# Regenerative education in practice

I believe regenerative design is simply enlightened good Design. Bill Reed of Regenesis once described regenerative design as the opposite of "degenerative design"…meaning the antidote to design which, despite our best intentions, has somehow damaged the planet and risked our collective future.

In 2019, signatories to the Institution of Structural Engineers climate declaration committed: *"To adopt more regenerative design principles in practice, with the aim of providing structural engineering design that achieves the standard of net zero carbon."*

To the Institution's great credit since then it has championed practical guidance for professional engineers through its programme of Climate Action under the leadership of Will Arnold and many others.

This article is a companion to the Institution's efforts, looking at the wider context for engineering education and practice beyond Climate Action. What else will empower our future engineers to compensate for two centuries of "degenerative" design and to deliver regenerative design in its place?

Regenerative design is an emergent and broad field, the undercurrent to everything and everyone we serve, including direct and indirect clients, societies, politics, industry and environments. Although the motivation for regenerative change is perhaps most keenly felt by Millennials and Generation Z, our lack of capability in the regenerative space means everyone needs education now, whatever our vintage. Regenerative engineering goes well beyond sustainable design, so it impacts "design" in the round and drives our ongoing education and the learning we need to think regeneratively in practice.

## The imperative for change in education and practice

As context I have our professional practice at Expedition and the Useful Simple Trust, and the first year of an educational R&D initiative at the University of Bath, co-funded by the Royal Academy of Engineering. The Bath project looks at Regenerative Design Education through the lens of undergraduate teaching across all the Bath Faculty's programmes: Architecture & Civil Engineering; Chemical Engineering; Electronic & Electrical Engineering; Mechanical Engineering: in all 2,700 undergraduates.

The integration of regenerative design into structural engineering is itself a design project. Our companion professions are also in a state of flux. For example, the RIBA have updated their Plan of Work and Sustainable Outcomes Guide, and for COP26 produced "Built for the Environment" treating regenerative design as the logical extension of sustainable design without definitive recommendations.

Success in regenerative engineering will require innovation in education and in practice. Is adaptation enough, or do we need disruption and paradigm shifts? The resources of today may not be the resources of tomorrow, and we may be wrong to assume there will always be people to do the work. The likelihood is that people may not choose to work, may not need to work, or may be supplanted by non-human technology. As we have already seen, our reluctance to do manual or routine work has led to our replacement by automation. With this in mind we need to recognise the climate emergency will alter us all. Our industry focus has to be regenerative and as generous ancestors, our cultural legacy should be to help life flourish in the future as a result of the regenerative groundwork we lay now.

Education will require a curriculum which places technical knowledge at the service of progressive pro-social and pro-environmental values. Practice will need advocacy and leadership from engineers to change the rules, legislation and rewards for projects by adapting degenerative business and political models into those rewarding regenerative success. Taken together, regenerative design offers this generation of engineers every opportunity to use their skill to wield more beneficial influence than many in practice for decades.

## It's Design but not as we know it

Two decades ago Ed McCann (immediate past ICE President) and I defined engineering as "*the art and practice of changing the physical world for the use and benefit of humanity*", adapting the ICE's 1829 charter by Thomas Tredgold *"…harnessing the great forces of power in Nature…."*.

Now, inspired by the definition of regenerative design by Sarah Ichioka and Michael Pawlyn, my best shot at defining regenerative engineering for our future becomes:

*"Regenerative Engineering is the art and practice of changing the physical world to enable the flourishing of all life for all time".*

This statement implies:

- As professionals we hold the wellbeing of society and the environment in trust and so they become our significant stakeholders.
- Regenerative projects take Time and Adaptive Reuse as seriously as gravity or materials science.
- Regenerative projects are always context-driven and connected. This converts the traditional solid red line around a project into an ever-adapting semi-permeable membrane.
- Regenerative practice takes us into a connected world without definitive business models and so we need to change the terms on which we are appointed.
- Regenerative projects are open problems which cross many discipline boundaries, so we need many T-shaped generalist engineers rather than just I-shaped specialists.

By way of explanation, "I-shaped people" have a deep specialist knowledge but others to define a framework in which to apply it. "T-shaped people" reach out beyond their specialism with a working knowledge of their context.

## WIP summary of Regenerative Design for use in Project Briefs

I have gathered the thinking of many inspiring regenerative leaders into the WIP table below which distils out some key characteristics of "Regenerative Design". These are offered as ingredients of regenerative project briefs, equally relevant for academics working with students and commissioning bodies for real-world regenerative projects.

| | | | |
|---|---|---|---|
| ***Definition of Regenerative Design*** | "Regenerative design supports the flourishing of all life, for all time"<br><br>*(Ichioka and Pawlyn 2021)* | goes beyond degenerative, and beyond sustainable | Everything is connected and co-dependent<br><br>Regenerative: Humans participating as part of nature: co-evolution of the whole natural system |
| ***Design for Time*** | The planet for the first time exhibits a form of consciousness….we understand our impact over many generations | Design for possibility:<br><br>to enable the future, not to disable it | "Reduce, reuse and recycle"<br><br>upgraded to<br><br>"Restore, renew, replenish, repeat" in a self-sustaining and systemic manner |
| ***Adaptability*** | Build from what we already have<br><br>Then | Design for adaptive reuse:<br><br>Treat everything we already have as a material bank | • Build Nothing<br>• Build Less<br>• Build Clever<br>• Build Efficient |

| | | | |
|---|---|---|---|
| | Lean start: Long life: Loose fit | | This is a locally sustainable but not regenerative |
| ***Adaptive Systems Integration*** | Regenerative design is the art and practice of adaptive systems integration | Everything possible is made from by-products of a former process, fuelled by the sun | Integrate the specialisms<br><br>……be a "Specialist Generalist" |
| ***Redesign Value*** | Revalue "Value":<br><br>to an integrated set of Natural, Social, Human, Produced Value | Re-balance our use of "stuff" with empathy and equity…fair shares | This needs "Philosopher" engineers to frame the purpose |
| ***Impact*** | Balance the interests of society, environment shareholders | Treat health as a form of prosperity | Recognise the disproportionate impact of the architect and the engineer |
| ***Ecosystem continuum*** | Use local knowledge, local materials, local people for a local environment | Make multiple positive connections in space and time | Change the paradigm from discrete projects to playing a part in a continuum.<br><br>Not a note but a symphony<br><br>Treat each project as part of a wider interactive economic and ecologic ecosystem |
| ***Optimisation*** | Prototype, learn, and feedback…then do it again better | Design with waste: minimize new material and process waste | Work hardest on mass products |
| ***Nature positive*** | Work with the environment not against it | "Recognise the "rights" of Nature and its inhabitants" | (some people call this rewilding) |
| ***Holistic, symbiogenetic*** | The whole is greater than the sum of the parts | Use naturally generated forms, structures, symbiotic systems | Design for beneficial performance outside a project as well inside it |
| ***Treat health as capital*** | Use natural science and natural design to mitigate impacts and enable health | Adapt economic models to encourage joined up government | |

## Developing our values so we get the outcomes we need

The absolute crux of our regenerative future is to configure our profession to respond with a new Value-Set which captures what we need in a holistic way. The role of professional institutions and educational powerhouses is to research evidence and drive alternative project models to enable that reconfiguration. Engineering practice will flourish when we are brave with our regenerative demonstrators because, according to the "Design Paradox", *"We don't know what we want until we know what we can have."*

This implies a change in our culture to adopt a “triple-bottom line” of responsibility: reaching beyond shareholders to society and to the environment on an equal basis. Some BCorp practices like our own now have the needs of society and the environment etched into our constitution. This value-set gives representation to many impacted indirectly by projects:- end-users; those whose legacy we inherit; our descendants even if we don’t know what they will need; and all of Nature. Representation implies a voice, so part of our job is to open new avenues of communication.

We shouldn’t underestimate the difficulty of doing this: we have only to look at our collective and individual selectiveness about the values we sometimes use when we judge the impact of our work. In the long term we might want to be socially-positive and nature-positive, but in the hustle of professional life we find ourselves asking about the value of integrity, ethics and the greater good tomorrow if we can’t run a business and pay the mortgage today? Regenerative design reflects the understanding that humans and nature must evolve together on the planet; a process known as symbiogenesis. Our challenge is to survive in the shorter term so there actually is a long-term.

Kate Raworth’s “Doughnut Economics” defines a sweet spot for the planet between the impacts and the benefits of human projects. Economics itself is evolving and seriously considering post-growth alternatives which recognise the obsession with economic “growth” of GDP is inconsistent with sustainability at a planetary scale. For example Prof. Tim Jackson at CUSP, Surrey University has championed four pillars of a post-growth economy: *“enterprise as service; work as participation; investment as commitment; and money as a social good”* (https://cusp.ac.uk/themes/s1/blog_tb_common_consciousness/). But Tim’s proposition still needs to be realised through “projects”.

“Projects” are a shorthand for what engineers do yet we cannot do them on our own. So we need collaborations to raise the quality and rigour of our regenerative engineering through inclusivity. We will need a broadening of our compass…our own post-growth model. T-shaped individuals will spill in from other disciplines contributing to 'engineering'. Our computational collaborators will be I-shaped and T-shaped too. And only when we have collectively persuaded the scrawny old “chicken” of the economy to change to meet the planetary “egg” will a critical mass of engineers be able to re-educate their practices to respond with regenerative projects which support “the flourishing of all life for all time”.

## Stretching the engineer’s role upstream in “projects”

It has been pointed out to me that “projects” are only interventions on a 13.5 billion year continuum. And those “project” interventions don’t have a “start” or an “end” but just piggy-back the sum total of all human knowledge from our past and ride on it for a while. In time, we might put something back downstream, and regenerative design asks us to do that. Our work becomes a small part of the story of evolution, which inconveniently reports that over 99% of all species that have ever lived are now extinct.

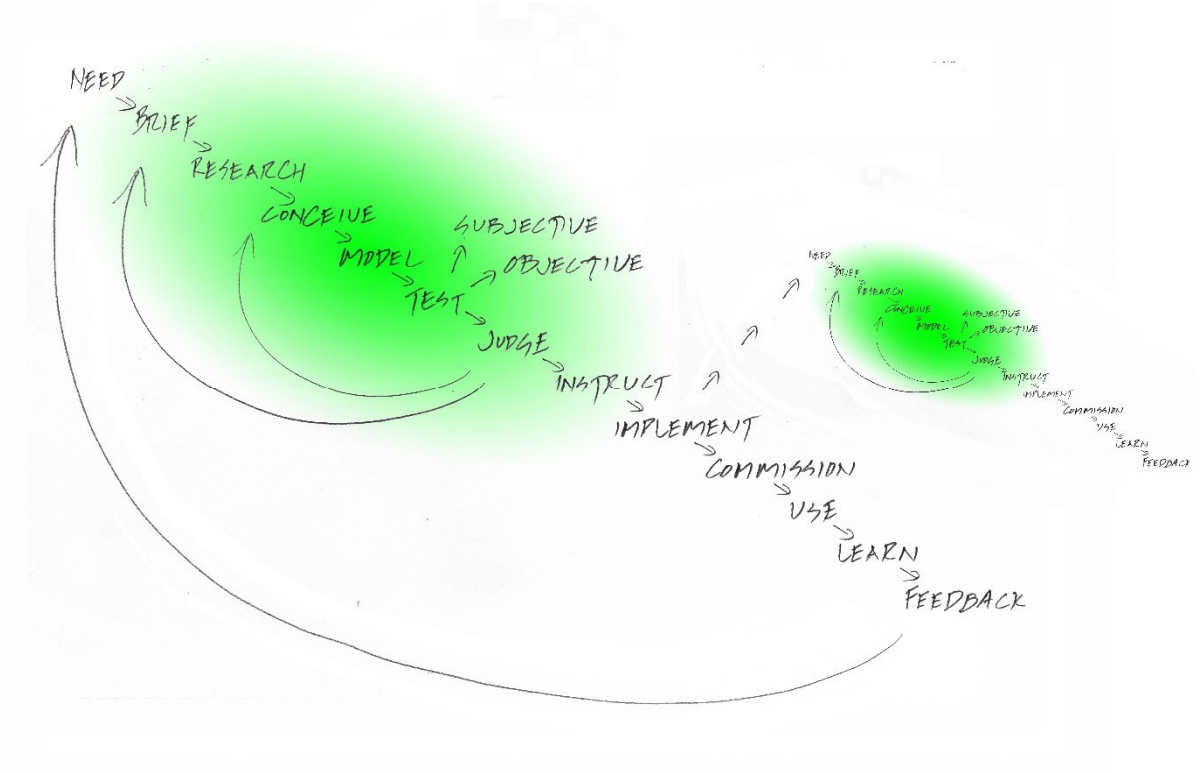
We know that with engineering capability comes disproportionate responsibility for what we do. The outcome of a “project” is contingent on its brief, a brief which is often borne out of a narrow value-set which is prone to ignore inconvenient truths. So a key role of engineers is to change such degenerative briefs into regenerative briefs by becoming far better at what the Greeks call rhetoric: Ethos, Logos and Pathos. In English this means we must be active in framing our projects, not just doing them, using professional authority, logic, and charm if we have it.

## Fine words, but can we deliver when it matters?

Bath University has adopted a “Curriculum Transformation”, driving sustainability and research towards regenerative design, recognising this as a key professional skill for the future. Undergraduate courses are tailored to accrediting bodies but, right now, regenerative design needs to inform the 5-year JBM inspection cycles which otherwise may play behind the curve. For example Bath’s Curriculum Transformation in Civil Engineering echoes the definition of regenerative engineering from earlier:

> *‘Design-led learning that provides students with the experience and intuition to know which questions to ask to change the world in which we live’*

In practice, when engineers “*change the world*” through a project, we need an intellectual and practical framework like the diagram suggested below. Its purpose is to demystify projects to instil a useful iterative mindmap beyond the nonsensical linear gant charts beloved by project managers.




*Nested "Project" Process with iterative design loop shown in green*
*(Developed with Ed McCann at Imperial, refined at UCL, and constructively challenged by Tristram Carfrae of Arup)*

In interpreting this for regenerative projects, key features of this diagram are:

- The sum total of all human knowledge and human experience precedes the definition of Need, so there's plenty to learn.
- Nesting: The entire process is nested, meaning that each stage can itself be a mini-project.
- "Brief": It is a future engineer's responsibility to change a degenerative brief into a regenerative one.
- "Design", including regenerative design, takes place in the design loop of Brief>Conceive>Test>Judge, shown in green and iterating many times.
- "Conceive": Ideas should be informed by "Research" as well as life experience.
- "Tests" use "Models" and are a mix of subjective and objective tests. The design of suitable tests is a critical design process, borne out of the regenerative Values in the Brief.
- "Judge": There is a pivotal moment in any "project" in which the team has to make a judgement, as follows: Based on the suite of regenerative tests we have designed, do

we judge our concept meets the need expressed in our regenerative brief? If the answer is yes, proceed. If not, go around the design loop again.

- "Implement": Recently we have changed this from 'make' to "implement", recognising that a regenerative project may involve 'making' nothing at all in the old manufactured sense. So we reset our ambitions to implement a project whose outcome is the regeneration of a process or ecosystem.
- "Use" includes adaptive re-use for All Time.
- "Learn": There is a critical feedback loop to pass on learning from one intervention to the next one...and disseminate to others. The IStructE's data-capture of carbon performance of common building types shows how powerful this can be to drive improvements when tackled across a profession like ours.

Case studies by Andrew Wright of Constructive Collaboration have shown that the more innovation, the greater the degree of collaboration required (https://constructivecollaboration.com/resources/). Because regenerative design needs a great deal of innovation, collaboration like this becomes a central skill in in regenerative projects.

We can see that the expression of the Need is also a mini-project involving not just engineers but many of Tim Jackson's wider post-growth cohort. In the future world, engineers cannot any more just say to their immediate client: *"Tell me what you want and I'll work out a way to do it"*. To capture the Need, we can learn from Indy Johar of Dark Matter: as he says *"Here's a hypothesis: the world for the first time is exhibiting a form of consciousness"* . The natural and social stakeholders of the world are trying to tell us something.

## The complementary balance of design strategies:- "artist"; "artisan"; and "philosopher"


Engineering is not a monoculture. Ed McCann and I have described elsewhere how an engineering design cohort tackles projects in different ways. Our friend the late theatre

designer Tim O'Brien RDI dubbed these design strategies as the "Artist"; the "Artisan" and the "Philosopher" (see ICE Manual of Structural Design published by Thomas Telford).

Every regenerative design project needs at least one good "Philosopher" in the Need and Briefing stage to understand the regenerative purpose and derive its value set. Such a philosopher may not be an engineer but come from the user or wider society, skilled at interpreting natural and ecosystem drivers. "Artists" and "Artisans" have complementary roles: "Artists" majoring with multiple ideas at concept stage; "Artisans" strong in perfecting best practice, and in testing; "Philosophers" help again when we make balanced judgements which map to the original need.

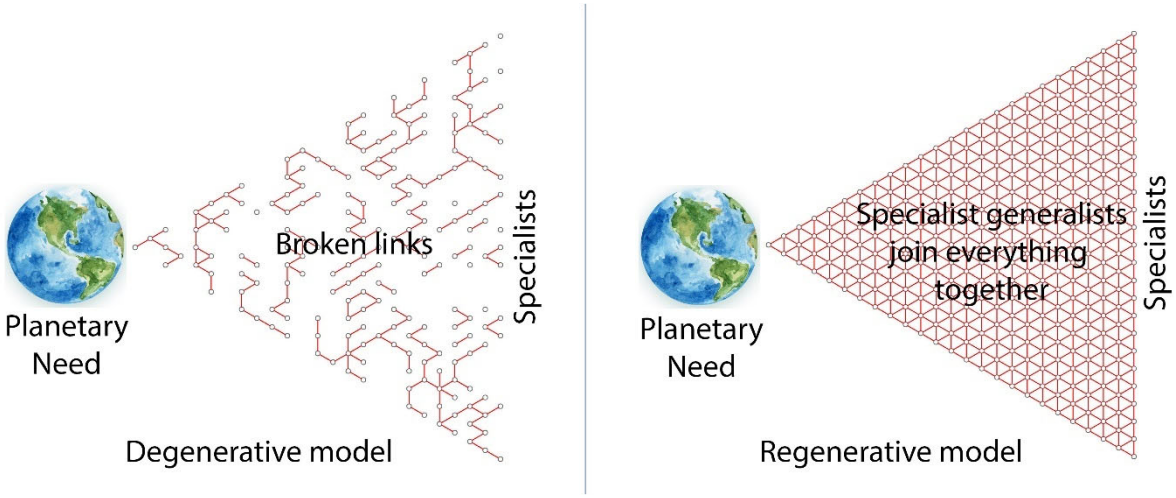
A regenerative project team will perform better if people with these strategies complement each other and don't play out of position.

## We need a cohort of "specialist generalists" for multi-disciplinary synthesis

Multi-disciplinary projects with multiple stakeholders can follow the law of unintended consequences. The causal links over time and over oceans are only now becoming clear...for example, we link the flooding in Pakistan this year to decades of industrial emissions in countries thousands of miles away. Responding to this complexity, Prof Doug King wrote in his report "Engineering a low-carbon built environment" (RAEng, 2010): *"In order to assimilate sustainability into our approach to construction projects we must re-integrate all the engineering disciplines to deliver holistic solutions".* At the time, he advocated a new role of "building engineering physicist", expert in environmental physics.

Hugh McGilveray and Simon Pierce writing in the ISE in 2020 developed a similar idea of specialist generalists focussed more squarely on structures. (https://www.istructe.org/journal/volumes/volume-98-(2020)/issue-1/the-specialist-generalist-engineer/).

These are a partial answer, because they are discipline-centred. A decade earlier, Ed McCann and I championed a more general professional role into which both of these suggestions would fit…a version of the "specialist generalist" as a holistic systems integrator. In the simplified slice of the world shown below, and in innovation like regenerative design, the team usually has missing links as shown below left...which the specialist generalist joins up beautifully as shown on the right:




*Specialist generalists weave their magic*
*(Ed McCann and Chris Wise)*

The specialist generalist, or a group of them, occupies the centre of every project and provides integrating links between the regenerative need at one end and the expert skills of the specialists at the other.

T-shaped people need to be connected to each other, creating a single "diatomic team" as shown on the right below. Specialist generalists link many disciplines including engineers, and many species and machines who are not even human. economists, politicians, environmentalists or think tanks. I believe all regenerative project teams should be made like this.

*The evolution of the "diatomic team" from I-shaped to T-shaped to diatom*

## Enabling the future, not disabling it

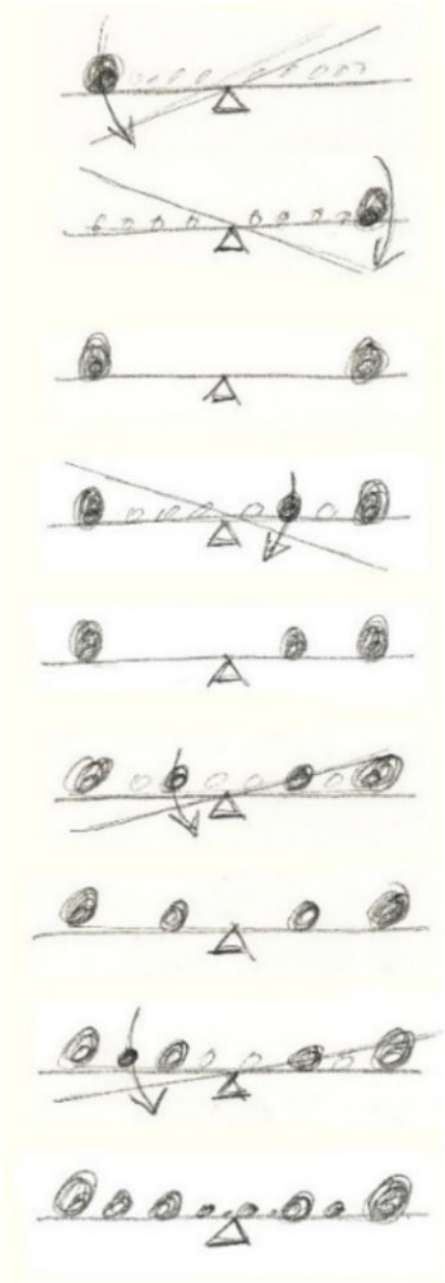
The consideration of Time means regenerative design is an ongoing and iterative collaboration between designer, environment and society...over multiple generations of

both. Our strategy in the fog of the future is to go carefully and normalise the need for frequent course corrections. Engineers enable the future rather than disable it, as "instruments of possibility". This requires engineers who plan for adaptive reuse as an inevitable consequence of any project while still satisfying their clients that there is at least a plausible first step to meet their Capex needs. Working recently with Arup and others we have developed a "triage system" for assessing the potential of a project for adaptive reuse: it treats existing building stock like medical patients and works sequentially through a planned suite of diagnostics and possible interventions to assess appropriate treatment aimed at positive regenerative outcomes.

This adaptive approach is rather daunting, especially for engineers more familiar with artificial project boundaries which ring-fence outcomes even as they close off others. Ed McCann called the adaptive responsive approach the "bionic algorithm" because the project itself is designed to adapt fast to any change in future circumstances even if we don't what they will be.

## The strategy of Dominant Uncertainty

It is very hard to consider all a regenerative project's key drivers simultaneously. A strategy to tackle this is the principle of "dominant uncertainty". You respond to the single biggest concern first, then balance it against the next. And so on, eventually converging on a solution in which all the key drivers are balanced. As a simple example, when designing a bridge, the dominant uncertainty may not be *"What is the mid-span bending moment?"* but *"Where should we put the bridge to connect the communities on either side of the ravine?".* Dominant Uncertainty is suitable for design in general and is a transferable skill.



*Dealing with dominant uncertainty by iterative balancing*
*(Ed McCann and Chris Wise)*

But while single bridge can be designed regeneratively, a better strategy to address the dominant uncertainty of our time might be to design one good thing that can be copied a million times….in our practice we have been designing low-carbon versions of the humble paving slab because carbon emissions from concrete are our dominant uncertainty. I felt great about that until James Norman pointed out that *"One design that works 1,000,000 times creates super-nodes. What happens when the process stops working? Where is the*

*robustness and alternatives? Look at global supply chains right now to see how risky this is? It's adaptive systems that avoid supernodes and become more robust."*

## Making better judgements in holistic, open problems

Regenerative design complements other drivers for projects; an engineer still needs to follow the laws of physics, just as an economist will still consider affordability, or a constructor still needs to build safely.

Imagine you are designing that bridge regeneratively. Within the Iterative Design Loop you would frame the problem with a regenerative set of values, and test your concepts against those values. Your testing metrics would be chosen to respond co-equally to Shareholder, Environmental and Social values…not just $wL^2/8$ but not forgetting about it either.

A fabulous regenerative project that ignores the technical underpinnings of engineering will certainly fail. A linear technical project that only complies with every technical clause of every code may only be a partial answer to the wrong question. Synthesised into a balanced solution, this complementary juggling is at the heart of what the world needs from regenerative engineers going forward.

## The importance of inclusive language

Regenerative design needs a common inclusive language so that talented people do not disenfranchise themselves with their jargon. Diversity of experience, background, aspiration, and reward from well beyond traditional technical disciplines demands more inclusivity. Feedback from three generations of scientists and designers attending an "About-Change" gathering this spring at London's V&A called for the participation of many absent stakeholders in regenerative projects: economists, sociologists and community leaders, funders, planners, biodiversity specialists, health practitioners, priests. If a priest offers counselling when an engineer talks about "stress and strain" we all need an interpreter.

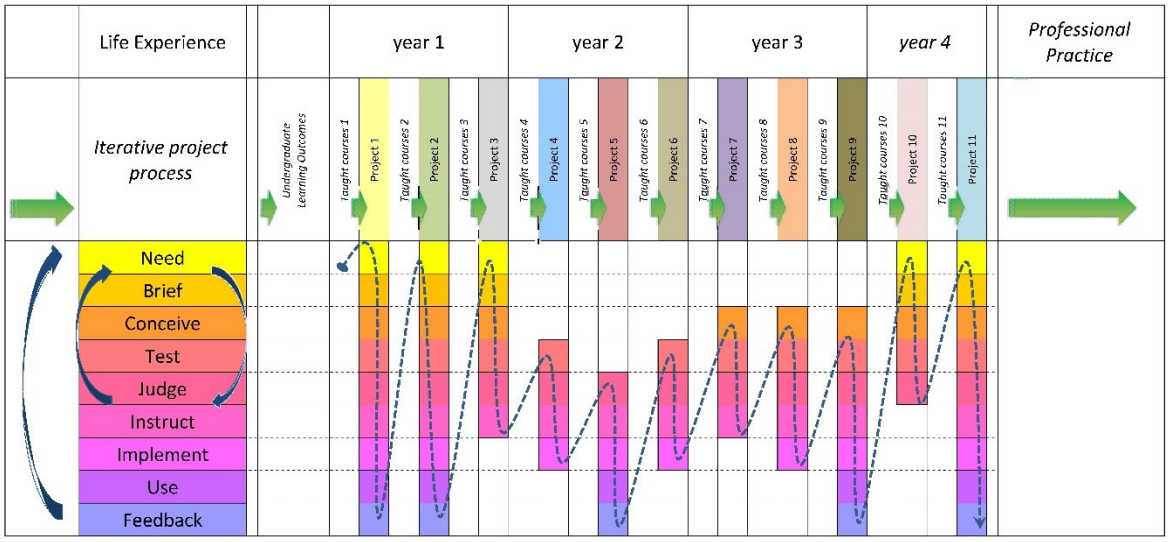
Don't laugh, but we might ask ourselves whether structural engineers are in our own little bubble, an echo chamber where we live harmlessly but peripherally? In the meantime the world gets on with something else? Even if that's true, we have the bones of a great story to tell even as long as we can all channel a bit of David Attenborough: we increasingly have evidence-based data which explains cause and effect on a global scale, and we have the capability to design a regenerative future. Not so many people can do that. So it could be a

virtuous circle: good data which drives understanding becomes the root of our global "consciousness", and this awareness liberates the cultural fuel for people to ask us to design their regenerative projects.

## Patient practice through educational mapping

A key challenge of a regenerative (re) education is to distil these principles to develop competence and eventually mastery through patient practice, to build confidence in trial and error: in learning through hypotheses, experiments and mistakes. This mimics genetic evolution in which random mutations can be viewed as "trials" which survive or die through their fitness to adapt to their environment. Engineers and ballerinas are doing the same thing when they practice, spotting "errors" and adapting to correct them through feedback loops.

From the learning perspective, patient practice can be visualised by means of an iterative "map". Shown here is a curriculum map for an undergraduate engineering programme, but the iterative model works equally well in professional life. The essential feature is that the development of experience maps explicitly to the project process. "Patient practice" uses repeated cycles of gradually increasing sophistication to develop capability. At every point the map locates you in the project process..."*Now we are looking at value "judgement";* or *"now we are going to research regenerative "concepts*". The purpose of the map is to frame a journey, linking taught content and life experience into our design work. The map starts fast and broad and builds in complexity as competence increases along the way. Practice also allows a collaborative team to learn how to map its skills to the stages of a project and optimise its performance.




*4 year curriculum map showing iterative design loops*

## Regenerative engineering strategy

This draft strategy has been developed to help engineering into its regenerative future, whether in education or practice:

| Regenerative engineering strategy (work-in-progress) | |
|---|---|
| **Adopt:** | Adopt regenerative principles as part of the sustainability and climate awareness foundation for all projects |
| **Pool:** | Pool industry expertise across disciplines for knowledge transfer and to establish a common language and centre of excellence |
| **Collaborate:** | Collaborate outside engineering practice to develop transitional business and economic and entrepreneurial models that maximise regenerative possibility |
| **Share:** | Share regenerative principles, knowledge and research on an open-source basis. |
| **Integrate:** | Develop a “systems integrator” stream for regenerative designers |
| **Challenge:** | Include regenerative principles in all project briefs and challenge and adapt degenerative briefs with clients, economists and users |
| **Diversify:** | Diversify project crit and review panels beyond the traditional project team to assimilate real-world impact and benefit. |

| | |
|---|---|
| Measure: | Include life cycle costing, whole life carbon modelling and impact evaluation as part of all projects |
| Be an instrument of possibility: | Design the potential for adaptive reuse over multiple generations in projects following the principles of Lean start: Long Life: Loose fit |
| Connect cause and effect as levers of change: | Include collateral, indirect, subjective benefits as key metrics demonstrated through a regenerative impact assessment. |
| Feedback and iterate; Feedback and iterate; Feedback and iterate; Feedback and iterate; | |

## Feedback and Iterate

A couple of final thoughts: First, how can this article and others like it become a part of engineering's regenerative feedback loop? It would be great to consider the development of a regenerative engineer as a project, perhaps beginning with feedback from this article and iteration in future issues of The Structural Engineer. Second, how should the Institution build a regenerative capability through its accreditation, and thirdly, how can the Institution accelerate the adoption of good regenerative design and practice at the heart of the engineering curriculum?

## Credits

With thanks to civil engineer Ed McCann for sharing the early development of some of these ideas, educator Oli Broadbent and all at the Regenerative Design Lab, Eva MacNamara and James Norman for their constructive criticism and the late theatre designer Tim O'Brien for his wise counsel on design strategy.