Original Paper

Learning Design for Sustainable Development

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Abstract

Purpose: The purpose of this paper is to theorise an approach to learning design for formal education and training contexts, which can empower the student-led acquisition of competences for sustainable development with particular reference to engineering education.

Design: the paper presents a conceptual framework which synthesises two extant bodies of empirical research (i) into the development of systems engineering proficiencies and (ii) the development of learning power and authentic enquiry.

Findings: Bringing these two research-based bodies of knowledge together enables the conceptualisation of a practical learning design which integrates the development of self-leadership, learning relationships and complex problem solving for sustainable futures. These two approaches, and their synthesis, have been implemented in practice but not reported on or theorised before.

Originality: This transdisciplinary theoretical study was undertaken by the original researchers to integrate and transcend the limitations of disciplinary and siloed approaches to learning design for 21C meta-competencies and to explore a common architecture capable of deployment over time and adaptable to different contexts.

Research limitations/implications: Whilst the two strands of research underpinning this synthesis are well researched, the integrated model has yet to be empirically verified through appropriate scientific methodologies.

Practical implications: this study provides a foundation for the development of a core curricular spine to be developed as an accreditation framework in formal education and work-based settings. The development of a rigorous measurement model has significant implications for policy and practice.

Keywords

sustainable development, learning design, competencies, systems thinking, knowledge, proficiencies, complex problem solving

1. Introduction: The Need for Learning Design for 21C Competences

We introduce this conceptual paper by exploring the notion of 21C competences and argue that although there are different interest groups and discrete bodies of literature which focus on differing societal outcomes, such as sustainability, resilience, employability or entrepreneurship – there is an underlying common pedagogical structure to their facilitation and development. Whilst there exists a proliferation of 'lists' of 21C competences that governments and policy makers around the world have identified, with a variety of labels and priorities (Voogt & Roblin, 2012), they have common antecedents and a common remedy from the perspective of learning design and pedagogy.

Essentially, they all require formal education and training curricula to move beyond a narrow set of pre-determined discipline-based outcomes, measurable through standardised testing made 'high stakes' through a neo-liberal regulatory framework, towards a learning design which values, develops, assesses and accredits a wider set of learner outcomes. Sometimes referred to as education for 'head, hands and heart' this approach counters a societal condition that Goodhart (2020) describes as 'Peak Head' where cognitive achievements are highly valued and rewarded at the expense of technical, practical abilities and at the expense of social and empathic skills.

The negative impact of 20C education systems' measurement models and regulatory frameworks was well described in a systematic review of evidence of the impact of high stakes testing and summative assessment on students' motivation for learning as long ago as 2002 (Harlen & Deakin Crick, 2003). Subsequent systematic reviews of evidence also demonstrated that education for wider student outcomes, such as citizenship, required a more holistic approach to both pedagogy and assessment (Deakin Crick et al., 2004). In the intervening years there have been many attempts to develop pedagogy and assessment for wider student outcomes strongly supported by such policy initiatives as UNESCO's report by the International Commission on Education for the 21C (Delors, 1996). Unless policy makers take this imperative seriously at a societal level – as for example in New Zealand (Note 1) – the power of the status quo presents a real challenge and education for wider 21C competences remains 'icing on the cake' rather than the production of a different sort of cake.

We seek to move beyond territorial debates about outcomes and focus on the requirements of learning design: the facilitated process through which 21C competences are developed as an outcome of a learning journey which results in the learner being able to do something in the world that they could not do before. For clarity, we use the term 'capability' to refer to the ability of a human being to do something and 'competence' when we refer to the ability of a human being to do something in a particular domain with a degree of proficiency and evidence of success. Our focus on 21c competences is on *how they are achieved* over time rather than *what they are.*

1.1 The Purpose of this Paper

Our purpose in this paper is not to debate the differences between 21C competence discourses and the associated proliferation of languages and lists, abstracted from practice, but rather to explore the commonalities between them from a pedagogical or androgogical perspective. We focus on the 'how',

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rather than the 'what', the learning processes that need to be designed, facilitated, assessed and accredited in order to embed these wider learner outcomes in mainstream curricula.

In order to ground our working theory in pedagogical practice, we draw on two independent strands of research led by the authors. Our arguments in this paper are based on the integration and synthesis of findings from empirical, theoretical and practical strands of these two bodies of practice and evidence. The first concerns the development of a competency framework derived from systems engineering proficiencies based on longitudinal and empirical studies from the Systems Engineering Research Center at the Stevens Institute of Technology (Hutchison et al., 2019; McDermott, 2019; McDermott et al., 2016; Hutchison et al., 2018; Hutchison et al., 2020). The second concerns the development of learning power, learning-how-to-learn and authentic enquiry based at the University of Bristol and subsequently the University of Technology Sydney (Crick, 2020; Crick & Jelfs, 2011; Crick & Yu, 2008; Deakin Crick et al., 2004a; Deakin Crick et al., 2013; Deakin Crick et al., 2015; Deakin Crick et al., 2007; Deakin Crick, 2009; Deakin Crick & Wilson, 2005; Jaros & Deakin Crick R., 2005). These two strands of work developed separately, in the US and the UK, over the first two decades of the 21C. The first explored the necessary conditions and processes to develop engineers into competent systems thinkers, capable of addressing and solving 21C problems and meeting the need for resilience and sustainability in engineered systems. The second explored the learning dispositions or learning power qualities that people need in order to become effective lifelong learners and engage in authentic enquiry projects which are personally meaningful and address real world, authentic challenges.

2. Methodology

In this paper we bring these two strands of research together into a generic learning architecture which we believe is applicable in a range of contexts and at a range of developmental levels and makes a novel contribution to this global debate. Our approach has involved a conceptual exploration of the underlying pedagogical variables and processes identified as important in each body of work, together with several practical implementations in user led projects. We present the generic model that has emerged from our exploration as a practical and theoretically robust contribution to the debate of this special issue.

2.1 Knowledge Generation and Agency in a Relational Context

Essentially the development of competences requires the learner to develop personal agency, or self-leadership, and to engage on a learning journey to solve a problem to which the solution is not known in advance, because it is located in an authentic place or territory, and therefore existing funds of knowledge need to be adapted to context. We have referred to this previously as the Knowledge Agency window (Godfrey et al., 2014) and present a simplified version in Figure 1. The development of competence happens in pedagogical conditions described in the top right-hand window – where students have to use their head, hands and hearts to solve complex problems: existing funds of knowledge are useful, but do not by themselves provide solutions to new problems without adaptation by the learner who is required to engage with the complexity of real-world challenges and their transdisciplinary and

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ethical implications in order to find a suitable solution. The identification of the purpose of the project by the learner is crucial, and their personal motivation and self-leadership to learn their way forwards to solve the problem is key to the learning design. Problems which do not have pre-determined solutions require problem solving skills and inevitably involve understanding and engaging profitably with complexity and uncertainty. Real world, authentic problems have ethical and relational implications – and this requires moral, relational and emotional literacy as well as cognitive capabilities.

In this way we locate our conceptual argument about learning design for sustainable development in project-based and context driven enquiry, positioned at the interface between knowledge generation and use and grounded in a generic notion of responsibility for the future of life. We seek to move the debate beyond the tired language of oppositions between the academic and the vocational, between the universal and the particular and between subject and object. Real development of competences involves all of these in a continuous cycle of learning, in an environment that enables development. We are working towards a more embodied, contextual and participatory paradigm that does justice to the complexity of what it means to be human in today's world. This theoretical approach draws on practical examples from the University of Newcastle UK, (Jaros, 2009; Jaros & Deakin Crick, 2007; Jaros & Deakin Crick R., 2005) and from the University of Bristol, UK (Blockley & Godfrey, 2017; Godfrey, 2013; Godfrey et al., 2014) and school-based research in the UK (Crick, 2009).
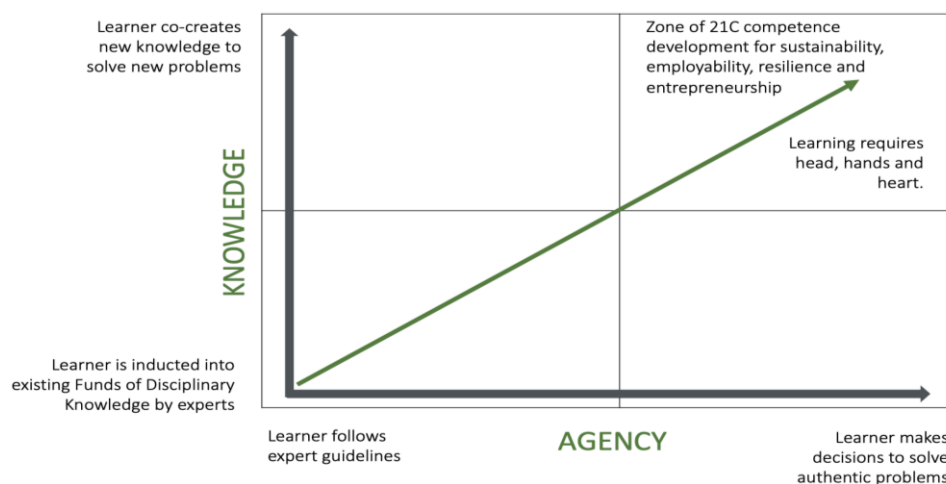

Figure 1. Knowledge Agency Window

2.2 The Language of 21C Competences: Common Themes

The language of complex problem solving, critical thinking and creativity is well documented in the global discourse about the development of 21C competences considered necessary for economic and environmental wellbeing in the 21C (Care & Kim, 2018; Gordon et al., 2009; OECD, 2012). The shift from industrial age reductionism, mass replication, and top-down decision-making to the information age focused on customization, adaptation, empowerment and speed and the concomitant ecological crisis has led to a proliferation of 'lists' of learning outcomes which education and training systems are

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called to attend to. In a significant example from the World Economic Forum, The Future of Jobs Report surveyed global human resources and strategy experts in an effort to clarify and identify this developing discourse. Their 2016 publication identified Complex Problem Solving, Critical Thinking and Creativity as the top three skills for 2020 (World Economic Forum, 2016). Figure 1 shows the evolution of the most in-demand skills over the previous 5 years. These are capabilities which require the mobilisation and the engagement of the full range of human qualities – affective, volitional, dispositional, cognitive, relational and ethical.

Most In-Demand Skills of 2015	Most In-Demand Skills of 2020
1. Complex Problem Solving	1. Complex Problem Solving (same)
2. Coordination with Others	2. Critical Thinking (+2 spots)
3. People Management	3. Creativity (+7 spots)
4. Critical Thinking	4. People Management (-1 spot)
5. Negotiation	5. Coordinating with Others (-3 spots)
6. Quality Control	6. **Emotional Intelligence (new)**
7. Service Orientation	7. Judgement & Decision Making (+1 spot)
8. Judgement & Decision Making	8. Service Orientation (-1 spot)
9. Active Listening	9. Negotiation (-4 spots)
10. Creativity	10. **Cognitive Flexibility (new)**

Figure 2. Top 10 Skills Survey Results (World Economic Forum, 2016).

The latest World Economic Forum report demonstrates this evolution more dramatically, with analytical thinking and innovation in top place, followed by active learning and learning strategies, and complex problem solving coming in third place (World Economic Forum, 2020). A notable new inclusion in this list is leadership and social influence.

Figure 3. World Economic Forum Top 10 Skills for 2025 (World Economic Forum, 2020)

In parallel with this focus on employability, scholars and practitioners in Education for Sustainable

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Development, since its recognition as a field in 1992 (UNESCO, 2013), have focused on improving the relationships between humans and nature with the purpose of the sustainability of human and planetary life on earth. This has developed from an applied science approach with a positivist orientation to a range of more holistic approaches which focus on a deep transformation of the self, leading to changed values and behaviour in relation to the care of the environment (de la Sienra Smith et al., 2017; Mitchell et al., 2004; Stevenson, 2013).

The key competences for sustainable development in use in higher education have been reviewed and summarised as falling into broad categories of (i) responsibility (values, ethics, reflection) (ii) emotional intelligence (transcultural understanding, empathy, solidarity, compassion) (iii) systems orientation (interdisciplinary) (iv) future orientation (v) personal Involvement (self-motivation, learning, motivating others) and (vi) the ability to take action (participatory skills). The analysis pointed out that, despite valuable efforts, the integration of competences for sustainable development in higher education is too implicit, too fragmented, and incomplete. Lambrechts et al.'s (2013) conclusion is that although Universities have generally embraced the *language* of sustainable development, the *integration* of such competences into curriculum in general and within subject disciplines is too implicit, too fragmented, and incomplete (ibid). The 'why' and the 'what' are generally agreed – the challenge is in the 'how'.

Sipos et al. (2008) describe an emergent property of curricula that meet these learning objectives as transformative sustainability learning, which are framed around cyclical processes of innovation, implementation and reflection. They are organised around 'head, hands and heart' balancing cognitive, psycho-motor and affective domains of human development.

In the field of education for employability, the focus is on the development of skills and traits for entrepreneurship which are presumed to help individuals cope with the uncertainty, risk and ambiguity which characterise contemporary market economies (European Commission, 2006; Klapper et al., 2015). Pedagogy for entrepreneurship requires non-standard curricular approaches which do justice to the heterogeneity of entrepreneurship – its domains of application as well as the range of human capabilities it draws on. Fletcher and Watson (2006) suggest that it is about the processes of creativity and innovation – where the solution to the problem being addressed is not known in advance. Pillay and James (2013) argue that traditional subject based curricula have limited effectiveness in entrepreneurship education because they don't cater for different types of learners nor do they prepare learners for the 'real world'.

Although these two emergent discourses around sustainability and employability can be understood as mutually exclusive - because unbridled economic and technical growth has fuelled the climate crisis - together they point towards a common need for a renewed pedagogical framing for both formal education and work-based learning and development. Such framing needs to enable a wider, more holistic and grounded set of human learning outcomes which are valued through assessment and accreditation. Indeed, there is growing evidence that the interdependence of economic, environmental

and social wellbeing is increasingly understood as this quote from the preface to the Institution of Civil Engineers report on a Systems Approach to Infrastructure Delivery demonstrates:

> *Reflecting on the evidence we have gathered, it is abundantly clear that continuing as we are is not an option. Big generational challenges such as the UK's commitment to a net-zero carbon economy are adding further layers of complexity to what we do. Technology in areas such as communications, transportation and power generation, distribution and storage is evolving at such a pace that it is forcing a change in how we design, integrate and commission infrastructure systems.* (Institution of Civil Engineers, 2020, p. 3)

2.3 Towards A Generic Learning Design Architecture

An analysis of the multitude of approaches and lists, combined with our own research outcomes, indicate that there are three essential and inter-related psycho-social processes which together support the human ability to evolve intelligently and to engage in practices in education, workplace and community which contribute to the sustainability of the range of systems that humans inhabit. These are 1) Self-Leadership, (2) Learning Relationships and (3) Complex Problem Solving. These psycho-social processes are distinct but interdependent and develop iteratively through practice in authentic contexts. Each involves evolutionary learning, and each integrates affective, cognitive and volitional capabilities. Drawing on interpersonal neurobiology (Siegel, 2012), we have defined these as the process through which humans regulate the flow of energy, data and information over time, in the service of a purpose of value (Deakin Crick et al., 2015). Our core argument is that each of these processes can be facilitated, measured, assessed and accredited as flows of futures oriented, self-directed change which are necessary for the development of competence in any domain.
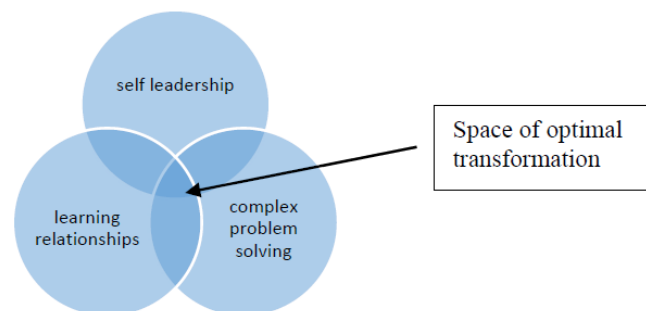

Figure 4. Optimal Transformation at the Intersection of Three Core Systems Thinking Processes

Traditional education systems do not assess or accredit these processes and thus they are not equally valued outcomes alongside more traditional learning outcomes. The reason why they are important is firstly because of the unprecedented need for innovation in knowledge generation and use and secondly because the future of life on earth requires a participatory morality focused on sustainability, resilience and wellbeing. Both of these societal goals need individuals to be able to align around a shared purpose and be capable of systems thinking and productive engagement with complexity in a pursuit of their goals.

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In a work or project context, this means that there is an alignment between the agency and purpose of the individuals, the teams and the organisation/s involved. People do not learn effectively unless they have a reason to – and if that reason is intrinsic then purposeful agency is stronger and learning how to learn will follow. Sustainability and resilience are properties of systems and represent a social outcome that invokes a sense of moral purpose for many people, which describes a measurable future, and this provides a stimulus for transformative learning. The moral purpose is the 'sustainability of human and planetary life'. Resilience as a property of a system that can adapt and respond effectively to uncertain and challenging future shocks is necessary to achieve that purpose. By attending to the development of each of these three core human processes, aligned around the purpose of sustainable development, we can begin to map out key elements of a learning infrastructure that will support the learning and development of people able to identify, address and find sustainable solutions for complex problems.

Having argued that self-leadership, learning relationships and complex problem solving are core human processes to be accounted for in learning design for 21C competence development, we now focus on complex problem solving as a bridge into formal curricula and project based professional learning design with particular reference to the domain of Engineering, drawing on our work in the Helix Project (Hutchison et al., 2018, 2019). We do this to explain why complex problem solving is fundamental to learning design for sustainable development competences. We will argue that complex problem solving is key to sustainable development, that it requires systems thinking and that it is already, to some extent, embedded in project development in Engineering contexts.

2.4 Complex Problem Solving: An Overarching Competence for Sustainable Futures

The paradigmatic shift in the human relationship to bodily life on this planet caused by an unprecedented growth of the human power to manipulate flows of energy has changed the way human beings experience the world. In particular, knowledge and its manifestations are no longer 'out there' to be mastered from a centre, acquired and used. The top-down theorising à la Kant or Newton can only be confined to front line research in a few specialities. New technologies have challenged the boundaries separating traditionally 'autonomous' domains of science and morality, nature and culture, but also of memory and consciousness, of duty and right, of cognition and affect (Jaros & Deakin-Crick, 2007). Many scholars have abandoned Cartesian causal, linear systems of thought in favour of models of society based on the theory of complex systems and new materialist thinking. To bring the educational curriculum closer into contact with the material condition of humanity today means simply to take this new condition on board and to create learning architectures which enable individuals and teams to productively navigate the intricate webs of connections, relationships and networks which they inhabit, with self, with others and with the natural world. This needs to be done on such a way that it opens up fresh opportunities for creating a consensus about the notion of stability and sustainability of life on this planet without destroying the technological base on which our prosperity depends.

It is in this context that complex problem solving emerges as an overarching competence: an outcome that should arguably be an entitlement for all learners as a core 'literacy' developed throughout an

educational career and then pursued in professional learning in the workplace in all domains. Complex problem-solving re-sequences the learner's encounter with existing funds of relevant knowledge: it is grounded in a context-based, purposeful and agent-driven approach, in which the capability to postpone resolution, to embrace 'ontological (quantum) in-determinacy' and to respond appropriately to emergence is key (Juelskjaer, 2020). It requires what O'Donnell (2013) describes as the need for creating educational 'atmospheres' which support the capacity to receive the unpredictable and invite surprise. In the process of doing so, learning one's way forwards becomes a way of establishing one's identity and purpose in the material world, or a Frieranesque 'naming of the world' (Freire, 1972). It is an 'integrative, whole body process that consists of rational, intuitive, affective, sensory and volitional ways of knowing' (Clark, 1997). The learning agent is a complex, relational organism, engaging in evolutionary learning (Blockley & Godfrey, 2017) and pursuing an impelling purpose, interrogating layers of meaning and complex interdependency the context of ubiquitous change. Such a competence is not acquired and individually held – it is in the words of Juelskjaer, 'radically entangled becoming with no fixed beginning or end' (ibid, p. 57).

2.5 Complex Problem Solving Requires Systems Thinking

Sustainability and resilience are properties of a system. Achieving a sustainable future in any domain is a complex challenge. The human capability underlying complex problem solving is sometimes referred to as systems thinking particularly – though not exclusively - in engineering contexts. This capability is difficult to instantiate in an organization because 'Systems Thinker' is not a defined organizational role, and the development of systems thinking is highly experiential – it needs to be learned 'on the job' and involves the cognitive, affective, volitional and relational aspects of human development. It is equally difficult to instantiate in a formal education system because curricula, assessment and accreditation systems remain discipline bound within the wider silo of the formal learning institution abstracted from practice in industry. Systems thinking is a process of identifying, analysing, conceptualizing, and then composing solutions to situations, problems, or opportunities. It is most useful in situations where complexity is high: where scale, uncertainty, newness, or external uncertainty drive project risks and success. In simpler, routine situations, solutions can be developed using well-known disciplinary methods drawing on existing funds of knowledge. In complex situations, systems thinking brings a set of learning dispositions, values and attitudes, thinking skills and tools needed for higher-level problem solving and decision-making and the generation of new knowledge precisely because the solution is not known in advance. The practical application of systems thinking focuses on 'simple tools for complex problems'. Proficiencies in using these tools can be acquired 'in the lab or the training room' but are more difficult to apply effectively in context – they generally must also be learned experientially for effective application and the development of competence. This is why a robust learning architecture for work-based learning is important.

2.6 The Imperative of Sustainable Development in Engineering

The landscape of engineered systems is changing. The pace of technology innovation continues to speed up. Data is increasingly open and available for analysis. Everything is becoming interconnected,

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and complex global systems of systems abound. Automation and user customization make systems more efficient, configurable, and adaptive. Meanwhile challenges abound – sustainability and resource use, balancing openness versus security and privacy, high assurance and safety, ethics, and scale. The number and complexity of relationships in modern systems force engineering teams to deal with issues well beyond their discipline. This is context for the imperative of attending to sustainable development competences in engineering education and practice (McDermott et al., 2016).

Sustainability projects often require a re-engineering of the world as we know it today. Synthesis of multiple disciplines and practices into a new whole is an engineering challenge that spans technology, policy, economics, environment, and social relationships. However, engineering is generally a reductionist process. Problems are decomposed into smaller and smaller boundaries until a set of deterministic abstractions, or rules, can be applied to solutions. Systems thinking runs paradoxically counter to reductionist practices. In the face of complexity or uncertainty, we are encouraged to "zoom out" to a more holistic view of the problem space, in order to synthesize solutions that have qualities that appeal to the whole. Lawson provides a "universal mental model" of systems thinking in the problem/solution space, shown in Figure 5 (Lawson, 2010).
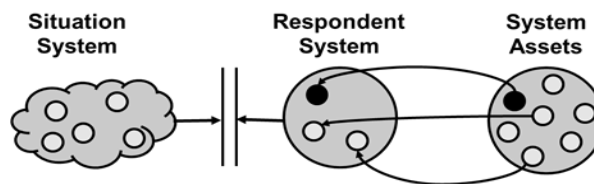

Figure 5. Universal Mental Model of Systems (Lawson, 2010)

Lawson visually expresses the idea that a response to a problem should be viewed more holistically in the situation where it exists; that solutions should not be determined individually, but as part of a response system; and that the situation and response are initially decoupled, requiring learning over time. Systems thinking is an approach which addresses this challenge – it is a way of thinking about complexity combined with specific tools and approaches which enable engineers to apply systems thinking to engineering problems and thus design, implement, maintain and decommission more resilient and sustainable engineered systems.

2.7 Complex Problem Solving as Process Flow in Engineering Projects

The systems thinking process follows a sequence characterised by problem structuring, critical thinking, systems analysis, systems modelling and design – which lead to the implementation of new, more purposeful solutions. Core to this process is personal and collaborative cognitive flexibility, the ability to change one's mind, see problems from new and multiple perspectives, and respond appropriately in context. Figure 6 depicts this as a process flow leading to design activities. The inclusion of time and purpose, as key elements of this process flow is critical to our understanding of how we can design and facilitate learning for sustainable development competences in engineering.

Dörner and Funke (2017) describe complex problem solving as a collection of processes and activities related to cognitive, emotional, and motivational aspects of self, applied to dynamic situations to achieve ill-defined goals. Complex problem-solving capability is measured in relation to dynamic systems that involve many variables and processes, as opposed to static situations. In complex problem-solving, multiple stages of generalized abstract learning are required, which develop collaboratively in response to grounded and unique challenges in a particular place. These abstractions are used - through tools - to harness collective intelligence, to reflect upon, and theorise the problem, the process and the eventual selected solution.

Complex problem-solving, critical thinking and systems thinking are highly interrelated knowledge generating capabilities which are often referred to under the general term systems thinking. They are learnable human capabilities which are components of a systems thinking process that starts with a complex problem, proceeds through collaborative insight and knowledge generation, and results in families of solutions for leadership decision making. They arise from a range of personal and inter-personal learning power capabilities, particularly Mindful Agency – or Self Leadership, Curiosity, Creativity and Sensemaking. They relate directly to the capacity a person has to generate new knowledge through identifying, collecting, curating, manipulating data and information which is relevant to the problem in hand.

Critical thinking can be described as a research process where individuals explore theirs and others' mental models to gain new perspectives and overcome existing belief systems which limit or constrain the possible approaches to a problem. Systems thinking then encourages exploration of the identified situation system and possible respondent systems between internal system entities, relationships, dynamics and perspectives, as well as external ones. In the process, models and maps are used as tools to make abstract concepts visible, to harness collective intelligence, to engage in collective sense-making and to "zoom in" on more detailed models for designing solutions.

Cognitive flexibility refers to one's ability to hold in their heads, and make sense of, multiple concepts simultaneously and switch concepts contextually – in other words to learn their way forwards. It is an individual capability that is necessary to adapt one's own thinking and behaviour in response to changes in the situation – at a mature level it can be described as a paradoxical mindset (Pyster et al., 2018). It is a foundation for learning how to learn and self-leadership.
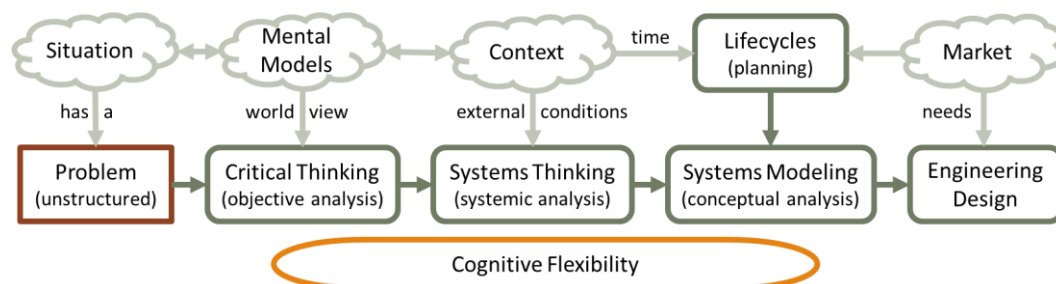

Figure 6. Complex Problem Solving and Systems Thinking as a Process Flow.

2.8 Projects as Process Flows and Human Learning Journeys

Visualizing complex problem solving as a Process Flow is important in organizing and sequencing the activities one must perform in order to learn how to learn and improve over time. It is also fundamental to learning design in formal education. It positions Process Flows as Learning Journeys of exploration rather than simply the accumulation of information or the following of a standard procedure or rule book. What can be easily overlooked by traditional engineering is the fact that this process is inspired, conceived, pursued and implemented by humans – which by definition increases the complexity of the problem exponentially because of the human agent's capability for cognitive awareness and consciousness (Goldspink & Kay, 2009). Thus, the quality of the learning agency of the individuals, teams and organisations involved in any given Process Flow is a critical success factor which cannot be ignored. The answers are not found in textbooks – people are required to engage effectively in the process of complex problem-solving, which means that the individuals, as complex organisms in their own right (Deakin Crick, 2012), need to manifest the personal and interpersonal qualities that enable them, jointly and severally, to learn their way forwards. This interface between the human and the technical is under-explored although as the many lists of 21C competences demonstrate, these are not optional extras, but are considered core to future sustainability of the human, technical and natural world.

People management, coordinating with others, negotiation, judgement and decision making are essential collaborative learning and leadership capabilities, particularly associated with learning together in teams. Creativity, emotional intelligence, cognitive flexibility and a service orientation (ability to recognize and respond to others' needs) might be categorized as personal qualities which empower and require self-awareness, self-leadership and the ability to 'lean into' the challenges of risk, uncertainty and complexity.

Whilst it is useful for the sake of learning program design to work with the categories we have identified we seek to avoid reductionism and reflect that human beings operate as complex organisms in their own right and their learning and development is grounded in their embodied engagement in the world in authentic contexts. Human decision making is influenced by a range of factors – rarely just cognitive ones – and once a team is working together within an organization, then the psycho-social learning complexity increases exponentially. One of the outcomes of the legacy reductionist worldview referred to above, is that we so often fail to address interfaces between human, technical and ecological systems in our learning infrastructures in the workplace or in formal education systems. Our earlier definition of learning power seeks to capture this complexity through focusing on learning as the ways in which humans make sense of and regulate the flow of energy and information over time in the service of a purpose of value. Regulating flows of energy, data and information are core to the understanding of the dynamics of the learning architectures we design.

2.9 Towards a Learning Architecture for Education for Sustainable Development

We now build on this framework as an imperative for the development and deployment of learning design for the development of competences for sustainable development. **Our proposal is that by**

designing learning infrastructures which support an integrated approach to self-leadership, learning relationships and complex problem solving, we are more likely to produce a workforce and leaders capable of addressing the challenges of sustainability and resilience in the 21st Century in Engineering and other domains. We summarise these as three flows of personal change below:

1. **Self Leadership: Personal Mastery Capabilities** associated with a person's orientation to learning – how they respond to risk, uncertainty and challenge and their ability to purposefully 'learn their way forwards' to design, engage, fail and learn and generate new knowledge which improves or transforms the job to be done. Described as learning power, this capability is itself 'learnable', 'measurable' and is embedded in relationships. A range of diagnostic, self-evaluation tools can support the development of competence in this process through self and peer assessment and formal evaluation.

2. **Learning Relationships: Collaborative Learning and Leadership capabilities** associated with individual and group learning capacity as it is manifested in relationships between people who are aligned around achieving a shared purpose of value. This is about collaborating in teams to identify problems, conceptualise broad responses, and compose successful new solutions which add value for the stakeholders. It is about the ability to conceptualize (model), plan for, and successfully implement transformative change. A range of diagnostic tools can support the development of competence for teams, organisations and communities in this process. This capability includes leadership as the effective harnessing of collective intelligence which arises from collaborative project-based learning: using it effectively to scale up change.

3. **Complex Problem Solving: Generating New Knowledge in conditions of radical uncertainty** which we categorize as sensemaking, cognitive flexibility, design mindset, architectural competence, and team leadership. A range of tools are available for problem structuring and knowledge generation which are linked to and employed in the engineering processes for complex problem solving. The outcome can be assessed and accredited – as can the process of the learning journey undertaken by the individual or team that propose the outcome.

These three flows of personal change are most effectively developed in authentic contexts, where individuals and teams work together on projects which require complex problem solving. Self Leadership and Learning Relationships, sometimes called 'soft skills', are developed from the 'inside out' – they are part of person's particular purpose, personal narrative, identity and learning dispositions. They are developed through learning relationships with self and others – the ability to reflect mindfully on one's personal processes, either alone or in the context of coaching type relationships. Complex problem solving requires a particular 'way of thinking and feeling' as well as a range of strategies and the tools that scaffold them. Each of the core processes operate at different levels of maturity and sophistication: we argue that they operate in junior classrooms and nurseries as well as in corporate executive leadership contexts. The language and particular focus may vary depending on the domain of their application and their sophistication varies with maturity. There are multiple languages in use which describe them.

When they are designed and attended to together in the process of Work Integrated Learning Design, these three flows or processes create positive reinforcing loops for an individual, their teams, the learning organization and community. They provide an infrastructure for learning how to learn 'on the job' or for 'double loop learning' – an essential element of a self-organising complex learning system (Bateson, 1972). This quality of intentional evolutionary learning cannot be mandated: an organization can only create the conditions which best support it and reward the development of competence in these areas as it emerges. It depends on the motivation and agency of the individuals and the will of the leaders: it is 'inside out' change. However, the development of proficiency in the technical strategies and tools for complex problem solving in engineering projects can be required, taught, evaluated and rewarded through more familiar performance management strategies and more traditional curricula and methods, ideally in the context of their application rather than extracted from practice in the 'lab'. Furthermore, these flows of personal change do not negate the need for foundational subject matter and domain expertise. They provide a central spine for a curriculum, rather than replacing students formal encounter with existing funds of knowledge and technical applications.

We now turn to each of these processes and explore how they operate in more detail. We do this in the context of an Engineering Project in order to ground our argument in rigorous practice. This builds on the two strands of research evidence that we integrate in this paper (i) building systems thinking capabilities as they are required in the Engineering Process and (ii) developing learning power in authentic enquiry projects. Our purpose is to demonstrate the need for an integrated approach to learning design which can operate at the interface of technical, ecological and human systems and draws on the full range of human learning processes.

2.10 Unpacking Complex Problem-Solving Capabilities: Defining Variables for Systems Thinking in the Engineering Process

McDermott et al. (2016) developed a framework for increasing systems thinking characteristics in engineering using the categorization of sensemaking, cognitive flexibility, a design mindset, architectural competence, and team learning and leadership. These were described as five bridges between systems thinking and systems engineering. Systems thinking moves the focus from technical and project level processes to domain level processes and the optimization of architectural attributes – in other words from a reductionist focus on the technical requirements of the project itself, to the location and successful deployment of the project in a dynamic, wider political, economic, social and ecological complex system. Personal learning power and self-leadership capabilities are implicit in each of these high-level learning design categorizations for increasing systems thinking competences – indeed learning power could be understood as the personal manifestation of these public capabilities.

Sensemaking is the process of understanding connections between people, processes, and events in order to anticipate future trajectories and act effectively (Klein et al., 2006). It is a methodology of systematic and reliable dialogue," that verbalizes the situation, context, and potential outcomes focused on bridging gaps between peoples' understandings (Dervin, 2005). It is a collaborative and purposeful

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learning process of forming and reforming models that can be used to test specific representations of information (Russell & Stefik, 2007; Russell et al., 1993). In team leadership, sensemaking is a process of exploring the wider system landscape, modelling the system, and acting in the system to learn from it (Ancona, 2012). We use sensemaking as a process for structuring system understanding (problem structuring), designing and evaluating candidate responses or solutions, and aiding decision-making in early engineering project stages. Complex problem solvers use visual modelling tools to document the situation and potential responses.

Cognitive flexibility refers to one's ability to hold in their heads multiple concepts simultaneously, and switch concepts contextually. It supports our ability to be adaptive, allowing us to situationally adjust thinking and activities in response to unexpected situations. It is often computational, employing analytics and simulation to make sense of large amounts of data (or to understand when data is lacking). Complex problem solvers augment these capabilities with visual modelling tools, allowing them to situationally capture, discriminate, and filter information to maximize cognitive function. Learning power is implicit in cognitive flexibility and its more mature manifestation in a paradoxical mindset.

Design Mindset shifts the discipline of engineering from the application of established theory and practice in design and development to a participatory process of understanding form and function and an iterative process of design. Such activities will likely be part of teams, so facilitation skills are important. Again, visual modelling is a core design process, capturing early abstractions of form and function that lead to successful solutions. Learning a way forwards is implicit in a design mindset.

Architectural Competence relates to the ability to structure complex problems and to apply patterns that provide both insight and possible responses or solutions. Educating engineers in the discipline of systems thinking requires moving from disciplinary memorization or application of principles, laws, and equations toward case studies and experiences where the solutions are unknown in advance, trans-disciplinary teams are required and problem solving is a continuing adaptive process. "Architecting" a system forces the team to take a bottom-up, top-down and inside-out approach, understand context, explore organizational, technical, and business-related aspects of the system, and work together dialogically with all stakeholders to solve problems. Architecting again produces visual models - architectural views require the team to organize and discuss information, analyze context, set goals and strategy, and create models with different abstraction levels. It requires the sophisticated application of individual and team learning power.

Team Learning and Leadership refers to a knowledge exchange and transfer process through learning together, where teams move between specialization and abstraction. It requires collaboration across the team, but also a feeling of belonging and contributing to the team and the concomitant emotional safety to do so. Team leaders understand when and how to "zoom out" to explore new pathways in a project and know how to facilitate the sensemaking process allowing the team to learn and adapt together. This includes the intellectual humility to know what they don't know and the ability to listen deeply to alternative perspectives and the courage to pursue new avenues. In complex situations, the ability to

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visualize the situation and potential solutions is critical, as visualization tools are the framework for knowledge transfer and learning together (McDermott, 2019).

Figure 7 relates these Complex Problem-Solving capabilities to the process flow or learning journey of complex problem solving. The process view of complex problem solving is surrounded by these five competency sets, all of which require the problem solver to use tools to capture the products of the core processes visually to aid in knowledge development through learning together and transfer across teams.
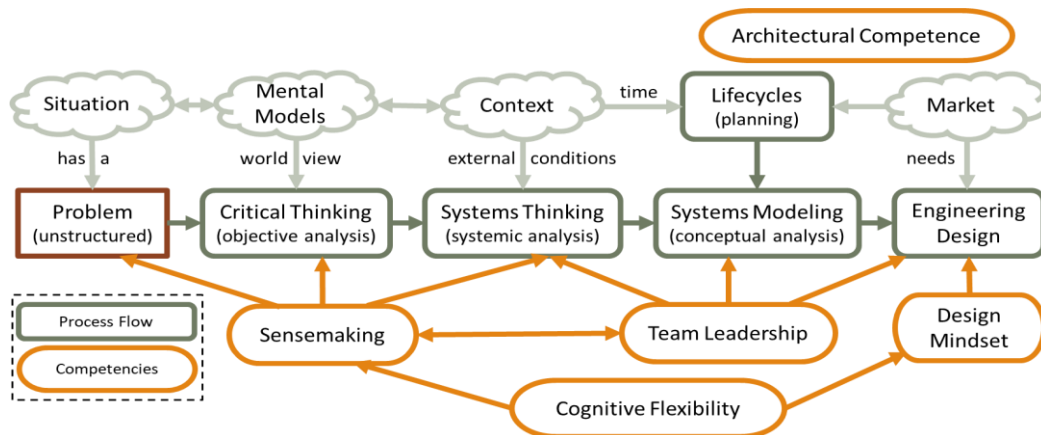

Figure 7. Five Complex Problem-Solving Competencies Supporting the Complex Problem-Solving Process

2.11 Development of Personal Learning Power and Self Leadership

In complex problem solving, knowledge exchange and transfer within and across social networks is critical and knowledge visualization is a primary tool for developing shared understanding as a foundation for generating new knowledge. The complex problem-solving process can be viewed as a set of iterative human social learning cycles (McDermott, 2019). The relationship between the process of critical thinking, systems thinking and design, and the personal and relational learning capabilities of the individuals on the team – and their wider stakeholders - has not been emphasized enough in the literature in either pedagogical design, delivery or assessment. To develop effective problem-solving skills, one must focus on both the process view and on the inter- and intra-personal skills related to learning (Godfrey et al., 2014).

Learning is itself a social process which involves the learner-in-relation to themselves, to others and to their environment. Learning is complex and relational and is itself learnable, and Bateson (1972) refers to this as 'double loop' learning – the reflexive, self-awareness that enables a person to learn how to go about doing something, and thereby to improve and intentionally transform a situation. It is an agentic, human capability that focuses 'inwards' on an agent's sense of identity and purpose and their values, attitudes and dispositions as well as 'outwards' on the ways in which that agent goes about learning and knowledge generation in order to add value in their particular context. Understood as a process, learning how to learn can be usefully understood through the metaphor of a 'journey', that begins with

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a purpose and concludes with the realization of that purpose, utilizing relationships with others, and with existing funds of knowledge and utilizing a range of types of tools to generate new knowledge in the realization of that purpose. Understood this way, learning underpins all three elements of a learning infrastructure – self-leadership, learning relationships and complex problem solving.

In learning how to learn and take responsibility for one's learning narrative there is a significant 'inward looking' process of the development of reflexive and mindful self-awareness, this entails understanding, then utilizing, one's sense of identity and purpose and one's own learning dispositions, values and attitudes (learning power) as they manifest in different contexts in order to get better at learning something and thus performing more effective solutions. Mindful Agency is a key dimension of learning power, which fuels self-leadership, and predicts a person's ability to learn in the dimensions of sense making, curiosity and creativity as well as their hope and optimism (Deakin Crick et al., 2015). Drawing on 20 years research into the assessment of learning power, learning how to learn first entails a conversation with one's Self - What am I like as a learner? Does my learning power profile ring true? How does it connect to my experience? Can I tell my personal learning story…? Secondly it looks 'outwards': how can I decide on what and how to change? How can I use my learning power strengths to develop an effective response to challenge, risk, and uncertainty? Who can I call upon to help me? How can I identify, collect, curate, and utilize the data and information I need to achieve my purpose? Who should I be learning with and from?"

Self-Leadership is a key concept in learning how to learn because it involves more than simply 'learning a set curriculum' and positions the learner as agent, identifying and pursuing his or her own purposes, developing personal qualities that enable and empower the journey and finding ways to achieve those purposes. Although learning is traditionally associated with formal education, learning complex problem-solving skills is a continual process which is embodied and enacted in the situations and choice of responses in our daily lives, in the workplace and community. Learning the skills most desired in the workforce means integrating learning with the 'job to be done' and aligning personal purpose with the business purpose (Crick, 2020). Research shows unequivocally that 'top down' high stakes assessments of formal education settings actually depress the sort of motivation for learning required for systems thinking and leading in conditions of rapid change and complexity. It impacts negatively on people's sense of professional identity, self-efficacy, and agency (Harlen & Deakin Crick, 2003).

In the framework for complex problem solving, it is critical to also include components for the individual learning capabilities, called learning power. Derived from successive studies, there are eight dimensions of learning power which can be utilized for learning how to learn and self-leadership. These learning power dimensions are qualities which people can develop and also use in knowledge generating processes – particularly useful for systems thinking, when, by definition, the solution is not known in advance. Disposition toward learning begin with mindful agency and hope and optimism. Core personal traits of the systems thinker are curiosity and creativity. Learning in teams requires both collaboration skills, and also a sense of belonging. These come together in the complex problem solver

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to combine individual openness to learning with the professional sensemaking skills (Deakin-Crick et al., 2015). Figure 6 adds the dimensions of individual learning power to the process flow and competency sets of the complex problem solver.
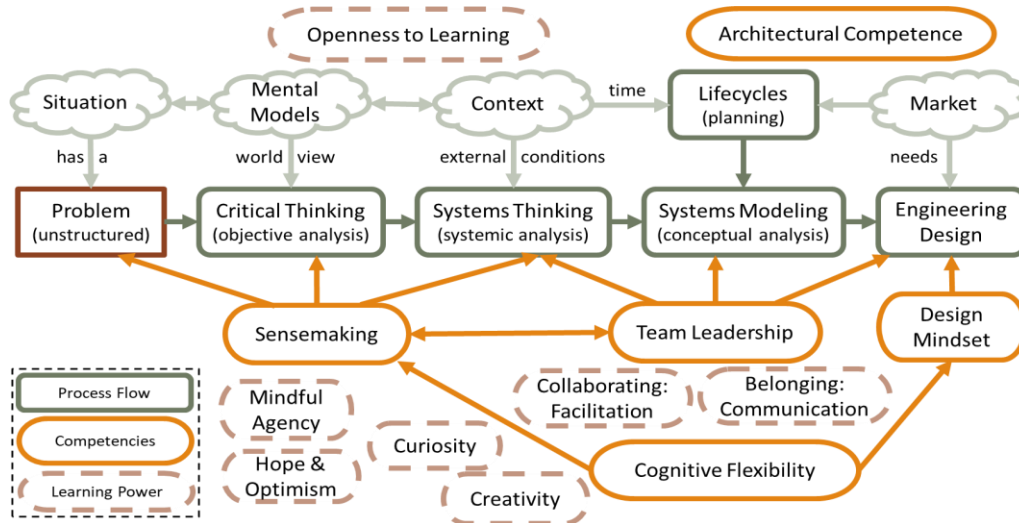

Figure 8. The Full Complex Problem Solver Capability Model

Openness to Learning is the swim lane through which the process flows. The complex problem solver must be open to new ideas and have the strength to move forward towards learning and change – to lean into risk, uncertainty and challenge, without either repeating past mistakes through rigid persistence or giving up too soon. Becoming more open to learning is the pathway to all of the other dimensions of the process.

Mindful Agency and **Hope and Optimism** are the underlying dispositions which drive change. Mindful agency is taking personal responsibility for learning and purposeful personal and professional change. It is often called self-leadership or personal mastery: becoming the pilot and not the passenger in the journey. It requires managing beliefs, feelings, energy, and actions needed to reach personal learning goals. These include learning about the situations we address. Complex problem solvers tend to be lifelong learners, applying learning power to both the problems they take on and their careers. Hope and optimism is an underlying attribute that creates confidence that one can learn and improve over time. This is often called the growth mindset. It is also important to give others on the team the confidence that they can learn and improve.

Curiosity and **Creativity** combined with **Sensemaking** are the fuel for the problem-solving process. The process begins with individual curiosity about the situation or problem. Curious learners do not just accept others' perspectives, they ask why and want to find evidence themselves for those positions. Creativity allows us to "zoom out and in" between situation and context. It allows us to explore ideas beyond our experience and to visualize them in meaningful ways to others. It allows us to dream up new questions, ideas, and answers to the complex problems we address and to access our tacit

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knowledge and experiential knowledge. Sense Making is how we synergize data, information and existing knowledge so that we can draw on it effectively in problem solving.

Collaborating and **Belonging** are the relational qualities people need to engage effectively in learning together. Collaboration is how we exchange knowledge and learn through others in our social networks. In complex problem solving, team leadership is a **Facilitation** process done in service to the team (service orientation). Belonging is the sense that you are part of a team not as a member but as a community of learning. It is knowing that you are part of a group that learns well together. It is exemplified in good team **Communication** skills. It is guided by empathy and emotional intelligence, and it results in good judgment and decision-making.

2.12 Development of Collaborative Learning and Leadership Capabilities

Whilst personal learning power and self-leadership are key to systems thinking, their application to teams through the harnessing of collective intelligence for problem solving is critical. These are often referred to collectively as 'soft skills', although their value in successful systems thinking is quantifiable in 'hard' terms. The collective learning power of a team is critical for how it proceeds in learning together; this includes the ability to listen, to articulate, present and sustain a point of view, to represent knowledge in different forms to different audiences and to co-develop new knowledge through cartography of all sorts. People management, negotiation, a service orientation and the ability to conceptualize (model), plan for, and successfully implement transformative change within a team are all foundational people skills for complex problem solving at whatever level that is taking place. Developing domain specific capabilities in 'technical' team leadership, and the soft and 'harder' skills and tools to achieve that is a key competence for effective complex problem solving.

The Learning Quotient of a team - the combination of the learning power of all members and how they interact – is critical to the success of a project and it requires appropriate organisational cultural conditions for success, such as high levels of interpersonal trust, transparency, participation and permission fail fast and learn fast on projects. Building effective teams is a familiar element of professional learning: there are many well-tried approaches that we do not need to rehearse here. What we would add, however, is an element of focusing on learning relationships and how they can be embodied and enacted, in relation to individual and team learning power: there are learning relationships of all sorts, expert, coach, mentor, peer and counsellor, though we would argue that coaching is the most effective learning relationship to support the development of learning power and self-leadership.

2.13 Bringing These Together: Work Integrated Learning Design

Together, and aligned with project lifecycles, these three processes constitute the elements of a learning design for development of competences for sustainable development. We have argued that complex problem solving and systems thinking can be seen as a Process Flow, and that learning power is the way in which human beings regulate the flow of energy, data and information in the process of complex problem solving and systems thinking. We build on our argument now by presenting way of framing this learning architecture as a practical Work Integrated Learning Design (WILD). This is by

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integrating the processes of learning with the 'job to be done', as visualised in Figure 10.

Taking a learning architecture seriously requires the ability to identify and measure the core human processes we have described. New technologies enable this in radically new ways, providing real time feedback of a range of 'fit for purpose' data which can be used diagnostically and formatively, alongside the success criteria, purposefully determined, for the project itself. This requires assessment and evaluation literacy with metrics drawn from a variety of data sources (analytical, hermeneutical and emancipatory) as well as triangulation of weights of evidence from a variety of positions. This use of data and learning analytics is not the focus of this paper but has been discussed extensively elsewhere (Buckingham Shum & Deakin Crick, 2012; Buckingham Shum & Deakin Crick, 2016).

Figure 9. Learning Integrated with the Job to be Done

What we focus on now is the 'agency' of the individual and the team engaged in the project, since purposeful agency is the driver and the source of the energy for evolutionary learning aligned to project outcomes. Projects begin with a purpose – a projected future that adds value. The achievement of that purpose requires complex problem-solving competences, often by a team of people. The alignment of project purpose, with the personal and professional purpose of the individual as 'learning agent' is key to successful learning because it will bring with it self-directed commitment. Autonomy, mastery and purpose are drivers of human behaviour (Pink, 2009) and this alignment tunes into these drivers. Sustainable development as a project success criterion is also a personal driver for many people because sustainability is a critical issue for all of humanity. The essential processes of a learning architecture require time and attention and the use of tools to facilitate and 'evaluate' such as Learning Power self-assessment (Deakin Crick et al., 2015, etc.) or Grit (Duckworth & Gross, 2014) or leadership tools (Ryan et al., 2019).

In our Process Flow, problem structuring, critical thinking, analysis and modelling follow after the identification and alignment of purpose and precede the design and implementation phase of the project. This element of the project is the critical space where team members as 'learning agents will add substantial value to the process. Described in our WILD model below as 'planning' this is the space and time for 'doing it differently' and innovation – the application of systems thinking, and the intentional, agentic development of the competences for complex problem solving described above.
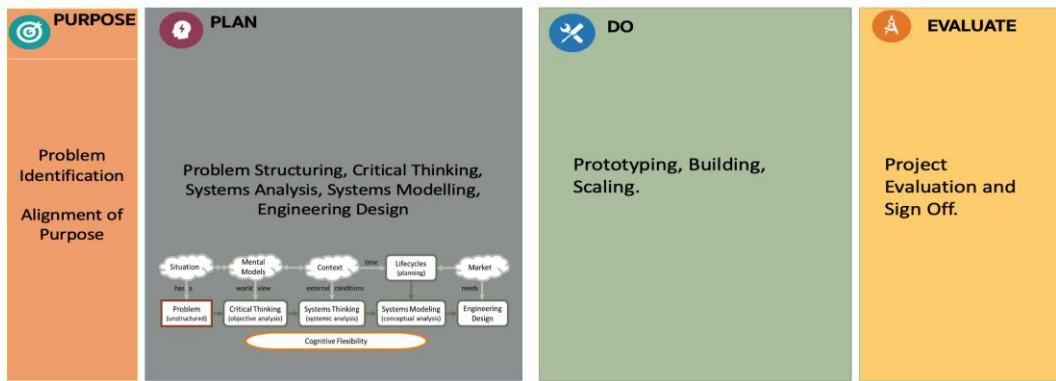
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Figure 10. Learning Journey and Process Flow

The Learning Journey Flow begins at the problem identification state and continues throughout the lifecycle of the project until sign off. Figure 11 identifies these key stages in the learning architecture for a project and Figure 12 shows how the three psycho-social processes run iteratively through each of these stages. In this model, we present a fourth process as the link between the individual's learning journey and the organisation's improvement or transformation purpose: harnessing the collective intelligence arising from authentic project-based learning marks the transition from individual learning to organisational learning. As we have argued elsewhere (Crick, 2020) the focus on coupling the knowledge processing environment (double loop learning) with business-as-usual processes (single loop learning) is key to successful organisational learning and requires a dynamic, digital knowledge base (Stary, 2014) but this on its own is not sufficient to drive the sort of changes required by the sustainability agenda. What is also required is the effective engagement of human beings with the discomfort of learning and personal behaviour change that arise from learning on the job, in authentic contexts that are personally and professionally significant. Hence, we have added a fourth process which is the bridge between personal learning and performance management and organisational learning and transformation.

Figure 11. Four Psycho-social Processes of Work Integrated Learning Design

2.14 Helix: Mapping the Life-wide and Lifelong Development of Systems Competences

In this final section we turn back to the HELIX Project to explore how WILD learning design fits

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within the wider various career stages for systems engineers. We suggest that WILD does not replace foundational discipline and subject knowledge, nor particular domain knowledge or specific technical capabilities in systems engineering. Rather it complements them as the location for their meaningful application and use. We argue that learning for self-leadership, learning relationships and complex problem solving should be an entitlement for all, but complements, rather than replaces deep disciplinary knowledge or technical capability.

This model is currently called Atlas 1.1 (Hutchison et al., 2019). Systems engineering was created as a discipline for managing complex systems and projects. Experienced systems engineers exhibit advanced complex problem-solving skills. As a framework for the development of such skills, Atlas provides a starting place. The following discussion generalizes the outcome of 'effective systems engineer' in Atlas to 'effective complex problem solver'. This change has not been validated in research but is an effective starting point for the synthesis because of its research foundation and the advanced level at which it operates. In this section we use the HELIX study and its Atlas model to propose a framework for developing complex problem-solving, self-leadership and learning relationships competences in Engineering.

The HELIX study found six proficiency or competency areas critical to development of effective systems engineers: (i) math/science/ general engineering foundations (ii) domain experience and operational context (iii) systems engineering disciplines (iv) a systems mindset (v) interpersonal skills, and (vi) technical leadership. One might view a career in the first three areas as a progression from foundational learning in formal education to experience in domain to expansion into larger systems responsibilities. The other three areas are the individual capacities and skills developed with experience and learning on the job and these relate to the three core processes of human development that are discussed in this paper.

We have generalized the Atlas model as a proficiency framework for complex problem solving as shown in Figure 13. We use a metaphor from the popular child's game of "jacks" to visually represent this, both because a "jack" rests on a three-legged foundation and because the game is one of many children's first experience with complex problem solving. Again, this theorization is not validated in empirical research but is useful for designing a career long proficiency program for the development of complex problem-solving competences.
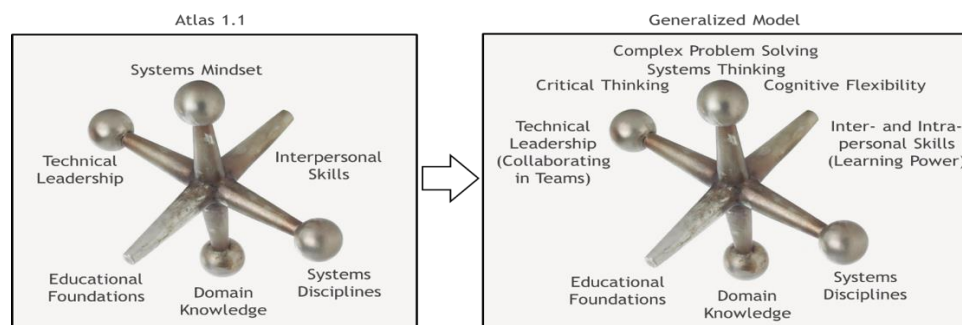

Figure 12. Generalization of the Atlas 1.1 Model to Complex Problem Solving

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The importance of the Atlas model is how it is applied in an organizational learning environment to create the desired individual competences. Figure 13 is a generalization of the Atlas model in use, diagramming how the organizational context affects the generation of learning and problem-solving skills. An "effective problem solver" would be an individual who provides consistent delivery of value to the organization using their complex problem-solving proficiencies. The Helix study determined a list of these value "products" which are relevant to the complex problem-solving domain. These are maintaining the system purpose and vision, translation between technical and operational language and views (solution versus operation in context), enabling team success, managing the "emergence" of the solution or response in the context of a project and decision-making, enabling good and holistic decisions at the system level, and supporting the business case for the system. These last three are a good definition of "architectural competence."
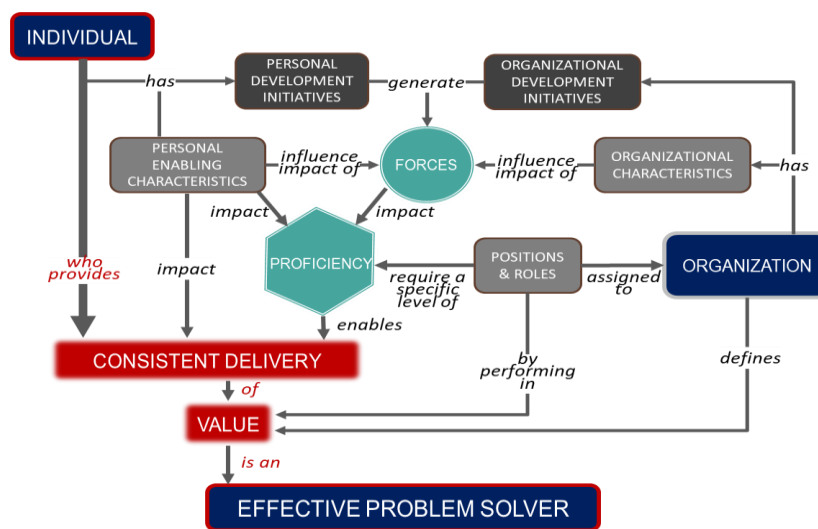
Figure 13. Atlas Model of Individual Proficiency Development

Individuals have personal enabling characteristics that impact the development of proficiencies in complex problem solving. As we have argued, the core characteristics in complex problem solving relate to self-leadership, personal learning power and learning relationships and these can be decomposed in more detail (Pyster et al., 2015; Pyster et al., 2018). The Atlas model discusses the generation of forces that affect the development of proficiencies or competences in the workplace. A complex problem solver fills a position in their organization – probably not titled or even focused on that aspect of their work. However, attainment of roles defines an employee focus and ability for work-integrated learning and problem solving. Systems thinking education must be focused on practical methods and tools that can be applied across many different roles. An individual's personal development initiatives are often linked to role.

The organization influences the forces that build complex problem-solving proficiency through not just roles but enabling organizational characteristics and organizational development initiatives. Formal education and development of experience in the systems and critical thinking processes, methods, and

tools are critical. Also critical is an orientation to working in teams. McDermott (2019) discusses the activities performed to visualize and communicate knowledge in complex situations. The organization must support periods of reflection within projects where the complexity of the situation can be reanalysed, and solutions visualized. It is easy in the pace of today's business activities for organizations to actually apply forces that inhibit cycles of learning as it takes time and often produces disruption and change. Organizational leadership must establish and incentivize a collaborative environment, support data collection and analysis activities that support situational understanding of both internal and external context, establish effective environments and times where individual can share knowledge and create shared meaning, and promote creative narrative and storytelling along with analytical data.

3. Conclusion

In this paper we have explored the commonalities in the discourse of 21C competences to identify a generic learning design focused on the development of competences for sustainable development. We have focused on the 'how', rather than the 'what', developing a learning architecture for project-based and context driven enquiry, positioned at the interface between knowledge generation and use and grounded in a generic notion of responsibility for the future of life. We have proposed that an integrated and embodied learning design will connect the intentional development of self-leadership, learning relationships and complex problem-solving capabilities, supported by subject knowledge and technical skills. This can be rigorously measured and assessed using traditional and progressive data analytics in the service of self-directed change for the individual and the organisation. Complex problem solving as a capability cannot be reduced to the cognitive and the abstract: it is irreducibly linked to self-awareness and self-leadership and the ability to form and maintain effective learning relationships, in the service of a shared purpose of value in a grounded, embodied context or place. This capability will continue to become more important as more basic skills become automated and intensely human skills like complex problem solving are prized.

We proposed a model of Work Integrated Learning Design (WILD) as a means of integrating these otherwise siloed psychosocial flows of purposeful, personal change, and position WILD as a spine for curriculum and programme planning in formal and workplace settings. In addition to designing and facilitating the self-directed development of these competences, we draw on the Helix research and suggest that WILD complements, but does not replace, students' encounters with the traditional funds of knowledge in their discipline and in particular domains, nor the disciplined development of technical skills associated with higher level systems modelling and analysis.

The link between WILD and organisational learning is in the effective harnessing and scaling of authentic learning on the job: dynamic digital knowledge bases are necessary but not sufficient. They need to be produced and used by people who are purposefully engaged in learning in authentic contexts as agents of change in an organisation or community. Complex problem solving and critical thinking proficiencies, along with individual capacity for cognitive flexibility, are not developed through roles in

the workplace and must be integrated into formal education and work based learning and performance management. This paper proposes a framework for integrating and developing proficiencies for complex problem solving, based on established research in systems engineering proficiencies and learning power. The authors are currently testing this framework in educational programs with organizations, using work-integrated learning methods.

Sustainability is a paradigm for thinking about a future in which environmental, social and economic considerations are balanced with the pursuit of an improved quality of life and the wellbeing of people and planet. It represents a major change from the previous paradigm of unbridled economic development (Basera, 2016). Paradigm shifts are always painful as Thomas Kuhn has demonstrated, plunging communities of specialists into periods of turmoil, uncertainty and angst (Kuhn, 1970) accompanied by cultural, political and social unrest. Paradigm shifts require us as human beings to re-consider how we see the world, how we know what we know and how we integrate thinking, designing and acting. These are fundamental elements of educational theory and practice with its core focus on learning design and knowledge generation. Our purpose in this paper has been to make a contribution to this state of affairs by exploring how learning design can be adapted to account for the challenges of the emerging relational and ecological paradigm. In the words of the late Sir Ken Robinson *"The fact is that given the challenges we face, education doesn't need to be reformed — it needs to be transformed"* (Robinson, 2009, p. 238).

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Note 1. https://www.nzcer.org.nz/research/key-competencies