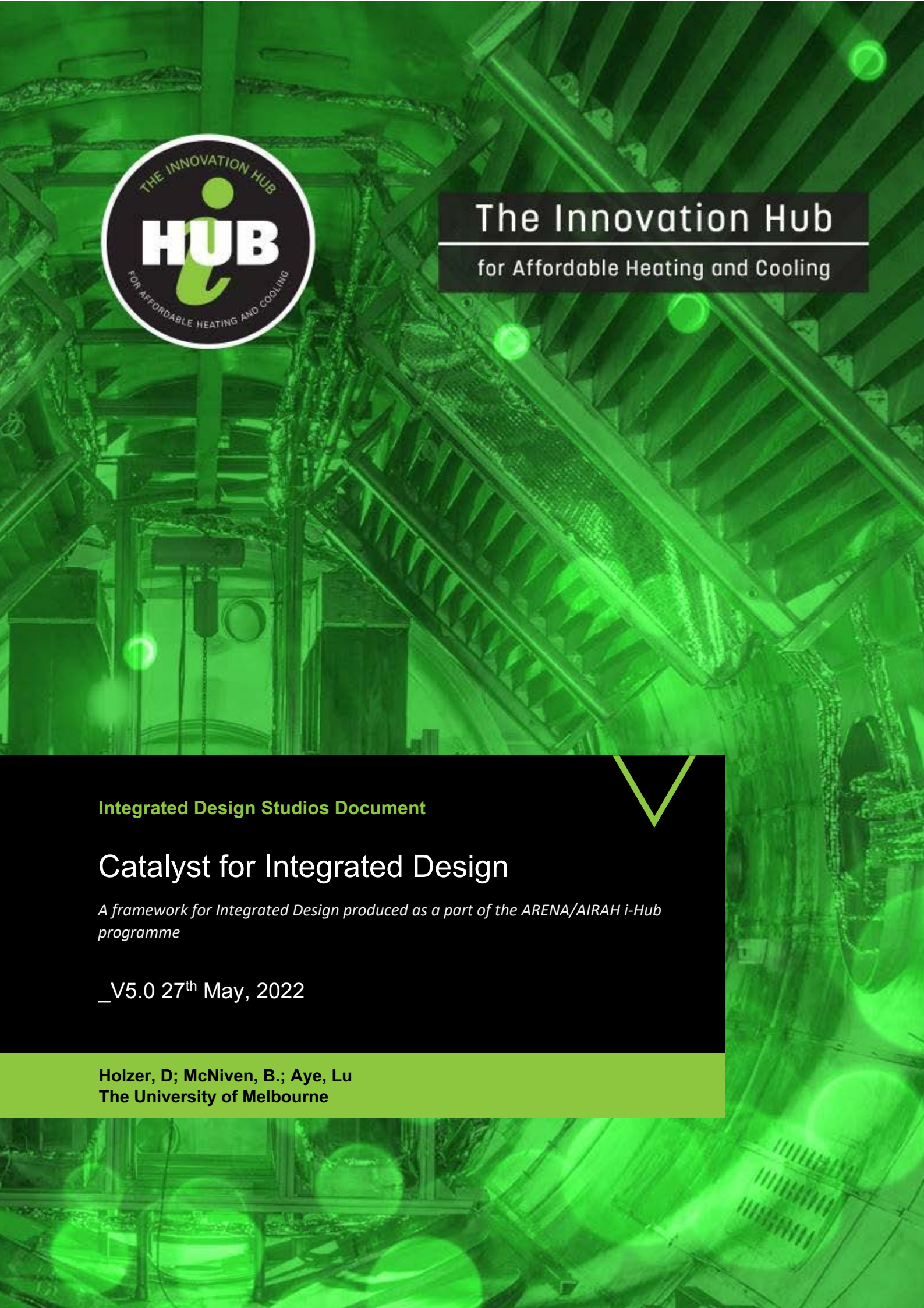

Integrated Design Studios Document

Catalyst for Integrated Design

A framework for Integrated Design produced as a part of the ARENA/AIRAH i-Hub programme

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About i-Hub

The Innovation Hub for Affordable Heating and Cooling (i-Hub) is an initiative led by the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) in conjunction with CSIRO, Queensland University of Technology (QUT), the University of Melbourne and the University of Wollongong and supported by Australian Renewable Energy Agency (ARENA) to facilitate the heating, ventilation, air conditioning and refrigeration (HVAC&R) industry's transition to a low emissions future, stimulate jobs growth, and showcase HVAC&R innovation in buildings.

The objective of i-Hub is to support the broader HVAC&R industry with knowledge dissemination, skills-development and capacity-building. By facilitating a collaborative approach to innovation, i-Hub brings together leading universities, researchers, consultants, building owners and equipment manufacturers to create a connected research and development community in Australia.

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The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

Primary Project Partner

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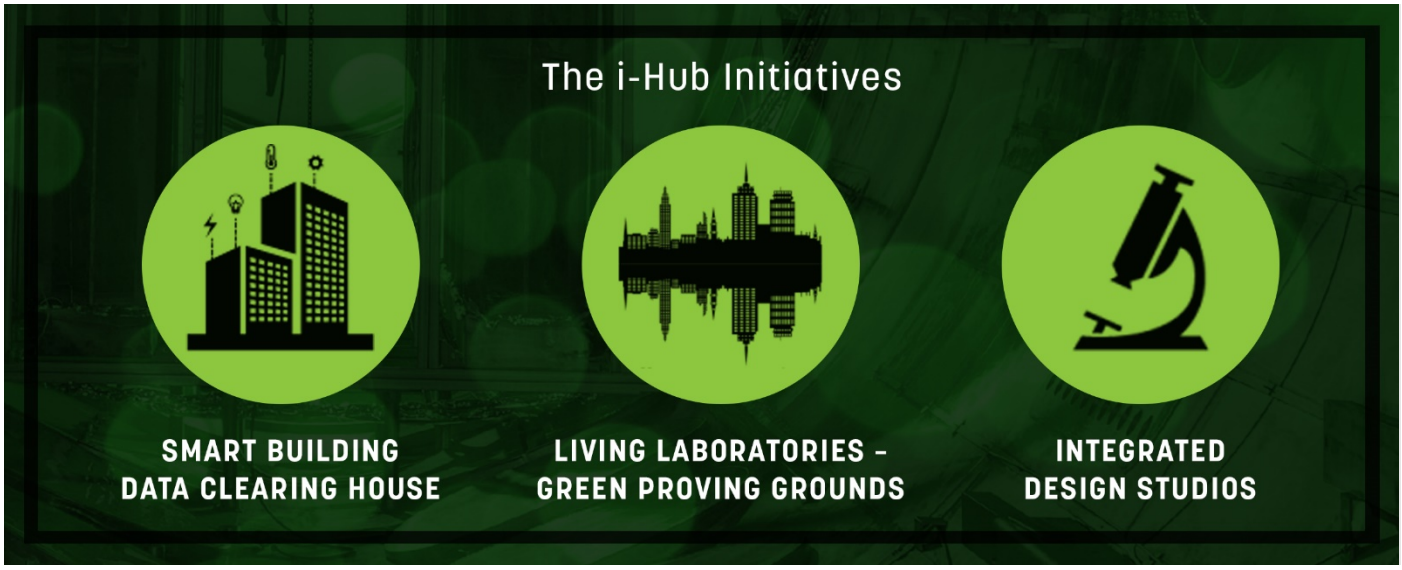

1. Introduction

Integrated design aims to produce better built environment outcomes through the integration the many often disparate parts of the design process. The ultimate aim is to create a 'whole that is greater than the sum of the parts'.

Implemented effectively integrated design promises outcomes that respond better to the various project stakeholders involved, are cheaper to build and maintain, and that perform better on an architectural, technical (engineering) and environmental basis.

Integrated Design is not new, it is however sporadic and often ineffectively implemented in industry. Many of the reasons for this are related to aversion of perceived risk and change which results in design teams resorting to the comfort of what they know. This often takes the form of working in silos to solve their part of the design equation without minimal reference to others.

The *Principles of Integrated Design* presented here offer an alternative to the status quo often encountered. They describe possible pathways for design processes that embrace co-rationalisation rather than a sequential exchange of information that sits segregated within individual (professional) boundaries. They encourage connections to be made across disciplines, bringing new insights and ideas that would not have been apparent in one discipline alone, and design outcomes where "The whole is much larger than the sum of the parts"[1].

This document presents guidelines to the establishment of integrated design processes in multi-disciplinary design teams. The guidelines were formulated by testing integrated design theory documented in the literature for practical design environments.

The work was undertaken as a part of the i-Hub Integrated Design Studios (IDSs) activity at the University of Melbourne, Queensland University of Technology, and the University of Wollongong. The i-Hub program was initiated and managed by the Australian Institute for Refrigeration and Air Handling (AIRAH) and funded by the Australian Renewable Energy agency (ARENA).

One of the early findings of the research was that integrated design processes need to be adaptable so as to cater to individual designers preferred methods of working. This document should therefore be used as a flexible framework for discussion with the design team in question to structure an integrated design process that is bespoke to the situation at hand.

1-Radcliffe, D. F. (2006). Shaping the Discipline of Engineering Education. *Journal of Engineering Education*, *95*(4), 263–264. https://doi.org/10.1002/j.2168-9830.2006.tb00901.x

2. Integrated Design – A Road Map

Integrated Design can be said to consider all aspects of a project from initial conception and framing, through to final construction, commissioning, and operation. The following table presents a high-level summary road map of recommended actions to implement integrated design on projects. A fuller description of specific aspects can be found in Section 3.

Phase	Integrated Design Principles
Before design starts	Establish a clear set of clients integrated project delivery motivations and establish a supporting framework for this within the client organisation.
	Establish clear, shared, ambitious, client goals, and timeframe for achieving those goals.
	Put in place a behavioural based procurement framework that - rewards outcomes performance against KPIs, - encourages collaboration and co-design, - makes communication and information sharing easy.
	Write integrated design into the brief including specific goals and targets that cut across disciplinary boundaries ensuring these are clearly communicated as part of the project tender.
	Identify and assign an integrated design manager role that is independent and external to the client/design team.
Design Initiation (Culture Setting)	Create supportive environment for design: - Identify common spaces where team can assemble (ideally a project office if size allows). - Identify common communication/software platforms and protocols to facilitate collaboration (in consultation with design team members).
	Conduct culture setting exercises: - Common project inception workshops communicating goals/vision. - Be clear designing differently, articulate co-author mindset. - Establish understanding of reward for performance culture. - Establish relationships through face-to-face meetings. - Articulate culture of learning, understanding and valuing. - Embrace open ended solutions (encourage divergent thinking).

	Establish return brief with whole of design team.
	Determine and agree KPIs with design team.
During Design	Convene a transdisciplinary design team (e.g. engineers, architects, construction contractors, building owner/manager/occupants, ID specialist/facilitator) with diverse skills and experiences. Secure dedicated senior and junior resource time commitments.
	Understand the 'whole of life' purpose of the building. Allow designers the time to understand their own disciplinary issues in responding to brief/purpose and share these with the rest of the team.
	Conduct non-linear design workshops across different project aspects sharing outcomes or challenges across the team (weighted to front end). - Search for and articulate systems in design. - Examine architectural and engineering 'extreme solutions'. - Extend beyond initial perceived barriers (cost, feasibility etc.) to generate and develop new ideas. - Recognise the circular/iterative nature of design by revisiting workshops at different times. - Consider the use of option evaluation matrix frameworks for decision making. - Value place, understand materials/energy flows. - Use visual based early design evaluation tools or rules of thumb. - Stipulate multi-functionality. - Articulate results against purpose/KPIs and share across team. Include multi-discipline critique/constructive feedback sessions.
	Establish a hierarchy of approaches: i.e. energy efficient building envelope (design and materials), building services (technologies and controls), and renewable energy (generation, storage, and control).
After Design	Follow through and close the loop. Ensure successful implementation of designs developed by involving future parties. This may be through informed commissioning with the parties responsible for maintenance and operation, or through education of end building tenants/users.

3. Implementing Integrated Design: Detailed Learnings

The principles of implementing integrated design uncovered through reviewing/interrogating the literature, and subsequently testing this in actual design environments fell into four general categories:

- Client Aspects,
- Procurement and Planning,
- Culture Setting,
- Design Process Specifics.

2.1 Client Aspects

The enemy of integrated design is 'business as usual', or more specifically individuals and teams doing things on projects the same way they have done them previously. The tendency to operate in the comfort zone of what we know is a basic human condition we often default to. Real change requires changes in mindsets and attitudes challenging what we think we know right from the start of a process.

It is for this reason that the client plays a crucial role in establishing integrated design on projects. As project instigators clients are responsible for setting the tone of a project that will carry through every aspect of the process to completion.

To successfully implement and facilitate integrated design on a project:

Clients need to be committed to changing from business as usual delivery in the interests of better design. Client management personnel should be capable passionate individuals believing in changing existing processes for the better.

Clients need to provide project personnel with an empowered environment. Integrated design often fails through ideas presented to management by project personnel not being taken on board. Client project personnel need to be able to work in an empowered environment where they are supported by the wider client organisation to implement change.

2.2 Procurement and Planning

Procurement and planning set the operational structures that the delivery team will work within for the remainder of the project. Getting these structures right is core to achieving successful integrated design on projects. Individual's, and company's behaviours will respond to the incentivisation embedded in the structures in which they have been employed, the design will respond to the brief provided, etc.:

Procure the right behaviours. Contract procurement frameworks that encourage people to think and change the way they currently do things in order to improve outcomes encourage integrated design. Performance based contracts with incentivisation such as alliancing with 'pain share/gain share' arrangements fall into this category (refer Figure 1). The Integrated Project delivery suite of contract documents developed by the AIA in the United States is a good example of such a contract.

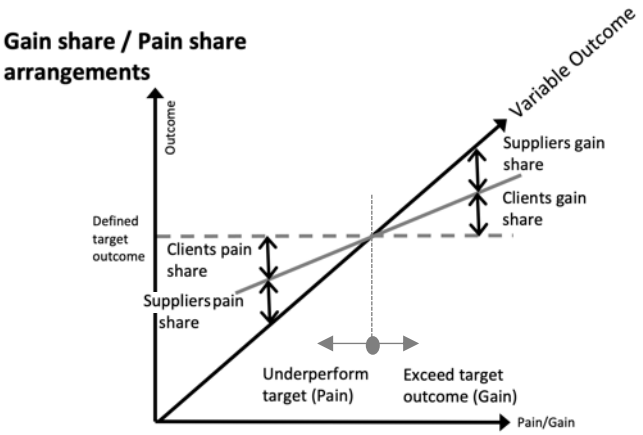

Figure 1 – Indicative Gain share/Pain share arrangements on a project. (adapted from www.builtintelligence.com – 'How to intelligently set the Contractor's share percentages and share ranges', John Broome).

Developing a brief that provokes a different way of thinking - One key element of integrated design is to foster a different attitude about collaboration among project participants. The design brief hence needs to move away from familiar approaches and instead trigger novel approaches to design that – at times – may take participants out of their comfort zone in terms of 'Business as Usual (BAU)'. In some instances, the formulation of the brief can be left open to allow collaborators to develop their own approach. This needs to be complemented by clear targets to be achieved by the designers, in order to provide them with a strong framework to define their collaborative process.

Establishing the role of a Design Integrator – The role of an impassionate third-party design integrator was found to be highly beneficial in the studio testing that was undertaken. The design integrator was able to maintain a big picture view of design direction that many participants involved in the design were unable to. This role was often served by the studio leaders in the design studios. Overall, research shows the advantages of clearly defined roles and responsibilities, spread across the design collaboration process.

Create a supportive environment for co-design: An integrated design team is most effective in a comfortable space, encouraging innovation and experiment, built on strong social connections. It is paramount that an integrated design team is a safe space where innovation and experimentation may occur in collaboration, built on strong social connections. Without these foundations the convention of design team hierarchy results in a serial structure, where engineering follows architectural design, validating and documenting but not sculpting or motivating a scheme. For this reason, most engineers shy away from open-ended design problems and experimental ideation for fear of critique or negative feedback and want the security of clearly outlined problems.

Identify common spaces where team can assemble (ideally a project office if size allows). Provide a variety of space to facilitate different collaboration activities, i.e. formal workshopping spaces, casual discussion spaces, project resource spaces etc. Identify common communication/software platforms and protocols to facilitate collaboration. This should be done in consultation with design team members to ensure fit with IT and infrastructure capabilities and also to ensure buy in.

2.3 Culture Setting

From the right culture and values, the right behaviours and results will naturally flow. Establishing the right unifying culture in a project team is essential for integrated design:

Common Goals – Key to the formulation of the integrated design process is the articulation of common goals that are (equally) relevant to engineers as well as architects (over individual goals by either group). Ensure all participants feel involved right from the start. Goals should not only be high level, but also include specific measurable targets against business-as-usual outcomes. Measurement of targets need not be confined to the objective aspects of a project, subjective aspects may be assessed and measured in subjective terms in consultation with the design team.

Establish a trust culture – Relationships and mutual respect are key to facilitating collaboration. Face to face project initiation workshops should be held where designers get to know each other. These should contain both social and technical aspects where fellow designers understand the perceived challenges and opportunities facing each other. It is important for designers to understand importantly 'value' what other disciplines bring to the project.

Avoid minimising individual agendas - Seen in the context of achieving common goals, design collaborators frequently work towards specific 'individual' goals and agendas that are not clearly communicated to the rest of the team. Even worse, these agendas may at times even conflict with the common goals of the design team. An integrated design approach therefore requires a consolidation of individual goals into a broader agenda, or at least a clear delineation about how and where individual goals need to be 'spun-off' the joint effort. Clarity and transparency related to these issues is essential for integrated design to succeed.

Allow space for innovation in program – The integrated design process should facilitate an environment where creativity and innovation can unfold. Too many, or too tight deliverables will likely over-constrain and limit ability to explore novel design solutions. Designers should have 'permission to fail', when searching for integrated design solutions.

Vision, intent, strategy and culture first – The integrated design process should trigger designers to first reflect on *why* they design in a certain way. The limitations of traditional design and opportunities available in integrated design should be understood, i.e. explain the 'why' of integrated design.

Flexible Structure – It is important for any integrated design process or structure developed to be flexible and non-judging enough to cater for the different skills and often idiosyncratic ways of working different designers will bring to the collective table to extract the best input from all designers involved.

Good integrated design requires a 'design co-author' mindset – It is important that all participants in an integrated design process contribute to the authoring of the design. This requires setting expectations on this front, and curating environment where individuals either feel empowered to contribute or are actively brought into design conversations. Environments where it is ok to fail need to be established and individuals natural communicating preferences respected and facilitated. It is worth noting that the design co-author mindset proved more difficult for the engineers taking part in the studios than for the architects.

Face-Face interaction is important – Face-to-Face interactions were found to be far more effective in encouraging the quality of interactions required for integrated design. Much of this was due not only to the improved communication but to the stronger social relationships established. If projects are necessitated to be delivered remotely it is suggested that designer relationships be first set up through face-to-face interactions at the start of the project.

Co-design is a terminology that needs clarification - 'co-design' as a terminology that needs to be discussed by participants. Participants in an IDS project would need to collectively determine how co-design will be interpreted and implemented for that particular project.

Understand and value the other – It is only once a designer understands and importantly values the input from disciplines 'other' than their own, that true collaborative design occurs. Not only are designers willing to give ground on their own wishes but the understanding invites opportunities for them to contribute to others objectives through multi-functionality.

Stipulate multi-functionality – Establishing a culture of multi-functionality in design engenders integrated design. Having one design element serve multiple functions at the same time results in increased value and effectiveness of design elements. It also makes them less subject to removal during value engineering exercises as they are contributing to outcomes on more than one front.

2.4 Design Process Specifics

Once team members have been set up in a project framework that encourages them to think out of the box towards better outcomes, and the right culture and values have been set, what remains is to create on the ground processes that facilitate production of the outcomes:

Balancing individual and integrated approaches – The integrated design process should facilitate an appropriate balance to group thought (time interacting) and individual thought. It should articulate the desired project outcomes both from architectural and engineering perspectives, encouraging designers to understand what the 'other' has to offer, and to value this in the interest of embracing and incorporating it into their own ideas.

Embrace design as an open-ended solution-finding activity. Make it clear to designers that it is not merely about solving well-defined problems.

Recognise Integrated design ideation happens only after designers reach a level of base understanding in the disciplines to be integrated – The studios found that the process of integrated design only occurred effectively after designers had time to understand and feel comfortable with the value 'others' disciplines bought to the process.

Experience levels of designers is an important consideration in integrated design – The experience of designers in 'designing' was found to be just as important as their experience in their technical fields. For this reason, a balance of design experience should be provided around the table. Experienced designers skilled in collaboration and development of designs balance the enthusiasm and fresh ideas of inexperienced designers. Both are important to the process.

Considering 'extreme design' as a starting point- Not necessarily the only approach, but nevertheless a rewarding alternative to common team-collaboration approaches, 'extreme architecture' and 'extreme engineering' ask project team members to first consider only their own goals and to work on concepts that only respond to those. These can then be shared with the design partners to highlight what solutions might look like if their input wasn't considered. It is a great discussion-starter for teams with a strong integrated design agenda. In this context it is crucial to establish the engineers as co-designers and not simply as 'consultants how help realise the architects' ideas'.

Avoid focusing on detailed solutions too early as well as the production of captivating visuals, that mainly address aesthetic aspects of the project. Accept that integrated design can be messy, with many options to be explored and discarded early on, and results emerging from interactive collaboration.

Combine face-to-face and online collaboration & Make decisions explicit! - Research shows that a key element to successful integrated design is co-experience of participants. Some elements of this can occur via face-to-face meetings and presentations, others happen offline. Recent COVID experience shows that online collaboration platforms such as Microsoft Teams or online visual collaboration software tool Miro assist collaborators to engage online and share/log their work-in-progress and the associated decision-making process. This is an essential step to build up knowledge across collaborators and to increase their understanding about their tasks, and the tasks of their peers in other disciplines.

Complement aesthetic and functional design considerations with associated performance feedback - Feedback from the IDS highlights the tendency of engineering designers to lean towards the integration of project specifics, whilst architectural designers thrive in a context of visual form-making. In order to allow a shared perspective to emerge, it is highly beneficial to consolidate these two approaches and allow solutions to emerge via multiple design iterations. Being able to discuss design options with different visual and performative information combined, boosts the designers'' capability to confidently advance their design-thinking and decision-making.

Introduce early environmental simulation/energy performance software tools - Focusing predominantly on architectural designers, the research suggests that a crash-course in environmental simulation boosts their understanding on how to extract trend analysis regarding the physical building performance of their projects. Adding a component for energy performance analysis opens the door to work towards specific (carbon) targets. The introduction of associated tools/processes must be facilitated with great care as there is a danger that designers who are new to these tools at times lose sight of holistic design considerations and focus on meeting performance targets instead. It becomes essential that performance guides design but does not 'drive' it.

Accept that better performance outcomes don't necessarily improve the aesthetics - As much as it is a declared goal of integrated design to improve the quality of a project, there is no guarantee that it will benefit/improve its aesthetics. Feedback from the IDS clearly points towards an understanding that optimising performative aspects of design (if done well) does not compromise a project's aesthetic qualities. At the same time, these optimised solutions are often not immediately recognisable in the formal expression of a project. They are frequently embedded in various choices that form a holistic total. There may be some cases where the aesthetics are closely tied to physical building performance, but those involved on integrated design projects ought to be aware that this likely will be the exception.

Architects and engineers have different preferences in communicating and engaging – Architects tend to be more visual in the way that they deal with the world and communicate, engineers more abstract and objective. Visual communication was found to be the best universal language and was also useful as an analysis/collaboration tool with engineers presenting visual representations of figures.

An informed process of interrogation and iteration can assist in the process of integration - An informed and intentional process can make a significant difference to the level of 'integratedness' of a project or team. In the conventional design process, the role of any engineering designer is to validate architectural design. It was observed that the most valuable shared attribute of all engineering specialties is the practice of systematic analysis. The process of rigorously defining criteria, simulating potential scenarios and exploring the results with some level of objectivity can lead to optimized and unexpected results.

Time pressures on delivery often negatively impact integration – The negative effect time pressures can have on ideation and integration should be considered in setting project timelines for delivery. It is also worth noting that shorter timeframes can be useful in smaller independent design charrettes or exercises as they encourage succinctness of solutions and encourage rationalisation of complexity.

Materiality is a nexus of integration - Drawing together architecture, structure/construction, and sustainability decisions on materiality are a nexus for design integration as it has direct and generally easily understandable impacts on all disciplines. The discussion of materiality is often a good way to commence integrated design discussions.

Reminders of how the common goals established at the start of the process translate to outcomes throughout the design is beneficial - Reminding participants of how the common goals established at the start of the design translate to outcomes at progressive design moments was found to be beneficial in this IDS through the hands-on guidance of the studio tutor and industry consultants to maintain designers' focus. Analysing the design regularly to assess performance against the outcomes and KPIs established at the start of the project is important to both ensure desired design direction is maintained and to also maintain designers focus.

Multi-discipline design critiquing found to be important in facilitating integrated collaborative outcomes - The process of bringing multiple perspectives into focus, via collaboration and critiquing, as designs develop was felt to be important. The process of design critiquing was discussed and observed to be more common in architectural design environments that in engineering. It was felt that an environment that encouraged a constructive critique process involving all disciplines through the design was beneficial to the integrated design process as it assisted with communication and upskilling of disciplines in each other's areas of expertise.

Existing structural form restricts integrated design opportunities - Architects and engineers are willing and very much capable of working collaboratively to produce integrated design solutions for clients who are cognisant of the benefits of efficient building design. This fact holds for both new and retrofitted structures. While both engineers and architects can work collaboratively to achieve this goal, the scope of possible opportunities is narrowed in existing structures due to the restrictions imposed by the prevailing structural form and can be further compounded by the client brief. This is especially true if the client is resistant to any structural alterations.

Follow through and close the loop – Even the best designs can fail through implementation or commissioning. In is important to follow designs through bring future parties into the picture through informed commissioning involving the parties who will be responsible for operations and maintenance, or through education of building users.

Appendix 1 - Integrated Design Process Guidance used in the IDSs

The following integrated design process guidelines were the final iteration used in the academic studios carried out.

Project Inception > Weeks 1-3

The very first interaction between student designer, studio tutor, client, consultants, and academics are of outmost importance to the success of the Integrated Design process. This is where the tone for the coming 13 weeks is set. This is where the seed it planted to establish the culture behind integrated design concepts. In the first three weeks of semester, student designers will become familiar with the particular IDS setup and its goals, as well as getting exposed to a broad variety of environmental / building services design concepts and associated technology. This period is highly formative for the student designers' development and should be accompanied by a great variety of *'information downloads'* that address various aspects of integrated design and associated environmental design approaches (Knowledge and Comprehension in terms of Bloom's Taxonomy). Next to joint introductory workshops in weeks 1 and 2, there are likely going to be several guest presentations by project participants within this period.

- Introduce project participants to each other and establish **trust** among them (open/non-judgmental/sensitized/willing/etc).
- Discuss the **limitations of traditional**, non-integrated design (solutions).
- **Aim to remove all barriers between disciples** – these may be, cultural (language, work methods, customs etc.), availability/time etc.
- Select **assessment tasks** (or sub-tasks) that need to be tackled by Architecture and Engineering students **jointly**, and not simply in isolation (where everyone just does 'their part').
- **Empathy** – Allow every participant to understand what the other does and why it is important.
- **Discuss the expected roles of each participant** (Arch/Eng students / consultants / client / tutor / observers).
- Explain the **process** each participant (group) typically goes through, in order to derive their desired **output**.
    - for engineers

      > reasons for the non-linear architectural design process

      > how architects respond to a functional brief, the site, and social/human factors

      > how architects address aesthetic considerations

      > how architects factor environmental considerations into their design
    - for architects:

      > give a sense of how engineers approach problem solving

      > how engineers respond to a functional brief

      > what feedback is typically expected from engineers and when

      > how do engineers measure the success of their design

      > how engineers factor environmental considerations into their design
- Understand **why** we often see things **different**ly, and
- develop a **common language** that cuts across discipline silos (metaphors/analogies/co-experience). Engineering should empower architecture and vice versa.

Criteria Design > Weeks 4-7

The weeks leading up to mid semester represent the major opportunity for architecture and engineering designers to advance (what the US AIA refers to as…) *criteria design*. After the major information download in the first few weeks, they should by now have embodied the major characteristics of their site (including its key environmental context), as well as having gained a basic understanding of environmental sustainability issues on the project. This period offers the best window to jointly develop and test innovative and integrated solutions across disciplines (Application, Analysis

and Synthesis in terms of Bloom's Taxonomy). It is essential that studio tutors, as well as the industry participants, *actively curate* the integrated design processes within this period.

- Instil a sense of **joint ownership** – introduce a sense of **shared responsibility** across (group) participants. Everyone is a creator or 'co-author'.
- **Maintain strong engagement** between Arch. and Eng. student designers (even outside class times).
- **Passive before active** (& application before equipment) – student designers will explore the interdependences between architectural and engineering design where passive solutions (orientation/geometry/building materials/etc.) get prioritised over equipment (mechanical/electrical).
- Explore **common targets** that address **performance and functionality at the same time**.
- **Define clear performance targets for student designers to work towards** – e.g. % in carbon reduction
- **Knowing in action/heuristics**: discuss and advance integrated design solutions on the fly.
- **start with** educated guesses/**rule of thumb**, **then verify** validity of assumptions for preferred solutions.

At mid-semester the student designers will receive their first feedback by a panel including architecture and engineering experts. Arch/Eng student designers should **jointly present** their projects.

Refining Solutions > Weeks 8-13

The attention of the architecture students will now clearly shift towards their (individual) projects. The integrated design aspect will remain until the final weeks of semester with more detailed solutions (Synthesis and Evaluation in terms of Bloom's Taxonomy).

- Advance architectural and engineering design solutions as an **integrated whole**.
- Run designated design integration workshops to **advance design interatively**.
- Search for integrated design responses to human **comfort** and environmental **loads;** examine how various aspects of the Architecture and Engineering design are connected.
- Facilitate **larger-group** interaction, as well as **smaller/individual feedback** sessions between student designers and the industry participants. Encourage active engagement with the material presented (interactive sketching over sections/plans/3D/etc. by various participants).
- Apply end-use performance metrics for joint environmental **targets**
    - What are they and what are the mechanisms to address them in the **advanced** design stages?
- Foster **Multi-functional design** – Successful ID results in design elements performing more than one function across different disciplines at the same time.
- **Define** the **characteristics** that represent the '**integratedness**' of a design solution. That's what the success of this project should (also) be measured against!
- **Weave participant feedback into future pedagogy to advance integrated design teaching**

At the end of semester-crit, student designers will receive their final feedback by a panel including architecture and engineering experts. Arch/Eng students should jointly present their projects.

Appendix to IDS studio process guidance - Integrated vs Conventional

Integrated Design Process		Conventional Design Process
Inclusive from the outset	vs	Involves team members only when essential
Front-loaded — time and energy invested early	vs	Less time, energy, and collaboration exhibited in early stages
Decisions influenced by broad team	vs	More decisions made by fewer people
Iterative process	vs	Linear process
Whole-systems thinking	vs	Systems often considered in isolation
Allows for full optimization	vs	Limited to constrained optimization
Seeks synergies	vs	Diminished opportunity for synergies
Life-cycle costing	vs	Emphasis on up-front costs
Process continues through post-occupancy	vs	Typically finished when construction is complete

Integrated design process (Source: Roadmap for the Integrated Design Process)