Chapter 10
Doctoral Creativity as an Epistemological Force in Saving and/or Destroying the World

Liezel Frick

The current state of the planet demands that researchers carefully consider how they might meaningfully contribute to addressing current and future socio-environmental issues. Doctoral research in STEM fields have a particular role to play in pushing the knowledge boundaries of how we view and exist within a post-industrialised and post-human world. Such knowledge creation demands creativity in terms of being creative (the creative person), doing research creatively (the creative process), creating a supportive environment for creative endeavours (the creative curriculum), and producing something deemed creative (the creative product). This chapter explores how this complex and multi-layered conceptualisation of doctoral creativity may be an epistemological force in saving and/or destroying the world in the context of STEM research, and, in doing so, problematises the notion of doctoral creativity as inherently "good."

Introduction

Scientists across the world are warning of imminent global destruction driven by global warming, which seems to be ignored by some governments, policymakers, industries, and large sectors of the public (Ripple et al. 2017). Such ignorance is borne out of what Latour (2016) describes as scientists' lack of public engagement and the failure of scientific evidence to trickle down to all sectors of society. Yet, scientists do not study the natural and social world in isolation, but form part of the same system they are criticizing – and may even have been responsible for part of the ongoing destruction through research-based technology and innovation.

L. Frick (✉)
Centre for Higher and Adult Education, Department of Curriculum Studies, Stellenbosch University, Stellenbosch, South Africa
e-mail: blf@sun.ac.za

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Particularly in STEM disciplines[1] – which is the focus of this chapter – there is a growing emphasis on contributing to knowledge production in tangible, applicable, and profitable ways through innovation while environmental and social responsibility and sustainability often seem less of a concern. Doctoral research is particularly disposed to scrutiny in this respect, as it is expected to push the boundaries of scientific endeavour by means of knowledge creation. Such acts of epistemic creation require creativity as a necessary underlying process (Baptista et al. 2015), hence the focus of this chapter on doctoral creativity as a key concern for the future of science in STEM areas.

Creativity is both an implied and explicit expectation within the original contribution a doctorate is expected to make (European Universities Association 2007; Frick 2011), meaning that doctoral creativity is complex and multi-faceted, which can be conceptualised in terms of doctoral becoming (the creative person), doctoral curriculum (the creative situation), and doctoral outcomes (the creative process and product) (Frick 2010). As such, doctoral creativity could easily be seen as a "force of good" – serving the interests of the scientific community by extending epistemological boundaries and serving society and the environment by ensuring a sustainable future. But with all creative endeavours come risk and responsibility. Within the context of doctoral education, it means that we need to question and problematise the notion that creativity is inherently "good" (Rauth et al. 2010). Creativity in research has consequences and the potential for harm. Though particularly STEM doctoral research may, of course, be a meaningful creative force that contributes towards saving the world amidst the rising awareness of human impact on the environment, there is a potential destructive side to scientific endeavours where research can have (unintended) damaging consequences that also needs to be acknowledged.

This chapter therefore explores how creative forces at play during the doctorate might influence socio-environmental well-being, which is the interface where a major part of STEM research is situated. I here take a pedagogical stance, conceiving of pedagogy as a process where meaning is constantly (re)created, where the identities of those involved develop through discursive practices and power/knowledge relations in the co-creation of such knowledge (Howard and Turner-Nash 2011; Lusted 1986). Through pedagogy students become socialised into the academic community, which provides a sense of collective direction (McWilliam and Dawson 2008; McWilliam et al. 2008). Doctoral pedagogy thus involves the knowers (including both students and supervisors), the known, and the unknown and what the rules of engagement are under which these elements combine to eventually produce knowledge – the ultimate goal of a doctorate – with creativity as the epistemological force driving this process.

[1] Even though I fully acknowledge that creativity is an aspect present in all doctoral research regardless of the discipline(s) in which it is situated, I have chosen in this chapter to focus the argument on doctoral creativity in STEM fields of study, as such research is often positioned at the interface between the human and non-human worlds and thus also often has bearing on how we (as humans) live within and how we have an effect on these interlaced worlds.

Defining Doctoral Creativity as an Epistemological Force

Creativity demands a thorough understanding of the basic principles of and knowledge within a field of study through often lengthy, purposeful and arduous engagement with the existing knowledge in the field of study (Hennesey and Armabile 1988; MacKinnon 1970; Sternberg and Lubart 1999). The importance of knowledge and immersion in the field of study in identifying problems and gaps in order to move beyond the existing perspectives and to create something new has been well recognised (Dewett et al. 2005; Nickerson 1999; Sternberg and Lubart 1999). Thus, in the doctorate, the saying *knowledge is power* holds true. However, such knowledge needs to extend beyond mastering the specifics of the discipline(s) within which the study takes place. At the doctoral level, creativity may manifest in transforming the field of study and/or extending the current boundaries thereof, and – if we follow Latour's (2016) argument – extending the reach of such knowledge beyond the confines of narrow scientific ivory towers. Doctoral creativity thus becomes an epistemological force, driving knowledge creation, application, and change.

Libby (1970) describes scientific creativity as discovery through research and creativity as the purpose of science. He furthermore distinguishes between science and technology: science discovers natural law, while technology applies the discoveries of science. Yet, creativity extends beyond a technicist view of scientific discovery to the person(s) behind the science. Pope (2005: xvi, 11) defines creativity as "the capability to make, do or become something fresh and valuable with respect to others as well as ourselves," which involves "a grappling deep within the self and within one's relations with others: an attempt to wrest from the complexities and contradictions we have internalised" – thus facing the complex and nuanced interplay between creativity as both potentially constructive and/or destructive within the science and within ourselves. Those in STEM areas might argue that such a focus on researcher positionality may not be relevant in areas claiming objectivity. Yet, Latour (2000, 2004) highlights the contested nature of the notion of objectivity in both social and natural sciences, while the National Research Council of the United States of America (2002: 2) defines all scientific inquiry as:

> *Scientific inquiry is the same in all fields. Scientific research, whether in education, physics, anthropology, molecular biology, or economics, is a continual process of rigorous reasoning supported by a dynamic interplay among methods, theories, and findings. It builds understandings in the form of models or theories that can be tested. Advances in scientific knowledge are achieved by the self regulating norms of the scientific community over time, not, as sometimes believed, by the mechanistic application of a particular scientific method to a static set of questions.*

And so although science itself may be concerned with ideas regardless of power, relationships, impact, or consequence, the practice of science is not immune to these factors. It is thus not surprising that Watson (2007) emphasises the socio-ecological responsivity and responsibility of all those engaged in higher education, regardless of their discipline.

Following this line of argument, it is helpful to consider the doctorate as a perpetual desire and search for wisdom (Barnacle 2005), thus moving beyond the notion of knowledge for the sake of knowledge. Wisdom refers to a comprehensive understanding of knowledge, sound judgement, and insight relevant to the context in which it operates. The doctoral graduate is therefore more than a mechanic of knowledge, but can judge knowledge and can advise with insight, which speaks to Freire's (1970, in Lin and Cranton, 2005: 458) notion of a student as someone having "the courage and confidence to take risks, to make mistakes, to invent and reinvent knowledge, and to pursue critical and lifelong inquiries in the world, with the world, and with each other." This notion of wisdom implies an understanding of the responsibility researchers have to think about the consequences of the knowledge they create, the power they wield in creating knowledge, and finding ways of managing the possible tension between knowledge creation as a force of innovation and as a pursuit of wisdom.

As the production of knowledge has come to be of increasing importance to national economies, university research is expected to better serve the needs of industry, through innovation in science and technology in particular. The Lisbon Declaration (European Universities Association 2007) on the purpose of Europe's universities strongly links university research with innovation, emphasising the importance of universities' "capacity for promoting cultural, social and technological innovation" and that "to meet the challenges of the twenty-first century (…) [requires] technological and social innovation which will solve problems as they arise and ensure economic success." The doctorate is increasingly economically positioned as an important source of skilled and innovative knowledge workers, as required by a knowledge-based economy with a strong emphasis on research and development (Bastalich 2010; Halse and Mowbray 2011). This position has led to an exponential growth in the number of doctorates awarded internationally, especially in STEM-related disciplines (Cyranoski et al. 2011), and a shift in expectations of employment after the doctorate away from academia and towards industry, government, and private enterprise (Auriol 2010; Enders 2005). Innovation has claimed a prominent place in defining a key purpose of the doctorate as preparing the candidate for a future or current career in either academia or industry and developing skills for employability. Thus, innovation as part of doctoral research privileges the production of knowledge that is economically useful. The extent to which these developments have changed the conditions under which knowledge is produced in doctoral theses and science in general is unclear (Geiger 2004).

The unease between creating (applicable) knowledge and developing wisdom is amplified in doctoral education as wisdom is not easily commodified nor does it develop overnight. In addition, it may be difficult to foresee the outcome (and possible unintended consequences) of a project at the onset thereof, particularly as doctoral research is expected to be at the cutting edge of the discipline. Defining doctoral creativity as an epistemological pursuit in search of wisdom leads us to think about the doctorate beyond a mere knowledge product – in the form of the so-called original contribution contained in a thesis, a collection of scholarly articles, a patent, or an artefact – and resultant social and technological innovations

often prized within the current highly competitive higher education environment (even though it is sometimes criticised by scholars, e.g. Bastalich 2010). Creativity in doctoral education is therefore as much about *what* is created as about *how* it is created and by *whom*. It also speaks to the convoluted nature inherent to the creative process, where what we create now might have unintended uses, adaptations, and consequences in future for both ourselves, others, and the environment.

The Risky Business of Doctoral Creativity

Research by its very nature is a risky endeavour (Frick et al. 2014). Being creative raises serious risk-related ethical issues, including possibly breaking rules and standard operating procedures; challenging authority and avoiding tradition; creating conflict, competition and stress and raking risks (Baucus et al. 2008), which is a particular concern within STEM areas where research often lies at a social and environmental interface. The outcome of the creative endeavour may have dire socio-ecological consequences, even though it might at the same time advance scientific understanding in the area of study. CRISPR gene editing and other genetic modification technologies, nuclear energy, synthetic polymer science, and artificial intelligence systems are but some of the many current examples of research areas where scientific advances have greatly contributed to both science and our everyday lives, but where there have also been questions about the potential impact of research in these areas on the planet and all its life forms. These might be obvious examples, but all research projects contain an element of risk. Herein lies a pedagogical paradox – in as much as doctoral education has to foster creativity, there is also the responsibility to ensure that students understand their moral responsibility to carefully consider the social and ecological risks and consequences of their research (a responsibility also referred to by Kampylis and Valtanen 2010).

But the notion of risk in doctoral education is not a simple dichotomy between risk/no risk. There is a risk to taking risks, but equally, there is risk to fearing or avoiding all risk. A basic scientific premise is *doubt*. Yet, in order to be constructively doubtful, in, for example, coming up with a hypothesis, the scientist needs to build such a hypothesis on a set of assumptions that need to provide some (pseudo-) certainty as a point of departure. This interplay between certainty and doubt is not always easily managed, and the fear of failure may inhibit doctoral creativity. So although untethered risk-taking may not be ideal in science in general and doctoral education in particular, fearing and avoiding all risk may stifle creativity and limit the contribution a doctorate can make. If creativity is not explicitly facilitated and valued, one cannot expect doctoral students to bring about future epistemological changes as responsible scholars, and innovation becomes less likely. More likely, only moderate contributions to knowledge development will be made (Brodin and Frick 2011). The most pressing problems facing science and society will not be solved if they are viewed from a limited perspective (Manathunga et al. 2006; Max-Neef 2005), and thus risk is an unavoidable part of the doctorate.

It therefore becomes necessary to conceptualise risk-taking in the context of doctoral education as adaptive risk. Adaptive risk-taking does not avoid all risk but rather pursues some (acceptable) risks while avoiding so-called hazardous risks (Byrnes et al. 1999). The Lisbon Declaration (European Universities Association 2007: 3) argues that universities "should encourage a culture of risk-taking (…) in order to produce an institutional milieu favourable to creativity, knowledge creation and innovation," which underlines the idea that the doctorate requires a certain amount of risk-taking. In addition, Reichert (2006) emphasises the need for universities that optimise and nurture the creative potential of individuals and teams, which requires resources, time, and opportunities to conduct high-risk unpredictable research.

From a pedagogical perspective, the context, relationships in the supervisory process, and individual characteristics of doctoral students and supervisors all play determining roles in calculating acceptable levels of risk. In terms of context, it is necessary to (re)consider the purpose of a doctorate within a super-complex and uncertain society (Barnett 2000; Park 2005, 2007) and how this influences pedagogical roles and responsibilities. In addition, the interplay between individuals' subjective perceptions of risk and related perceptions of the larger community has pedagogical implications, as risk may be interpreted differently by different role players (including students and supervisors, which may influence their relationships and study foci). Furthermore, individual characteristics determine the extent of possible risk – for example, a study may be less risky if the doctoral student/supervisor has particular research and/or subject expertise. Finally, context determines "who can take what risks and how" (Hood et al. 1992: 136). A project may be less risky when expert supervision and/or particular resources are available. Hence the supervisor becomes a risk manager and risk mitigator, mediating between the demands of society, the discipline(s) involved, the institution, and the doctoral candidate (Evans 2004). This means balancing rather than controlling risk – containing risk in a responsible manner – while encouraging creativity.

Following the Master, or Not

Whose responsibility is it to develop doctoral creativity? Doctoral students are not the only role players in developing creativity. Supervisors are also key role players in this power-laden pedagogical relationship, particularly in lieu of the new generation of students who prefer "pedagogical exchange as a form of *value creation* rather than *knowledge transmission*" (McWilliam et al. 2008: 228). This speaks to MacKinnon's (1970) idea that creativity should not be seen as something to be taught but rather as developed by leading through example. In doctoral education, this would mean "cognitive apprenticeship" (Austin 2009: 175) by involving students in all the phases of supervisors' own research – including conceptualisation, planning, implementation, and eventual reporting. Such an approach makes experts' thinking processes in understanding and addressing problems visible. It also

enhances students' meta-cognitive abilities – that is, awareness and control over implementing their knowledge in a practical and unpredictable professional setting and subsequent reflection on performance (Lizzio and Wilson 2004).

Supervisors need to create nurturing, student-centred learning environments that provide a solid scientific foundation yet value divergence and diversity. Exercises that require the transference of knowledge from one area to another; searching for common principles where facts from different areas of knowledge can be related; developing analogies, metaphors, and symbolic equivalent experiences; engaging in imaginative play and experimentation, and helping students to step back from facts to gain a greater perspective may foster creativity. Problematising of subjects and the deconstruction of knowledge may encourage creativity (Belluigi 2009; Pope 2005). Examples of such pedagogic practices cited by supervisors in the STEM areas required students to transfer knowledge from one area to another, search for common principles where facts from different areas of knowledge can be related, and engage in imaginative experimentation. In this way, supervisors helped students to step back from facts to gain a greater perspective. Such supervisors were also able to create a space for debate through problematising and deconstructing knowledge, which promoted a respectful yet challenging learning environment (Austin 2009; Frick 2012).

Yet we also need to acknowledge that it is difficult to develop a sense of responsible creativity in doctoral students. Creativity takes time to develop and needs to be fostered in an atmosphere that allows exploration and expression (even failure!), regardless of the discipline or programme format (Jones 1972). It is therefore not surprising that the doctorate is seen as a process of becoming, which is not straight forward or linear and, as we know, neither is the research process itself (Archer 2008; Barnacle 2005; Batchelor and Di Napoli 2006). Becoming a researcher may entail conflict, feelings of inauthenticity, marginalisation, and exclusion, and data from various studies show that doctoral students often experience stress and feelings of anxiety (Stubb et al. 2011; Pyhältö et al. 2012). In addition, students immersed in creative processes often act in ways that may make supervision difficult (MacKinnon 1970). These students may be characterised as non-conformists, which may result in tension and adjustment problems. They often strive for independence, are curious and perceptive, search widely for related information, act intuitively, do not like being confined to pre-determined courses, and need to explore options – even though some options may lead to failure (Jones 1972). In addition, not all students will develop their creativity in similar ways, or in a linear fashion, or to the same level of manifestation equally across all the research phases.

Knowledge production is furthermore highly contextualised. Contextual factors (including bureaucratic institutional systems, ethics, and funding policies) act as determinants of the extent to which risk-taking is possible in doctoral studies (Backhouse 2009; Frick 2012; Holligan 2005; Wildavsky et al. 2015). Further tension may result from the difference between institutional demands for completion and students' needs to engage with ideas over time through incubation (Brew 2001). The current emphasis on doctoral throughput in the minimum allocated time may lead to risk-avoidance, steering clear of complex and less defined problems. In

addition, only about 10% of all innovations are ultimately successful, which makes trial and error essential but risky (see Florida et al. 2010, Reichert 2006, Uyarra 2008 and Youtie and Shapira 2008 for more extensive arguments on the role of universities in innovation-driven agendas). Ultimately, the process of doctoral education is influenced by the various cultures in which creative work takes place. In particular, how such cultures define innovative knowledge outcomes is highly relevant (Baptista et al. 2015).

A pedagogical understanding of developing creativity in STEM doctorates therefore demands a nuanced appreciation of the interplay between doctoral students' inherent qualities, supervisory practices, and environmental factors that interact in the process of doctoral becoming. Future debates on doctoral pedagogies may have to focus on how an implicit notion of creativity can be made more explicit.

Hurtling Towards the End of the World, but All Is Not Lost

Does the STEM doctorate still have relevance in a world shaped by forces sceptical of what science might add to our understanding of this world, where universities are no longer considered the authoritative vanguards of knowledge creation? Latour's (2016: 2) work seems to suggest that it could – if we are willing to rediscover (or research, if you may). Latour (2016: 10) notes that such rediscovery "should create as much creative energy as during the period that had been called the 'age of discovery'. Especially that now the project of reinventing how to live on the planet might be a project shared with the formerly dispossessed."

What role can the doctorate play in shaping change (rather than trying to stop it)? The existence of so-called wicked problems (Brown et al. 2010), the emphasis on applied knowledge (Enders 2005; Enders and De Weert 2004; Gibbons 1998), and public demands for higher education accountability (Barron and Zeegers 2006) force doctoral students, supervisors, and universities to look at research problems more holistically and "mobilize our forces in a different way" (Latour 2016: 10). This requires some creativity from all the role-players concerned. The idea of being a creative university (Reichert 2006) does not exclude being efficient or economically viable, but it takes a longer-term view on the benefit it might add to society and the economy and allows more space for creativity, dialogue, experimentation, and innovation (Florida et al. 2010). A narrow focus on the economy of the system (both in terms of fiscal and efficiency indicators) may inadvertently infringe on the potential for innovative knowledge transfer, creation, and production through both teaching and research, and the eventual positive contribution the higher education sector can potentially make to industry and society.

From a pedagogical point of view, how do we enable both individual doctoral students and such individuals as part of groups to become creative? We need more research that explores universities' potential to nurture the creative potential of both individuals and groups, which requires time, resources, and space for more flexible programme structures, improved student support structures, and an investment in

developing creative higher education pedagogies (even leading up to the doctorate), as well as research that may not have an immediate and applied impact. A more holistic notion of doctoral development that acknowledges the importance is essential to positioning creativity as an epistemological force that can help save the world.

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