successful, whereas if he were an instrumentalist, he would only have expected that the sixth hypothesis would be successful.

This historical episode is intended to support the following contentions. First, scientists usually make a breakthrough after trial and error. Second, realism and instrumentalism instil fortitude in scientists so that they keep thinking up new theories and experiments, whereas pessimism drains fortitude out of them so that they stop entertaining new theories and experiments. Therefore, realism and instrumentalism have a positive impact, whereas pessimism has a negative impact, on scientists' theoretical and empirical creativities.

Let me now turn to the thorny issue of what better nurtures scientific creativity realism or instrumentalism. In my view, realism is more helpful than instrumentalism for fostering scientific creativity. If scientists are realists, they are interested in developing new theories that describe unobservables better than old theories and in adding new theoretical claims to existing theories so that the existing theories can inch closer to truths. They are also interested in developing new theories that are better instruments than old theories for making predictions and in adding new theoretical claims to existing theories so that the existing theories can make new true predictions. By contrast, instrumentalists are only interested in developing new theories that are more successful than old theories and in adding new theoretical claims to existing theories so that the existing theories can be more successful. In a nutshell, realists pursue both theoretical and instrumental gains, whereas instrumentalists pursue only instrumental gains.

This difference between the realist aspiration and the instrumentalist aspiration can be illustrated as follows. Suppose that there are two competing theories: T_1 and T_2. They make incompatible claims about unobservables, so, at best, only one of them is true. They are, however, empirically equivalent. That is, they make the same claims about observables. Hence, neither theory makes more true predictions than the other. Suppose also that T_1 is accepted by scientists and that T_2 has not yet occurred to them. That is, T_2 is an unconceived alternative. Realists and instrumentalists would have different attitudes towards T_2. Realists would attempt to ideate T_2 in the hope that it might be closer to the truth than T_1. Instrumentalists, by contrast, would not attempt this because, in their view, it would be no more successful than T_1. It follows that realism stimulates scientists to be creative more than instrumentalism does.

In sum, realism encourages scientists to be creative, whereas pessimism discourages them from being creative. Pessimism is an efficient philosophical doctrine for stifling scientists' creativity. Realism and instrumentalism are equal in terms of their capability for stimulating scientists to devise new theories that are more successful than old ones. However, realism is

better than instrumentalism in terms of its capability of stimulating scientists to develop new theories that are closer to truths than are old theories. Hence, realism is the most effective philosophical doctrine for stimulating scientists to be creative and make scientific progress.

Objections and replies

Pessimists might protest that they can embrace instrumentalism, i.e., that pessimism is compatible with instrumentalism. Recall that pessimists believe that present theories will be rejected as past theories were. Although they believe that present theories are false as past theories were, they can believe that present theories are successful as past theories were. In other words, although pessimists are pessimistic about a scientific theory's capability for correctly describing unobservables, they are not pessimistic about a scientific theory's capability for making true predictions. In that spirit, Stanford embraces instrumentalism although he is a pessimist. He states that "we might use our theories for prediction, intervention, and other pragmatic purposes without believing the theoretical descriptions they offer of the natural world" (2006: 197).

In my view, however, Stanford is not aware of the tension between pessimism and instrumentalism. Scientists have successful theories in their hands today. As noted previously, however, scientists arrive at a successful theory by first making trial and error, i.e., by first conceiving and testing unsuccessful theories. If scientists were pessimists, they would not be motivated to develop new theories and experiments. As a result, they would not have successful theories in their hands today. The fact that they possess useful theories today shows that they kept devising and testing unsuccessful theories over time despite trial and error. That is, they were not pessimists. Thus, pessimism and instrumentalism cannot go hand in hand.

Let me turn to instrumentalists' possible objection against my defence of realism. Recall that realists pursue both theoretical progress and empirical progress. Instrumentalists might say that they care whether science makes empirical progress or not, but they do not care whether science makes theoretical progress or not. That is, they hold that empirical progress is worthy of pursuit but theoretical progress is not. Therefore, according to instrumentalism, scientists need to be creative as a way of making empirical progress, but they do not need to be creative as a way of making theoretical progress.

In my view, before instrumentalists make such criticisms against realism, they need to be aware of the criticism that pessimists would, in turn, launch against instrumentalism. Pessimists would declare that both theoretical progress and empirical progress are not worthy of pursuit. If scientists have made some failed attempts at theoretical progress and empirical

progress, it is only a waste of time to make further attempts. Hence, scientists do not need to be creative to make empirical progress and theoretical progress.

Instrumentalists would respond that it is absurd for pessimists not to pursue empirical progress. Our ancestors could not predict when the next solar eclipse would occur. They did not know that continents moved around and that Hawaii would bump into the Kamchatka Peninsula. They could not produce new crops by manipulating genes. We know and can do all these things now because science has made empirical progress. How can pessimists say that such feats are worthless?

Realists, however, contend that it is absurd for instrumentalists not to pursue theoretical progress. Our ancestors did not know that the earth revolves around the Sun, but we do now. As this example illustrates, new theories are closer to truths than are old theories. How can instrumentalists say that theoretical progress is worthless? In sum, theoretical progress and empirical progress are on the same boat; that is, it is difficult to find a reason for pursuing empirical progress, but not theoretical progress.

Conclusions

I explored how realism, pessimism, and instrumentalism are related to the issue of how scientists' theoretical and empirical creativities can be fostered. My conclusions are that realism is the best philosophical doctrine for helping scientists to increase their theoretical and empirical creativities. If scientists want to make progress by conceiving new theories and conducting novel experiments, they should embrace realism and resist both pessimism and instrumentalism. These conclusions are intended to be a strike against pessimism and instrumentalism.

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