MODULE INTEGRATION TO STIMULATE CRITICAL-THINKING, INTEREST & PROFICIENCY: A CASE-STUDY IN BUILT ENVIRONMENT DESIGN & TECHNOLOGY (D&T) EDUCATION

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Abstract

Holistic building design, Integrated Design process (IDP), green-building rating and Building Information Modelling (BIM) are common terms within the built-environment discipline today. The framework of all these approaches dictates various consultants to synthesize their expertise towards achieving sustainability targets moving away from the conventional model of transferring drawings or concepts from one consultant to another. It is hence vital to step away from this traditional system starting with the education model. With 'skills' being the focus of technical education most modules are taught in isolation from each other creating perspective gaps. Experiential gaps (Bloom, 1956) within every level reduces iterative approach to address fundamental knowledge. These gaps have led to focussed learning but with disconnected perspectives. The teaching team of the diploma in Architectural Technology & Building Services (ABS), at the School of Engineering, Temasek Polytechnic has attempted to bridge these disconnections in learning gaps by the horizontal and vertical integration of knowledge and skills across various core modules. As a pilot initiative, effort was made to design projects and lab-sheets, to focus on a common authentic scenario, in this case a new building development. In another case, project timelines and deliverables were framed to drive knowledge and skill amalgamation satisfying the project needs of either module at the same time. Taken forward to the next semester, the same scenario was revisited and built-upon using a newly learnt skillset. Focused group interviews and surveys indicate critical thinking, deep-learning, and ability to inter-connect concepts were positive outcomes of the exercise. The integration of teaching materials had a greater impact on cognition than assessments, in this case projects. However, the ability of students' grasp in one module impacted their performance across all the integrated modules. Changes in groups and peers across modules and levels also impacted learning integration and project deliverables.

Keywords: *critical thinking, built environment, curriculum integration, sustainable design*

Introduction

The global directive towards sustainability have led to an increasing demand of sustainable developments in the built environment (Keeler et al., 2016). In line with this global mandate, the Singapore Green Plan 2030 sets out to achieve specific goals for the next ten years. The three key targets set out for the built environment sector of Singapore are:

- Green 80% of the buildings by 2030
- 80% improvement (from 2005 levels) in energy efficiency for best-in-class buildings by 2030
- 80% of new developments to be Super Low Energy (SLE) buildings by 2030.

Conventional building design approach buildings as an isolated object, yet each of them is comprised of various systems impacting each other. However, sustainable designs deal with much broader perspectives and enormous complexities. These include fulfilment of green building objectives/criteria, involvement of multiple stakeholders with specializations, as well as creation and application of innovative solutions within the proposal. To address these complexities, built environment professionals have developed and practice concepts such as systems thinking (Checkland, 1981), Integrated design process – IDP (Reed, 2009), and software-based technologies to share information through Building Information Modelling – BIM (Eastmen et. Al, 2011). As a common denominator, all the approaches intend to integrate knowledge and skills by promoting iterative decision-making through critical thinking and innovation.

The main purpose of polytechnic education is to prepare students for the workplace. It is hence vital that the education system for built environment-based disciplines fosters similar integration of knowledge to mimic the need of an inter/intra-disciplinary workplace to achieve sustainability targets. Taking the case of a typical student at present, he/she is equipped with knowledge, skills, and attitude to carry out tasks as an architectural or engineering assistant/ technologist including the 'knowing how' that is necessary for the job description. However, it not necessarily includes the 'knowing why' of the task addressing complex issues that impact the overall sustainability performance of the building.

To overcome such challenges inductive teaching methods have been highly adopted within the polytechnic education system. The literatures are replete with examples of inductive teaching encouraging higher levels of student cognition (Felder and Prince, 2006) and confidence during design innovation (Aditomo et. al., 2013). In most cases instructors adapt their lecture, tutorials, and laboratory courses in ways that present students with more open-ended or design-based challenges. These pedagogies help learners to increasingly cluster concepts in their mental models, forming direct links between concepts, speeding up the retrieval process (Boshuizen, 2003). Few projects found in literature, compel students to work systematically understand and apply their engineering skills across their curriculum to design work. Sheull (1990) argued that though someone familiar with the subject (a lecturer or expert) sees an organizing structure with interrelationships among various parts of the curricula, it does not mean that a novice learner makes similar connections. Tasker (1980) also highlights this gap in his findings that lessons are perceived by students as isolated events, while to the teacher they are parts of a related series of experiences. This gap has been experienced by most of us during final-year projects as project supervisors, the task being to integrate learning across curricula to develop a product or solution.

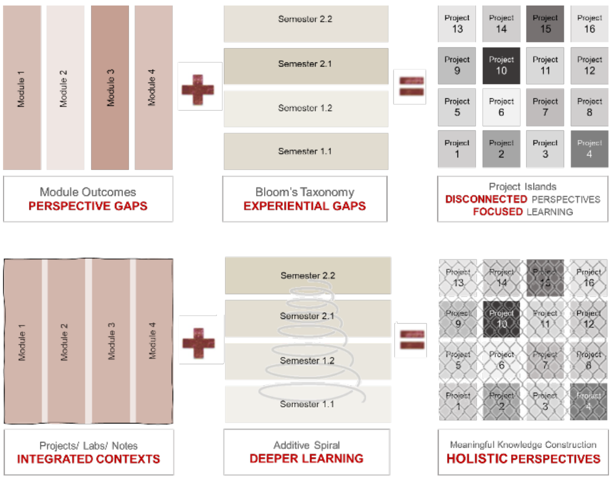

Figure 1: Current problem with the proposed framework for module integration

The paper shares a pilot attempt by Diploma in Architectural Technology & Building Services at the School of Engineering, Temasek Polytechnic, to bridge disconnections in learning gaps in the course curriculum, in particular, core modules related to the knowledge and skills of the built environment sector. The teaching team have taken an initiative to integrate knowledge and skill by developing lab sheets and projects addressing common building scenarios to cultivate a holistic perspective as demanded by the sustainable building industry, the future work-environment of graduates. Figure 1 graphically represents the problem and the proposed integrated framework.

Aims and objectives

Temasek polytechnic adopts Practice-based education (PBE), an outcome-based curriculum whereby the learning process has been designed to help students develop relevant skills, knowledge, and attitude which they are expected to apply and perform at the workplace. The objective of this paper is to understand the implication of the proposed module integration on these desirable graduate outcomes built upon the K-S-A (Knowledge-Skills-Attitude) framework. KSA are the abilities and characteristics that enable a job holder to accomplish the activities described in a task statement (Quinones, Ehrenstein, 1997). Theories of cognitive constructivism influence the proposed framework (Wadsworth, Barry, 1996). The key terms K-S-A are defined as follows in context of this paper, based on studies of cognitive constructivism:

- *Attitude* – Attitude is driven by meaningfulness established from prior experiences. Motivation to learn, self-efficacy, perception on ability to tackle complex scenarios with open-mindedness and confidence to identify alternative solutions.
- *Knowledge* – To make sense of experience. Ability to understand concepts by constructing relationships and studying implications of one concept/module over another. Perceiving the big picture for reasoning and decision making.
- Skills - Capabilities being developed by repeated hands-on experience. With skills, one can apply their knowledge and understanding in a demonstrable way establishing procedure linkage.

The aims of the study or the research questions to identify the impact of module integration on learner :

1) Attitude - Do students develop an increased interest towards the built environment industry ?
2) Knowledge - Do students make connections across modules enhancing their critical thinking capacity ?
3) Skills - Do students increasingly explore the tool (repetition) building their capabilities. ?

Implementation

The diploma in Architectural Technology & Building Services is a three-year course within the School of Engineering with the final year dedicated towards the cap-stone or major project and industry internship to cultivate a spirit of work-readiness amongst graduates. Diploma-core subjects form the crux of semesters one to four in the first two years, the target-bed for vertical and horizontal integration. The integration of the project across modules was carried over a span of 16 weeks including two weeks of term-break and a week for term-tests. modules are assessed separately for their respective syllabus-based learning outcomes. The outcomes of the modules are independent of each other.

Module integration using project scenarios: Three subjects were chosen for the pilot implementation. Individual module focus includes BIM (Architecture) skills, fundamentals of green building design and BIM (Mechanical, Electrical and Plumbing) listed in Table 1.

The subject delivery, semester and project objective have also been included. The modules A and B run in parallel during the same semester beckoning horizontal integration of projects while Module C is conducted in the following semester entailing vertical integration.

The project-scenario remained the same across the modules – Proposal for an Eco-hostel at Temasek Polytechnic campus. The spatial requirements, Gross Floor Area (GFA) and site for all the project-scenarios were crafted as a team and repeated in the individual module project briefs.

A typical building design process may be broken down into three-stages prior to construction – Concept or pre-design with site analysis including preliminary envelope massing options; schematic design taking forward the chosen massing for an iterative analysis on performance and costs; detail or technical design towards construction tender. The scope of the project mirrors the process carried out during the 'concept-design' stage of a green-building design process adopted in industry practice. The final product is ready for handover to the schematic design stage thereby taken over to Module C in the following semester. The vertical integration includes design review for the implementation of Mechanical, Electrical and Plumbing (MEP) systems and recommendation of spatial changes to accommodate these building services. As engineering BIM technologists, students learn and propose a MEP system along with clash-detection ready for valuation and performance appraisal.

Module integration in coursework (practical labs): Singapore's thrust towards a green and digital economy, drives the need for skill development in 3D-modelling and performance simulation of buildings. An attempt was made to revise lab-sheets for teaching material to focus on the same building scenario across all modules that were involved in software-based skill development.

Four subjects, module C, D, E and F within the year 2 curriculum, were targeted for this integration. Module D was focused on skill development for construction drawings, Module E on passive design performance, Module C on modelling skills for an MEP engineer and Module F on energy or performance of active systems in a building. The key aspects of these modules have been captured in Table 2.

The objective of the integration was to shift the focus from the need to understand the subject of study in the lab work towards skill development and contextual application. A typical office building was adopted as the subject for all the lab-sheets. Students are thus taken through a holistic experience of building design – sustainability, architectural and engineering services – not compromising the individual module-based learning outcomes. Figure 2 showcases implementation snapshots from student project work based on an integrated scenario and lab-sheets incorporating the same building across various modules.

Methodology

A mixed method research methodology integrating both quantitative and qualitative approaches was adopted in this study. The quantitative phase which employs a survey was followed with a quantitative phase or interview to complement each other for a complete understanding of the research questions. Survey results provides a general picture of learner's perception of module integration while open-ended feedback enhance those results by reasoning the perceptions.

Cross-sectional surveys were conducted across both the research groups – students involved in project and lab-sheet integration. The surveys were conducted during the last-but-one week of the semester, followed by interviews the following week.

Table 1: Modules integration of project scenario

Module	Year.Semester	Expected learning outcome	Delivery
A	1.2	Skills to mass and construct a three-dimensional architectural model for schematic design	Practical labs
B	1.2	Fundamentals of sustainable building design	e-Lecture & tutorials
C	2.1	Skills to design and construct a three-dimensional MEP model for schematic design	Practical labs

Table 2: Module integration of coursework lab sheets

Module	Year.Semester	Expected learning outcome	Software
C	2.1	Skills to design and construct a three-dimensional MEP model for schematic design	Revit (MEP)
D	2.1	Skills to produce construction documentation based on authority guidelines and requirements	Revit (Architecture)
E	2.1	Passive performance simulations for green building design	SketchUp and Sefaira
F	2.2	Energy analysis and optimization through simulations	IES-VE

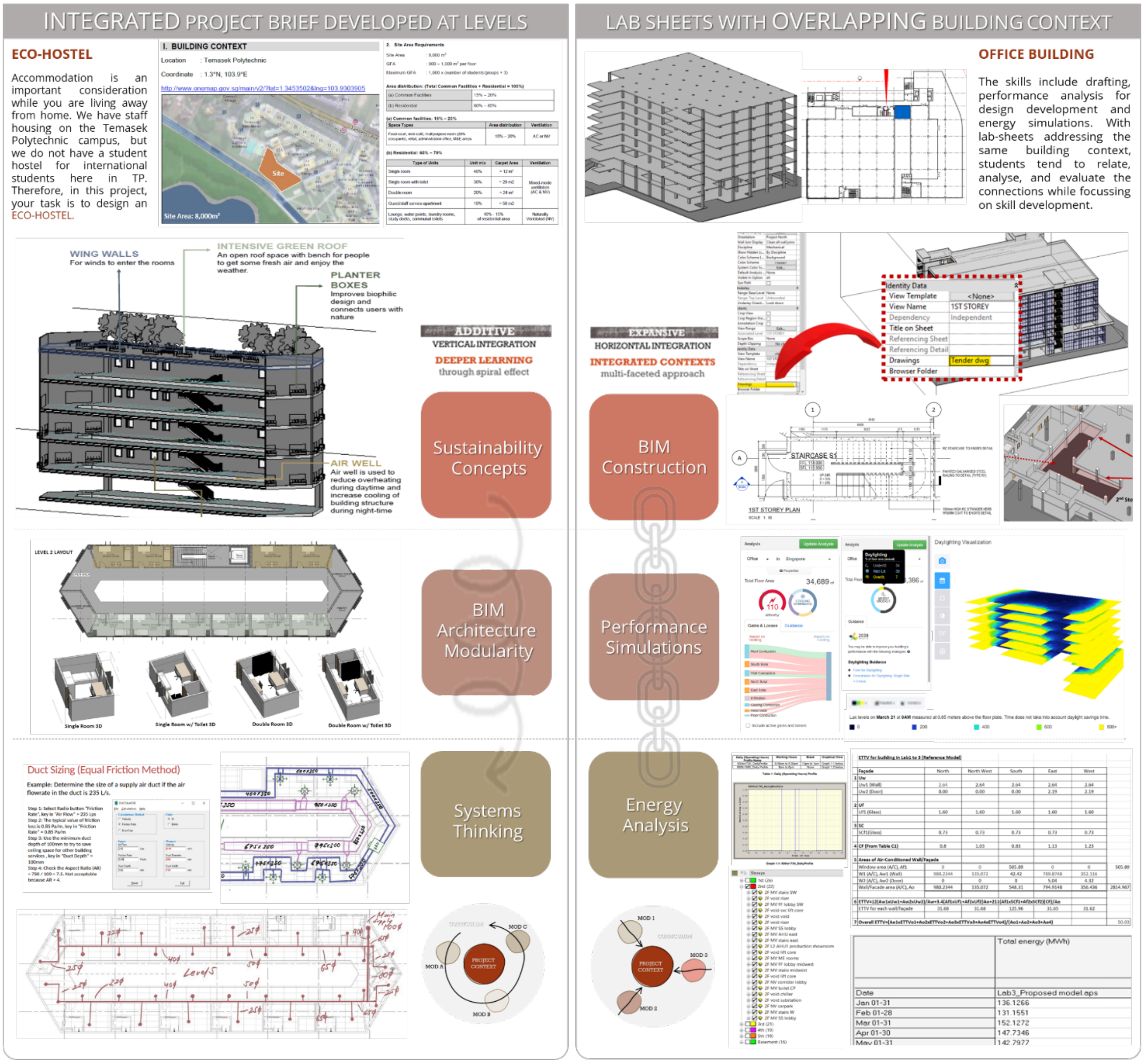

Figure 2: Implementation of integration framework

Table 3: Survey questions

ATTITUDE	Q1	Integration provides a wider perspective increasing my interest and open-mindedness to the building industry.
	Q2	Having a similar design context has helps in to develop confidence and working efficiency
KNOWLEDGE	Q3	Working on the same context helps in a holistic understanding of the design process followed by the industry
	Q4	Integration gives opportunities for critical thinking skills as I had to consider various concepts across modules
SKILLS	Q5	Working on the same context allows to focus on various software, their specific capabilities and relevant application
	Q6	Integration required reviewing the model a few times which helps me sharpen my modelling and simulation skills (or) Integration of lab-context helps my learning speed and thus exploration of the given tool beyond lab-work

The 2021 intake, from semester 4 (year 2) provided the sample for module integration using coursework and the 2022 intake, from semester 3 (year 2) for module integration using project scenario. A random-sample of 40 - 45 students each cohort participated in the survey (approximately 60% of the intake) . The survey consisted of six-questions (Table 3) over a 7-likert scale conducted using Microsoft Forms. Though the survey responses were from cohorts, the overall profile of the intntake quality were similar. Informal interviews were conducted with a random 10 students for each scenario to clarify and probe into open-ended feedback from the survey questionnaire. This helped increase the validity of the quantitative strand.

Results and discussion

Module integration through project scenarios: The survey outcome tends towards '*Agreeable*' with an average above 5 as captured in Figure 3. It is evident that there is a correlation between the learning integration and impact on knowledge, skills, and attitude, with highest impact on skills, closely followed by knowledge and then attitude.

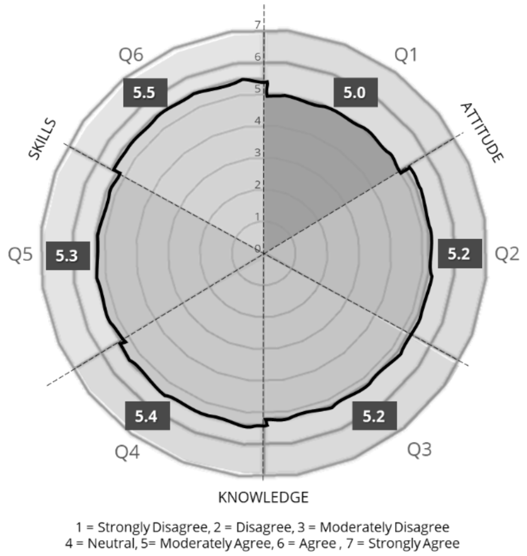

Figure 3: Survey outcome on module integration using project scenario

The design process for a sustainable building involves multiple iterations to building design at its inception during the concept phase. Since the project adopted a similar implementation process, students required to re-construct their models while revisiting green-building concepts along with feedback at regular intervals. This additional practice may have contributed towards the tilt on skills acquisition in an integrated project scenario. Most students shared the following when probed during open-ended interviews:

- Appreciation of the interconnectivity towards gaining a broader picture of the module-level learning within the vast building industry.
- Ability to visualize usefulness of the learning content in their future workplace (Meaningfulness)
- Deep learning as they do not need to shuffle thinking different context amongst modules. This also led to overall time-management.

Students also shared few challenges:

- Limitations to the ability or depth of learning from one module project impact the other module and thus their overall grade and performance, especially in a vertical integration scenario.
- Comprehension of the integrated work-process along with new learning.
- Compromise in project consultations for groupmates placed in different classes for the modules involving integration.

Module integration in coursework (practical labs): The survey outcome of integrated coursework is presented in Figure 4. It is observed that the overall average is slightly higher than integration using project scenario. The impact on knowledge (critical thinking) was also higher followed by a clear demarcation to skills acquisition followed by attitude. The ability to better comprehend knowledge when presented in teaching materials is evident, in comparison to self-directed integration within project-scenarios.

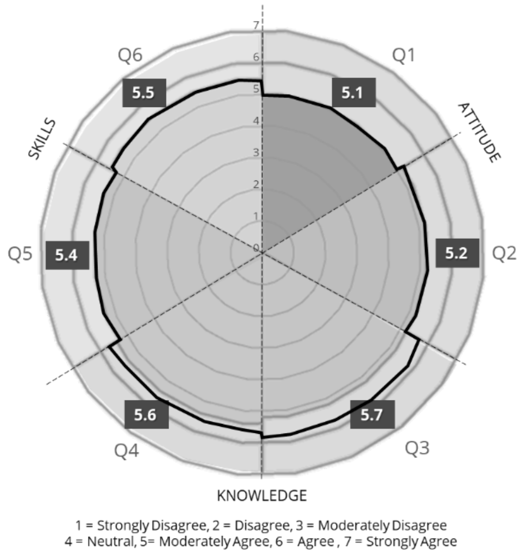

Figure 4: Survey outcome on module integration in coursework (practical labs)

During the open-ended interviews, many students re-confirmed the following:

- Ease of software comprehension as the course material integrated subject of study amongst the core-modules, allowing them to focus on the skills and further application.
- Possibility of sharing of data, drawings, 3D-models, or information across modules resulting in the ease of learning-transfer to integrated projects, if need be.
- Visualize the same subject (building scenario) from various perspectives providing an in-depth understanding which otherwise is quite challenging.

It has been observed that most students recorded that there were no challenges, and the integration made learning easier and convenient thus enabling them to establish connections beyond a specific module. Few struggles recorded by students were:

- Confusion in the use different software, keyboard, and mouse triggers, particularly when integration of lab-sheets happened during the same semester.
- In case of absence, since the lab-sheets involved the development of the 'same' building and not independent of each other, the catch-up with learning for the forthcoming lesson involved additional effort.

It was also acknowledged that the conscious integration of subject materials from the lecturers motivated students towards to voluntarily think across modules while working on self-directed assignments and projects.

Conclusions

The basis for a major curriculum integration though project and coursework materials was explored in this paper. The integration intended to construct learning connections across modules in order to replicate the real-world green-building industry. Based on the result of the present study, it is observed that an integrated curriculum could significantly stimulate critical thinking, interest and skill-proficiency by promoting awareness, cohesion and re-emphasis of concepts across modules. The impact on critical thinking and skill-proficiency is comparatively notable, especially when driven by the teaching team and learning materials. It is simply a question of becoming familiar with this iterative cognitive process. Challenges of subject integration on student learning have also been identified but can be negated using addional time and resources by the lecturers considering the benefits of cognitive constructivism through this process.

Integration of other discipline-based modules is yet under development, particularly thouse pertaining to building services, and there are many plausible perspectives yet to be explored. The challenges of implementation, from the perspective of lecturers is another plausible area of study. This may account to additional time and motivation from the teaching faculty to ensure a convinced application of an integrated curriculum.

The population chosen for the survey though similar ni profile were from differnt cohorts. A continuous longitudenal study across the same cohort for both scenarios could provide a more comprehensive data, particularly when run through for atleast three consecutive cohorts. Differences in lecturer approach, subject delivery and project consultation may also contribute to the variations in survey response. A relative study using contriol and experimental groups would be an approach with higher validity. However, considering the limitation that it is essential that all graduates from the same cohort have similar experience, the approach could not be adopted.

Additional categorization and data analysis based on student background such as entry score to the diploma, current grade-point average for data analysis could reaveal further correlations in the findings. Further research comparing the survey outcomes and student scores in their respective modules would validate the extent to which critical thinking, interest and profiency have been gained at an individual level. This study could identify clashes in confidence and perception of integration against actual application and outcomes in assessments.

Acknowledgements

Teaching team and course chair (2021 – 23) of the Diploma in Architectural Technology & Building Services, School of Engineering, Temasek Polytechnic.

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