Epistemological treatment of Design in Technology Education

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Abstract

Design as a construct has multiple meanings depending on context, function, and agenda. This paper proposes to set out functions of design as it manifests in the context of technological activity for the purposes of technology education.
The importance of context and by association intention in technological and designerly activity is presented with reference to recent reforms of lower secondary school subjects in Ireland, in an attempt to demonstrate the complexity of design's treatment in technological activity.
Critical to the success of designerly outcomes and outputs, is having a clear intention for the objectives of learning. This paper proposes a framework of articulations of design in the context of technological activity that attempts to position its utility with respect to the development of capability. Unpacking 'learning about design', 'learning by design' and 'learning to design' provides delineated intent that makes explicit learning, pedagogical, and evaluative decisions, reinforcing the position that it is what learners can *do* opposed to *know*, that is central to technological activity.

Keywords: Designerly, Technology

Context and Introduction

In this paper the term Technology is used to describe the subject area, while the term technological utilises Mitcham's typology (Mitchan, 1994) to capture the nature of the engagement beyond object and knowledge to describe activity and volition. Appreciating that there are multiple ways of knowing in Technology Education, this paper is specifically interested in knowing with respect to the treatment of design in technological education. The economic, cultural and societal impacts of design are well evidenced and underscore the case for the design related learning outcomes in formal education (Expert Group on Future Skills Needs, 2017). However, the treatment of design activity in education can be an elusive construct and it is the goal of this contribution to unpack potential epistemological treatments commensurate with the discipline and systemic articulations that define secondary school technology subjects.

This article does not intend to address design learning and the complexity that emerges from perspectives on evolutionary process, etymology, or sociological-cultural filters, instead it attempts to frame a foundational enquiry that can support the application of design as it manifests within context, intention, and expression, that is bounded by technological activity. This article is premised on a particular direction of causation, utilizing design capability and competency to develop a better understanding of technological knowledge, skills, and application in the context of innovative activity. It is this hierarchy of direction that frames the technological subject specifications for national curriculum in Ireland. The objective of this paper is not to define design epistemology, but to consider a perspective on the epistemology of design within the context of technological activity. Design epistemology has a history of debate and yet to some degree still lacks foundational definition. However, the importance of design cannot be overstated, but why is it not more fully considered and defended on its merit and contribution.

Building on the work of Buckley et al., (2021), where the alignment of design with technology is considered from the perspective of 'learning to design' and how designing as an act relates to biologically primary attributes, this paper further considers the role of design from a broader epistemological perspective. Raising questions in relation to the knowledge base, ways of knowing, and know how (Dunbar et al., 2019) that manifest in technological acts. In the absence of offering a discrete curriculum for design, the importance of the technological subjects is amplified. Integrating or emphasizing design activity in technological education moves the focus from the explicit knowledge base of critical technical processes to more implicit and tacit knowledge merging speculative and synthesising actions. This brings with it difficulties in articulating both learning outcomes and the performance of students in the discrete subject contexts. The binary perspectives of which is more important, 'the clever idea' or 'the well-executed artifact' has historically problematised the position of technological activity and has little relevance to contemporary education. A contemporary view on technological capability must embrace designerly activity as a means of mediating a more fundamental focus on critical and emancipatory education acts. With the development of cloud based advanced manufacturing capacities and open source data that democratises the application of technologies, innovation becomes a more central tenet of student learning.

There is some ambiguity that exists with the treatment of design in technological education that is not helpful when confronted with the complexities of teaching and learning practices. Often design is (unintentionally) compartmentalised by way of a process, but to ensure that its treatment is commensurate with supporting effective designerly actions and activity in the context of the discrete technological subject offering, its function must be carefully articulated. Although 'process' is a critical aspect of designing, process models are often limited by linear, formulaic, and bounded interpretations of the nature and role of designerly activity. Relying on process models that are often executed as managerial or operational models of activity to conceive and articulate design is not useful at a foundational level and falls short of a sound epistemological underpinning which needs to be adaptive to contextual demands. These models often lack the focus of educational intention and occupy the space of solution and output, avoiding the discussion on designerly activity and giving visibility to how learning is supported. Challenged by the lack of specificity to be foundational, these models are useful in progressing guided actions, but weaken their utility to be tangible in defining and supporting the development of independent and adaptive innovative activity. Supplementary to the development of technological capability and literacy, designerly activity occupies the functions or nuanced agendas that are difficult to articulate, yet lauded due to the transient utility. So how do we support 'general design ability' in the context of general technological education? We will start by examining the concept of design and then progress to how it manifests in technology classrooms.

Dyadic synthesis

A critical issue with the construct of design is that it is synonymous with a breadth of perspectives and constructs that can lack precision and as such utility. Design as a 'noun', 'verb' and 'adjective' are all reasonable and useful attributes to enact a design agenda, but ensuring that there is an explicit and shared meaning is critical in the context of education. Similarly, technology education has its own challenges with the lack of universal understanding with multiple difference international interpretations (Buckley et al., 2020) (Buckley, In Press) (Buckley YEAR) (Barlex YEAR), variances within country (Spendlove, 2017) and possible additional baggage associated with misattribution from its origins. Although this epistemological freedom supports creative, innovative activity, and volition as fundamental, the resulting pedagogical and organisational behemoth can render designerly action a significant challenge. Both technological and designerly modalities share many critical features from conception to realisation in the pursuit of outcomes of value, but it is in the synthesis of this dyadic pair that the real value of design in technology education emerges.

Design as a professional act is governed by pragmatic decisions, budgets, assumptions, expectations, resources, norms, and cultural comparisons, etc. that mediate the creative process of delivering a design (re)solution that is of value. The challenge with many design tasks in education contexts is that they are void of the parameters that provide the richness that makes interpretation of the designerly action significant. This is where the concept of problem solving (or problem resolving) challenges the parameters of the speculative and critical approach.

As a process, problem solving is not agnostic to value laden decision making and can take assumed positions, not necessarily shared with designerly activity. Defining a technical problem treats knowledge and knowing as absolute, determining the cause of the problem and working towards selecting alternatives for a solution and ultimately implementing a solution. A cyclical process of 'reflection on action', refines the goal orientated solution, within the known world. This brings with it the concept of 'optimal', considering decisions that are bound by the parameters of the syllabus. Designerly action requires a more speculative and critical approach to resolving a problem. The process relies more on heuristics than knowledge, where the rationale for actions are not always apparent, but the innovation is in bringing the best ideas to reality (Bisadi et al., 2012). So what does innovation look like in the context of technological and designerly capability? The challenge in essence, is in the treatment of design in technology education. 'Seeing the world as it could be' by making changes based on new ideas, methods and conceptions is a strong foundational idea. However, when in some incidents the intent is to learn new methods, knowledge and processes, - emphasis, balance, priority now become the central pedagogical challenge.

Both technological and designerly actions need to be situationally bounded activities, the potential formative and transformative educational impacts are limitless, if correctly harnessed. Designerly actions have unique characteristics, they can be evaluated on multiple levels, with multiple lenses. Kimbell (2011) recognises this and qualifies that success can look different for individual students. Therefore, developing students' capability to find information and make good decisions, imagine new realities and synthesis possibilities, and refine individual interpretation of interdisciplinary contexts can build confident young citizens that have the capacity to critique, evaluate, and utilise technology in a responsible and effective way.

Design as an intentional technological act

Design as a construct is both broad and vague (Expert Group on Future Skills Needs, 2017 *Pg.8*) and can be described by a myriad of design disciplines, while also being claimed as an integrated element of most functions of social, economics, and political activity. Design is a process that can be used for strategy or execution, with its function being of practical interest in technology education. It can be argued that execution of design is not a long-term skill and is a function of available materials and technologies that are ever evolving. Therefore the transactional nature of design must have a more lasting impact on the learning. This highlights the bidirectional association between design and technology, marrying propositional and procedural knowledge (Ryle, 2009) and balancing the speculative with the critical (Seery, 2017, Stables, 2008). All technologies are a result of designerly acts (Keirl, 2017, pg 22) and technologies support learning to design.

"Design is an essence of the being of every person" (Ibid), framing design as a function of innate human activity, supports both the ubiquitous and transient nature of designing, but also its elusive epistemological basis. These characteristics are both its strength and weakness when we attempt to explain it in terms of curricular intent. While design is worthy of discreet treatment, like technological education, context plays a critical function in mediating design meaning. Positioning design in the context of technology education forces us to consider multiple ways of knowing and supporting the learner with the rigour of realisation and utility as a form of proof or interpretation. Not to confirm a hierarchy, but the following quote captures the nature of knowing, that is a useful frame of reference for designs treatment in technological activity.

> "*At times I feel certain I am right while not knowing the reason. When the [solar] eclipse of 1919 confirmed my intuition, I was not in the least surprised. In fact I would have been astonished had it turned out otherwise. Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution. It is, strictly speaking, a real factor in scientific research*."
> [From Einstein, (1931) *Cosmic Religion: With Other Opinions and Aphorisms,* p. 97]

The intention of design as an integrated element of technological contexts and activity must be considered as central and foundational, inclusive of all phases of designing solutions and not just the realisation of an artefact. Conceptual and speculative design activity rely heavily on intensive phases of information gathering and processing because of problem structuring and preliminary problem-solving (Goel, (1995), Haupt, (2015), Restrepo & Christiaans, (2004). This iterative process, well captured by Kelly et al., (1987) iterative dialectic model highlights the tacit transactions that become apparent in the translations from thinking to actions. The dominance of tacit knowledge, knowledge which is acquired through practice becomes more apparent. While explicit knowledge, knowledge which is acquired through the articulated rules and process (Schmidt & Hunter, 1993) are necessary and often critical in the realisation and refining of the imagined, (Héder & Paksi, 2018). Yet, much technical and explicit knowledge is more transient, with the shifting nature of technical knowledge of objects and activity becoming more evident with advances in manufacturing technologies. Kimbell & Stables, (2007) reinforce this position by recognising that the current articulation of Design and Technology (D&T) education was a "transitory phenomenon" and that design-based learning would outline any manifestation of the subject (pg. xii). Critically it is not a question of tacit or explicit, but the utility of various ways of knowing as a function of the intended learning objective.

Polymorphic functions of design in technology education

Design has many characteristics, but its temporal relations are a critical feature in the context of education and in the context of design education it is even more significant. Historical perspective on design can engage students in discussion in relation to the issue of equity, diversity, and inclusion with a multitude of examples of where design processes lacked diverse or representative inputs and resulted in suboptimal solutions. Time as a context also ensures an emphasis on evolution, progression, and the future state. This is a critical aspect for considering sustainability, environmental, and societal issues and orienting individual agency towards the greater good and the betterment of humanity. This foregrounds the idea of social capital as an empowering agency beginning with the individual (Bourdieu, 1984). The temporal dimension of design further supports the technology education mantra of 'seeing the world as it could be' and frames a subject that embraces a critical and inquisitive disposition (Williams, 2011), giving relevance to the idea of 'optimal'.

With the overarching agendas of empowering young people through individual agency of designing new realities and learning the technical and technological knowledge and skills to realise (at least as concepts) their ideas, reframes 'optimal'. This orientation makes the function of design activity central, where the goal is as important as the solution/resolution. Critically, learning outcomes and outputs are mediated and considered with respect to the knowledge base and level of maturational experience associated with the students stage of development. Therefore all tasks and activities can be designed to balance the engagement with primary research, empathy, experience, epistemic justification, etc. appropriate to engaging in the stages and functions of design not as prescriptive engagement but naturally mediated with explicit intent.

This paper proposes the consideration of three treatments of design in the form of *learning to design*, *learning by designing* and *learning about design*. These are not intended to be mutually exclusive but delineated to demonstrate specific learning intentions. Learning to design and learning by designing interact very closely and are delineated by treating design as an outcome of learning and as a conduit of learning respectively. The model in figure 2 makes explicit the three ways in which design can manifest in technology education and their resultant intents and outcomes in any frame of reference. Although outlined as distinct components in each of their columns, learning to design, learning by designing and learning about design originate from a common treatment of design learning and work towards a common goal of developing capability. They function as a whole but are involved to different degrees depending on the intent of the task. Where intention is the single most critical factor in ensuring that the utility of design is effective and fully realised.

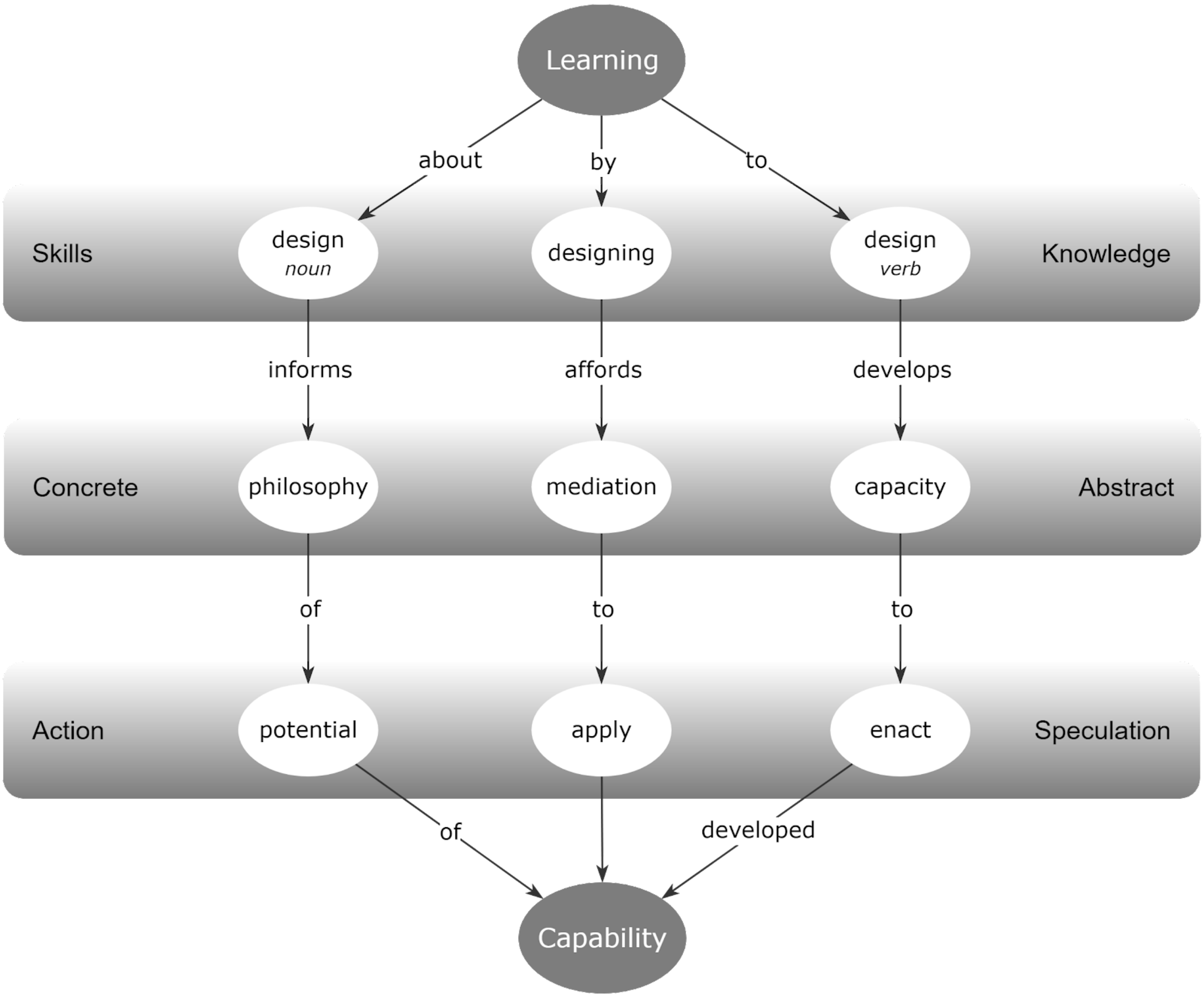

Figure 2. Treatments of Design Learning

Design as a Concept in Technological Education

Design is a broad construct that manifests differently depending on the context, with the context mediating the critical decisions that govern effective design. Design has apparent career identities and can be understood (at some level) when framed as industrial design, product design, fashion, or graphic for example. These are tangible articulations of what design is or how it relates to functions within creative and innovative activities. Focusing on a discrete design discipline or context can bring much clarity to the design activity and the associated boundaries of knowledge, application, impact, and cultural mediators. Embedding design with the context of a broad, weakly bounded (Norman, 2013, McGarr & Lynch, 2017) school subject or one that lacked 'sufficient disciplinary coherence' (Atkinson, 2017, p13), frames the challenge of how to treat design activity as a subordinate construct of curricular constraints.

Reform of UK technology education in 2013 is a useful example of how design as a discrete activity aligns with technological activity and how it can be framed within the definition of a school subject. Advocates for D&T in the UK lauded the need for design education and the significant contribution it makes to the learner, community, and economy. However, it is acknowledged that "*dividing the curriculum into subjects is never going to make it easy to develop effective strategies for Design learning"* (Norman, 2017, *pg.9).* Framing design through subject orthodoxy or as a discrete element of a subject has emerged as a real challenge, one that has not been fully rectified. This is a shortcoming that has the potential to weaken not only the potential contribution of design or its related subject, but also the definition of designerly activity and its value to learning. Discussing design education as a construct within general education, when general education is categorised by fragmented discipline structures is a challenge. Norman (2017) argues that design cannot be bounded by a subject definition and yet this is what we try to do with curriculum models. Technology education has evolved as a subject from clear utility within vocational education to a subject that now finds itself within much debate as to its position and contribution to general education.

Subject Specifications

Recent curriculum reformation in Ireland has confirmed a suite of technological subjects that are offered at lower secondary school level. Ireland uniquely maintains four contexts for the development of technologically literate and capable pupils. The subjects of Engineering, Applied Technology, Wood Technology and Graphics are discrete subjects that all aim to develop technological literacy and capability, mediated through specific technological contexts. These contexts all subscribe to the importance of design learning and its relationship with thinking, processes and execution. While these contexts are rooted in the traditional vocational medium of the parent subjects, it is not true to say that the subjects are following a derivative interpretation of the vocational role, but instead are utilizing the context as a foundational medium to further development in design, innovation, and technological capability as they are interpreted within a general education mandate. These multiple contexts for the delivery and development of technological capability in general education support a useful context for the treatment and consideration of design capability. The four subjects, all committed to the development of technological literacy and capability as appropriate to the goals of general education. However, the manifestation of design within each individual context has a nuanced treatment that supports meaning making of the disciplined knowledge and skills in the formation of solutions to design problems appropriate to each treatment.

Junior Cycle reform implemented in 2019 moved curricular articulations from explicit subject syllabi to subject specifications and as a result built a more learning centred approach to personal development, while affording the teacher more autonomy in the selection, organisation, and treatment of relevant knowledge and skills. Although design occupied an aspect of previous technological practice, it is now an explicit dimension of the revised specifications.

Supplementing the 8 key skills (*Being Creative, being literate, being numerate, communicating, managing information and thinking, managing myself, staying well and working with others* (NCCA, 2015a), each subject specification outlines specific disciplined learning strands. Each specification defines three inter-connected contextual strands that are unpacked by associated elements that ensure a coherent interdisciplinary learning experience for the students, expressed through learning outcomes. While the JC framework (NCCA, 2015a) supports a consistent approach to teaching and learning and the technological subjects are consistent in the aim of developing technologically capable and literate students, it is interesting to consider the emphasis, organisation, treatment, and function of design as it manifests in specific technology subject contexts. For example, Engineering and Wood Technology identify strands of *Design Application* and *Design Thinking* respectively, with the elements of the Engineering specification focusing on Engineering Knowledge and

Awareness, Developing and Manufacturing, Innovation and Exploration, and Communicating. The emphasis on the learning experiences mediated by the Wood Technology elements relate to, *Environment and Sustainability, Creating, Communicating, Planning and Managing*. While both subjects consider the impact of design decisions, Wood Technology purports that students will produce '*purposeful, functional, appealing artefacts*' (NCCA, 2015e, pg. 10) and *consider environmental and social impacts*. Also emphasising the need to consider materials and processes, Engineering has a similar approach but mediates activity through a different contextual lens, in the production of *functional and efficient* solutions to problems that "*consider end-user experience and the economic and social impact of the product*". Both subjects build on the creative and synergistic relationship between design and make (Norman & Seery, 2013) and purposeful application of knowledge to frame the designerly/technological act. This approach blurs the boundaries between learning to design and through design as the separation of capability and evidence of learning is not always exclusive or even apparent.

The subjects of Graphics and Applied Technology furthers the breadth of consideration for the role and treatment of design in the context of technological activity. Graphics frames the strands of *2D*, *3D* and *Applied Graphics*, while the strands in Applied Technology focus on *Principles and Practices*, *Energy and Control*, and *Technology and Society*. The transversal element of *Design Thinking* manifests in all strands of Graphics, while *Design and Innovation* is the defined design element in Applied Technology. Design Thinking is purported to develop ideas to solve real and conceptual problems utilising graphical techniques, media, and principles, where much emphasis is placed on the communication of design solutions and thinking. *Design and Innovation* encourages students to "thinking outside the box" (NCCA, 2015b, pg.11), *"considering the end user, the environmental impact and the functionality of their designs"*.

While not defined in Graphics and Wood Technology, Design is defined in Engineering and Applied Technology as *"planning the features of a solution that solves a perceived user problem"* (NCCA, 2015c, pg 22 and NCCA, 2015b, pg 23). All specifications aim *"to strike a balance between exploring the breadth of possibilities the study of the subject presents and providing opportunities for in-depth experiences of particular areas as appropriate."* (NCCA, (2015b), NCCA, (2015c), NCCA, (2015d), NCCA, (2015e)). To this end, it allows for a certain amount of flexibility and freedom for teachers to facilitate learning in a way that reflects students' own choices, their curiosity and their creativity. The achievement of learning outcomes should be planned in a way that is active and stimulating (NCCA, 2015b). For design activity to deliver on the promise of its potential, the object of the learning needs to be intentional and explicit. Teachers must be supported in navigating the complexity of designing and have the professional and pedagogical tools to move learning forward.

Learning about design

Much like the justification for the study of humanities, learning about design engages students in a conceptual frame of reference that helps them build a construct that is culturally mediated and considers factors that have influenced how we live today. The temporal dimension of designing forms a useful synergy with the humanities argument, reflecting on past evidence to better understand the implications of future decision. Learning about design can make explicit the amplifiers and filters associated with design activity and their role in the efficacy of design outcomes. This area of learning concerns itself with the development of knowledge and awareness of the potential of design to change and impact the world. Historical milestones achieved through design as well as contemporary design and innovation can be drawn upon as case studies to qualify the potential of design on society and the environment. Learning about design can provide students with a sophisticated appreciation for how design can change the world, but also recognise that design and technology are value laden activities. Understanding the environmental, societal, economic, and political agendas that influence outcomes is a critical factor in learning about design.

In the context of technology education, learning about design represents an under emphasised addition to the perception of how learners interact with design to meet the intended educational outcomes. When learners learn about design they develop knowledge about the remit of design as an institution of human capacity. The significance of this learning is based on the importance of learners gaining a broader understanding of how their agency can change the world and how design has changed the world over time and continuously. Like study within the humanities, learning about design can be a very personalised experience, engaging with various design philosophies and in fact crystalizing one's own. Without the inclusion of this broader perspective the learners' experience and construct of what design entails would depend solely upon their individual experiences of enacting designerly thinking, which can be a limiting feature of practice.

Learning to design

It is well accepted that the ability to design (in its broadest definition) is an innate human universal (Stables, 2008), the work of Nelson & Stolterman, (2003, p. 9) argues that the wheel was not a human discovery but a function of design action. They argue that design is something that we engage with in everyday activity. This natural capacity makes it difficult to capture, articulate, and therefore teach and if considered from a biological primary knowledge perspective it is not even teachable. The paradox of design as it manifests with the novice is that the motivation of the imagination is often disappointed by the realisation.

From a curricular perspective, what would be a useful scaffold to support the development of designerly capability? Building on knowledge and comprehension of design impact (but not a precondition), learning to design focuses on the development of learners' capacity to enact their designerly capability. This enactment or realisation presents the critical alignment with the definition of technological capability, bespoke to design activity. When learning to design learners are developing concrete and actionable skills which relate to the multimodal mediums through which designerly thinking manifests. Not unlike early humans' capacity to use stones, timber and vines to 'manufacture' tools that enabled them to act beyond their physical limitations and improve their situation, learning to design extends learners' capacity to utilise tools, techniques, and processes to realise their objectives.

The development of competencies in modelling and regulation of the application of different forms of modelling forms a central role in *learning to design* as modelling is the tangible manifestation of designerly thinking (Baynes, 2013, Roberts, 1992). The practical and observable nature of the outcomes of learning in this component of designerly learning fit the definition of biologically secondary knowledge (Sweller, 2011) as it relates to the development of teachable and learnable skills. The learning to design component is responsible for developing the learner's capacity to act effectively in a designerly way as reduced capacity to design can act as a limitation to the enactment of designerly thinking. This incorporates the development of skills of externalisation which, when utilised as a means of offloading cognitive demand, can facilitate more efficient ways of working with information (Sweller, (2011), Kirsh, (2017), Kirsh, (2013). When externalisation of thinking manifests in this way there are also clear implications for learning as cognitive load can be reduced and therefore more efficient acquisition and utilisation of knowledge and development of skills can be achieved. There are also implications beyond the efficiency of learning which this can potentiate in the form of task efficiency and increases in the individual's agenda in effecting change. By learning to design the individual is better equipped to act effectively when confronted with a problem or issue which requires the application of designerly thinking. This component treats design as a verb and therefore a tangible and observable outcome of learning is the proficiency with which the learner enacts designerly thinking.

Learning by designing

The constructed 'disequilibrium' (Piagetian theory) that emerges from the speculative student agency with the critical iterative enactment of designerly action, forms the basis of learning by designing. This inquiry based approach builds on experiential learning models and actionable knowledge (Argyris & Schön, 1974) that include emphasis on conceptualisation, abstraction, experimentation and concrete experiences (Kolb, 1984) with knowing in action, reflection in action and reflection on action (Schön, 1983). Learning by design recognises and affords the ability of students to develop knowledge and skills as a result of engaging in designerly actions. This approach to learning is essentially experiential in nature and represents a unique medium of learning associated with technology education through design-based activity.

The claim that people's ability to enact designerly thinking is innate holds much consensus (Stables, 2008, Baynes, 2013). This suggests that designerly thinking is biologically primary knowledge. Arguments have been made for the exclusion of biologically primary knowledge from school curricula as such knowledge cannot be taught through explicit instruction. However, this knowledge is still learnable by an individual and its development is dependent on the learner experiencing it as a capacity (Paas & Sweller, 2012). Therefore, exposure to designerly thinking is important in both the holistic development of the student and supporting the tangible delivery of curricular goals. This poses a problem from the point of view of determining explicit and tangible learning outcomes that are supported by learning through design. Learning by designing is positioned as a means of developing learners' ability to mediate the application of their capability. Such development is dependent on the learner's exposure to the enactment of designerly thinking in a diverse plethora of contexts with differing emphases on and manifestations of the forms and functions of design. Metacognitive prompts should play a critical role in the development of capability as an explicit component of the learning intent.

Treatment of design in technology education

Language development is a useful analogy for considering how design can be treated in technology education context. A person's ability to learn language is innate and therefore biologically primary knowledge. The more the individual is exposed to the language in diverse contexts and applications the more they gain an understanding and capacity to utilise that language in different contexts and for different purposes. The manifestation of grammatical language develops as an individual grows older but more importantly evolves their experience of its application. However, just because it is the case that learning their first language is innate does not mean that its application cannot be developed explicitly by way of explicit learning transactions. There are many areas of human development and educational pursuit which attest to this for example drama, creative writing, legal writing. These are defined by distinct contexts in which the application of language is somewhat required to meet certain constraints. People need to and can learn the appropriate and different ways language can be applied in these contexts. There is also a meta perspective where people can become aware of and study the language itself. Here they can learn about the language as an institution of human capacity so that they better understand its forms and functions.

This analogy presents the distinctions between:

- Learning by designing - learning through exposure as innate capacity,
- Learning to design - learning to enact as it may manifests in its most useful form in different contexts and being empowered to utilise the most appropriate form of enactment for the given context,
- Learning about design - learning about the role and capacity of design as an institution of knowledge and human endeavour.

All in the support of individual agencies.

Teacher as mediator and moderator

With clear intentions designing and making can be a powerful medium for the holistic development of the students when viewed as critical and emancipatory development. Once the intention is positioned correctly, the relationship between designing and making can ensure that students liberate their innate capacity to design. This is a critical feature of the foundational treatment of design in the context of technology education. Anecdotal evidence would suggest where there is ambiguity in the intention and function of design activity in the learning transaction, students' confirmatory position is that *'I am no good at design'* or worse teachers confirming *'they can't design'*. This anecdote, although recognisable, is restricting the very essence of innate human capacity and must be reconceived in the formulation and articulation of deignerly activity in technological education.

Understanding the intention of design activity as it supports technological activity requires the management of the dyadic modalities of technological and designerly approaches to problem solving. Amplified by the reformed positioning of the JC specification in Ireland, teachers are required to navigate the knowledge, skill, and activities that support student development. "*To this end, it allows for a certain amount of flexibility and freedom for teachers to facilitate learning in a way that reflects students' own choices, their curiosity, and their creativity. The achievement of learning outcomes should be planned in a way that is active and stimulating" (NCCA, 2015b, pg 9)".*

Many design education proponents qualify that asking the right questions begins the process of design and this phase of designing often takes an iterative path of refining the question and solution in an amalgam of possibilities, limitations, and potentials. Therefore, designing requires a compatibility of relationship between the epistemology of the subject and the pedagogical decision making necessary to ensure student success. Design has the potential to facilitate idiosyncratic ways of thinking and working, embracing a more learner centric learning. However, as a result the more fluid pedagogy required to mediate the reasoning, decision making, and articulation of proposed innovations, it becomes even more complex. Knowing about learning, enactment, and process activity falls short of knowing why and how thinking and behaviours manifest. Navigating a path through designerly activity requires a breadth of abstracted reasoning. The speculative agenda of what could be?, what might work?, what if?, are often mediated through physical and tangible interaction, as described by Kelly et al., (1987). The associated supportive and pedagogical decision making challenges the teacher to mediate and even moderate these activities as bounded by classroom, resource, and school time constraints.

The interconnection with learning about, to and through design requires skilled mediation by the teacher with critical decisions being made continually to move learning forward. When moderating what appears to be chaotic, four critical types of reasoning are useful to consider in relation to the nature of the thinking and action: deductive, inductive, abductive and reasoning by analogy (Lu and Liu, 2012). Qualifying the characteristics of reasoning are a useful frame of reference to unpack the myriad of observed activity that is typical of technological actions and more so if tasks are premised on designerly activity. For a teacher, deductively and inductively reasoning through the breadth of knowledge, processes and applications that form the bases of goal oriented tasks is complex yet apparent. Observations of these learning behaviours can logically be interpreted by the teacher and decisions on scaffolding, redirecting, critiquing, guiding can be actioned to support the learner moving forward. When reasoning requires a more abductive nature, pedagogy becomes somewhat more challenged. Lu and Liu, (2012) describe abductive reasoning as a type of '*intelligent guessing*', while Yoshikawa (1989) suggests that it is critical for design synthesis. Tangentially, reasoning through analogy circumvents the limitations of knowledge and or language to capture the ideas that have synthesised in the students mind and are described with reference to known examples or representations. The construct of creative-abductions is an early stage function of designerly activity that requires probable conclusion and speculative propositions from intangible intent and incomplete information (Lu and Liu, 2012). This type of thesis generation begins the speculative/critical actions on the students journey towards agency.

It is difficult to observe and differentiate reasoning as it is observed through process or even the output of a product. The contextual learning and reasoning supports Kimbell's (2011) position, who describes the distinctively dynamic technology learning environment as mandating the need to operate in an *"intermediate zone of activity where hunch, half-knowledge and intuition are essential ingredients"* (pg. 7). Acting on 'hunch' creates the opportunity for acquisition of a posteriori concept. The experience of thinking through and interacting with technology exposes the learner to experiences that are bespoke to the intent of the speculative enquiries and as such frames the critical relationship between designerly and technological activity in the support of learning and the development of technological capability. Considering the fragility of communicating the imagined, the role of the teacher as a mediator of the then unknown is even more critical that the usual classroom based discourse.

Conclusion

While acknowledging the impracticality that would result in separating design into mutually exclusive intentions, this paper presents a potential framework for considering the treatment of design as it manifests in a breadth of technological activity. It is intended that this framework will support teachers in the organisation of learning activities, transactions and agendas that will support the development of innate capacities, while building the technical and technological capacities to realise the imagined. Designerly activity when harnessed is a powerful emancipatory capacity that must be articulated, refined, translated and actioned as a central tenant to contemporary and relevant technological education.

References

Argyris, C., & Schön, D. A. (1974). *Theory in practice: Increasing professional effectiveness* (1st ed). Jossey-Bass Publishers.

Atkinson, S. (2017). So what went wrong and why? In *Design epistomology and curriculum planning* (pp. 13–17). Loughborough Design Press.

Baynes, K. (2013). *DESIGN: Models of Change*. Loughborough: Loughborough Design Press.

Bisadi, M., Mozaffar, F., & Hosseini, S. B. (2012). Future Research Centers: The Place of Creativity and Innovation. *Procedia - Social and Behavioral Sciences*, *68*, 232–243. https://doi.org/10.1016/j.sbspro.2012.12.223

Bourdieu, P. (1984). *Distinction: A social critique of the judgement of taste* (11. print). Harvard Univ. Press.

Buckley, J. (In Press). Historical and philosophical origins of technology education. In *In The bloomsbury handbook of technology education: Perspectives and practice.* Bloomsbury.

Buckley, J., Seery, N., Gumaelius, L., Canty, D., Doyle, A., & Pears, A. (2020). Framing the constructive alignment of design within technology subjects in general education. *International Journal of Technology and Design Education*.

Buckley, J., Seery, N., Gumaelius, L., Canty, D., Doyle, A., & Pears, A. (2021). Framing the constructive alignment of design within technology subjects in general education. *International Journal of Technology and Design Education*, *31*(5), 867–883. https://doi.org/10.1007/s10798-020-09585-y

Clark, A. (2008). *Supersizing the mind: Embodiment, action and cognitive extension.* Oxford University Press.

Dunbar, R., Buckley, J., & Seery, N. (2019). *Curriculum development for technology teacher education: Integrating pedagogy, epistemology and capability.* In S. Pule (Ed.), PATT2019: Developing a knowledge economy through technology and engineering education., Msida, Malta: University of Malta.

Einstein, A. (1931). *Cosmic Religion: With Other Opinions and Aphorisms*.

Expert Group on Future Skills Needs. (2017). *Winning by design: An introduction to the design skills required for firms to be innovative and competitive in global markets*. National Skills Council.

Goel, V. (1995). *Sketches of thought*. MIT Press.

Haupt, G. (2015). Learning from experts: Fostering extended thinking in the early phases of the design process. *International Journal of Technology and Design Education*, *25*(4), 483–520. https://doi.org/10.1007/s10798-014-9295-7

Héder, M., & Paksi, D. (2018). *Non-Human Knowledge according to Michael Polanyi." Tradition and Discovery: The Polanyi Society Periodical*. 50–66.

Keirl, S. (2017). Some thoughts on locating design knowledge. In *Design epistomology and curriculum planning* (pp. 22–27). Loughborough Design Press.

Kelly, A. V., Kimbell, R., Patterson, V., Saxton, J., & Stables, K. (1987). *Design and Technological Activity: A Framework for Assessment.*

Kimbell, R. (2011). Wrong...but right enough. *Design And Technology Education: An International Journal*, *16(2)*, 6–7.

Kimbell, R., & Stables, K. (2007). *Researching design learning: Issues and findings from two decades of research and development*. Springer.

Kirsh, D. (2013). Thinking with External Representations. In S. J. Cowley & F. Vallée-Tourangeau (Eds.), *Cognition Beyond the Brain* (pp. 171–194). Springer London. https://doi.org/10.1007/978-1-4471-5125-8_10

Kirsh, D. (2017). Thinking with External Representations. In S. J. Cowley & F. Vallée-Tourangeau (Eds.), *Cognition Beyond the Brain* (pp. 61–84). Springer International Publishing. https://doi.org/10.1007/978-3-319-49115-8_4

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development (Vol. 1)*. Englewood Cliffs, NJ: Prentice-Hall.

Lu, S. C.-Y., & Liu, A. (2012). Abductive reasoning for design synthesis. *CIRP Annals*, *61*(1), 143–146. https://doi.org/10.1016/j.cirp.2012.03.062

McGarr, O., & Lynch, R. (2017). Monopolising the STEM agenda in second-level schools: Exploring power relations and subject subcultures. *International Journal of Technology and Design Education*, *27*(1), 51–62. https://doi.org/10.1007/s10798-015-9333-0

Mitchan, C. (1994). *Thinking through technology: The path between engineering and philosophy*. University of Chicago Press.

NCCA. (2015a). *Framework for Junior Cycle*. Department of Education and Skills.

NCCA. (2015b). *Junior Cycle Applied Technology*. An Roinn Oideachais agus Scileanna.

NCCA. (2015c). *Junior Cycle Engineering*. An Roinn Oideachais agus Scileanna.

NCCA. (2015d). *Junior Cycle Graphics*. An Roinn Oideachais agus Scileanna.

NCCA. (2015e). *Junior Cycle Wood Technology*. An Roinn Oideachais agus Scileanna.

Nelson, H. G., & Stolterman, E. (2003). *The Design Way*. Educational Technology Publications.

Norman, E. (2013). Design epistemology and curriculum planning. *Design and Technology Education: An International Journal*, *18(2)*, 3–5.

Norman, E. (2017). First thoughts on design epistomology. In *Design epistomology and curriculum planning*. Loughborough Design Press.

Norman, E., & Seery, N. (2013). The Creative Relationships between Designing and Making. In *Design Education: A vision for the future* (pp. 78–86). Loughborough Design Press.

Paas, F., & Sweller, J. (2012). An Evolutionary Upgrade of Cognitive Load Theory: Using the Human Motor System and Collaboration to Support the Learning of Complex Cognitive Tasks. *Educational Psychology Review*, *24*(1), 27–45. https://doi.org/10.1007/s10648-011-9179-2

Restrepo, J., & Christiaans, H. (2004). Problem Structuring and Information Access in Design. *J. of Design Research*, *4*(2), 0. https://doi.org/10.1504/JDR.2004.009842

Roberts, P. (1992). *Of Models, Modelling, and Design: An applied Philosophical Enquiry. In P. Roberts, B. Archer, & K. Baynes (Eds.), Design: Occasional Paper No.1: Modelling: The language of designing (pp. 32–42). Loughborough University*. In P. Roberts, B. Archer, & K. Baynes (Eds.), Design: Occasional Paper No.1: Modelling: The language of designing (pp. 32–42)., Loughborough University.

Ryle, G. (2009). *The concept of mind*. Routledge.

Schmidt, F. L., & Hunter, J. E. (1993). Tacit Knowledge, Practical Intelligence, General Mental Ability, and Job Knowledge. *Current Directions in Psychological Science*, *2*(1), 8–9. https://doi.org/10.1111/1467-8721.ep10770456

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. Basic Books.

Seery, N. (2017). Modelling as a Form of Critique. In P. J. Williams & K. Stables (Eds.), *Critique in Design and Technology Education* (pp. 255–273). Springer Singapore. https://doi.org/10.1007/978-981-10-3106-9_14

Spendlove, D. (2017). Spendlove, D. (2017). Design thinking: What is it and where might it reside? In *In E. Norman & K. Baynes (Eds.), Design Epistemology and Curriculum Planning* (pp. 39–42). Loughborough Design Press.

Stables, K. (2008). Designing matters; designing minds: The importance of nurturing the designerly in young people. *Design and Technology Education: An International Journal*, *13(3)*.

Sweller, J. (2011). Cognitive Load Theory. In *Psychology of Learning and Motivation* (Vol. 55, pp. 37–76). Elsevier. https://doi.org/10.1016/B978-0-12-387691-1.00002-8

Williams, P. J. (2011). Dispositions as Explicit Learning Goals for Engineering and Technology Education. In M. Barak & M. Hacker (Eds.), *Fostering Human Development Through Engineering and Technology Education* (pp. 89–102). SensePublishers. https://doi.org/10.1007/978-94-6091-549-9_6

Yoshikawa, H. (1989). Design Philosophy: The State of the Art. *CIRP Annals*, *38*(2), 579–586. https://doi.org/10.1016/S0007-8506(07)61126-3