**DATA-INFORMED DESIGN THINKING FOR SUSTAINABILITY:   
An Interdisciplinary Learning Approach**

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**Abstract**

**Data-informed design thinking (DIDT) is a collaborative approach to problem-solving that combines design thinking principles with data analysis. By incorporating a range of data sources, multidisciplinary teams can effectively address complex issues and develop relevant solutions that better meet the needs of end-users. The Apex Harmony lodge (AHL) project serves as a case study demonstrating how DIDT enhances student learning by helping them to ground their design solutions in evidence and data.**

**The project involved collaboration between students from different schools to enhance the liveability and sustainability of a residential healthcare facility for patients with dementia. The students used digital technologies to manage and integrate data and better understand and articulate architectural design and the physical environment. They also used the design process as a framework to integrate vast amounts of data and translate complex information into objective outcomes.**

**The empathy stage of DIDT involved research to gain an understanding of the needs of the users. The data collected informed the design, visualization, resulting in better-tailored solutions that improved the overall effectiveness of the design process. Students synthesized their research findings, analysed key information to generate and evaluate potential solutions, and prototyped and tested their solutions to ensure they met the needs and expectations of users and stakeholders.**

**The use of data analysis facilitated problem-solving by providing valuable insights into complex problems. It grounded designs in evidence and data, justifying design decisions and fostering accountability. Additionally, the interdisciplinary learning approach helped to nurture and train a new generation of critical thinkers and doers to be ready for our ever-changing job market.**

**Teaching DIDT to students is imperative due to the rising demand for data-driven decision-making in today's organizations. Adopting DIDT helps students create more efficient products and equip students with crucial skills for succeeding in the modern workplace while addressing user needs.**

**Data extracted from performance-based design analysis simulations such as air flow and solar analysis, energy-modelling, and carbon life cycle analysis, influenced the sustainable building design. The students used integrated spatial analytical models, including computational simulations, to quantify and measure sustainable design performance in AHL.**

**AHL Client engagement makes this Interdesciplinary learning (IDL) setting authentic for student learning, exposing them to the realities of work-life. In conclusion, DIDT is an effective approach to problem-solving and decision-making that leverages information to drive innovation.**

**Keywords:** *sustainable design, integrative learning, industry engagement, interdisciplinary learning, data-informed design thinking, architectural design.*

**Introduction**

Due to rapid advancements in technology and automation, preparing students with the necessary skills to excel in the continuously evolving job market has become an increasing concern.The objective of this paper is to investigate how interdisciplinary learning can prepare students for success in the industry and how the integration of data analysis into the design thinking process can enhance the pedagogy of Design and Engineering, with a particular emphasis on the context of sustainable buildings.

Research has shown that interdisciplinary learning enables students to integrate knowledge and perspectives from different fields, resulting in a more comprehensive understanding of complex problems (Ney,Steven. Meinel,Christoph., 2019). Interdisciplinary learning has been found to enhance students' problem-solving abilities, creativity, critical thinking, and communication skills. Moreover, it has been demonstrated that interdisciplinary learning prepares students for jobs that necessitate collaboration and adaptability (Self, J., & Baek, J. S., 2017). In addition, interdisciplinary learning plays a pivotal role in addressing the topic of sustainability, which is a fundamental aspect for the case study presented in this paper. By integrating knowledge, perspectives, and methodologies from various academic disciplines, interdisciplinary learning provides a multifaceted approach that acknowledges the complex and interconnected nature of sustainability challenges. This approach recognizes that a comprehensive understanding and effective solutions require collaboration and synthesis across diverse fields. (Zeltina, M., 2021).

The design thinking process is a systematic and iterative approach that involves problem-solving and decision-making to create innovative and functional designs. It typically consists of several stages, including research and analysis, definition of the problem, conceptualization and ideation, prototyping, testing, and refinement. The design thinking process, employed as a pedagogical approach for design students, provides a systematic framework to guide their learning (Brown, T., 2008)

This process is widely utilized across various fields to tackle complex problems and foster the creation of innovative solutions (Leifer, L., Plattner, H., & Meinel, C., 2013).

Utilizing the design thinking process offers several advantages in problem-solving and solution development (Kelley, T. R., & Knowles, J. G. , 2016).

* Creativity and Innovation: Design thinking encourages divergent thinking and fosters creativity by emphasizing exploration, brainstorming, and idea generation, thereby allowing innovative solutions to emerge (Brown, T., Katz, B., 2011).
* User-Centered Approach: The design process incorporates a user-centered perspective, ensuring that solutions meet the needs and preferences of end-users. This user-centric focus enhances the usability and acceptance of the final product or service (Ackermann, R., 2023).
* Iterative and Collaborative Nature: The design process follows an iterative and collaborative approach, allowing for continuous refinement and improvement. Feedback from stakeholders and end-users is gathered and integrated throughout the process, leading to better outcomes (Liedtka, J., 2014).
* Holistic Problem-Solving: The design process considers multiple dimensions and factors involved in problem-solving. It promotes a holistic understanding of the problem, leading to comprehensive and effective solutions (Sanders et al , 2008).

Despite its strengths, the design process is not without limitations:

* Subjectivity and Bias: Design thinking relies on subjective judgments and individual perspectives. The identification and interpretation of user needs and preferences may be influenced by inherent biases, potentially limiting the diversity of solutions (Norman, D. A., 2013).
* Time and Resource Intensive: The design process is typically time-consuming and resource intensive. Extensive research, prototyping, and testing may be required, resulting in longer development cycles and increased costs (Kolko, J., 2018).
* Lack of Predictability: The iterative nature of the design process can introduce uncertainties and make outcomes difficult to predict. This lack of predictability can be challenging for organizations seeking concrete deliverables within fixed timelines.

Engineering students are typically trained in data collection and solution development techniques to address findings within their field. However, they often lack a comprehensive understanding of the contextual factors and problems at hand, as well as the ability to think creatively and innovatively.

Data-informed design thinking (DIDT) is a collaborative approach to problem-solving that combines design thinking principles with data analysis (Brown, T., Katz, B., 2011). It aims to use data sources to make the design process less subjective, more efficient, and more predictable.

Research has shown that integrating key data sources into the design thinking process leads to better outcomes in terms of product design (Buchanan, R., 2019) Furthermore, computer simulations that predict building behaviour can aid designers in identifying potential issues with their designs prior to implementation, thereby mitigating the risk of expensive errors. In the built environment industry, interdisciplinary and data-informed design processes have become standard practice. However, in the academic context, engineering and design are still taught in isolation. Moreover, it is crucial for future Design and Engineering professionals to possess versatility and adaptability in order to effectively engage in diverse fields of work that demand skills beyond their specialized area of expertise. The isolated approach to their respective fields may not adequately prepare them for the multifaceted challenges encountered in real-world scenarios (Bear, A. & Skorton, D., 2019).

The adoption of an interdisciplinary approach in education is vital in equipping students with the necessary skills and knowledge to meet the demands of future employment, which often necessitates a diverse skill set and the ability to integrate knowledge across various disciplines (Sanders et al , 2008).

**Materials and Methods or pedagogy**

The present case study delves into an interdisciplinary industry project that centres around designing a healthcare facility specifically tailored for patients with dementia. This project serves as the focal point for investigating collaborative interdisciplinary learning (IDL) initiative, which brings together the Diploma in Interior Architecture & Design (IAD) program from the School of Design and the Architectural Technology & Building Services (ABS) program from the School of Engineering at Temasek Polytechnic. The primary objectives of this collaboration were to provide students with practical exposure to industry settings, showcase the effectiveness of data-informed design thinking (DIDT) in enhancing student learning through evidence-based design solutions and identify the skills that students develop through IDL to prepare them for future employment opportunities. By examining this case study, we gain insights into the outcomes and implications of integrating interdisciplinary approaches and data-informed design thinking in the educational context, especially in the fields of architecture and architectural technology and building services.

During the study, ABS and IAD students collaborated to improve the liveability and sustainability of the healthcare facility, with a specific focus on addressing the challenges and needs of dementia patients. The project encompassed all stages of the design process, commencing with site analysis and extensive research. This was followed by the formulation of the design brief, ideation of potential solutions during the Concept Design phase, prototyping of solutions during the Schematic Design phase, testing of solutions during the Detailed Design phase, and ultimately presenting the final design to the client for feedback. This feedback, in an industry setting, would serve as a foundation for refining the proposal.

During the Site Analysis and definition of the design brief stages, engineering students facilitated simulations of wind flow, solar and heat mapping of the site during different times of the day and year, while design students investigated the client and patients' needs, dementia, and its implications for Singapore's future. They also explored the urban context of the site and future developments for dementia institutions.

The ideation phase of the project focused on developing potential solutions to the design problem. The design students were encouraged to explore a wide range of potential solutions and ground their ideas in evidence and data. They were also required to consider the social and cultural implications of their design solutions and ensure they were appropriate for patients with dementia.

In the Schematic Design phase, design students were encouraged to define their ideas and transform them into tangible, well-defined forms. This phase involved the development of visualizations and technical drawings of the design solutions. Once the forms were reasonably defined by design students, engineering students facilitated the creation of 3D models for the designs and conducted simulations to test how the new designs would perform in relation to wind flows, solar orientation, and heat gains. The aim was for Design students to integrate these findings into their design process and utilize them to inform their design solutions. To accomplish this, we expected students to actively seek feedback from their peers and iterate on their designs in response to the feedback received.

During the detailed design phase, the design students further developed visualizations and created physical prototypes of the design solutions. They gained a more detailed understanding of their design solutions and began refining their ideas. Finally, the students presented their final designs to the client, who provided relevant feedback on the designs.

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**Results and Discussion**

To gather data for this study, a multi-faceted approach was employed. Firstly, student submissions and final presentations were collected and analyzed (Self, J., et al, 2017).

These materials provided valuable insights into the students' learning and project outcomes.

In addition to the analysis of student work, surveys were administered to gather the perspectives of students on the effectiveness of the interdisciplinary collaboration and their learning outcomes (Donnelly, S., et al, 2019).

The surveys allowed for a deeper understanding of the students' experiences and perceptions related to the project.

Interviews, both with teachers and with IAD students, also played a crucial role in this qualitative analysis, providing rich, in-depth insights and perspectives from participants. The interviews enabled researchers to explore complex phenomena and gain a nuanced understanding of the subjective experiences and meanings attributed to them.

Furthermore, subject teachers conducted observations to gain valuable insights into the overall effectiveness of the interdisciplinary collaboration project and identify potential areas for improvement. These observations provided first hand findings on student engagement, effectiveness, timing of data exchange, and the learning process. The utilization of this multi-dimensional approach to data collection ensured a comprehensive and nuanced understanding of the impact of the project on student learning and the overall effectiveness of interdisciplinary collaboration.

The surveys and interviews conducted among IAD and ABS students provided valuable insights into their collaborative experiences and outcomes of the IDL project. The surveys highlighted the importance of diverse perspectives and thinking styles in enhancing the project, while also identifying communication difficulties as a notable challenge. ABS students reported skill development in visualization techniques and critical analysis. Challenges related to workload, motivation, timetable synchronization, and submission coordination were also observed.

The interviews with IAD students revealed positive aspects of collaboration with ABS students, including gaining an understanding of their responsibilities and receiving feedback. Challenges included partner commitment, communication difficulties, conflicting perspectives, misalignment in design approaches, and timing issues with submissions. Weaker students benefited from ABS input but experienced decreased ownership and control over the project. The IDL experience was stressful due to divergent requirements and expectations, but IAD students agreed that the data suggested by ABS students helped them solidify their concepts and propose more realistic solutions to the client.

The analysis of engineering students' work reveals significant improvements in their understanding of the subject matter, core skills, and specific design abilities. ABS students without IDL focus exclusively on incorporating technological advancements and designing for energy efficiency in buildings. ABS students, with their interdisciplinary learning (IDL) experience, were equipped to utilize data in order to inform design solutions and create designs that are more adequate and relevant. They also utilize comprehensive simulations for wind, solar, lighting, and façade design, considering factors such as aesthetics and human wellbeing Through interdisciplinary learning (IDL), ABS students are able to broaden their exploration of design solutions beyond environmental factors of sustainability. They also incorporate human factors into their considerations, thereby encompassing a more comprehensive approach to design. ABS students with IDL conduct life cycle analysis calculations and utilize collaborative software and communication platforms for real-time collaboration and streamlined interactions. They also incorporate design thinking principles and iterative processes into the environmental analysis. Overall, the findings highlight the positive impact of IDL on ABS students' design skills and their ability to work collaboratively using advanced tools and approaches.

Feedback provided by the client indicated that the students effectively addressed their realistic needs and inspired them with tangible innovative solutions.

Despite the numerous benefits reported by students, such as the preparation for the work environment and the enhancement of critical thinking and communication skills, there are important learning points that should not be overlooked. These should be incorporated into the design of the Interdisciplinary Learning (IDL) experience to further improve the students' learning journey.

According to the feedback provided by design teachers, challenges emerged due to inherent disparities in approaches and perspectives between design and engineering students. Design students exhibit a tendency towards a conceptual orientation, adopting a holistic view of the collected data, while Engineering students lean towards a more focused and specific mindset (Tan, V., et al, 2019), primarily concerned with translating the gathered information into tangible design elements. Consequently, Design students engage in exploring various iterations of intentions and conceptual ideas for the overall design, while Engineering students concentrate on specifying precise sizes and locations of components such as fans and openings. This divergence in perspective created misalignments regarding the perceived significance of information at different stages of the design process. Furthermore, the students' limited maturity hindered their ability to synthesize the collected information and translate it into relevant insights that could be effectively shared among their peers (Swan, et.al. 2020). As a result, during the concept phase, Design and Engineering students appeared to be communicating in different languages, making it challenging for them to establish a shared understanding of the pro­­ject.

The existence of divergent working cultures between design and engineering students further contributed to the misalignment, particularly in terms of embracing change as an integral part of design development. The design process inherently involves the iterative refinement of ideas, demanding extensive dedication, passion, and a constant drive for improvement (Brown, 2008). However, engineering students may perceive frequent changes as inefficient and frustrating. Unlike design students, engineering students typically do not embrace iterative approaches; instead, they tend to envision a final product from the beginning of the process and work towards achieving that predetermined outcome (Nieusma, D, 2018). This difference in working approach did not align with the evolving concepts developed by design students.

Moreover, a restricted number of students were granted access to simulations depicting the projected building's environmental behaviour, which were shared belatedly in the design phase. This limited availability of simulations hindered design students from effectively assimilating valuable experiential knowledge and impeded their capacity to incorporate essential modifications in response to the simulation outcomes.

Based on these findings, it is crucial to address communication difficulties, workload management, motivation levels, and scheduling coordination to enhance future interdisciplinary collaborations.

To address these challenges and enhance future collaborations, several recommendations were proposed. An initial ice breaker session is of key relevance to help students from different diplomas to gain the trust needed as a base for collaboration. The kick-off briefing should clearly define the different stages of collaboration throughout the design process, emphasizing the need for a breakdown of critical stages and specific deliverables. Regular joint briefings throughout the semester should be implemented to facilitate progress updates and enable effective feedback exchanges between design and engineering students.

In addition, it is necessary to re-evaluate the timing of sharing key data between design and engineering students. In an industry context, professionals have the ability to synthesize and extract valuable insights from various fields of work, integrating them coherently into the design process. However, as students are still acquiring knowledge and have not yet reached a more advanced phase of analytical reasoning, they may struggle to distil and effectively communicate information (Swan, et.al. 2020). To optimize the outcomes of this collaboration, we have determined that students need sufficient time to acquire new skills, distil information, and share it with their peers in a more coherent manner. This process prepares them for more intensive collaboration in an industry setting.

To facilitate this, we propose that in the initial stages of the design process, students should build upon each other's work. design students can begin with a holistic understanding of the site, while engineering students adopt a more data-oriented perspective. They can exchange their findings during the design brief stage. Design students should then incorporate the input from engineering students into their exploration of concepts and ideas. Engineering students can progressively develop essential skills to support design development, such as Revit modeling and compliance with local green building rating regulations.

During the concept phase, design students should share their concepts and ideas with engineering students, who can utilize them as a foundation for conducting simulations. At the beginning of the Schematic Design phase, engineering students should share their findings on how the proposed buildings interact with environmental elements. Design students should then revise the project to optimize building performance. Throughout the Schematic Design phase, engineering students should collaborate as consultants to enhance the final design. Finally, design students can focus on prototyping and rendering the final design proposals.

By implementing these adjustments and fostering collaborative exchanges at appropriate stages, we aim to enhance the overall effectiveness and integration of Design and Engineering students in the design process.

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**Conclusions**

In summary, the interdisciplinary collaboration between IAD and ABS students in the IDL project has shown both positive outcomes and challenges. The surveys indicate the benefits of embracing diverse perspectives and the skills gained by ABS students in visualization, presentation, and critical analysis. The interviews reveal the positive impact of ABS students' feedback on IAD students' design leadership and idea development, despite challenges such as partner commitment and misalignment in design approaches. The analysis of ABS students' work highlights improvements in integrated understanding and design skills, with collaborative software aiding real-time collaboration (Van den Beemt et al, 2020).

Overall, students acknowledged the importance of interdisciplinary learning in adequately preparing them for the future job market, given its potential to cultivate the requisite adaptability and collaborative disposition. Such an educational approach holds the promise of nurturing versatile professionals capable of thriving in dynamic work environments characterized by complex problem-solving and effective teamwork.

We acknowledge that within the industry, the seamless integration of expertise between designers and engineers is highly recommended. However, in the context of polytechnic academics, where students are in the process of acquiring fundamental skills and exploring their future professional roles, instructors should facilitate a closer guidance in the process of exchange of information. To enhance the IDL experience, it is recommended to adjust the timing of sharing key data, allowing students sufficient time to acquire and distill information before sharing it coherently. The proposed approach suggests design students starting with a holistic understanding while engineering students adopt a data-oriented perspective, exchanging findings during spessific stages of the design process.By implementing these recommendations, future IDL projects can foster effective communication, engagement, and shared understanding between IAD and ABS students, leading to enhanced outcomes and a more enriching educational experienceThis collaborative approach can be replicated for integrative learning across other disciplines of study as well. By engaging with industry partners, this approach facilitates the development of skills that are highly sought after by the industry, thus preparing students to be industry-ready.

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