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ABSTRACT

Computational creativity is the modelling, simulating or replicating of creativity computationally. In examining and learning from these "creative systems", from what perspective should the creativity of a system be considered? Are we interested in the creativity of the system's output? Or of its creative processes? Features of the system? Or how it operates within its environment? Traditionally computational creativity has focused more on creative systems' products or processes, though this focus has widened recently. Creativity research offers the Four Ps of creativity: Person/Producer, Product, Process and Press/Environment. This paper presents the Four Ps, explaining each in the context of creativity research and how it relates to computational creativity. To illustrate the usefulness of the Four Ps in taking broader perspectives on creativity in its computational treatment, the concepts of novelty and value are explored using the Four Ps, highlighting aspects of novelty and value that may otherwise be overlooked. Analysis of recent research in computational creativity finds that although each of the Four Ps appears in the body of computational creativity work, individual pieces of work often do not acknowledge all Four Ps, missing opportunities to widen their work's relevance. We can see, though, that high-status computational creativity papers do typically address all Four Ps. This paper argues that the broader views of creativity afforded by the Four Ps is vital in guiding us towards more comprehensively useful computational investigations of creativity.

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1. Introduction

A practical issue arises when considering the evaluation of a computational creativity system: from what perspective should creativity of a system be considered? Are we interested in the creativity of the system's output? Or of its creative processes? Creativity as measured by internal features or by external interactions?

The computational creativity community has traditionally considered creativity from the perspective of the creative output produced by a system, or the processes employed within creative systems (with notable exceptions, such as Saunders, 2012). The call for the key international conference in this area (ICCC) invites papers addressing the "Process vs. product: addressing the issue of evaluating/estimating creativity (or progress towards

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it) in computational systems through study of what they produce, what they do and combinations thereof".

This paper argues that to consider process and product is not enough; computational creativity should be considered and explored from four different perspectives, known as the Four Ps: the creative *Person*,[1] *Product*, *Process* and *Press* (or environment) (MacKinnon, 1970; Rhodes, 1961).

The Four Ps have long been prevalent in creativity research relating to humans[2] and enable a more inclusive and encompassing approach to the study of creativity and accommodating multiple relevant perspectives. Here the Four Ps are presented and considered in the light of how they help computational creativity researchers in their overarching goal[3] to model, simulate or replicate creativity computationally. The computational creativity research community is already, as a whole, covering all the Four Ps; however many individual projects within this research field do not address all four perspectives. This paper argues that individual projects that carefully address all Four Ps provide a wider contribution to computational creativity research than those projects which only address, for example, one or two Ps. Therefore if we highlight and raise awareness of each of the Four Ps within computational creativity research, drawing upon similar research on human creativity, the Four Ps framework can guide individual research projects to increase the contribution to knowledge that their work is capable of.

2. The *Four Ps* of creativity

One major approach in creativity research is to break down creativity into four perspectives, commonly referred to as the *Four Ps* (MacKinnon, 1970; Mooney, 1963; Odena and Welch, 2009; Rhodes, 1961; Simonton, 1988; Stein, 1963; Tardif and Sternberg, 1988):

- *Person*: The individual agent that is creative. I propose in this paper that the term *Producer* is more appropriate as it allows us consider the Four Ps in the contexts of both human and computational creativity.
- *Process*: What the creative individual does to be creative.
- *Product*: What is produced as a result of the creative process.
- *Press/Environment*: The environment in which the creativity is situated.

In 1961, Rhodes (1961) identified the Four P perspectives. Rhodes collected 40 definitions of creativity and 16 definitions of imagination. On analysis of these definitions, the '*Four Ps*' of creativity emerged. It appears (from lack of referencing citations to each other's work) that several people independently identified these Four Ps of creativity (MacKinnon, 1970; Mooney, 1963; Stein, 1963). This pattern of (seemingly) independent discovery helps support the credibility of the Four Ps, especially at a time when Guilford's highly influential paper on the study of creativity (Guilford, 1950) strongly encouraged a focus on personal characteristics of creative people, rather than a broader study.[4]

Plucker, Beghetto, and Dow (2004) conducted a literature survey investigating the use (or absence) of creativity definitions in creativity research. As part of this review, Plucker et al. used their analysis to derive their own definition by identifying reoccurring themes and forming these into an inclusive definition which (perhaps unintentionally) accounts for each of the Four Ps:

> Creativity is the interaction among *aptitude, process, and environment* by which an individual or group produces a *perceptible product* that is both *novel and useful* as defined within a *social context*. (Plucker et al., 2004, p. 90)

In reviewing Four Ps research, Kaufman (2009) described addendums that have been suggested for the Four Ps: persuasion (Simonton, 1988) and potential (Runco, 2003). In general, however, the Four Ps have been adopted as they were originally conceived by various researchers (MacKinnon, 1970; Mooney, 1963; Rhodes, 1961; Stein, 1963).

2.1. The Four Ps: Person/Producer

This perspective addresses human characteristics associated with creative individuals or groups of people. Encouraged by Guilford's influential call in 1950 for studying the creative person, an abundance of different personal characteristics have been associated with creativity (Koestler, 1964; Odena and Welch, 2009; Rhodes, 1961; Stein, 1963; Tardif and Sternberg, 1988), ranging from personality traits, attitudes, intelligence and temperament, to habits and behaviours such as curiosity, persistence, independence and openness. Some of these are closely related; others are contradictory. Rhodes mentioned the relevance to creativity of people's personality traits, attitudes and habits, physique and intelligence and the identifiable features of creative people, as well as referring to people's temperament, habits, self-concept, value systems, defence mechanisms and behaviour (Rhodes, 1961, p. 307).

Empirical studies up until 1968 were summarised by Stein (1968) into a list of 18 distinct personality characteristics of a creative person, including aspects such as curiosity, persistence, independence and openness. Stein used these characteristics to identify creative individuals for study. Stein's method is prone to some circularity, as creative individuals were identified using pre-defined creative characteristics/criteria, but Stein's study involves empirically examination of those characteristics and criteria. Stein's work has not stood the test of time, with few current citations.

Several researchers subdivide the 'Person' category into finer-grained groups. Three sub categories of the 'pupil' perspective emerged during Odena and Welch's work (Odena and Welch, 2009): personal characteristics of the pupil; their individual learning style (either adapting to new information or deriving new information themselves); and the influence of the pupil's background. Koestler (1964) described three types of creative person: the *Artist*; the *Sage* and the *Jester*. Through Tardif and Sternberg's review of definitions of creativity (Tardif and Sternberg, 1988), three main categories were identified with which to describe creative people: cognitive attributes; personality attributes/motivation; and developmental influences. From their categorisation, Tardif and Sternberg suggested three resultant modes of study of human creativity: cognitive psychology; psychometric testing and study of human development.

The different subdivisions described above do not neatly align alongside each other. Tardif and Sternberg's review showed that as of 1988, different authors highlighted a variety of characteristics, with no general consensus and no characteristics common to all reports (Tardif and Sternberg, 1988, Table 17.1, p. 434). The sheer quantity of attributes collectively places an obstacle in the way of compiling a definitive list of attributes of a creative person and instead provoke disagreements on exactly which cognitive characteristics should be attributed to creative people.

2.1.1. The **Producer** *(Person) in computational creativity.*

Given that we expand our discussion of creativity to include the discussion of computational creativity, I propose here that it is more appropriate to refer to the creative *Producer*, rather than the creative Person.

The creative Producer could be analogous to the computer, or perhaps more accurately, to a computer program, software, robot or a creative agent within a multi-agent system. Here the machine is the hardware hosting the creative agent: more generally the implementation and/or embodiment of the algorithm in a particular computational system ,[5] much as we might distinguish between physical and functional characteristics of a 'Person'.

Some interesting work has been done on modelling creative agents, for example by Saunders (2012). Sosa and Gero distinguish between creative individuals and the creative brain in their investigation of multiple perspectives on creativity (Sosa and Gero, 2015). Generally, though, the emphasis in computational creativity software has tended to be on product generation and to some extent, process modelling (Cardoso, Veale, and Wiggins, 2009; Colton and Wiggins, 2012); computational creativity systems tend to be oriented towards a particular goal, domain or task. Relatively little work has directly focused on modelling a creative entity as a collection of various personal characteristics or abilities (at least, not independently of some creative application of those characteristics to a task). As argued in Jordanous (2012), different types of creativity require domain-specific skills to some extent, so domain-specific computational creativity systems tend to be built around the most prominent necessary skills for that domain.

In the task of categorising computer systems as creative, Colton's Creative Tripod (Colton, 2008) emphasised the need for systems to demonstrate skill, imagination and appreciation before they can be considered as a candidate creative system – all three of which are allusions to personal characteristics.

Features, traits and aspects of the creative system Producer can be studied, and it would be fascinating to explore how general creative personal characteristics could be specifically modelled within creative systems (see the *Process* section, next). This line of thought has been taken up by researchers within computational creativity to some extent, for example the aforementioned Creative tripod (Colton, 2008) as well as others (Grace and Maher, 2015; Maher, Merrick, and Saunders, 2008; Saunders, 2002; Wiggins, 2006). Computational modelling of characteristics that encourage creativity could help us progress our systems to be able to be creative in more than one system which they were originally designed for; this would be significant progress in our pursuit of modelling creativity as a phenomenon which transcends different types of creative activity.

The Producer could also include the individual(s) interacting with a creativity support system or co-creative system which interacts with people (Kantosalo, Toivanen, Toivonen, and Xiao, 2014; Maher, 2012). Another possible interpretation of the producer in computational creativity would be to acknowledge the role of the programmer(s), tester(s), researcher(s) and peers involved in shaping the project.

2.2. The Four Ps: Process

The creative process has been broken down into a series of sequential or cyclic stages occurring over time (Poincaré, 1929; Wallas, 1945) or subtasks (Odena and Welch, 2009). In their work on student creativity in school music lessons, Odena and Welch (2009) broke down the creative process into subtasks, identifying various types of process (e.g. different activities, group process, the structuredness or otherwise of a process and composition by improvisation) rather than tracing a linear progression of subprocesses.

It is often stressed that creativity is not just the first flash of inspiration, but is also the activity that validates, develops, and refines that first idea; rather than occurring at one point in time, creativity develops over a period of time (Poincaré, 1929; Tardif and Sternberg, 1988; Wallas, 1945). Tardif and Sternberg (1988) remind us that while creative processes can be those employed by individual creative agents, we can also consider creative processes where more than one agent participates.

2.2.1. The process in computational creativity.

In computational creativity, the creative process might be the algorithms employed by a single piece of software, or interactions between multiple machines or programs, or interactions between machine and human users, or between a machine and the environment it is embodied in. As described above, the computational creativity community has given some attention to the concept of creative processes employed within computational creativity, with growing attention paid to this aspect in recent years. For example, the FlowR framework (Charnley, Colton, and Llano, 2014) is designed to facilitate creative computational workflows by chaining together processes in a linear pattern; from personal communications with members of the project team, there are plans to consider nonlinear chains of processes as well. The work by Misztal and Indurkhya on poetry generation (Misztal and Indurkhya, 2014) is another example of the various projects that specifically focuses on various processes required for creativity. Genetic programming is another way in which the process itself can be generated computationally (Koza, Streeter, Mydlowec, Yu, and Lanza, 2003; Sims, 1994, for example).

The generate-and-test (McGraw and Hofstadter, 1993; Pease, Guhe, and Smaill, 2010, for example) or engagement-reflection approach (Pérez y Pérez, Aguilar, and Negrete, 2010) specifically models the creative process as a cycle of generating artefacts then amending the generation process via evaluating the generation phase. This is an approach which deserves broader adoption within computational creativity; evaluation is a critical part of the creative process (Csikszentmihalyi, 1988; Poincaré, 1929). In terms of post-implementation evaluation, the FACE model for evaluation of creative systems (Colton, Charnley, and Pease, 2011) places importance on computational systems being able to report on the creative process.[6]

There are multiple theories about how human creativity processes are structured, see, for example (Csikszentmihalyi, 1988; Hennessey and Amabile, 2010; Kaufman, 2009; Poincaré, 1929). Computational creativity research can provide a test-bed for these psychological theories and allow us to explore if implementing the theories result in creative behaviour. For example, useful work has been done by Thornton (2008), Wiggins (2006) and Ritchie (2006) on Boden's creativity model (Boden, 2004). Similarly, Csikszentmihalyi's Domain-Individual-Field-Interaction (DIFI) framework has recently been implemented within computational creativity research (Chordia and Rae, 2010; de Silva Garza and Gero, 2010; Saunders, Gemeinboeck, Lombard, Bourke, and Kocaballi, 2010). Conferences such as the Creativity and Cognition series showcase work that links between theory and practice to some extent; further activity along these lines would help emphasise the validity of computational creativity research, and help findings flow better between computational creativity and human creativity research.

2.3. The Four Ps: Product

Many authors advocate that *proof* of creativity is necessary to be considered creative (Kagan, 1967; Plucker et al., 2004; Ritchie, 2001; Tardif and Sternberg, 1988). The product-centric view adopted by computational creativity researchers such as Ritchie (2007), that creative products are both necessary and sufficient for creativity, was present in earlier human creativity research (Kagan, 1967). But, inspired by Guilford's seminal 1950 address on creativity research, emphasis in human creativity research shifted from identifying creative individuals post-production of creative work, to predicting future potential for creativity in individuals. This change in emphasis is illustrated in the proliferation of psychometric tests (Jordanous, 2012; Kaufman, 2009) within creativity research.

Tardif and Sternberg (1988) considered the creative product more briefly than the other three 'Ps' in their review, deciding that while a creative product is essential for creativity, it is not enough merely to generate a product; the product should also be considered in a domain-specific context.

Computational creativity research has long acknowledged the importance of the output or artefacts generated by creative systems, as described above. To borrow a metaphor from human creativity research, it has been common (until recently) for computational creativity to follow the product-centric approach to creativity as advocated by Kagan: "*Creativity* refers to a product, and if made by a man, we give him the honor of the adjective ". (Kagan, 1967, p. viii)

2.3.1. The product in computational creativity.

Generating creative products has been an area of significant success for computational creativity. To see examples, one just needs to consult any year's proceedings of the International Conference on Computational Creativity where there are multiple examples to be found of systems which are reported in terms of the products they generate (Besold and Plaza, 2015; Harmon, 2015; Misztal and Indurkhya, 2014; Monteith, Francisco, Martinez, Gervás, and Ventura, 2011; Sims, 1994, to cite just a selection of these many examples). The success of systems is often reported in terms of what kind of artefacts they generate, as noted in Jordanous (2011). Some systems have been evaluated using Graeme Ritchie's empirical criteria (Ritchie, 2001, 2007), which exclusively focuses on evaluating the products of computational systems without considering any of the other three Ps.[7]

2.4. The Four Ps: Press/Environment

The Press perspective encompasses a bidirectional perspective between the environment which influences the creator and receives the creative work, and the creator who publicises their work and is given feedback on what they produce. Tardif and Sternberg (1988) considered both creative domains themselves and the social environments in which creative people are influenced as they employ creative process, advertise their creative products and receive feedback. Rhodes (1961) concentrated on the role that the environment plays on a person during the creative process, rather than how the creative produce is judged by the external world after being created. Rhodes reflected on how everyone is different, so everyone perceives the world in a unique way and processes ideas according to their own contexts.

Of the Four Ps, this is the perspective that is often neglected when one takes an individualistic view of creativity. In general creativity theorists do however acknowledge the influence of the environment in which creativity is situated (Hennessey and Amabile, 1988; Simonton, 1988). If one concentrates on an individual's creativity, however, the Press perspective is often neglected, even if unintentionally. For example, although stating that "[t]o be appreciated as creative. a work of art or a scientific theory has to be understood in a specific relation to what preceded it" (Boden, 2004, p. 74), Boden's treatment of creativity mainly focused on different cognitive processes of creativity, rather than a detailed examination of social or environmental influences.

2.4.1. The Press in computational creativity.

Some computational creativity researchers are starting to highlight the importance of the environment in which a creative system is situated (Jennings, 2010; Pease and Colton, 2011; Saunders, 2012; Sosa, Gero, and Jennings, 2009), with some of this work influenced by the DIFI (Domain-Individual-Field-Interaction) framework (Csikszentmihalyi, 1988) mentioned above. The role of the audience in interpreting creative content has been acknowledged (Gervás and León, 2014; Veale and Li, 2015). Sosa and Gero (2015) identify different sub-perspectives of Press in their multi-dimensional creativity framework: MDC-C (cultural dimensions at an epistemological level), MDC-S (societal implications) and MDC-G (creativity at the scale of individual groups or teams).

Social interaction between creative agents and their audience is an area which had been neglected till recently: for example nearly 75% of papers in the 2014 International Conference on Computational Creativity failed to make any reference to social or interactive aspects of creativity. But creativity cannot exist in a vacuum. A recent increase in development of the interactivity of creative systems[8] (especially where this affects the way these systems works) has been highlighted as a positive advance (Colton and Wiggins, 2012). At the AISB workshop on computational creativity in 2015, a panel discussion on social creativity and its implications for computational creativity underlined the way in which researchers within the field are aware of the dangers of a "silo" -like approach to modelling or simulating creativity. This discussion also explored the breadth of meaning behind the term "social creativity" in computational creativity; similar considerations have also recently been explored (separately) and published by Saunders and Bown (2015).

There is a separate point to acknowledge regarding Press in computational creativity. As computational creativity researchers, we should stay aware of any potential biases that may be introduced, should an audience be aware that the creative agent of interest is computational rather than human (Jordanous, 2012; Moffat and Kelly, 2006).[9]

2.5. Interaction between the Four Ps

The mysterious impression often associated with creativity (Boden, 2004; Kaufman, 2009; Williams, 1976) can be explained to some extent when one or more of the Four Ps are not accounted for:

> Each strand [of the Four Ps] has unique identity academically, but only in unity do the four strands operate functionally. It is this very fact of synthesis that causes fog in talk about creativity and this may be the basis for the semblance of a "cult". (Rhodes, 1961, p. 307)

Simonton (1988) saw discrepancies between combining the Four Ps in theory and in practice:

> Now, in an ideal state of affairs, it should not matter which one of the four p's our investigations target, for they all will converge on the same underlying phenomenon. . . . But reality is not so simple, needless to say. The creative process need not arrive at a creative product, nor must all creative products ensue from the same process or personality type; and others may ignore the process, discredit the product, or reject the personality when making attributions about creativity. (Simonton, 1988, p. 387)

From this, one conclusion which seems to follow naturally is that an accurate and comprehensive definition of creativity must account for the (potential) presence of all four aspects, in order to be complete. Simonton, however, concluded that "[i]f we cannot assume that all four aspects cohesively hang together, then it may be best to select one single definition and subordinate the others to that orientation" (Simonton, 1988, p. 387), with his natural research inclination leading him to focus his work on *persuasion*, his term for the effect that the creative individual has on their environment.

Rhodes argued that creativity research should follow a specific path: "from product to person and thence to process and to press". (Rhodes, 1961, p. 309)

> Objective investigation into the nature of the creative process can proceed in only one direction, i.e. from product to person and thence to process and to press. (Rhodes, 1961, p. 309)

Such a statement makes Rhodes's contribution less useful. For example, the Press (environment) in which one is creative has some influence on the creative Process, so one may prefer to study how Press and Producer interact before looking at Process issues. Simonton viewed creativity as how a person's ideas emerge as influential when that person, by chance, has new ideas and promotes them to influence others. Creative people would not be equivalent to lucky people, by this interpretation, but chance would intervene in their success. Simonton refers to this as the "chance-configuration theory" that "outlines the general conditions that favor creativity" (Simonton, 1988, p. 422).

Tardif and Sternberg (1988) treated each of the Four Ps individually, "as these really are separate levels of analysis, and it is from comparisons within levels that coherent statements about our knowledge of creativity can be made" (Tardif and Sternberg, 1988, p. 429). Tardif and Sternberg's summary is weakened somewhat by this as it does not make comparisons across the Four Ps, despite highlighting Simonton's emphasis on the interactions and relations between these four views (Simonton, 1988). In contrast Mooney (1963) argued that the four approaches should be integrated in a model of creativity, proposing a model that "puts together the four approaches by showing them to be aspects of one unifying idea" (Mooney, 1963, p. 333). While Mooney's claims become rather grandiose at points, Mooney's more specific contributions on creativity match neatly with the Four Ps approach identified elsewhere at that date (Rhodes, 1961; Stein, 1963).

2.5.1. Interaction between Four Ps in computational creativity.

Sosa and Gero (2015) advocate that creativity is a construct containing multiple levels of information; therefore it is most appropriate to take a multi-dimensional approach to the study of creativity (which, they argue, is reasonably well afforded by computational approaches). In a similar vein, this paper argues that we can make significant progress in computational creativity by considering all Four Ps in our computational creativity work.[10]

Generation of creative products is only a quarter of the full picture of creativity, only one of the Four "Ps". Granted, we have achieved much success in product generation, as exemplified by exhibitions, concerts and other demonstrations of creative products reported in various papers on computational creativity systems (Jordanous, 2011). However, the more mature work and exciting potential comes from the incorporation of the other three Ps, at least to some extent, such as in Saunders (2012), Gervás and León (2014), Misztal and Indurkhya (2014). Saunders' work (Saunders, 2012) looks at models of creative Producers as autonomous agents that employ a Process of interacting with their Press (via an agent-based system) to produce creative Products. Misztal and Indurkhya have written "empathic" software: a computational Producer of poetry that can be affected by and can express different moods and emotions in its poetry Products (Misztal and Indurkhya, 2014). The Processes employed by the system are based on cognitive models of consciousness, with a Press of several "experts" interacting together using a "Blackboard" architecture to pass information between each other. The ICTIVS model (Gervás and León, 2014) is an example of more theoretical work that considers how Products (in this paper the S in ICTIVS stands for stories) can be generated by the multi stage Process model of ICTIVS: individual Producers employing stages of Invention and Composition to generate stories, then within a Press, employing stages of Transmission for the stories to be subject to Interpretation and Validation.

3. Four Ps and computational creativity in practice

3.1. The product/process debate in computational creativity evaluation

> As a research community, we have largely focused on assessment of creativity via assessment of the artefacts produced. (Colton, 2008, p. 1)

As illustrated by the ICCC 2014 call for papers, one important debate in computational creativity is about whether evaluation of a creative system should focus exclusively on the output produced by the system, or whether the processes built into the system should also be taken into account. Should both product and process be included in evaluation (Colton, 2008; Jordanous, 2012; Pease, Winterstein, and Colton, 2001), or should evaluation concentrate solely on the product of systems (Ritchie, 2007)? Ritchie (2007) stated that examining the process is unimportant for creativity, arguing that humans normally judge the creativity of others by what they produce, because one cannot easily observe the underlying process of human creativity. Ritchie therefore advocated a black-box testing approach, where the inner program workings are treated as unknown and evaluation concentrates on the system's results. Later, however, Ritchie (2008) conceded that it can be important to consider a system's "mechanisms" in the case of "more theoretical research" (Ritchie, 2008, p. 147).

While it is true that we can only use the material we have available to form an evaluation, evaluation experiments (Jordanous, 2012; Pearce and Wiggins, 2001) show that people often make assumptions about process in their judgements on product. As Hofstadter pointed out, "*covert mechanisms* can be deeply probed and eventually revealed merely by means of watching *overt behaviour* ... [this approach] lies at the very heart of modern science". (Hofstadter, 1994, quoted in p. 10, Pease et al., 2001). Pearce and Wiggins (2001) discussed how our interpretation of how something was produced is important, even if the actual method is unknown, and that such an interpretation can be derived if people are repeatedly exposed to the compositional systems (human or computational) that they are evaluating. Collins (2008) discussed how making reasonable assumptions can assist the reverse-engineering[11] of program code from output, in scenarios where white-box testing (evaluation with access to the program code) is not possible.

Colton (2008) acknowledged Ritchie's arguments but quotes examples from art to demonstrate that process is as important as the end product when evaluating creativity, at least in the artistic domain. As evidence, Colton cites conceptual art for details on conceptual art in the context of this debate, where the concepts and motivations behind the artistic process are a significant contribution of the artwork. Sol LeWitt defined Conceptual Art (LeWitt, 1967) as an art form where "the idea or concept is the most important aspect of the work. ... The idea becomes a machine that makes the art". Jordanous (2012) makes similar arguments for creativity in musical improvisation, finding that the process of improvisation is often seen as more relevant for creativity than the end result.

If assessing how creative a piece of conceptual art or a musical improvisation is, solely by evaluating the product, then there are two negative consequences:

(1) A key aspect of the intentions of the artist/musician is overlooked (the evaluator's focus is on the end result rather than how the creative work is made).
(2) The level of creativity presented could be misjudged, especially if the creative process results in producing something that might seem commonplace outside the context of that art installation/musical performance.

Colton (2008) also posed a thought experiment that considers two near-identical paintings presented at an exhibition. In the first painting, the dots are placed randomly, whereas in the second, the dots' locations represent the artist's friendships with various people. Colton argued that the second painting would be more appealing to purchase than the first, though the end product is very similar, due to the process by which it was created. Colton's thought experiment illustrates how process can impact on our judgement of creative artefacts (as well as highlighting the role of the Press in attributing creativity), though one could question if the experiment explores perception of creativity, or of quality/appeal.

The thought experiment described by Ventura (2008) gives further evidence (perhaps unintentionally) on how knowledge of the creative process affects how we evaluate creativity. Two creative systems, the RASTER and iRASTER systems, were designed by Ventura to be decidedly non-creative. If these systems were implemented and their generated images were given to people to evaluate without telling the evaluators how they were produced, the evaluators may well rate the creativity of the system highly. Supplying the evaluators with details of how a program works, though, could have a detrimental impact on the subsequent evaluations (Colton, 2008; Cope, 2005).

One issue with creativity is analogous to the adage that a magician never reveals their secrets. This adage is based on the observation that tricks do not appear so impressive once you have found out how the magician performed the trick. Similarly things can appear to be less creative when you know how they were produced:[12]

> it is not unknown for critics of AI to refuse to accept programs as creative (or intelligent) once the mundane mechanistic nature of the inner workings are revealed. (Ritchie, 2001, p. 4)

Colton (2008) intentionally sidestepped this issue by reporting on his artistic system in high-level terms only, rather than giving details of the program (Colton, 2008, p. 8).

Until recently, computational creativity evaluation methodologies mainly looked solely at a system's *products* (Ritchie, 2007, for example) or at a combination of the *products* and the *process* (Pease et al., 2001). Recently it has been acknowledged that there is more to creativity than process and product, with the Creative Tripod (Colton, 2008), whose evaluative framework is influenced by how an audience perceives the creativity of a system, SPECS (Jordanous, 2012) which requires the researcher to investigate what creativity means in the context of their system, and the FACE/IDEA models (Colton et al., 2011) which consider various aesthetic features and interactions between audience and system. Work on computationally creative societies has also developed in the last few years (Saunders, 2012, is a significant example).

Along a similar broadening of perspectives, the next section brings in work from the wider creativity research community, examining further viewpoints – the creative *person* operating in a *press*/environment – and relating these viewpoints to a computational creativity standpoint.

3.2. Reviewing the Four Ps in recent computational creativity research

To what extent are the Four Ps implemented in current computational creativity work in practice? To answer this question, we can examine the work presented in the most recent International Conference on Computational Creativity, the key annual conference in this area of research and "the only scientific conference that focuses on computational creativity and also covers all aspects of it" (Toivonen, Colton, Cook, and Ventura, 2015, p. ii).

The 2015 edition of this conference was held in Park City, Utah, US[13] and 41[14] papers were presented, covering five categories:

> "(1) technical papers advancing the state of art in research,
> (2) system and resource description papers,
> (3) study papers presenting enlightening novel perspectives,
> (4) cultural application papers presenting the usage of creative software, and
> (5) position papers arguing for an opinion".
> (Toivonen et al., 2015, p. ii)

Each of the papers in ICCC'15 were reviewed to determine if they considered each of the Four Ps. As shown in Figure 2, all Four Ps were mentioned in the set of ICCC papers fairly evenly.

- 21 papers (51%) considered the Producer in computational creativity by some angle, for example, characteristics that a system should implement in order to be creative.
- 26 papers (63%) gave details of the creative Process(es) being used in the work being reported.

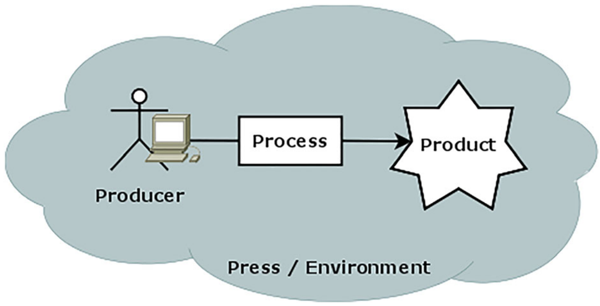

Figure 1. A simplified view of how the Four Ps fit together in creativity.

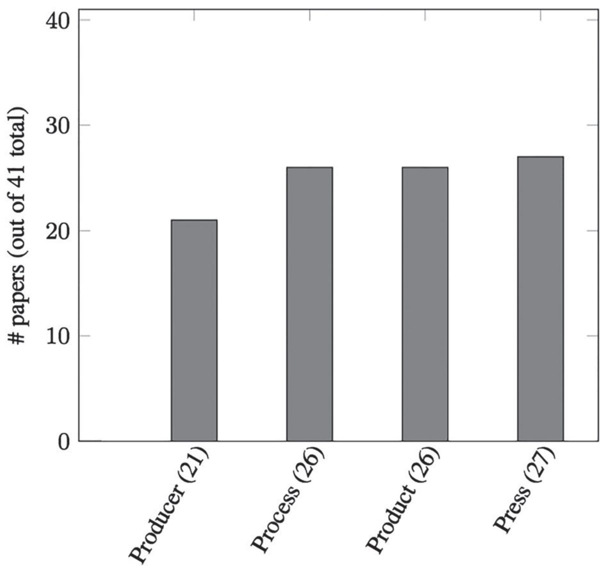

Figure 2. Coverage of the Four Ps in papers presented at ICCC'15.

- 26 papers (63%) focused some attention on the creative Products being generated computationally.
- 27 papers (66%) mentioned how computational creativity systems were influenced by external environments to some degree.

All Four Ps were covered by ICCC papers in 2015 to some degree; however, Figure 2 illustrates that we are not yet at the level where all papers consider all Four Ps.[15] The papers receiving best paper awards/recognitions at ICCC'15[16] each covered at least 3 of the Four Ps:

- Best Paper: Besold and Plaza (2015) focused on using conceptual blending (Fauconnier and Turner, 2002) as the basis for the creative Process, considering how Producers require abilities to combine concepts and to reason over such combinations. They exemplified their arguments with Products in the form of case study results.

- Best Student Paper (and Runner-Up for Best Paper): Harmon (2015) presented the creative system FIGURE8 which produced similes as its Products which related to contextual information (Press) and individual authorial style (Producer). The Processes behind FIGURE8 were presented as a computational model and architecture.
- Runner-up for Best Student Paper: Kantosalo, Toivanen, and Toivonen (2015) took unusual perspectives on many of the Four Ps. They looked at the Process of evaluation in computational creativity, using interaction design (i.e. the use of Press) as a framework for evaluation which would give formative feedback (Product) which could feed back into the creative Process of systems. The Producers they highlighted were computational creativity researchers who could use these evaluative results in work with creative systems.

As this present analysis looks at papers which were presented a few months before the time of writing this paper, it is less helpful to use additionally measures such as citation analysis to identify which papers will potentially have longer term impact. Using a more personal reflection of my own impression of the overall general contributions made by ICCC'15 papers, Grace and Maher's paper on "specific curiosity" (Grace and Maher, 2015) and Bown's paper on attributing creative agency (Bown, 2015) stood out for me as being very well received and useful. Both these papers aroused much constructive discussion at the conference. It is intriguing to find that the content of both of these papers includes discussion of all Four Ps:

- Grace and Maher (2015) consider the intent of autonomous Producers to transform creative domains (Process) via exploration of the contextual Press, giving example Products to illustrate their arguments.
- Bown (2015) discussed how creative agency can be attributed to Producers interacting in networks (Press) to contribute to the existence of some artefact(s) (Product), and considered a formal framework for creative authorship (Process).

Specific sessions at ICCC'15 showed that the computational creativity research community is collectively considering each of the Four Ps in its own right, with none being neglected. The *Creative autonomy* and *Imagination and curiosity* sessions investigated different aspects of the creative Producer, while sessions on *Creative mechanisms* and *Conceptual blending* covered Process aspects in creativity. Sessions on *Co-creativity*, *Musical interaction* and *Creativity support and interaction* reflected recent work on the role of Press in computational creativity, while the *Visual arts* and *Language* sessions included various computational creativity Products.

We can look back at papers which have been highlighted in previous years as useful contributions, either through being currently most highly cited papers on "computational creativity"[17] or through winning "best paper" awards in recent years at conference:[18]

- *ICCC'12: Best Student Paper* Baydin et al.'s paper on evolutionary generation of analogies (Baydin, DeMantaras, and Ontanon, 2012) considered the Products (analogies) of a Producer algorithm with encoded "common-sense knowledge" and knowledge of memes drawn from a cultural Press including different domains of knowledge, that uses this knowledge within an evolutionary Process of genetic algorithms to generate new analogies.

- *ICCC'11: Best Student Paper* Carlson, Schiphorst, and Pasquier (2011) reported "Scuddle", a Producer with knowledge of physical bodily movement which also uses an evolutionary Process of genetic algorithms to generate Products in the form of "catalysts": selected constraints to be imposed on what choreographic decisions are available to choreographers, Scuddle's Press.[19]
- Machado and Cardoso (2002, # citations = 66) reports NEvAr, an artistic Producer system which has the ability to critically evaluate its results, and generate image Products using a Process of genetic algorithms. In terms of Press, it can run several instantiations of the genetic algorithm at one time, and individuals from each population (each instantiation of the genetic algorithm) can be swopped between each other, affecting the operation of NEvAr by introducing new "genetic material" for evolution of the next population.
- Ritchie (2007, # citations = 51) presents Ritchie's *empirical criteria* for assessing the creativity of computational creativity software; it concentrates on the creative Products produced by creative systems and how they sit within a Press (how typical and valuable those Products are perceived to be). To some extent it considers Producers, via creative systems' knowledge of *inspiring sets* of examples: artefacts in a particular domain which the system is aware of and which it is "inspired by" in its Process. Ritchie's work has been criticised (Colton, 2008; Jordanous and Keller, 2012, e.g.) for neglecting to take into account the creative Process during evaluation.
- Wiggins (2006, # citations = 40) considers a theoretical framework for creative Producers with a key ability: being able to search a conceptual space for new creative possibilities. The environmental Press in this case is a set of acceptable artefacts within a creative domain (in this case, "acceptable" is determined by various rules that govern how that Press is defined). Wiggins cites a model of creative Producers that can search this Press, with a set of rules and a vocabulary for expressing both the rules and the artefacts which the Producer can generate. Process is modelled in Wiggins' framework as a function generator.[20]
- Gervás (2009, # citations = 29) summarises progress to date[21] in computational generation of stories. This paper addresses all Four Ps from the start: with a discussion of the creative Process in different systems, which includes reference to "explicit action by some agent that we shall refer to as the creator" (Gervás, 2009, p. 49) – suggesting the Producer; the output of these systems – the Products; and the audience whose points of view are relevant in perceiving and evaluating the results – the Press.

4. Applying the Four Ps: examples of *novelty* and *value*

Novelty (originality, newness) and value (usefulness, appropriateness) form key parts of creativity (Boden, 2004; Jordanous, 2012; Mayer, 1999; Ritchie, 2007), often being identified as the two main aspects of computational creativity (Brown, Boden, D'Inverno, and McCormack, 2009, Pease et al., 2001; Ritchie, 2007, for example). [22] Work in computational creativity illustrates both novelty and utility from each of the Four P perspectives, although some perspectives are represented more plentifully within computational creativity than others. To illustrate the discussions above, we can discuss novelty and value in computational creativity from each of the Four P perspectives. Considering novelty from each of the Four Ps:

Product Novelty is well associated with system outputs and products: how novel are the generated artefact(s)? The novelty of artefacts generated by computational creativity systems is a key consideration in Ritchie's empirical criteria for evaluating creative systems (Ritchie, 2007).

Process A creative process can take a novel approach or be implemented in a novel way, perhaps employing new algorithms or techniques or different approaches. Efforts at trying new processes and combinations thereof are being encouraged by systems such as the FlowR framework (Charnley et al., 2014), which focuses specifically on enabling us to chain different processes together for creative purposes.

Producer Incorporating new personal traits into computational creativity systems gives scope for new research results. More broadly, as is often encountered in computational creativity work, implementing or running a creative system on new hardware or in new software implementations may also impact upon the system's performance and may have unexpected results.[23] The number of new systems presented each year at the International Conference on Computational Creativity exemplifies how novel creative entities continually arise in computational creativity research.[24]

Press The creativity demonstrated by a system can be noted as being novel in a particular environment, even though it may be commonplace in other environments. The system may also exploit the surrounding press in previously unexplored ways. This was demonstrated neatly by the combination of two systems in Monteith et al. (2011), where a textual annotation system interacted with a system that generates emotion-driven music. The two systems essentially acted as part of each other's Press with one system affecting the environment the other was working in. The combination resulted in novel interpretations of fairy tales; such results would not have arisen were the systems operating in isolation.

Considering value from each of the Four P perspectives:

Product Value is also well associated with system outputs and products: how valuable or good are the generated artefact(s)? This is a highly current area of concern within computational creativity, with much evaluation concentrating on the quality of output (Jordanous, 2011).

Process The creative processes being incorporated within creativity can be useful in themselves for learning or studying how certain approaches and techniques work or for cross-application to new areas. Systems with an emphasis on modelling process, such as Misztal and Indurkhya's poetry generator (Misztal and Indurkhya, 2014) bring added utility by what they reveal about the processes being modelled.

Producer Some creators become more valuable than others as a contributor in their field, based on their personal characteristics, experience and influence.[25] The same can be noted for creative systems to some extent; some are cited more often than others. For example in a Scopus[26] search of the most highly cited papers on "computational creativity" (where the primary emphasis is on a single system), we see that the papers currently with the highest number of citations cover (at least to some extent) all Four Ps:

- NEvAr (Machado and Cardoso, 2002, # citations = 66) – as seen earlier, this system discusses all four Ps
- The Knowledge-Intensive Interactive Digital Storytelling (KIIDS) system (Peinado and Gervás, 2006, # citations = 22) is a Producer with knowledge of multiple domains encoded into it, to generate folk tales as its Products. The system knows details about its environment (its Press) through the encoded knowledge (in the form of Semantic Web ontologies, machine-readable categorisations of knowledge about particular domains). Though KIIDS cannot interact with its Press, it can pick up new information if the ontology it uses to populate its knowledge is updated with the new information. KIIDS uses a Process of case-based reasoning to generate tales by extrapolating from previous examples using its encoded knowledge.
- EvoEco (Kowaliw, Dorin, and McCormack, 2012, # citations = 17) is an "ecosystemic" Producer art system which has knowledge of – and the ability to judge – what is aesthetics pleasing in terms of images. It uses a Process of genetic algorithms to generate image Products. Its knowledge of aesthetics has been harnessed through an online survey, gathering information from its Press (respondents).
- al-Rifaie et al's work (Rifaie, Bishop, and Caines, 2012, # citations = 14) uses swarm intelligence algorithms as its Process for generating artistic image Products. By definition, swarm intelligence involves Press as it simulates the collective behaviour of multiple members of a population (mimicing the behaviour of flocks of birds or groups of foraging ants). One can interpret the Producer as being the system as a whole, or as the individual members of the population which each have knowledge of specific rules that govern the swarm behaviour (in this case rules governing how the individuals can collectively search regions of an image canvas).
- The Painting Fool (Colton, 2012, # citations = 9) is advocated by Colton as a Producer which is a "creative artist in its own right" (Colton, 2012, p. 3). It learns from interacting with its Press through processing various cultural sources such as news stories, to generate artwork Products which have been presented back to its Press in the form of exhibitions "where the effect of software which might be deemed as creative is tested in the art world and the wider public" (Colton, 2012, p. 3). It employs a collection of various algorithms as part of its creative Processes.

Press If creative activities benefit the external world in some way, then they have value to the press. As an example, Harold Cohen's AARON colouring system has received much external attention, from media discussions (McCorduck, 1991, as example) and other publicity[27] through to being the inspiration behind a screensaver for personal computers, with the AARON system "productized by Kurzweil CyberArt Technologies, Inc." (`http://www.kurzweilcyberart.com`).

5. Discussion

The above treatments of novelty and value are brief, and are not intended to be a full and conclusive portrait of novelty and value within computational creativity. What the above illustrates is the ease with which different viewpoints that can be uncovered using the Four Ps as *signposts* with which to guide our thinking around computational creativity. The breadth of issues mentioned above shows aspects of novelty and value within computational creativity which may not always be accounted for if taking a product/process-oriented viewpoint; however it is argued here that those perhaps-overlooked aspects give computational creativity researchers a closer rendition of creativity, guiding us away from incomplete viewpoints of creativity in the context of our computational work.

Analysis of papers recognised for their contributions to computational creativity reveals the common trend of including discussion from all Four Ps. While it is naive to say that all good papers cover all Four Ps, and papers that do not are in some way "bad", it would not be controversial to remark that a good breadth of discussion in a computational creativity paper makes the general content of the paper potentially more relevant across a diverse audience. Computational creativity research indeed covers a diverse range of areas and disciplines (Sosa and Gero, 2015) as can be seen by the breadth of sessions at ICCC'15, ranging in content from theoretical investigations of conceptual blending through to games and language applications. Papers covering all Four Ps will by definition include discussions from all four perspectives covered by the Four Ps; there is therefore an increased potential to make broader contributions to computational creativity research. Computational creativity researchers can use the Four Ps as a guide or "checklist" to think about their work from different perspectives, potentially uncovering further contributions their work makes which had previously been overlooked.[28]

As the field of computational creativity matures as a research discipline, it is pleasing to see wider consideration of the Four Ps at research events. For example, we see that in the most recent computational creativity international conference (ICCC'15), 66% of papers mentioned Press elements of computational creativity. This is significantly more than in the previous year, when nearly 75% of papers had *not* mentioned social/environmental-related aspects of the system in any way. As reported above, even though many papers did not cover all Four Ps at ICCC'15, the conference included an even balance of sessions across the Four Ps, which is pleasing to see.

6. Conclusion

The difficulty of understanding what creativity is should not discourage us in our attempts to do so (Colton, 2008; Plucker et al., 2004; Rhodes, 1961), either to understand human creativity or to work with computational creativity. In creativity research, the *Four Ps* construct ensures we pay attention to four key aspects of creativity: the creative Producer, the generated Products, the creative Process and the Press/Environment hosting and influencing the creativity. This framework helps us to consider creativity more broadly, and is a useful framework to guide computational creativity researchers in their work modelling, simulating or replicating creativity. For example, if viewing *novelty* and *value* from the perspectives of *product*, *process*, *producer* and *press*, we uncover various interpretations of these two key concepts within computational creativity which may otherwise have been overlooked.

The *Four Ps* framework helps to highlight different perspectives on creativity, to portray creativity in a fuller context. We can see from analysis of current computational creativity work that the research community is collectively acknowledging the usefulness of all Four Ps; however, individual papers might only address a subset of the Four Ps, not all Four (as seen by the analysis of the latest international research conference papers above). We have seen that papers acknowledged to be particularly useful contributions (e.g. through attracting prizes or numerous citations) typically address issues across all Four Ps. This paper argues that the Four Ps can be used by computational creativity researchers to help them maximise the potential of their work: to make broader contributions across multiple perspectives across the computational creativity community.

To conclude, it is worth repeating a point originally made by Rhodes over 50 years ago:

> Each strand [of the Four Ps] has unique identity academically, but only in unity do the four strands operate functionally. (Rhodes, 1961, p. 307)

Notes

1. As will be described in this paper, I shall revise *Person* slightly to *Producer* for the purposes of relating the Four Ps to computational as well as human agents. My thanks to one of this paper's reviewers for helping me settle on this revised term.
2. Variants of these *Ps* also arise in slightly different guises in non-related areas, such as software project management (Jacobson, Booch, Rumbaugh, Rumbaugh, and Booch, 1999) or education (Biggs, 2003).
3. As stated by the Association for Computational Creativity at http://computationalcreativity.net (last accessed January 2016).
4. Interestingly, as Rhodes' work was published in a relatively unknown journal, some later advocates of a "Four Ps"-style approach to creativity also seem unaware of Rhodes' contribution (e.g. Odena confirmed this in personal communications in 2009), failing to cite Rhodes' 1961 paper.
5. Suggestions from one of the review of this paper helped shape this generalised view.
6. This report is referred to in the FACE framework as a *Frame*).
7. Recently proposed evaluation methods such as (Colton, 2008; Colton et al., 2011; Jordanous, 2012) place more emphasis on the other three "Ps".
8. For example, see Section 3.
9. Many thanks to the reviewer of an earlier version of this paper, who raised this point.
10. A tagline originally devised by Tony Veale for ICCC conference materials in 2012 and 2015 sums up this shift in attitude: computational creativity research is now "scoffing at mere generation [of products]".
11. Reverse-engineering is the process of identifying and perhaps replicating how a product is made, through analysis of that product.
12. If the inner workings of a program are very impressive, complex or novel, then we may still be impressed by the program, but this is a different perspective to whether or not we think the program is creative.
13. Proceedings (Toivonen et al., 2015) are available via the conference website at http://computationalcreativity.net/iccc2015/.
14. Including 13 papers which were accepted conditionally with required revisions.
15. This might be expected to some extent because of the focused nature of conference papers on specific research projects, which may not be reporting fully completed work; however we should remember that peer-reviewed conference papers often occupy a similar status to that of journal articles in computer science, more so than in most other disciplines. This has been the case for recent computational creativity papers, where there is as yet no dedicated journal for computational creativity and papers at the key international conference ICCC undergo detailed peer review.
16. See http://computationalcreativity.net/iccc2015/?page_id=348.
17. Citation data are as measured by Scopus (http://www.scopus.com), which allows search results to be ordered by descending number of citations and which includes conference publications in its results.
18. Best paper prize information is taken from what is listed in the Association for Computational Creativity webpages at http://www.computationalcreativity.net.

19. There is intention for interaction between Scuddle and its Press to become two-way via the addition of machine learning of choreographers' preferences within Scuddle, though this work has not appeared in paper form yet to the best of this author's knowledge.
20. Details of each of these model aspects are left abstract, as the paper presents a theoretical framework rather than a practical implementation of a creative system.
21. That is, progress up till 2009, the date of this paper.
22. It should be clarified that for this author, creativity consists of considerably more than novelty and value, though these are two key components of creativity, see Jordanous (2012).
23. The novelty of unexpected results is often unintentionally exemplified when live demos of these systems are attempted in unfamiliar computing setups (the new hardware setup can be interpreted as a new Producer).
24. See http://www.computationalcreativity.net/conferences.
25. This has been found, for example, in the recent Valuing Electronic Music project http://valuingelectronicmusic.org (Allington, Dueck, and Jordanous, 2015), where some people's endorsements can have a greater influence on the perceived value of an electronic musician and their work.
26. http://www.scopus.com.
27. See http://www.aaronshome.com/ for an extensive list of talks and publications.
28. Certainly this author can report having experienced this positive effect of uncovering previously overlooked aspects, for example when considering novelty and value in computational creativity from the Four P perspectives.

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