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forward together · saam vorentoe · masiye phambili

Towards innovation:
Pedagogical perspectives on developing creativity in doctoral education

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Doctoral Students

Women	Men
621	1521

EPFL is one of the world's most dynamic and reputed institutes of science and technology. In the heart of Europe, it offers a combination of excitement, excellence, inspiring education, and outstanding facilities for research. Its doctoral school is organized into 21 doctoral programs, each covering a well-established discipline or one of today's interdisciplinary research areas. They form vibrant scientific communities that energize the exchange of scientific ideas and progress.

Prof. Pierre Vandergheynst, EPFL Vice President for Education

Country of origin

Switzerland	Europe	World
20%	50%	30%

Degrees

Delivered in 2017
431

Career

| = Academia	= Industry
35%	65%

High levels of mobility foster innovation
(UNESCO Science Report, 2015)

- Majority of doctoral students abroad are studying science and engineering
- 10 countries host 89% of international science and engineering doctoral students (Switzerland 3.1%)
- Swiss context
    - Most doctoral students in Switzerland are international students (51% inbound mobility)
    - Switzerland leads innovation through
        - High levels of investment in R&D (3% of GDP in 2012)
        - 30% of R&D expenditure for basic research
        - 61% of R&D funded by industry, business-friendly environment
        - More than half of labour force qualified for jobs in S&T (result of excellent vocational training and ability to attract international talent to private industry and academia)

Pedagogy (Lusted, 1986)

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Every pedagogical interaction can be perceived as a kind of feedback to the individual student, sometimes beyond the lecturer's intention (Brodin & Frick, 2018)

Student

Supervisor

Co-created knowledge

**The Doctorate**
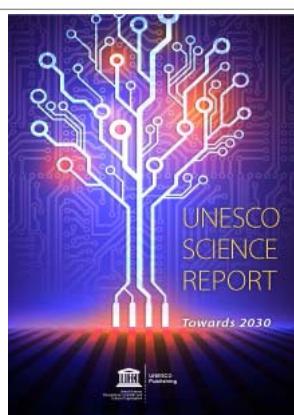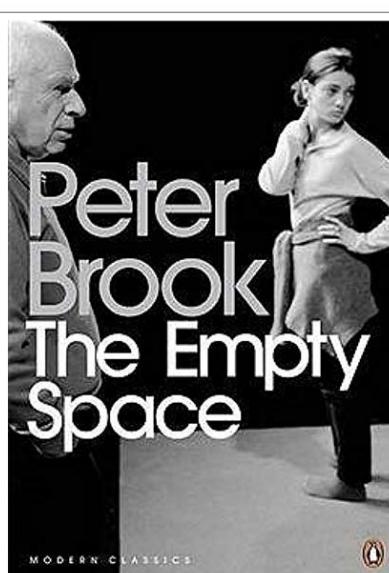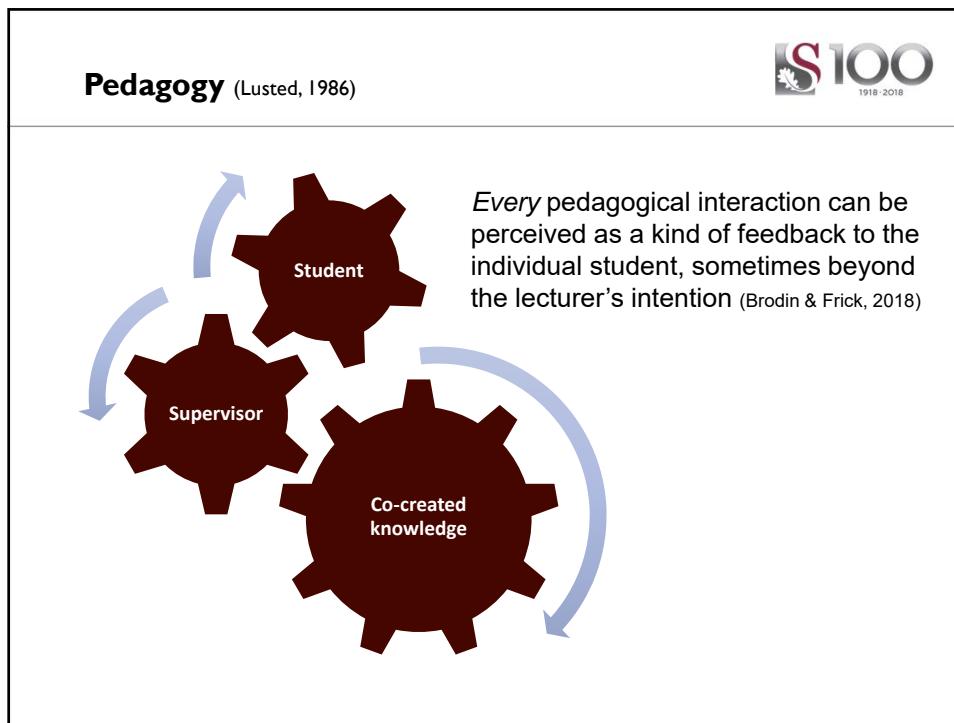
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Stop calling them soft skills, they're essential skills
(Trevor Muir, 2019)

The more I think about creativity
the more I realised
how little I know about it

(Parks, 1970:81)

The creative process
(Wallas, 1926)

Four Ps
(Rhodes, 1961)

- Person
- Process
- Product
- Press

CREATIVITY
the meaningful application of imagination
(Robinson, 2011)

Four C model
(Kaufman & Beghetto, 2009)

Originality

It is better to fail in originality than to succeed in imitation

Herman Melville
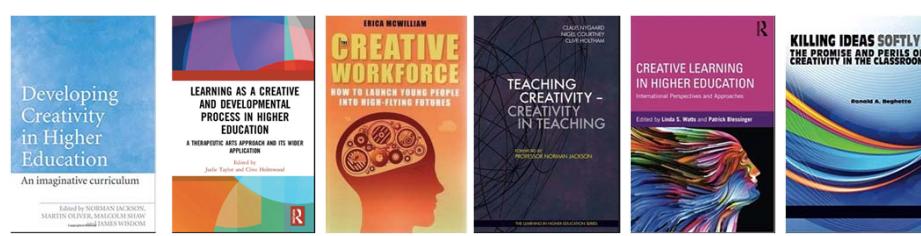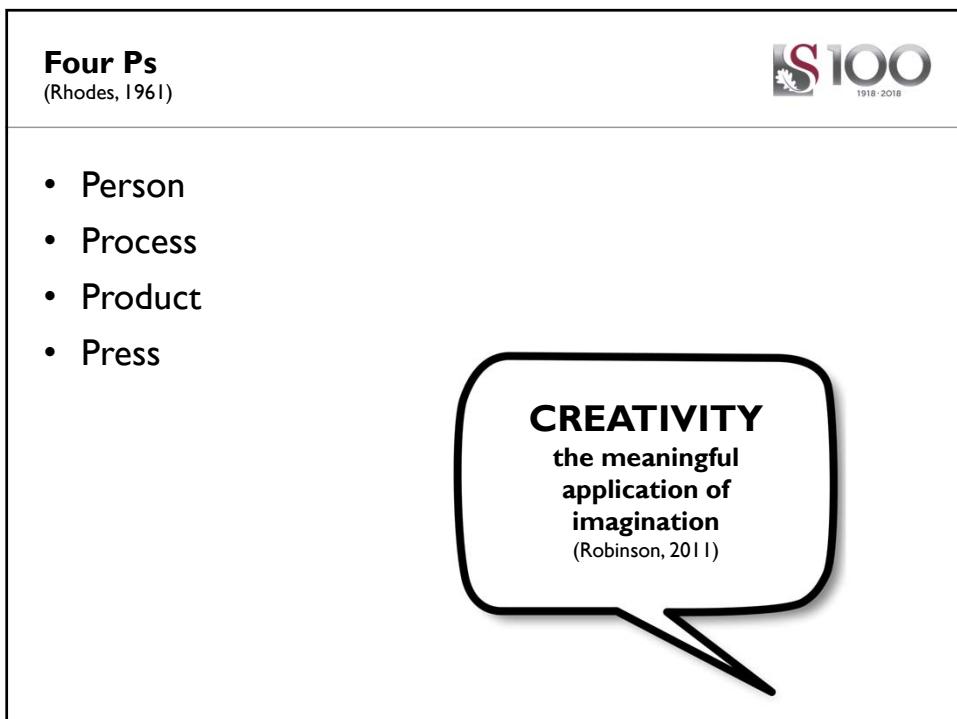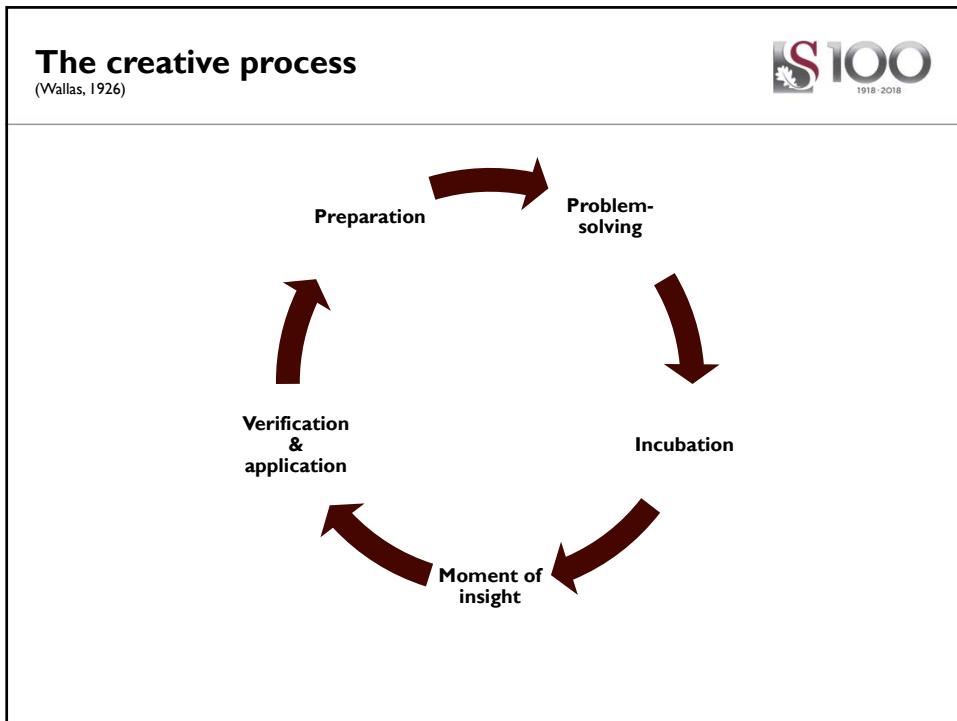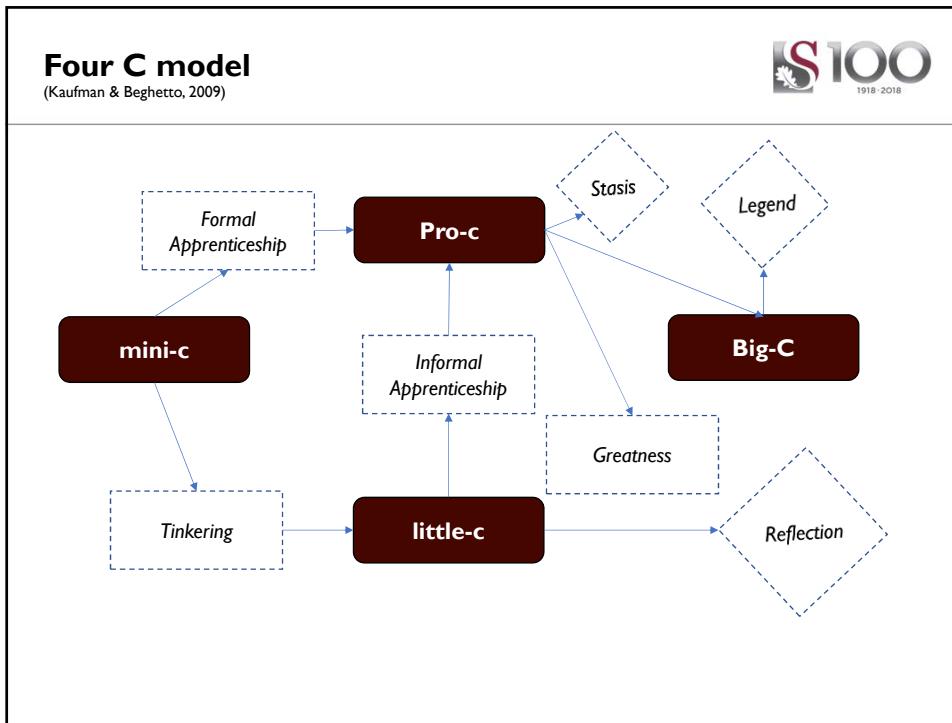
Innovation

Learning and innovation go hand in hand. The arrogance of success is to think that what you did yesterday will be sufficient for tomorrow.

William Pollard

The development of expertise
(Daley, 1999; Dreyfus & Dreyfus,1986; Rogers, 2001; Dewey, 1933; Flyvbjerg, 1990; Mezirow, 1991; Schön, 1983; Seibert & Daudelin, 1999)

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The relationship between originality, creativity and innovation
(Baptista et al., 2015)

Pedagogical paradoxes

- Pedagogical paradox 1: *Creativity as innate, and as learned*

- Pedagogical paradox 2: *The doctorate as individual pursuit, and as co-becoming*

- Pedagogical paradox 3: *Reaching for the skies, with your feet firmly on the ground*

- Pedagogical paradox 4: *Necessity for certainty and tolerance of ambiguity*

- Pedagogical paradox 5: *Valuing safety and risk-taking*

- Pedagogical paradox 6: *Permeable disciplinary boundaries*

Towards innovation – a beginning and not an end

Creativity is like murder –

both depend on motive, means, and opportunity

Johnson-Laird, 1988:208

<center>
Towards innovation:
Pedagogical perspectives on developing creativity in doctoral education[1]
</center>

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I acknowledge all the dignitaries present and wish to thank the organisers for the kind invitation to act as a keynote speaker at this auspicious event. I consider myself privileged to be part of this event in the 15th year of the Doctoral School and in the year that your institution celebrates its 50th birthday. My own university – Stellenbosch University in South Africa – celebrated its centenary last year, and I extend my institution's congratulations to you upon reaching this milestone.

So, what is a South African specialising in higher and adult education doing sharing the stage with prestigious scholars from other parts of the world at a Swiss institution specialising in science and technology? Believe me when I tell you that I have asked myself this question repeatedly over the past couple of months since I received your invitation. And I have wondered what I might add to the conversation at an institution that is already doing many of things that we propagate as good practice in doctoral education.

From my perspective as a researcher in the field of doctoral education and as a supervisor of doctoral students myself, I have been most impressed with what I could gather from your official policy documents and conversations with colleagues at your doctoral school. I have been particularly impressed by the doctoral experience survey that you have run three times over the past number of years, your inter-disciplinary approach to doctoral programmes, as well as the diversity of doctoral students you have enrolled. The available data seems to suggest that you are on a path towards giving your doctoral students the kind of creative learning experience that will serve them well as the scientists and creative problem-solvers of the future, even though the doctorate itself is often a stressful and somewhat daunting experience[1] [2] (as your data also shows).

L'Ecole Polytechnique Fédérale de Lausanne prides itself on offering "services to transform scientific excellence into economic value creation, jobs and quality of life" as part of its triple mission to *educate*, *research* and *innovate* in the fields of engineering, architecture and science. Doctoral education is key in achieving this mission, as it lies right at the intersection between education, research and innovation. Yet it would be interesting how the "mission as stated and mission as practiced" (to quote Barnett[3]) is aligned in the light of the current global emphasis on efficiency, effectiveness and economic sustainability in higher education.

The UNESCO Science Report Towards 2030[4] makes particular reference to the mobility of doctoral students as a way in which cultural and creative capital, professionalism of the academic workforce, and innovation may be fostered. In an era of global rankings where reputation and funding is determined by universities' standing, doctoral education lies at the centre of the debate on the role of competition and collaboration in developing higher education systems, as it plays a fundamental

role in both scientific standing and the advancement of science. But I can't help but wonder: where does the learner, the learned and the learning – the doctoral pedagogy – feature in all of this?

Too often universities get caught up in policy rhetoric – a spiral of promises, guidelines and targets that rarely make their way from discussion to agreement to implementation and, finally, constructive learning and change. Hence the topic of my presentation: *Towards innovation: pedagogical perspectives on developing creativity in doctoral education.*

But pedagogy, as with policy, has its own rhetoric, which is oft impenetrable, filled with disciplinary jargon, and (as Bill Green and Alison Lee[5] have argued) under-theorised. I too could thus fall into the trap of presenting here an opaque argument that sounds impressive, but has little to offer in taking us forward.

In *The Empty Space,* well known British theatre director Peter Brook[6] describes the essential elements of a play consisting of an actor and an audience. No more. Everything else – the stage, the music, the costumes – are but additives that may help us make sense of the play, but are not essential to what constitutes a play. I want to draw a parallel between Brook's conceptualisation of a play, and doctoral education. What, essentially, do we need for doctoral education to occur? I would argue that that what lies at the heart of doctoral education are students, supervisors – and what happens during the interaction between them.

Drawing on Lusted's[7] work, doctoral pedagogy refers to the relationship between the doctoral candidate, the supervisor(s), and the knowledge generated within this relationship. There are more complex notions and theories of pedagogy, I admit, but I think Lusted's explanation cuts to the core of our joint discussion (as does that of Brook on what constitutes a play). Doctoral pedagogy thus involves the knowers (students and supervisors alike), 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. Pedagogy is a formative element in doctoral becoming and may be a catalyst or inhibitor for creativity. Through pedagogy students become socialised into the academic community[8], which provides a sense of collective direction[9]. Your doctoral survey data highlights just how important the relationship between the students and supervisor is to both student wellbeing and knowledge creation.

The importance of independent and original knowledge creation in doctoral studies is evident in all definitions of the doctorate across the globe – also in yours here at EPFL. The emphasis on comparable qualifications, academic mobility and employability espoused in international agreements, such as the Sorbonne Joint Declaration[10], the Bologna Declaration[11], the Berlin Communiqué[12] and various documents from the League of European Research Universities[13] [14], provide pressure to trade in knowledge as a commodity, where universities take on an entrepreneurial role in commercialising research findings through partnerships with industry. Doctoral candidates become key contributors in creating prosperity through innovation, and consequently a doctoral degree becomes defined as a product rather than as a process[15]. However, it is arguable whether this focused approach to doctoral development adequately prepares the doctoral student for becoming a responsible and versatile "scholar" [16].

If we follow this line of argument, the doctorate entails more than a knowledge product – the so-called original contribution contained in a thesis, a collection of scholarly articles, a patent, or an artefact. Barnacle[17] describes the essence of a doctorate as a perpetual desire and search for wisdom, thus moving beyond the notion of knowledge. *Wisdom* refers to a comprehensive understanding of knowledge, sound judgement, and insight. A doctorate person is therefore more than a mechanic of knowledge, but can judge knowledge and can advise with insight, who Freire[18] describes as 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". Such scholarship has currency within and outside of academe.

But, as those of you with doctorates will surely know, wisdom is not easily commodified, nor does it develop overnight. It is therefore not surprising that Barnacle speaks about the doctorate as a process of becoming, which is not clear-cut, linear, or mechanical (and, as we know, neither is the research process itself) [19] [20]. Such becoming sometimes leads to conflict, feelings of inauthenticity, marginalisation and exclusion, which is implied in the data from your last doctoral survey that shows doctoral students do experience stress and feelings of anxiety. So, I would agree with Boud and Lee[21] that there is too often a focus on what is produced in doctoral work, the end product, and that such a product-focus often hides the process – that is _how_ the doctorate is produced.

Embedded within the outcomes envisioned of doctoral education are the notions of creativity, innovation, collaboration, problem solving, ethical conduct, interpersonal communication, interdisciplinary understanding, and entrepreneurial initiative. I have noted that many of these aspects are addressed in the coursework offered to doctoral students here, although the doctoral survey data seems to suggest that these initiatives do not always translate into transferable skills equally well. Today I would like to focus on creativity as a central aspect to achieving doctoral excellence, and as vital to enabling innovation.

Although I run the risk over over-simplifying rather complex conceptions of these terms, I'd like to offer the following condensed definitions of the key terms – creativity, originality and innovation – for the sake of the argument.

- **Creativity**

A variety of literature from across the world implies the notion of creativity as a central feature of doctoral education in that the student is expected to create an original, significant and independent knowledge contribution to a discipline, yet, creativity is not well defined within the context of doctoral education, even though it underlies the notion of _doctorateness_ (as defined by Trafford & Leshem[22]). Quite often the mention of creativity elicits notions of aesthetics, art, talent, innate ability, genius, or even mental instability [23]. In addition, creativity is often used synonymously to the terms originality and innovation. Yet there are distinct conceptual differences between these terms, even though they are interlinked in the doctoral education context.

Yet what I aim to offer here today is a much more pragmatic and systematic view to this often-ill-understood concept, and how it applies to doctoral education in particular. There is a wealth of literature on creativity in general, and Kapmylis and Valtanen[24] provides an insightful analysis and comparison of definitions in their article entitled, _Redefining Creativity_.

Libby[25] 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. However, this distinction is not always clear in the literature on creativity in the scientific environment, and confirms Lovitts's[26] argument that conceptualisations – such as creativity – are not operationalised or objectively defined in doctoral education. Creative potential is not identified systematically and nurtured responsibly in education preceding the doctorate, and only at this late stage is it explicitly expected as a requirement for original, independent intellectual work. This lack of conceptualisation and scaffolding between educational levels makes it difficult for students to understand what is expected of them, and complicates the task of the supervisor who needs to guide students on their doctoral journey[27].

In my own work on doctoral creativity, I have found three particular conceptualisations of creativity useful, amongst the many other noteworthy contributions. I will shortly draw on these as a foundation for our further discussion.

Wallas's[28] 1926 cyclical model of the creative process encompassing five phases including: preparation, problem-solving, incubation, moment of insight, and verification and application, has been instrumental in my understanding of creativity as a process, with links to the research process[29].

One of the most well-known conceptualisations of creativity –Rhodes's**[30]** 4P model of creativity – refers to creativity as the interplay between:
- the **person** (including personality, intellect, traits, attitudes, values and behaviour);
- the **process** (with reference to stages of thinking people go through when overcoming an obstacle or achieving a goal);
- the **product** (the characteristics of artefacts or outcomes of new thoughts, inventions, designs, or systems); and
- **press** (the relationship between people and the environment, the situation and how it affects creativity).

Each of these four strands operates as identifiers of some key components of the larger, more complex, concept of creativity. Thus, creativity extends from simple problem solving, to the full realisation and expression of a person's potential[31].

More recently, Kaufman and Beghetto's[32] 4C conceptualization of creativity consisting of:
- *mini c* (as the novel and personally meaningful interpretation of experiences);
- *little c* (as focused on non-expert everyday activities);
- *Pro C* (as developing professional expertise); and
- *Big C* (as prominent accomplishments)

provides a useful conceptualization of creativity as something that can be developed and can manifest in different ways and at different levels.

Building on this work in linking creativity and critical thinking in doctoral education, Eva Brodin and I[33] postulated that doctoral pedagogy may play a crucial role in developing creative capabilities. If the pedagogical approach does not explicitly facilitate and value creativity, one cannot expect doctoral students to bring about future conceptual and paradigmatic changes as responsible scholars, and eventual innovation becomes less likely. More likely, only moderate contributions to knowledge development could be anticipated.

- **Originality**

While creativity is sometimes a more implicit feature of doctoral education, the notion of originality features explicitly as an expected outcome of the doctorate across the globe[34]. Originality can be defined as something that is new or novel, but originality does not necessarily have to be applicable or relevant[35]. Originality can be seen as a component of the complex phenomenon of creativity[36], with originality as an eventual outcome of the (creative) doctoral process[37]. Herein lies the difference between originality and creativity.

The originality of a doctoral thesis can be expressed in a number of ways, and the kind of originality that is recognised and appreciated has traditionally been dependent on discipline[38] [39] [40]. For example, originality in science, technology, engineering and mathematics disciplines is defined by publishability, whilst in arts, humanities and social sciences it is related to intellectual originality[41]. Natural sciences define originality "as the production of new findings and new theories", while social sciences and humanities define it "much more broadly: as using a new approach, theory, method, or data; studying a new topic, doing research in an understudied area; or producing new findings"[42]. Disciplinary

implications are evident for the way students learn how to do research, and consequently what it means to be original.

Currently there is little literature on pedagogical processes for supporting the development of originality, even though there is an assumption that doing doctoral research *will* lead to originality, as for example demonstrated in the Salzburg Declaration of the European Universities Association[43]. Such vague notions for ensuring the development of such a central expectation of doctoral education seem inappropriate in the current focus on higher education efficiency, accountability and quality assurance. In practice, supervisors still often tell me "I'll know it when I see it", when speaking about originality.

The current economic and socio-political climate emphasises the need for applied relevance of the doctorate calling not just for originality, but originality that advances the field in a substantial way. While this demand need not include the focus on economic benefits or relevance attached to innovation or creativity, it still places constraints on the type of originality considered appropriate for a doctoral thesis[44].

What we haven't really answered is to what extent doctoral theses demonstrate an original and significant contribution to knowledge, apart from the subjective judgements of examiners? Theses by publication opens new analytical pathways for example through the application of bibliometric tools and content analysis of citations. But which stakeholders should be involved in this assessment and what bibliometric indicators might be utilized remain unresolved issues[45].

- Innovation

This brings us to innovation. Innovation is defined as the practical application of a novel, and thus original idea, but it must be an idea with a potential application. Innovation thus involves the process of transforming an invention (or something that is considered original) into practical application, and is most commonly associated with private industry[46] and feature in the in economic discourses on production processes or products[47] – even though the notion of social innovation extends this conceptualisation[48].

The Lisbon Declaration[49] 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". 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 academe 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[50]. The literature on thesis examiners shows hardly any expectation of innovation in doctoral theses in terms of developing applications for industry, though an exception in engineering should be made, where an application of existing methods to a problem from engineering practice is considered original, just as is the invention of new devices[51].

Innovators are considered creative entrepreneurs who successfully acquire monopoly positions with innovative products or production processes[52]. Yet, becoming an innovator requires expertise, as we have shown in some of our work linking creativity to the development of expertise through reflection[53]. This figure highlights the notion that innovation can only really be expected of a doctoral student after a certain level of mastery and expertise has been achieved.

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Figure 1. The development of expertise – linking creativity and reflection (based on Frick & Brodin, 2014)

Creativity – and thus also originality and innovation – do not emerge suddenly, but needs to develop and be fostered over time in an atmosphere that allows exploration and expression, regardless of the discipline or programme format[54]. Tensions may result from the difference between institutional demands for completion and students' needs to engage with ideas over time through incubation[55].

So, if we were to think about what creativity, originality and innovation might look like in relation to each other, based on the conceptualisations offered thus far, it could be argued that creativity and innovation all incorporate originality, in the form of novelty in research. Hence, it may be possible to have originality without creativity or innovation, but not vice versa. Meanwhile, all three concepts can contribute to the development of the doctoral contribution in overlapping but different ways.

Conceptually, the links between these concepts can be displayed as follows:
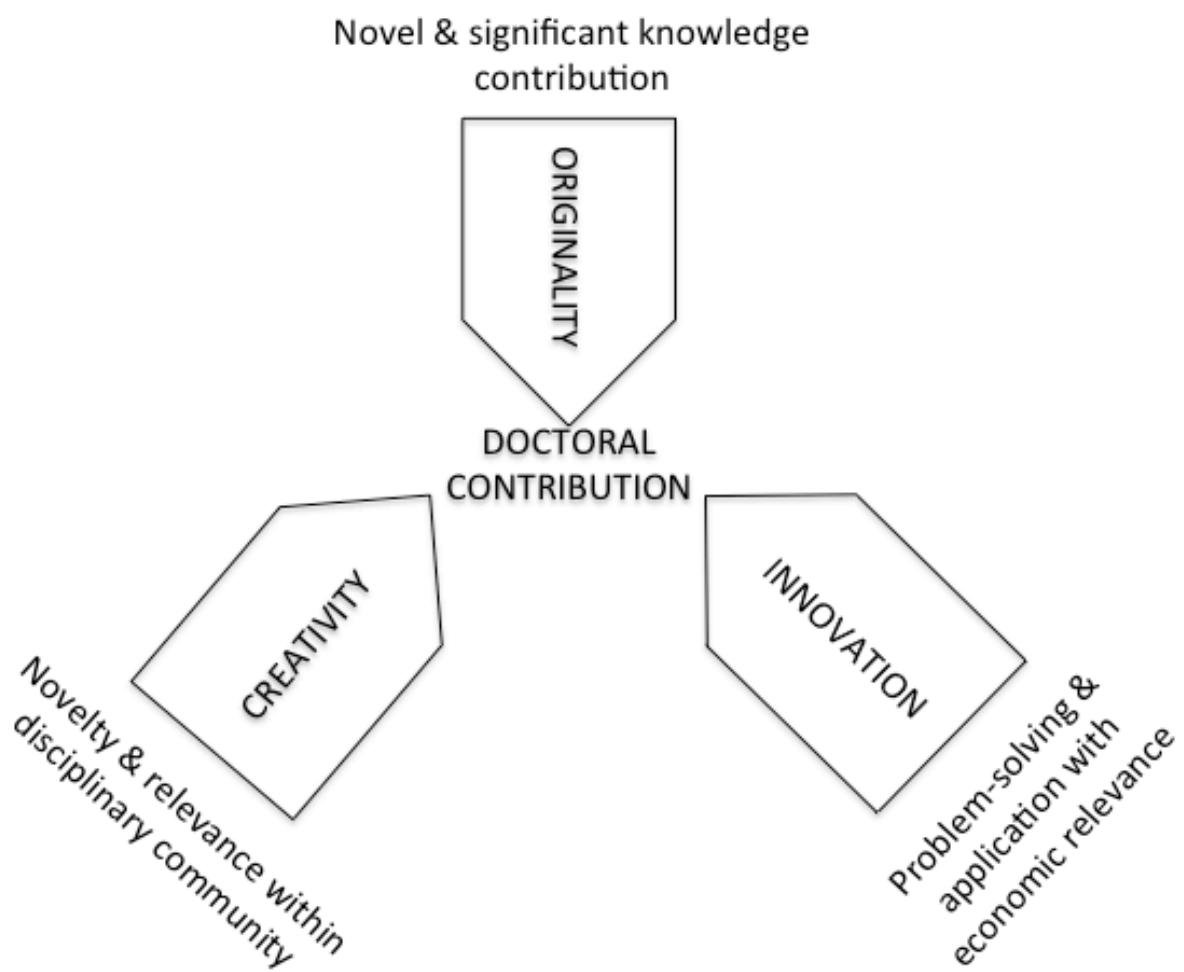
Figure 2. Distinguishing between and linking the notions of creativity, originality and innovation (based on Baptista et al. 2015)

In this figure, we[56] show that originality, creativity and innovation are related elements that can all contribute to the doctoral contribution, but that the emphasis shifts depending on the concept. While the three elements – creativity, originality and innovation – appear to be substantial building blocks of the potential contribution doctoral work can make, the extent to which doctoral theses fulfil these expectations is not clear. As doctorateness seems to be a multi-faceted concept itself[57], this fluid emphasis may be useful to allow for disciplinary, programme and individual differences in what it means to be doctorate.

So now that we share a conceptual understanding of the key terminology, we can progress to asking what are some pedagogical principles are may support doctoral students to become creative in a way that will enable them to make an original contribution, and support eventual innovation?

For the purposes of the argument presented here, I have developed six pedagogical paradoxes, which I hope will enable us to think how we might support doctoral creativity and move towards innovation.

- **Pedagogical paradox 1: Creativity as innate, and as learned**
Creativity is both an innate and a learned quality[58]. Thus, creativity can be developed, even though an innate talent for a specific field is, of course, helpful[59].

Back in the 1940s, Carl Rogers[60] painted a rather gloomy picture for the future of creativity by saying:

> *In education, we tend to turn to conformists, stereotypes, individuals whose education is 'completed', rather than freely creative and original thinkers… In the sciences, there is an ample supply of technicians, but the number who can creatively formulate fruitful hypotheses and theories is small indeed. In industry, creation is reserved for the few – the manager, the designer, the head of the research department – whereas for the many life is devoid of original or creative endeavour.*

Though I empathise with Rogers's concerns, I also understand why it is so difficult to develop creativity in doctoral students. Students immersed in creative processes often act in ways that may make supervision difficult[61]. Creative students are often non-conformists, which may result in tension and adjustment problems[62]. Such students 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. In addition, not all students will develop in similar ways, or in a linear fashion, or to the same level of manifestation equally in all the research phases. The ideal learning environment for these students would permit what Vermunt and Verloop[63] calls "constructive friction".

Creativity is not only determined by the ability to think creatively, but also by choosing to do so[64]. Intrinsic, task-focused motivation seems an important prerequisite for creativity[65]. External motivators – such as supervisors – may also play a role in creativity[66]. The role of external motivation leads us to consider a supportive and rewarding environment (and integral to this environment, the role of the supervisor) as a necessary stimulus for creativity[67].

A pedagogical understanding of creativity in science 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.

- **Pedagogical paradox 2: The doctorate as individual pursuit, and as co-becoming**

Creativity is often not the result of individual endeavour alone, but rather of systems that judge the merit of individual work[68]. Creativity may result in changes in how reality is viewed within a system, which may serve as evidence of doctorateness. Doctoral students should therefore be able and even encouraged to challenge the existing systems if creativity is to be fostered. However, creativity may be more difficult when rigid system boundaries occur as changes require a redefinition of the permissible problems, concepts and explanations within the discipline and its scientific community.

From a pedagogical point of view, how do we enable both the individual, and the individual as part of a group to become creative? One way is to look at our supervision approach. Team supervision, co-supervision, and peer learning are some ways in which we may create enabling environments for creativity to develop. Journal clubs, lab meetings and research group discussions could supplement individual student-supervisor consultations. More advanced students often help those at a less advanced level or those who have started their studies more recently, which lightens the load of the supervisor. Co-publication of research results may also enable such co-becoming. Another example involves the development of the group dissertation for certain disciplines. These so-called 'capstone projects' not only encourage students to work collaboratively, but they often involve external stakeholders.

We have evidence that supervisors in the natural sciences use these opportunities to create student-centred learning environments that encourage creative input from students. However, these notions often run counter to the apprenticeship model of supervision that is evident across the world[69] [70]. The

model focuses on applying science and scientific findings to practice through acculturation into the discipline by following a master (the supervisor), but it often disregards the elements integral to professional competence required in practice beyond the doctorate[71]. The apprenticeship approach is furthermore ill-suited to the new generation of students who prefer 'pedagogical exchange as a form of *value creation* rather than *knowledge transmission*'[72].

MacKinnon[73] warns that creativity should not be seen as something to be taught, but rather as developed by leading through example. The best way in which supervisors can facilitate research, is to involve students in all the phases of their own research – from conceptualisation and planning to eventual reporting[74]. Austin[75] calls this approach 'cognitive apprenticeship', that makes experts' thinking processes in understanding and addressing problems visible. Such a pedagogic approach may enhance students' meta-cognitive ability – that is, awareness and control over implementing their knowledge in a practical and unpredictable professional setting, and subsequent reflection on performance[76].

Future research should examine the extent to which these new requirements are part of institutional guidelines, supervisors' expectations and doctoral students' identity conceptualisations.

- Pedagogical paradox 3: Reaching for the skies, with your feet firmly on the ground

Creativity is not possible without a thorough understanding of the basic principles of and knowledge within a field of study – having your feet firmly planted on the ground. 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[77] [78] [79]. Creativity results from purposeful behaviour, and often lengthy and arduous processes[80] [81] [82], but which Pope[83] still describes as "work at play".

The notion of discipline-specific knowledge as a prerequisite for doctoral creativity in the sciences was strongly supported in a study I did on how doctoral supervisors in the natural sciences conceptualise creativity[84], as one supervisor commented, 'creativity favours the prepared mind.' However, such knowledge needs to extend beyond mastering the discipline within which the study takes place. At the doctoral level creativity may manifest in transforming the discipline and/or extending the current boundaries of the discipline[85] - thus, reaching for the skies.

- Pedagogical paradox 4: Necessity for certainty and tolerance of ambiguity

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 certainty. Within this interplay between certainty and doubt lies a supervisory paradox. Supervisors need to create nurturing, student-centred learning environments that provide a solid scientific foundation, yet value divergence and diversity.

I have found that many of the examples of pedagogic practices cited by supervisors 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. Supervisors are also able to create a space for debate through problematising and deconstructing knowledge, which promote a respectful, yet challenging learning environment[86].

- Pedagogical paradox 5: Valuing safety and risk-taking

Research by its very nature is a risky endeavour[87]. The Lisbon Declaration[88] argues that universities "should encourage a culture of risk-taking (...) in order to produce an institutional milieu favourable to creativity, knowledge creation and innovation", reinforcing the idea that an original contribution

requires a certain amount of risk-taking in choosing a topic and approach. In addition, Reichert[89] emphasises the need for universities that optimise and nurture the creative potential of individuals and teams, which requires "resources, time, and space for high-risk unpredictable research which cannot [easily] be defined ...".

But with risk comes responsibility. Within the context of doctoral education, it means that we need to question and problematize the notion that creativity is inherently "good"[90]. Creativity has consequences. Being creative raises serious ethical issues, including possibly breaking rules and standard operating procedures, challenging authority and avoiding tradition, creating conflict, competition and stress, and raking risks[91]. Thus, in as much as doctoral education has to foster creativity, supervisors also have the responsibility to ensure that students understand their moral responsibility to carefully consider the social and ecological consequences of their research[92].

The risk described here does not imply an untethered approach to risk-taking – which could be termed harzardous risk. Risk-taking in the context of doctoral education refers to adaptive risk, which does not mean avoiding all risk, but rather adapting successfully through pursuing some risks while avoiding others[93].

This conceptualisation of risk reflects significant forces that relate to elements in the context, relationships in the supervisory process, and individual characteristics of doctoral students. It positions the supervisor as that of risk manager and risk mitigator, acting as an intermediary between the demands of society, the discipline(s) involved, the institution and the doctoral candidate[94]. Risk mitigating supervisors encourage further research that explores ways of balancing rather than controlling risk, while encouraging innovation in the doctoral education process. Increased awareness of risk could lead supervisors to contain risk in a responsible manner.

We[95] have identified various strategies that supervisors use at different stages during the doctorate to support students and mitigate risk, including
- formulating clear expectations;
- determining and developing student capability, including creativity, during the student selection phase;
- encouraging wide reading, critical debate, benchmarking, time for incubation of ideas, and challenging students during conceptualising the study;
- developing academic writing and methodological skills through incorporating expert input;
- supporting networking; and
- promoting peer review and writing for publication during the doctorate.

Institutional systems act as determinants of the extent to which risk-taking is possible in doctoral studies[96][97][98][99]. For instance, a danger of the current emphasis on doctoral throughput in the minimum allocated time is that it may lead to avoiding the risk of choosing a complex and less defined problem. Not all research that may be considered original requires lengthy periods of time, but nor can all research be contained within minimum, finite time periods. In addition, only about 10 percent of all innovations are ultimately successful, which makes trial and error essential, but risky. Ultimately, the process of doctoral education is influenced by the various research cultures in which creative work takes place. In particular, how such cultures define innovative knowledge outcomes is highly relevant.

- **Pedagogical paradox 6: Permeable disciplinary boundaries**
The greater problems facing science and society will not be solved if they are viewed from a single disciplinary stance[100][101]. Even multi-disciplinary approaches have limited utility, as the knowledge systems and therefore ingrained language of the disciplines involved remain stagnant[102]. The shift in emphasis from basic to applied knowledge in recent times[103][104][105] and public demands for higher

education accountability[106] pressurises both doctoral students and supervisors to relate to the world outside the traditional disciplinary community.

Inter- and trans-disciplinary approaches to doctoral education promotes higher-order thinking, an understanding of divergent knowledge systems and creative problem-solving behaviour[107] [108]. Through transdisciplinarity the three intersecting spheres of the university, the discipline and the workplace infuse doctoral education[109]. In doctoral education, transdisciplinarity implies that "students are being exposed to a greater variety of values, choices and working environments and expected to develop a wider range of skills and knowledge"[110].

However, impermeable discipline-based boundaries between disciplines are still evident in much of the doctoral research produced worldwide. This tendency is mirrored in the work of Lovitts[111] who differentiated between disciplines in her work on making doctoral performance expectations explicit. Gould[112] adds that job security and promotion usually reside within departmental and disciplinary boundaries, wherein a jury of peers reside who valuate scholarly work.

In addition, creating spaces that support exploration across disciplinary boundaries leads unique challenges for doctoral pedagogy in which creativity needs to be fostered. I[113] have found that supervisors are positive about transcending disciplinary boundaries, but found it hard to implement in practice, as one supervisor commented:

> *Science has become very reductionist. I lament this – we don't have enough time to think about the bigger scheme. We don't have enough time to do that kind of thing. There is an information overload, a lot of detail, and you can get lost in that detail, and that's not creative.*

Towards innovation – a beginning and not an end

In conclusion, I would urge you not to get stuck in a policy rhetoric focused on issues such as quality, impact, research training standards, as well as workforce and economic demands alone when moving towards innovation, but also give careful consideration to the doctoral pedagogy underlying these more measurable outcomes.

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[114] [115] [116], as well as research that may not have an immediate and applied impact[117]. A more holistic notion of skills development in line with the so-called skills identified by the World Economic Forum[118] as essential to succeeding in future may be called for.

The idea of being a creative university[119] 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 dialogue, experimentation and innovation[120]. 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 contribution the higher education sector can potentially in future make to industry and society.

As supervisors, we need to create environments that motivate students to become creative, to provide the means for them to be creative, and the opportunity to showcase their creativity, since Johnson-Laird[121] claims "[c]reativity is like murder – both depend on motive, means, and opportunity".

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