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A Patterning Approach to Complexity Thinking and Understanding for Students: A Case Study

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Abstract

Complexity thinking and understanding are vital skills for young people in these times of uncertainty and change. Such skills contribute to resilience and capacities for adaptivity and innovation. Within my teaching practice I have found students to be aware of complex dynamics, uncertainty and change, both in their lives and in the world. However, the current curriculum lacks language and process to conceptualise, articulate and develop complexity understanding. To address this problem, I developed and introduced a patterns-based design and process to a cohort of Australian secondary students. Comprising flowform patterning together with ecological metaphors, the design forms a conceptual language and practical process for thinking about, understanding and engaging with complex phenomena and change. Together these capacities are described here as complexity competence. Implemented initially to engage with time as a complex phenomenon, the design is described as the *Patterns of Humantime* (PHT), and the process of implementation as *Complexity Patterning*. Implementation during the development phase demonstrated the design's capacity as a way to understand time as a complex phenomenon, as well as facilitating a relational and identity development approach to learning. In more recent research workshops with American undergraduate Liberal Studies students, the PHT design showed to be effective for understanding complexity and indicated the design's capacity as a patterning process for engaging in collaborative projects in complex situations of diversity, change and uncertainty. Avenues to develop curriculum and evaluation materials, as well as professional development workshops, are being explored.

1. Introduction

This paper introduces a patterning approach to complexity thinking and understanding for students. The *Global Education Futures Report* (GEFR) lists complexity thinking as one of the most important broadly applicable skills required for young people in 21st Century, stating that "The only way to go from here is onward; to evolve our ways of thinking, learning, and acting together in such a way that is coherent with the dynamic flux of our increasingly complex world." (2018, p. 97). Combining knowledge and understanding of complexity with practical skills for applying such knowledge in a wide range of situations, is

described here as complexity competence. It is a conceptual, experiential and practical form of knowledge.

Complexity competence is emerging as crucial for young people in a world that is characterised by increasingly complex problems and unpredictable change, as well as for active participation in possible and preferred futures (Bauman, 2005, 2007; Bell, 2016; Laszlo, 2001; Lans, Blok & Wesselink, 2014; Sardar, 2015). These 'postnormal' times require a form of logic and foundation for action that is itself complex in nature (Sardar, 2015). Such complexity logic can support students to navigate ambiguity, unpredictability, as well as cooperation and collaboration, across diversity, and can assist them to engage with transformation (Gidley, 2017). Indeed, preparedness to perceive and engage the complex, the multidimensional and multitudinous, may be one of the last frontiers of knowledge (Aldaheff-Jones, 2010).

Education is placed as the central site of response to this immanent need, according to the GEFR, and development of educational content and practice beyond the Industrial era model is required (Gidley, 2017). Education in the 21st Century is implicated in young peoples' preparation for the world they are growing into, including for jobs that are not yet evident, technologies that have not yet been invented and for emergent problems (Schleicher, 2016, in Bell 2016). All highlighting the need for complexity competence. In terms of future employment, the *Skills of the Future Report* (Loshkareva et al, 2018) explains that complexity competence is required to evaluate and respond to complex interaction, connectivity and change at multiple levels, both within work environments, between different work environments, and in relation to the wider world.

While there has been a significant increase in theoretical engagement with complexity thinking within the discipline of education generally in the last decade (Koopmans & Stamovlasis, 2016), practical application of complexity thinking in the classroom is a newly developing response. Complexity concepts are entering some curricula, yet there are no discoverable approaches to the explicit teaching and learning of complexity thinking and understanding for students and educators in the Australian or US curriculums. For example, Yoon, Goh and Yang (2019) explain that while the Next Generation Science Standards (NGSS, 2013; National Research Council, 2012) incorporate complexity concepts into the framework for the American Science curriculum, their investigation into the development of explicit learning pathways for complexity thinking discovered that many students continue to attempt complexity understanding using linear cause and effect logic.

In response to the imperatives and challenges outlined above an approach to complexity thinking and understanding is outlined here. I developed this approach within professional practice with Australian secondary students, and more recently in 2016 it was refined and implemented in research workshops with

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American Liberal Studies undergraduate students. Initially within my teaching practice in an Australian secondary school (Pers. Obs. 2005-2010) I observed that many of the young people were acutely aware of the increasing multiplicity and interconnectivity, in short, the complexity, of their lives and the world. However, the language and process to develop complexity thinking and understanding were missing from the curriculum and accompanying pedagogy. Subsequently, I introduced this visual conceptual ecology and patterning process to the students I was teaching.

As I initially used this approach to enable students to engage with the experience of time as a complex phenomenon (Aldaheff-Jones, 2017), the design was titled the Patterns of Humantime (PHT), and the design implementation process as Complexity Patterning, or simply, 'patterning'. The term 'humantime' was used to assist the students to think about their experience of time as a multilevel, asymmetrical and recursive phenomenon that is involved within complex causality and emergence, contrasting with the more usual idea of time as a linear, fixed parameter of life and human action that involves simple cause and effect processes. Further explanation of how the PHT were used to engage students in this view of time is placed further in this article.

Implemented as a transdisciplinary and meta-cognitive knowledge, I adapted PHT to the ages and learning needs of the students. The PHT was used to pattern and engage with classroom dynamics and to develop an identity development approach to learning. My aim was to engage the students in an integrated perspective of the full complexity and relationality of the teaching and learning experience. This included respect for diversity *and* common ground, as well as the unknown, the indeterminate, and the emergent as integral within the complexity of the learning environment and learning itself. Also, the PHT approach was implemented to support exploration of an ontological understanding beyond the mechanical Newtonian paradigm (Morin, 2008). This was for the purpose of assisting the development of a complexity worldview, and perhaps a complexity aesthetic, in a way that could be practically applied in complex situations (Wahl, 2016). Using spatial, temporal and relational experience and concepts familiar to the students through embodied cognition, allowed us to ground complexity thinking and understanding in immediate experience. In this way the students learned how complexity moves, not simply what it is.

The research workshops I later developed and facilitated with American Liberal Studies undergraduate students focused on applying complexity thinking to intercultural competence (Deardorff, 2009, 2011), and professional identity development. The students were undertaking a Global Studies Degree Course that focused on developing skills and knowledge for innovative and entrepreneurial engagement with sustainability projects with diverse peoples. Application of the PHT was in the context of projects the students would undertake in settings of

diversity and change, such as supporting the connection of sustainable local production to appropriate markets, ecosystem projects, or construction of water and sanitation facilities. Student responses were gathered after the workshops to investigate the usefulness of the PHT approach in the students' educational journey and their professional development (refer Table 1: Student Responses and Themes).

This article begins by outlining the complexity perspective underpinning this work. It goes on to discuss the concept of deep complexity thinking. Deep complexity is a concept used here to support the application of complexity competence in the students' personal and professional lives. It pertains to the inseparability of human cognition and embodiment within phenomena (Chapman, 2016; Maturana & Varela, 1980, 1992; Thompson & Varela, 2001; Varela, 1997; Varela, Thompson, & Rosch, 1991). Aligning with the work of Sumara & Davis (1997) who state that education and knowing are a completely 'knitted' complex phenomenon that is mediated by identity, deep complexity begins with cognition and identity. The co-implication of observer and observed is included within the concept of deep complexity, and is described using the term 'complicity' to express the inseparability in this paradoxical relationality.

Relevant ideas in the teaching and learning of complexity thinking are then briefly explored. Following, is a rationale for using patterning and metaphor as an approach to complexity competence, leading into the introduction of the Patterns of Humantime design. The paper then outlines how I implemented the PHT with the secondary students, including the aspects of learning with which they were specifically engaged. Afterwards, there is an overview of how the PHT were implemented within the curriculum of the Global Studies Degree Course, with the students' comments included as evidence of the resulting understanding of complexity concepts and their application. The paper concludes by considering the contribution of this work in the field of the teaching and learning of complexity competence for the 21st Century, and outlines directions for wider implementation and future research.

2. A Complexity Perspective

As an inherently dynamic knowledge, complexity is not a unified concept. It is conceptualised variously within diverse areas of endeavour and contains ambiguities (Aldaheff-Jones, 2008). This section outlines the complexity perspective taken in this project, in terms of both ontology and epistemology. The relationship between these dimensions of knowledge is discussed further in the section on deep complexity thinking.

The perspective of Edgar Morin (1977/1992, 2007, 2008, 2014) provides the theoretical underpinning for this work. Morin expresses an ontological

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complexity perspective of life as dynamic emergence; as perpetually calibrating phenomena, learning and evolving through organisational relationality and feedback loops. Described as general complexity, Morin's views highlight local particularity, historicity, and organisation within the non-reducibility of entity/phenomenon relationality, as well as non-linear complex causality with no central control. Paradox is also emphasised by Morin, in terms of the recursive co-generativity of a range of binaries including order/chaos, organisation/process, entity/phenomenon, and change/stability (Aldaheff-Jones, 2010).

Morin's general complexity also includes human inseparability within phenomena, bringing being and knowing into consideration, as both individuality and co-mutuality. The PHT approach to complexity understanding considers this relationality in terms of the dynamics of information, energy, matter and meaning (Barad, 2007), through exchange and communication. These dynamics are patterned in terms of flows of enablement and constraint, which can be at once corresponding, complementary and/or synergistic, as well as contradictory and antagonistic (Aldaheff-Jones, 2017; Morin, 2008). The paradox and tensions of this individuation/wider phenomenon relationality (such as self/group/culture, organism/ecology) is a central dynamic within the PHT, and is related to the tension between contingent and general perspectives central to complexity focused transformative learning (Aldaheff-Jones, 2012).

The term complexity is also used here epistemologically, as a "mode of knowledge" (Morin, 2014, p. 19). Complexity as way of knowing underpins the PHT as a conceptual and material practice for engaging with dynamic complex phenomena (Haggis, 2008). Using patterning in a way that corresponds with complexity epistemology, aims to make the organisation and interpretation of complex information within reach of students of all ages, in an approach designed to encourage the development of cognitive and emotional flexibility and agility (Kuhn, Woog & Salner, 2011). The PHT and Complexity Patterning also provides stimulus for generating questions about the phenomenon of focus, including our relationship with/in it. Questions about the qualities of relationality and dynamics within phenomena, and the effects generated, are of greater focus than the entities or elements within the patterning. Answers and solutions are subject to uncertainty and change in these times of turbulence, placing questions as potential threads able to be woven through change, and therefore useful for connecting knowledge and action (Wahl, 2016). Complexity as epistemology is integrated in this way within the PHT approach to complexity competence.

3. A Deep Complexity Approach

The conceptual and epistemological lens through which we 'see' complexity can define how we respond to and engage with phenomena (Bateson, 2017). Laszlo

(2019) explains that some 'systems' conceptualisations of complexity allow a view of interconnectivity, yet can also fix knowledge of phenomena within rigidly representational models. Laszlo calls for movement beyond the 'consummate cartography' of systems modelling towards integration of complexity thinking, feeling and being. Morin's general complexity perspective also warns against the use of complexity thinking in ironically restricted ways (1977/1992, 2008). In alignment with these views, the learning and practical application of complexity competence through the PHT can be described as a paradigm of deep complexity. In summary, deep complexity implicates human beings as complicit within any phenomenon of engagement. Not as additions or 'interference', but as inherently "of the world not in the world, and surely not outside of it looking in." (Barad, 2007, p. 206). This section of the paper defines deep complexity through delving into the epistemological and ontological ramifications of complexity thinking (Morin, 1977/1992), to consider the processes by which we are actively complicit within phenomena. Description of the PHT design and an overview of implementation follow in subsequent sections.

The term 'deep' is applied variously to complexity. For example, the term may be used to describe the discovery of complex characteristics and dynamics at many levels of scale within one phenomenon (for example see Mercer, et al, 2012). Delorme describes Morin's *Method* as a deep complexity approach, due to its transdisciplinary and transepistemological focus (2010). Delorme engages Morin's work within his process of Effective Deep Complexity, which is focused on tackling specific "ill-structured problem situations" within social science (2010, p. xix). While there are similarities through relationship with Morin's views, and a shared perspective that engagement with complex phenomena requires a transdisciplinary approach and complexity-based processes, I argue that the PHT have a different deep complexity focus from that as described by Delorme. Here deep complexity focuses on supporting students to learn and engage 'with' and 'as' complex phenomena, as well as the more usual 'about' approach.

As it is conceptualised and applied here, deep complexity is characterised by a set of four related principles, *cognition, identity, entanglement,* and *transdisciplinarity.* Cognition is the capacity to experience, know and engage with the world. Identity is the uniquely human organisation of cognition, experience and meaning. Entanglement describes fundamental connectivity within complex phenomena, as complimentary to the concept of emergence (Barad, 2007). While transdisciplinarity is based on the understanding that complex phenomena resist description by any one discipline or paradigm and therefore require a transdisciplinary and transepistemological approach (Morin, 1977/1992).

The first principle is based on the understanding that thinking about and engaging with complex phenomena requires the ability to perceive complexity

(Bateson, 2017). Cognition is therefore integral to deep complexity thinking (Barad, 2007; Tijus et al, 2007). Everything conceptualised, measured, articulated, represented and documented is done so by *someone*, and cognition is the process by which this occurs (Maturana & Varela, 1992; Varela, 1997; Varela, Thompson & Rosch, 1991). This view of cognition assists students to consider all human experience and action as inseparable and complicit within the phenomenon of focus (Barad, 2007; Beer, 2014). Perspectives in biology and neuroscience support this porously bounded view of both organisms and cognition, with cognitive systems considered to "cut across brain-body-world divisions" (Thompson & Varela, 2001, p. 418). Maturana and Varela's Santiago Theory of Cognition defines cognition as a fundamentally circular process of differentiating and autopoietic self-generativity that is concurrently co-generative of environmental change and emergence (1992). This view of cognition integrates being, knowing, and learning, as enactive in "bringing forth a world" (Maturana & Varela, 1992, p. 26). Together with the concept of autopoiesis, the relational enactment of cognition, described here with the term sympoiesis (Harraway, 2017), realises the entity/phenomenon paradox of complexity. Integrating these concepts, cognition is considered to be the basic process of life (Wahl, 2016).

Following this biological perspective, the view of cognition utilised here is described as embodied cognition, that is, body-brain-world coupling (Chapman, 2016; Maturana & Varela, 1992). Embodied cognition includes perception, proprioception and emotion (Damasio, 2000). In alignment with the 'enactivist model' in the work of Davis & Sumara, cognition is conceptualised here as far more complex than the often used mechanistic computer metaphor of information processing, and therefore requires a complexity based perspective (1997). Cognitive complexity is described here as '8E-cognition' – being *entangled* and *embedded*, *embodied* and *enacted*, *emergent* and *extending* across boundaries, *engaging* as a relational phenomenon, and generating *effects* through enactment. 8E-cognition can be imagined as a 'cog-octopus' with students, using an ecological metaphor for understanding their own cognition as it relates to deep complexity thinking, without the need for psychological or sociological concepts or language. The distributed cognitive capacity through all eight arms of an octopus makes this metaphor particularly apt. Considering cognition in this way enables complexity competence to be based on the understanding that we are immanently inseparable from the materialisation, the 'mattering', of complex phenomena (Barad, 2007), thereby disturbing the boundary between knower and known (Davis & Sumara, 1997). It might be considered unusual to be including cognition in the teaching and learning of complexity competence, yet the issues we all face in the 21st Century require us to not only understand complex phenomena generally, but to understand our relationship with and within particular phenomenon (Bateson, 2017; Morin, 1999).

The second principle of deep complexity concerns human identity as the central organising principle of human experience and expression (Leary & Tangney, 2014). Identity is the lens through which human cognition interprets and makes sense of complex phenomena (Bateson, 2017). Conceptualised here as also complex (Barad, 2014; Cilliers, 2005, 2010), identity includes all physiological, psychological, affective, material, cultural and historical factors (de Villiers-Botha & Cilliers, 2010; Kunneman, 2010), together forming a dynamic reflexive process (Varela, 1997). Such a view of identity as a multiplicity of relationality can be expressed through Complexity Patterning. Beginning with patterning their own identity, students can begin to engage with complexity thinking from the perspective of their existence as a complex phenomenon. Thereby enabling understanding of human complicity within phenomena.

The first and second deep complexity principles described above express human relationship with and within the phenomenon of interest, rather than beginning from a positivist perspective of 'external' phenomena 'out there' with humans aside as neutral observers and/or 'invisible' variables. It is an approach to complexity competence that begins with the complexity that young people already know about, and are already experiencing, both as bounded, individualised identities, and through the relational 'identity commons' and 'learning commons' within the educational environment. In this way the PHT provides a sense-making conceptual ecology and language for students' immediate experience of their embedded complicity within the complexity of teaching and learning, providing a grounded perspective for expanding deep complexity understanding into wider settings and situations.

The third deep complexity principle acknowledges the concurrence of entanglement as well as emergence within complex phenomena (Barad, 2007, Morin, 1977/1992, 2014). Understanding of part/whole, entity/phenomenon mutuality, and the generativity of this relationship, is the aim of this deep complexity principle. Entanglement relates to one of the principles of 'deep ecology', whereby all organisms are considered to be 'knots' in a "field of intrinsic relations" (Naess, 1973, p. 94). Here, the concepts of knots is replaced with patterns, based in the view that they express the relationality of difference, as well as connectivity (Barad, 2007; Rose, 2005). Causality in this patterned view of phenomena is multi-directional, and can be described through Morin's holographic view of 'parts' as containing general information about phenomena, as well as emergence (2008, 2014). Morin's view states that an entity is recursively both "product and producer… cause and effect… effects becoming the cause." (2014, p. 17). This principle of deep complexity places connectivity as intrinsic within phenomena, as well as developing from the interaction of parts.

The fourth principle places complexity thinking and understanding as a transdisciplinary and transepistemological knowledge (Davis, Sumara and Luce-

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Kapler, 2008; Morin, 1977/1992, 2008). The fact that phenomena cannot be absolutely correlated with one way of knowing and/or one discipline underscores this principle, engaging with Morin's view that the ramifications of complexity are "epistemological, cognitive and paradigmatic... [and] bearing on the organisation of knowledge itself" (2008, p. 6). PHT design and Complexity Patterning form an approach to using the reductionism highlighting attributes of complexity thinking to support a transdisciplinary approach to curriculum and knowledge, towards complexity focused transformative education (Aldaheff-Jones, 2008, 2010, 2017; Davis 2008; Davis & Sumara, 2006, 2010, 2012; Morin, 1999).

4. Teaching and Learning Complexity Thinking

Researchers Yoon, Goh and Yang (2019) outline the need to adapt complexity thinking and understanding to students' academic stage and learning requirements. The authors outline a continuum of complexity concepts from the easiest to the hardest for students to grasp, and place this continuum as appropriate to align with academic stages. This progression has similarities with the progression of concepts implemented in the research workshops within this case study. Beginning with scale and scaling effects, through complex connectivity, multiple causality, dynamic processes, through to emergence and unpredictability. While adaptable to the need for a developmental continuum of complexity concepts as described by Yoon, Goh and Yang, the PHT can also be used to develop a learning continuum of the same concepts from simple to increasingly sophisticated across academic stages, from early schooling to adult and tertiary education. For example, the emergent nature of learning through the contribution of all students and educators to the culture and opportunities in a class, with no absolute center of control, can be engaged with young students through using the tree pattern in its simplest form. While increasingly complex arenas of influence upon learning, as affordances and constraints, can be considered by more mature students in secondary and higher education, through engaging with the full range of complex attributes of the PHT design and patterning process.

Yoon, Goh and Yang (2019) also show that local ecological scenarios are relevant examples of complex phenomena for students, due to direct availability and familiarity. This finding that ontological visibility influences cognitive accessibility of complexity concepts accords with the PHT approach of engagement with the immediate and known phenomena of identity and learning, including the learning environment. The immediacy and familiarity of these examples of complexity, as well as the simplicity of known pattern and ecological concepts and language, enables the PHT approach to have a low cognitive load

(Van Merrienboer & Sweller, 2005), contributing to its usefulness for a wide range of students in terms of age and ability.

The mutuality of teacher, students, environment and knowledge are highlighted through teaching and learning approaches based in the PHT, contrasting with 'adding' complexity concepts within the transfer model of learning (Ricca, 2012). Morin calls for educational practice to move beyond current ideas of linear skill development as the basis of learning, to a complexity-based understanding of learning as the perpetual and iterative becoming of learners in relationship with-in phenomena (1999). Following this logic, rather than fitting complexity thinking and understanding to the need for certain and examinable linear learning outcomes, the PHT approach aligns with Bateson's view that effective responses to the complexity of current times requires an extension of 'learning about' towards 'learning with' complex phenomena; so as to connect human action with generativity in relationship with unpredictability (2017). This view is based on the understanding that complex phenomena are perpetually learning and evolving (Bateson, 2017; Davis & Sumara 2010; Davis, Sumara & Luce-Kapler, 2008). Approached this way the teaching and learning of complexity competence can operate as a meta-cognitive knowledge, alongside established curriculum.

5. Complexity, Pattern Logic and Metaphors

In considering how to effectively support complexity understanding for students, Davis & Sumara remind us that such thinking is "enabled and constrained by the available conceptual tools" (2000, p. 824). The authors consider non-linear forms of knowledge generation and understanding to be appropriate for the complex dynamic nature of education, and emphasise the correspondence of ecological and fractal imagery with dynamic adaptive systems. Ecological forms are described by Davis & Sumara as having the potential to support knowledge building within the complexity of teaching and learning in a way that is itself emergent, both socio-culturally and ecologically.

Aligned with this view the ecologically focused patterning and metaphors within the PHT express and articulate the overall perspective of ontological complexity whereby all phenomena are considered to be dynamic "processes organising into spatial and temporal patterns." (Chapman, 2016, p. 110). While not claiming to be correlational or representational, the multidimensional and multilevel flowform patterning of the PHT forms a simple yet non-reductive visual and conceptual ecology that creatively corresponds with complexity concepts, as described by Morin (2008), Mainzer (1997) and Mitchell (2009). This correspondence is based on the view that patterning and complexity are languages that share logic.

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Overall, the PHT design corresponds with the complexity logic of integration of all factors within emergent phenomena, through the generativity of non-linear order/organisation/disorder processes of dynamic coherence (Laszlo, 2003, Morin, 2008). Expressing the principle of change through the paradox of flow and form, the PHT comprises the patterning attributes of symmetry, non-symmetry, dimensionality, temporality, levels and a range of adaptive parameters that are at once limiting as boundaries, and generative as interfaces and thresholds (Barad, 2007; Human & Cilliers, 2013). The PHT design expresses the paradoxical dynamics of constraint and affordance, as well as continuity and discontinuity, and the indeterminate as well as the determinate (Barad, 2007; Cilliers, 2010; Human & Cilliers, 2013). Further detail of the correspondence between patterning attributes and complexity principles is outlined within each section describing the patterns.

The ecological pattern and metaphor based language of the PHT also aligns complexity thinking with living systems (Bateson, 2017; Davis & Sumara, 2012; Laszlo, Luksha & Karabeg, 2017; Morin, 2008). Following this the term 'ecology' is used to describe the visual and conceptual patterning language of the PHT, in place of the often-used term 'framework', as the latter suggests a static approach. Specificity of configurations, qualities and nuances within the phenomenon of focus are expressed through adapting the parameters, design elements and metaphors of the PHT in the process of Complexity Patterning. The wide range of metaphors work together with the patterns, and can include: soil and weather conditions, temperature, water and nutrient flows and other entities such as mycelium, microbes, plants, birds, reptiles, insects, and other mammals, as well as human actions that can be described in terms of gardening and farming metaphors. Using ecological metaphors to generate a patterning ecology assists to express the dynamical, paradoxical, indeterminate and nuanced aspects of complexity. It is also an approach to knowledge of ecologies as complex phenomena at a time when environmental education is also a 21st Century imperative.

In their work on human cognition, Lakoff & Johnson (1980, 1980/2003) describe ecological metaphors, and plants in particular, as the fundamental language and imagery by which we understand complex phenomena. In recent history a mechanical metaphor has garnered ontological currency; being a linear and limited Newtonian perspective that requires superseding as an ontological paradigm (Montouri, 2012; Morin, 2008). This shift is supported for students by using ecological patterns and metaphors to engage with their embodied and immediate experience of complex phenomena. Providing students with the opportunity for complexity understanding from within inherently corresponding conceptual systems (Chapman, 2016; Lakoff & Johnson, 1980, 1980/2003).

6. The Patterns of Humantime

The PHT design comprises four patterns: *spiral*, branching/mycelium *tree*, concentric *spheres*, and *seed*. Each of the patterns is described in greater detail in the section for each one below. Drawing on design perspectives of pattern understanding from the field of Permaculture (Holmgren, 2013; Mollison, 1988) the PHT comprises two generative patterns observed in nature, the spiral and the branching/mycelium tree form, with the third pattern, spheres, developed from the seven orders of branching found in nature's river and tree systems, as described by Mollison. The fourth pattern, seed, is a metaphor that is given pattern status due to its relationship with the other three patterns. These and many other patterns have been used for understanding, articulating and organising knowledge of, as well as generative engagement with, complex phenomena throughout human history (Bell, 2012), and continue to be used in patterns-based approaches within Indigenous Knowledges (for example see, Sheehan, 2003). Here patterns are used as a creative bio-inspired design approach to the teaching and learning of complexity competence.

All four patterns are an integrated design, together expressing the *when, where, what, who, and why* that we associate with phenomena, as well as the relationality within and between all of these aspects. Each pattern expresses a 'dimension' of the complex phenomenon of focus, and can be engaged separately for cognitive ease; for 'zooming in' for a range of practical purposes. Together the four patterns express the movement, state and relationality within the complex phenomenon being engaged and patterned. Spiral pattern expresses time. Spheres pattern expresses the spatial/material dimension including all entities and discursive arenas. Tree pattern expresses the state of the phenomenon of focus including its history and potential, in terms of relational connectivity. Seed pattern expresses uncertainty, indeterminacy and chaos as unpatterning, and the reiterative nature of cycles, legacy and transformation as reorganisation into reconfiguration/repatterning. The spheres, spiral and tree/mycelial patterns express the complexity concepts of the multicausality of decentralised control and emergence, as well as the local and cascading effects of movement and change through place and time. Spiral patterning expresses the growth of tree pattern over time, reflecting the spiraling branching of trees in nature.

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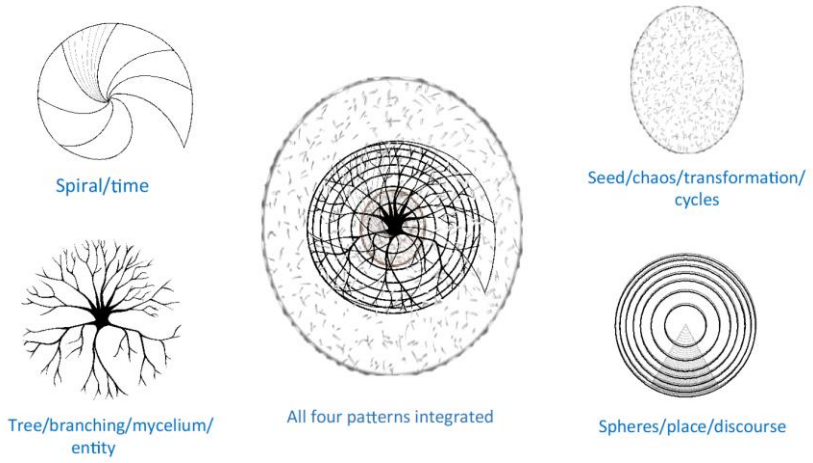

Figure 1. The Patterns of Humantime. Adapted from Pattern Understanding in the Permaculture Manual by Bill Mollison, 1988, p. 73. By Kylie McCaffrey for the author, from original drawings and images by the author.

In Figure 1, the four patterns are presented separately, as well as integrated in the center of the Figure. These simple images can be used as 2D drawings, and are also designed to be animated, to express dynamic movement and the relationship of the four patterns as one integrated patterning ecology. When patterning a particular phenomenon, considerable detail is possible through the foregrounding and backgrounding of configurational salience, and creative adjustment of design features such as texture and colour as well as the metaphors. This guards against reductionism, while expressing the paradox of diversity and generality within complex phenomena. Seed pattern can be both in the center of the PHT and around the outside, being the initial conditions of the coming into being of an entity/phenomenon, as well as expressing relationality beyond the other three patterns. Further discussion of each of the four patterns follows, with greater detail in the implementation sections.

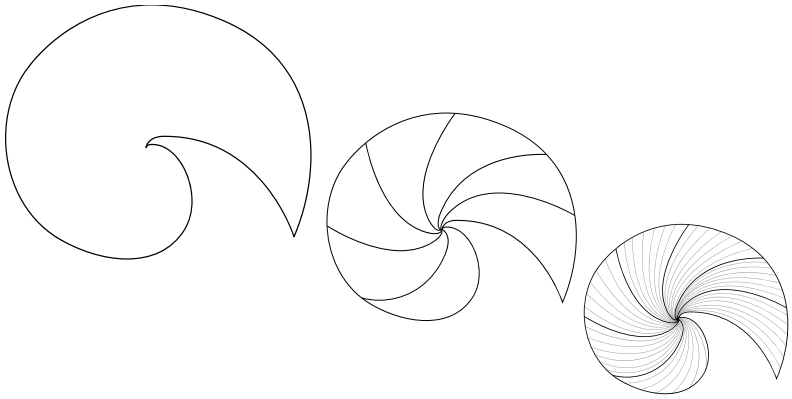

Figure 2. Spiral Patterning showing three levels. By Kylie McCaffrey for the author, from original drawings and images by the author.

7. Spiral Patterning

Spiral pattern corresponds with time as a complex phenomenon. This conceptualisation of time is designed to be useful for organising experience of time through the qualities of dynamic 'phases' based in ecological metaphors. Spiral pattern expresses the *when* of 'everything-at-once', through salient qualities of change rather than measured with numbers and fixed duration. Expressing non-linear 'rhythms' and qualities of movement and relationality, spiral pattern also corresponds with the complexity concepts of initial conditions, emergence through multicausal relational dynamics, the paradox of order/chaos, and the self-generativity of autopoiesis (Maturana & Varela, 1980), as well as the perspective of relational co-generativity described as sympoiesis (Harraway, 2017). Spiral patterning also expresses feedback loops, as well as unpredictability, thresholds and transitions. These concepts are expressed through three levels of concurrently active phases and the metaphors of phases in the lifecycle of a fruiting tree, including all conditions and associated ecological influences.

The three levels of phases express the complexity of non-linearity and multilevel concurrence of time as a complex phenomenon (See Fig. 2.). Movement as change, learning and growth, as well as the dis-integration of entropy, can skip or jump phases in spiral patterning, and/or recursively move to 'earlier' phases. Other rhythms of time such as the circadian and seasonal rhythms of earth time, the agreed rhythms of calendar and clock time as well as the linear rhythms of school time, can be engaged and mediated through the non-linearity of spiral humantime. Whilst used initially for patterning identity development as a lifetime phenomenon of learning, the spiral can be used for patterning non-linear time within any phenomenon or aspect of a phenomenon, such as a lesson, a unit of study, a meeting, project, an event or perhaps an era.

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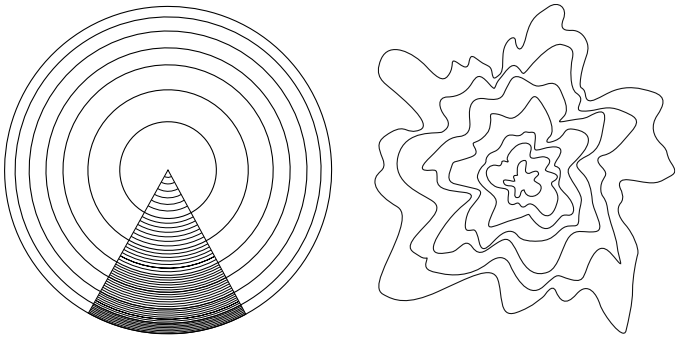

Figure 3. Spheres and Splat Patterning. By Kylie McCaffrey for the author, from original drawings and images by the author.

8. Spheres Patterning

Spheres pattern corresponds with the spatial and discursive dimensions within complex phenomena. This includes all human and non-human *where's, who's* and *what's*, as well as the *why's* that we identify with and engage, as well as those we don't identify with, suppress or exclude. Spheres patterning provides the opportunity to explore the categorisation/calibration parameters we use to understand and conceptually organise the complex phenomenon of interest. Each sphere can express a different realm of relationality, each with a different quality of dynamics and attractors (Kuhn, Woog & Salner, 2011).

Davis (2008) uses ellipses to similarly represent spatial and discursive arenas with corresponding temporalities. The use of nested concentricity has been critiqued as limited with regard to the complexity of phenomena (Barad, 2007; Bateson, 2019; Ricca, 2012), a view that considers it problematic as a fixed and essentialised representation. I argue that the use of spherical concentricity here is dynamic and adaptive, through patterning the arenas, categories and conceptualisations of place, matter and meaning that are negotiated, configured and reconfigured through our relationality with-in phenomena. These conceptualisations relate to what are described by Gregory Bateson as dynamic hierarchies of calibration, or arenas of logical type, rather than relating to a concept of fixed nested systems (1979, 2000). The number and relative size of the spheres can be adapted, as can the qualities given to the spheres. Possible impacts of these categorising decisions are included in the process, adding an explicit and critical aspect to creating knowledge of complex phenomena using the PHT. This potential of the PHT was realised when spheres was creatively adapted into an organic 'splat' pattern with the secondary students, breaking the symmetry of the spheres to more accurately express personal experience (See Fig. 3.).

Spheres pattern also moves beyond fixed nestedness by being designed with three levels, with all seven spheres repeating within each sphere (Fig. 3. shows two levels). From within the patterning perspective maintained here this multilevel concurrence of spheres expresses transphenomenal complexity. Transphenomenal is a term that describes more than one category of phenomena being experienced concurrently (Davis & Phelps, 2005). Teaching and learning is described as having a "transphenomenal character", with a concurrent diversity of temporal rhythms or transtemporality (Davis & Phelps, 2005, p. 1). The example that Davis & Phelps use describes the phenomenal categories of neural activity, the culture of teenagers, the classroom, society and the world, all as concurrently active within teaching and learning. The PHT express this concurrence across the patterns; the transphenomenal nature of spheres pattern is connected to transtemporality within the spiral pattern, through the branching of tree pattern. As all patterning 'boundaries' are porous and all segmentation internally interpermeated across levels, the spheres pattern - and indeed all of the patterns - express topological and dynamic rather than geometric relationality (Barad, 2007).

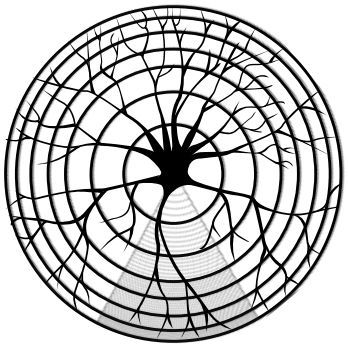

Figure 4. Branching Tree/mycelium Patterning. By Kylie McCaffrey for the author, from original drawings and images by the author.

9. Branching Tree/Mycelium Patterning

Tree pattern expresses material realisation as and within the 'body' of an entity or phenomenon. Tree patterns 'state', as well as history and potential. (See Fig. 4). The paradox of individuation and interdependence is patterned through mycelial/branching networks expressing relational flow and flux of influences, affordances and constraints from within spheres patterning. Tree pattern corresponds with the complexity principles of non-linearity, historicity, distributed causality, self-organisation, bifurcation, and emergence. Qualities and

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the effects of flows and relationships can be expressed through ecological and other metaphors, as well as design elements. Nerve cells, nervous systems, rivers and estuaries, patterns of Internet connectivity, and indeed the universe itself express the branching form (Mollison, 1988) placing this pattern as useful for understanding scale similarity. When patterned together, and considered as three dimensional, tree pattern permeates the categorisations within spheres pattern, with mycelial/rhizoid/branching expressing movement within and between the spheres and levels. In this way spheres and tree patterning together provide a starting point for creative adaptation of the PHT in relation to the complex phenomenon of focus.

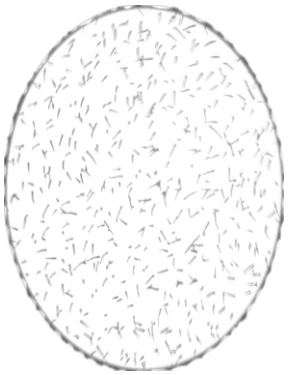

Figure 5. Seed Patterning. By Kylie McCaffrey for the author, from original drawings and images by the author.

10. Seed Patterning

Seed patterning is a simple form for assisting students to engage in a grounded way with concepts that can be challenging. This ecological metaphor corresponds with the complexity principle of chaos, through 'cycles' of dis-organisation and re-organisation of information, energy, matter and meaning. Through these attributes seed patterning expresses the paradoxical concept of phenomena dynamically at the edge of chaos as well as self-organising. In this way turbulence and change are expressed as an inherent and creative dimension of complexity rather than a force to be controlled (Kuhn, Woog & Salner, 2011). With no internal segmentation or apparent organisation other than an external and porous boundary, seed pattern expresses transformation, which can be slow or sudden, expected or surprising. Seed pattern engages with complexity thinking, understanding and knowledge production in terms of un-learning and re-learning. It also expresses what is indeterminate within and beyond the configurations of what is known and patterned using the other three patterns. Legacy is also a

central concept of engaging with seed patterning, whereby the effects, or historicity of one 'cycle' forms the initial conditions of another, with ongoing recursive iterations of non-linear non-closure. This is expressed by a small seed pattern in the center of the integrated design, as well as around the outside. Seed is designed to be the fourth pattern to be engaged, after students have had some experience with the other three patterns.

11. Implementation of the PHT during the Development Phase with Secondary Students

During teaching practice from 2005 to 2010, I observed that many of the secondary students I was teaching expressed awareness of the increasing complexity and uncertainty in their lives and in the world. Students also expressed understanding that notions of stability and certainty, including the idea of effective central control prevalent in the linear 'progress' model of modernism, had given way to a life of fluid and dynamic multiplicity in an unpredictable and rapidly changing world (Bauman, 2005, 2007; Bell, 2016; Sardar, 2015). Many also expressed frustration with curriculum content that did not engage with these developments in an immediately relevant or useful way for them. Curriculum content thus indirectly contributed to an overwhelming sense of hopelessness among the students by providing information of global problems without providing the complexity competence to engage with the world confidently. It was evident that many of the students could be considered to be 'complexity natives', with cognitive/conative/affective capacities already calibrating with multidimensionality, fluidity and change. In addition, many were motivated towards a more integrated, less disjunctive and reductionist approach to their education (Ricca, 2012). In response to these observations, I introduced the PHT and Complexity Patterning approach as a meta-curricular knowledge. Far from being a fixed knowledge that students could get right or wrong, we used the PHT to facilitate complexity thinking as an exploration of learning and life, as outlined below, through direct engagement with the dynamics in the classroom, and also as an approach to engaging with, critiquing, and applying curricular knowledge.

12. Time and Spiral Patterning

Time is documented as the most used noun in the English language (Rovelli & Boag, 2019). While it is beyond the scope of this article to discuss the nature of time, the complexivist perspective of time engaged here includes considering the multitude of temporalities within the complex phenomenon of interest and focus, and the relationship between them. This complexivist mind-set acknowledges the

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useful approximations of classical approaches to complex phenomena, and aims to be flexible enough to incorporate them within a broad complexity approach.

The spiral approach of the PHT conceptualises experienced time as a multilevel complex phenomenon. Introducing this conceptualisation of time as humantime with the students was based on two differently scaled but similarly challenging concerns with linear conceptualisations of time within education. Both concerns relate to the temporal discordance evidently contributing to difficulty for many students, according to my observations at the time. On an immediate scale, the rigidly linear view of learning and becoming that focused on the Higher School Certificate (HSC) as a 'finish line/cliff' of non/achievement was in my view inappropriately placed as the central measure of all possible learning and overall success as a human being. Based on this rigid timeline, some students expressed the hopelessness of their experience of already having 'failed' at becoming themselves, in their teenage years. These observations concur with the description by Aldaheff-Jones (2017) of young peoples' experience of temporal dissonance. Aldaheff-Jones contrasts the harmonising temporal rhythms of life and becoming as a source of coherence and increasing agency, with the dissonance of conflicting, and rigidly linear, temporality of much of education today. The author points out that this dissonance is a cause of confusion, stress and suffering that is disabling for students (2017, p. 105).

Seeking to uncouple learning and becoming from this rigid time frame, the spiral pattern was introduced to engage with learning and becoming as a lifelong and open-ended rhythming of ongoing iterations, transformations, continuities and discontinuities within emergence, both entangled and embedded within wider phenomena. This approach placed the HSC as a useful threshold for practical purposes, but limiting and potentially damaging as a measure of self-worth or capacity to learn and meaningfully engage in life ahead. Introducing the spiral pattern opened up the tight temporalities of school time and clock time, giving the students temporal breathing space. Engaging with how the complex phenomenon of humantime relates to these various rhythms of earth time, clock time, and school time, aimed to generate temporal coherence for student wellbeing and learning.

On a wider scale the spiral pattern was introduced to offer a generative conception of time more generally. The aim was to counter nihilistic, linear determinism evident within Newtonian and/or theological paradigms underpinning some areas of curriculum (Bateson, 2019; Prigogine & Stengers, 1997). Based in the generative/regenerative qualities of learning as a feedback loop within complex phenomenon (Jorg, 2017), the PHT were used to balance the evident dominance of linear deterministic ideas. This was achieved by emphasising the negentropy/organisational principle within emergence as the inseparable other side of the thermodynamic coin. In this view beginnings and

endings are considered perspectives of scale, dimension and parameter, rather than absolute moments in time. Engaging with spiral time that considers past events and those to come - including generations before and those not yet born - as enfolded in an enacted, mutually generative present is designed to contribute to a more optimistic view of time, together with an embedded understanding of responsibility (Barad, 2007).

I implemented spiral patterning to support the secondary students I was teaching to think about and understand their experience of time as a recursive, multilevel and often concurrently transtemporal complex phenomenon, and as a continuing process of learning as change (Illeris, 2007, 2009). The familiar terms 'identity' and 'identity development' were used to engage students with their experience of time, becoming and learning. Engaging with identity as a temporal phenomenon corresponds with Rovelli's description of the "Full temporal complexity of our experiential life" as "The source of our identity" amidst a patchwork of temporalities, a multitude of 'nows' with no absolute center of reference (Rovelli & Boag 2019, p. 76).

First, we discussed the idea of time as 'spiraling' rather than linear, and expressed these ideas visually. Connecting learning and becoming over a life time to this spiraling approach emphasised ongoing learning and growth cycles and emergence, with moments or durations of time as humanly delineated segments, rather than endings that foreclose possibility. It is an intergenerational and continuum of life approach that seeks to avoid temporal fragmentation. The necessity of time agreements for convenience and productivity was also explored, and the effects of these linear time frames in the students' lives and learning were discussed. This approach enabled the students to consider different temporalities or rhythms, for different aspects of life, with multilevel spiral humantime as a useful construct for self-confidence in lifelong learning.

We used the spiral patterning with three levels of repeating 'phases', expressing experienced time as a patterning of concurrently 'active' phases over all three levels. Calendar time in any one phase of the spiral pattern can be longer or shorter than in another; indeed, the 'passing' of time is expressed through the qualities of the phases rather than duration. The overall level expressed qualities of just one or two phases, as a general tendency over a 'lifetime'. The mid-level expressed seven phases. The inner level expressed a repetition of all seven within each mid-level phase (See Fig 2.). We related the qualities of the phases to the metaphor of the cycle of a fruiting tree, from seed to emergent 'harvest', and the subsequent 'processing' and 'preserving' of the emergent 'harvest' in phase six and the cyclic spiraling to 'seeding' in phase seven. These 'last' two phases express human capacity for intergenerationality, and conscious knowledge production and evolution (Laszlo & Laszlo, 2004). Movement in spiral time can be loosely or unevenly chronological or completely non-linear, with jumps to

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non-consecutive phases, and/or recursive movement to 'earlier' phases. There is room for creative adaptivity in attributing metaphors and qualities to the phases when implementing the spiral patterning in diverse settings and phenomenon of focus.

Time as spiral humantime can be experienced as having more than one phase with more than one 'quality' or 'rhythm' active. For example, a 'time' may have qualities of the initial conditions and 'beginnings' of phase one and concurrently the 'harvesting' qualities of phase five also active on another level. In an identity development example, a young person may engage with and express life through the qualities of the 'later ', 'preserving' phase, as well as an 'earlier' phase, particularly if the complexity of their lives has involved turbulence and radical emergent transformation. While an older person may express qualities of 'earlier' phases, as well as 'later' ones. Engaging with time in this way can open the temporal space within learning and identity development, and can encourage exploration of the theories, agreements and disagreements regarding time throughout history and science, as well as the different ways time is conceptualised within diverse cultures.

The students welcomed engaging with time as a rhythmic spiraling of dynamic phases, contrasting with a relentlessly linear view of time. Generally, the students expressed that engaging with time in this way relieved time pressure, as described by Aldaheff-Jones (2017). Engaging with spiral patterning supported the students to see learning as a lifetime phenomenon, as well as the possibility of a lifetime of perpetual emergence, a continual repatterning as a recalibration within opportunities to become themselves and contribute as valued members of society. The gifted and talented students in the class found the spiral patterning approach to time particularly useful, as it reconceptualised asynchrony (Neville, Piechowski & Tolan, 2013), as complexity focused multisynchrony. Gifted and talented students can be described as complex beings that are acutely aware of life as a multileveled complex phenomenon (Loveky, 2013; Piechowski, 2013; Roeper, 2013). Students who processed information in this way were assisted through engaging with the PHT design. Similarly, it showed to be useful in supporting students' understanding of the multisynchrony of their gifted classmates. I would argue also that conceptualising time as a complex phenomenon may be useful for Indigenous students. We need to counter linear conceptions of time that place Indigenous cultures as an historical artefact, which can have the effect of creating 'temporal displacement', disappearing the complex identities of Indigenous students and their cultures (Sheehan, 2018).

Complete detail of the use of the spiral patterning is beyond the scope of this paper. However, the approach showed capacity as an appropriate introduction to complexity concepts within lived experience. Further publications are planned with comprehensive explanations, and development of the PHT design into

teaching and learning materials is being explored. With experience of time thought to be based on our interpretation of causality and sequence, research on possible effects on students' conceptions of time through engaging with PHT spiral patterning may prove to be interesting to explore in further research.

13. An Identity Development Approach to Learning

Spheres and tree were used to generate patterning of the 'classroom' as a complex and learning entity. This included all dynamics and effects of different 'kinds' of influences, through 'arenas' of place, discourse and relationship, from within the room itself and all of the students, to the global environment. Tree patterning overlaid the spheres patterning to express the branching patterns of connectivity and flows of influence between the spheres, and the elements within the spheres. The process included acknowledging and patterning the vast amounts of information and energy dynamics occurring in the classroom and beyond, as affordances and constraints to learning and expression of being, as well as the paradox of the 'trade offs' between them. This is in stark contrast to the usual reductive non-acknowledgement of dynamics, with students and educators expected to ignore the 'everything-affecting-everything' occurring minute-by-minute in the classroom. By generating a shared conceptual ecology, everyone's complicity was emphasised, including my own, enhancing responsibility for the dynamics that co-generated each other's enacted identity and learning. Capacity to be safely present in the learning environment (Horsman, 2000) was supported with this identity development approach to relational learning (Brophy, 2005, 2008; Faircloth, 2009, 2012; Laszlo, 2018).

Relevance of curriculum content was also patterned into the complexity of students' lives now and ahead, with the patterns always on the board for metacognitive engagement at any time. A vital attribute of using the PHT is that the students can 'code' any individual information they are patterning through using metaphors, colours, textures and a range of other creative design features. Students are protected in this way from personal disclosure, and have agency over the patterning process. This also highlights that there is no absolutely correct way to express or pattern complex phenomena, and that each expression will be subjective as well as objective, with biased perspectives as well as a complexity of commonalities (Ricca, 2012).

14. Research Workshops with Liberal Studies Undergraduate Students

In the recent research workshops with American Liberal Studies undergraduate students, I implemented the PHT design to support the development of general complexity competence. The focus was application to the students' planned

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professional futures in areas relating to global sustainability and entrepreneurial leadership. The young people were moving towards project work with diverse peoples, providing a brief for the workshops to focus on the students' professional identity development and intercultural communication capacity. These two topic areas converged in the students' engagement and complicity with/in the overlapping arenas and dynamics of working with people in diverse cultural settings and sustainability projects. The dynamics involved include the interplay of change, unpredictability, and tensions, as well as collaboration (Deardorff, 2009, 2011; Hogan, 2013; Kurylo, 2013).

Two one-day workshops were conducted with different cohorts of students, within their regular course of study. Initially, all of the students expressed that they were not entirely sure what complexity really was. Some students knew the term 'complex systems', as a concept related to marine mangrove environments. The term 'system' was then incorporated into the workshop for continuity and was related to the boundaries constructed around certain aspects of a phenomenon for specific knowledge building and practical purposes. Using adult education principles, I facilitated the student workshops to enable mutual exploration of integrated learning, using known terms and concepts to connect to new concepts, and immediate activity-based implementation of the material.

First of all, we looked at a range of images representing branching patterns of complex phenomena across scale, including a neuron, a depiction of Internet connectivity, and a branching form representing the universe. These images introduced the students to branching/mycelial forms as literal forms of the flows and exchange of information, energy, and matter, and as a useful visual metaphor for patterning such ebbs and flows. After discussing the very general concepts of 'everything-is-connected-to-everything', 'everything-affects-everything' and the 'everything-all-at-once' nature of complexity, (Davis & Sumara, 2006), we reached a consensus that it was challenging to even begin to know how to think about an entire phenomenon. I introduced the design as a dynamic visual language for organising cognitive engagement with complexity, with the aim of enabling understanding with minimal reduction.

The patterns were each introduced as expressing a 'dimension' of complex phenomena, as outlined earlier in this paper. As a 'dimension' of phenomena, each pattern was considered as a useful perspective for seeing, understanding and/or engaging with a particular phenomenon, depending on situational factors and requirements. We discussed the usefulness of the spiral approach to time when working in contexts with diverse cultural conceptions of time. Combinations of the patterns were then discussed as a way to patterning a greater level of complexity.

As with the secondary students I used the familiar concept of identity to introduce the university students to their own experience of complexity through professional identity development. Identity is considered to be the central dynamic of importance for the development of intercultural competence (Deardorff, 2009; Kim, 2009). Intra-personal (self) understanding is considered a foundational strength for inter-personal (relational) communication across diversity according to Deardorff. As professional burnout is high in the field of global sustainability projects, intra-personal understanding became the entry point for engaging the students in Complexity Patterning their professional identity development. We engaged with the spheres and tree patterns to express the students' lives, learning and future plans, including the nuances and paradox of affordances and constraints, all as identity development. After demonstrating the use of the spheres and tree patterning through the complexity of my own professional development based in the current research, the students used a spheres template to hand draw a tree patterning overlay with the focus on their own professional development, including ongoing influences and projections into their lives ahead. They considered configurations of 'explicit/implicit' and 'available/unavailable' information, along with the concept of the 'indeterminate' and the 'emergent'. The students also created narratives as they engaged in the patterning, to understand and express the complexity-focused knowledge they were generating.

Within the students' unfolding lives and the work they would be undertaking with diverse peoples, discussion included the need for complexity awareness and management of the relational complexity of 'everything-affecting-everything'. Identity patterning in the workshops using the spheres and tree patterns, opened the students to considering that as project workers in diverse cultures they would bring an entire 'complexity' of influences and effects. The spheres and tree patterning that the students produced of their own professional identity development enabled them to see the extent of what they would contribute and/or impose in any situation of cultural diversity.

We discussed the meeting of 'two worlds', not as a meeting 'edge' between people or cultures, but as an 'interference' patterning that generates new patterns of relationality in constant dynamic process. Complexity thinking in this instance facilitated discussion of the material/discursive patterning configurations that may be active in the situations the students would encounter. Including the extensive patternings they themselves would contribute to those situations. Discussing optical diffraction metaphors of 'lenses', 'mirrors', 'reflection' and 'framing' engaged the students with thinking about the dangers of imposing and perhaps distorting or misinterpreting perception and information about complex situations, both with and without awareness, and considering the unintended effects of dissonance this may generate. Using the physical diffraction metaphor

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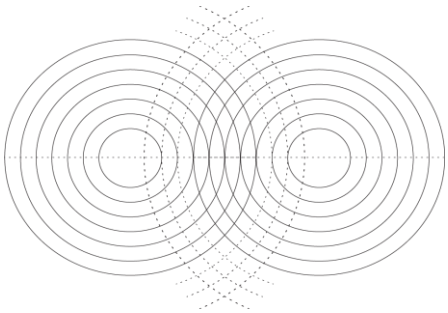
of the 'interference patterning' of two concentric wave patterns, allowed the students to express ideas of 'troughs and peaks', 'cancelling' and 'enhancing' each other as dissonance and resonance within cooperation, collaboration, conflict and how these might relate to the potential effectiveness of their project work. Diffraction as a metaphor is based in the quantum physics work of Barad (2007), describing complex relationality integrated at a more fundamental level than interaction between parts.



'Diffractive relationality'

Figure 6. Diffraction patterning. By Kylie McCaffrey for the author, from original drawings and images by the author.

Each spheres pattern concentricity was discussed as a full Complexity Patterning for the host culture and the visitor's culture respectively, or for each person of a one to one engagement. While the diffraction patterning is visually simple, after using the spheres and tree patterns together to express their professional identity development, the students easily engaged with the diffraction pattern to understand possible relationships and effects when working in settings of diversity in terms of complexity and complicity (See Fig. 6.). The centre overlapping area of the diffraction pattern can be used to express the co-mingling complexities of project and host culture. Seed patterning was not explored in any depth in these workshops, as the students were motivated to continue exploring spheres and tree pattern in particular. Further exploration of the usefulness of seed patterning within the teaching and learning of complexity competence is required. The adaptability of the PHT to the students' learning needs and interests of professional identity development and intercultural competence indicates the flexibility of PHT design.

15. Student Feedback

In an opportunity to respond to the workshops the students were asked if they would like to "Express their experience and/or perspective of the workshop?" Overall, the students indicated that they found the PHT and Complexity Patterning to be an effective approach to enhancing general complexity understanding. Many students also expressed interest in future opportunities to implement the PHT as a shared integrated conceptual ecology with diverse peoples for patterning and tracking a project in situations of complexity, uncertainty and change. The simple patterns and metaphors may support the use of PHT in settings of diverse epistemologies. Follow up meetings were held approximately two weeks later to afford the opportunity for the students to read their responses and add any additional comments, as well as ideas for the application of the PHT that may have subsequently occurred to them. Table 1. provides a summary of students' comments, organised according to the themes that emerged. Nine themes were evident in the students' responses, each with groupings of concepts. These themes covered three conceptual areas of complexity, as well as one based on the patterning itself and five relating to applied complexity thinking. One student reported that whilst they understood the complexity concepts, the visual approach for patterning information did not suit their way of learning.

The scale and scale effects theme relates to similarity of patterns and complexity dynamics across scale and local/universal connectivity. Themes of non-linearity and emergence include the concepts of interaction, connectivity, communication, and unpredictability. The theme of no-absolute centre includes distributed causality and dynamic processes, connecting to emergence. With regard to these themes I found correspondence between the arrangement of the workshop learning and processes and the emergent themes with the research of Yoon, Goh and Yang on the learning continuum of complexity concepts (2019). The five themes relating to application of complexity thinking and understanding illustrate that the students gained understanding of the ontological nature of complexity generally, and how this knowledge is useful in various areas of their learning and professional lives.

As these were introductory workshops, I suggest the students' comments clearly express the efficacy and potential of the Complexity Patterning process. The responses indicate that engaging with complex phenomena familiar to the students contributed to complexity thinking being developed as an immediately useful practical skill, reflecting the findings of Yoon, Goh and Yang (2019). An unexpected response to the use of the PHT in the workshops related to an increase in the students' understanding of their course of study, in terms of how the various subject areas within the Liberal Arts Degree Course fitted together as an

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integrated practical knowledge. This discussion expanded into how to use the PHT to pattern large amounts of the information from those different areas of study in a way that assisted integrated organisation of learning to support action in the world. Innovative creativity was evident in the research workshops with discussion of the possibility of 3D computer animations of the PHT with interactive features, leading to interest in the possibility of room size interactive holograms, and perhaps virtual reality experiences.

16. Conclusion

Complexity thinking and understanding is outlined here as a key competency for today's students. Many young people will have employment in areas that do not yet exist (Bell, 2016), and require the capacity to navigate and engage with complex change, characterised by uncertainty, indeterminacy and emergence (Thomas and Brown, 2009). Not only do students themselves require this competency, complexity thinking is also considered central to the development of pertinent approaches to their learning (Davis & Sumara, 2006; Lans, Blok & Wesselink, 2014; Montouri, 2012; Morin, 1996, 1999). As immediate examples of a complex phenomenon, and embodied experiences of complexity, identity development and the relationality of the teaching and learning experience afford the opportunity for deep complexity understanding, which can then be applied to complexity competence more widely. Complexity focused education is also notably appropriate for the increasingly imperative area of environmental education (Wiek, Withycombe & Redman, 2011). The Patterns of Humantime approach to engaging students in complexity thinking and understanding aligns with these imperatives for education. As outlined in this paper I argue that the PHT approach offers a firm foundation to the teaching and learning related to complexity competence needed by young people in the 21st Century.

The PHT design and Complexity Patterning process also contribute to knowledge of the use of visual and metaphorical approaches to applying ecological design to the teaching and learning of complexity competence. Explicit bio-inspired design is central to moving from a foundation of understanding human co-generativity within complex phenomena, to active re-generation of natural/cultural ecologies (Wahl, 2016). The limitations of the PHT in terms of correlation with complexity principles are acknowledged (Human & Cilliers, 2013), whilst emphasising its applicability as a broadly introductory and foundational approach to complexity competence. Any limitations provide possibilities for further research and creative innovation, as well as offering flexibility and adaptability in using the design within diverse situations of complexity and indeterminacy (e Cuhna & Rego, 2010). Future research directions for this work include developing teacher preparation materials and

workshops, as well as curriculum materials. The opportunity for further cohorts of Liberal Arts undergraduates to use the PHT as a project patterning and management tool for real life projects, and integration of the approach within undergraduate Environmental Science studies curriculum, are being explored.

The applied complexity perspective employed in this case study includes the understanding that emergent conditions cannot be known beforehand. Yet the notion that humans have the creative potential for imagination and generative foresight beyond current circumstances generates valid optimism (Patton, 2011). Complexity logic suggests that we can influence the future; through understanding that relationality with/in/as complex phenomenon generates the coherence required for further evolution (Laszlo, 2003, 2007). Complexity thinking and understanding through the Patterns of Humantime approach may contribute to the conditions for such coherence. While by its very nature we cannot control emergence, we can design our participation, considering the generative nature of complexity, and the generative nature of education.

Table 1. Student Responses and Themes

Theme	**Student Responses**
Scale and scale effects	*"I think it's really cool how everyone and everything is connected and you could make one of these [patternings] for any object, you could make one for this water bottle, and you could connect it to the universe, and connect the universe back to it."* *"I like that there is definition to all this as I've always thought of this as well, like how big the Universe is and how there is like scales to that vastness, the ocean is also vast, the inside of my body is also vast, there are whole different worlds within this world."*
Non-linearity and emergence	*"The way tree patterning grows and the way we can grow knowledge is emergently."* *"I like the adaptability in this, and like the idea of the ocean, like the tide goes away and goes up somewhere else and that it's like the breathing organism and that things don't move linearly, and that's ok."*
No absolute centre	*"Perspective is a big part of this. And anything, like things that we deem as not so important or a marginal issue, you could put that in the centre and you could go out from there, so I guess in terms of complex dynamic systems, you could turn absolutely anything into a complex dynamic system, because everything is a complex dynamic system,*

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	and this shows that very clearly." *"The design that you have here of a neuron, looks like the image of the Universe, when you showed us those two images, with the centre concentration of something and then it all webs out, so its incorporating the same idea of complex dynamic systems and we are seeing here with identity and everywhere else."*
Meaning making in patterning	*"Is there a meaning of going up verses going down?"* *"Sometimes you can't put ideas into words but if we start drawing something out, our minds can visualise it better than our words can organise it."* *"I feel like recently I've been thinking of time as scale, because I have been reading a lot of history, and at this time in history we are reaching a really critical moment in humanity because we have the internet, and I think that is a very big deal in the scale of time yeah so that is what the lines are representing."*
Complexity as experiential knowledge	*"I really like your description of complexity, you know it's very often times very vague, and it's used like "Oh its complex" and its used as a way of estranging the idea from yourself. I like that you made it like the complexity that I know, that I deal with every day, and what I am is complex."* *"Well yes I think we can change and these patterns can change."*
Professional identity development	*"To begin I think that this sort of knowledge is incredibly beneficial to every human being, I think that understanding your individuality is really important when interacting with another human being, and I'm now relating it to mediation."* *"I have a pretty business entrepreneurial brain and I'm always thinking of these big projects involving activism and NGO's and social media websites, but I never seem to be able to start working on these ideas because I'm always thinking so far ahead and about legal things and how its going to affect the community and there are all those things to think about. I feel like this strategy is a good way to get it all out and organised."*
Project management	*"It's pretty intimidating to look at all these layers and think where do I start? But this process shows you well, here you are and here's that, ... it makes the process of*

	reaching your goals [clearer], it illustrates it and is more sort of tangible and less intimidating." *"In terms of projects you can look at a project in a sustainable holistic manner and see how it will affect all of the different spheres of society and the nation and the world instead of just look at [temporary] solutions. It's a pretty helpful tool."*
Intercultural communication	*"There are a lot of simple things that lie within Intercultural Communications and the interconnectivity of human beings and the world."*
Knowledge integration	*"These days there is a big emphasis on, particularly in our course, on sustainability, looking at the big picture, lots of critiques on the Capitalist system and how linear it sees different issues, and I think in a program like this it would be really beneficial to have this tool known to us and have courses on it throughout the four years and maybe keep building on it."* *"I look forward to trying this approach in my research and just for any questions I have, like not knowing what to do for a thesis, I think that starting with myself and doing this is a great place to start, and also for each one of those things and seeing the questions that come up and how they overlap and it seems like a really good tool for clarity, seeing the questions you have and knowing even where to start."*

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