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COMPETENT DESIGNERS: INCULCATING DESIGN COMPETENCIES THROUGH COURSES

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ABSTRACT
This paper presents the use of the Design Competency Assessment (DesCA) framework to enhance collaboration between courses in an interdisciplinary design-based curriculum at the Singapore University of Technology and Design (SUTD). The paper illustrates the use of this framework in SUTD's second term Design Thinking Project (DTP). The DTP explicitly brings together the learnings of the courses taking place in that term, in particular the introductory Design Thinking and Innovation (DTI) course. DTP as a joint project is facilitated by faculty from different disciplines. Students have to demonstrate how different disciplines have influenced their design project. DesCA was introduced in the planning of the project to identify competencies needed for DTP and overlay these onto the existing course schedule. The results of this case study suggests that DesCA, as a competency-based approach, provides a common language between faculty of different disciplines and is an effective means: to gain a common understanding of the required competencies; to obtain coherence between courses in an interdisciplinary curriculum; and to form the basis for assessment. This should allow for a more coherent and integrated approach to design education, which is essential for producing graduates with a broad range of knowledge and skills and attitudes to tackle complex global challenges.

Keywords: Design education, engineering education, competency-based education

1 INTRODUCTION
Most educational programs follow a set schedule with semesters or terms. To graduate, students must complete a specific number of courses or credits [1]. Curricula are subject matter oriented and "are divided into courses on specific areas of expertise, often the result of a combination of historical factors (this was the way I learned it), a clinical analysis of the so-called structure of a domain or discipline (this is the 'objective' hierarchy of the subject matter), and analysis of the expertise of the teachers (Professor X is an expert in…)" [2]. However, the traditional view of knowledge as discipline-based has evolved to include an integrated understanding of education where the primary goal is not limited to knowledge acquisition but also knowledge application [3] and generation [4]. As the complexity of global challenges increases [5], students recognize the need to have a broad range of knowledge and skills to offer value to future employers [6]. The discipline of design challenges current thinking, adopting creative methodologies and practices to frame problems and offer solutions [4]. The integration of design thinking methodologies into a wide variety of curricula has highlighted the potential of creative processes and aided in the development of innovative solutions in various fields [7]. "Design thinking, combined with scientific and technological thinking, allows us to explore the new frontier of design and innovation and to link design to the future" [8].
Although efforts have been made to integrate design into the overall curriculum [9–11], design is still largely present as a distinct and separate subject and its "integration with other subjects is often left to the students" [12]. Interdisciplinary and multidisciplinary formats of design education offer promising approaches to provide students with opportunities to learn by seeking and integrating knowledge from multiple disciplines in contexts of varying complexity [13]. The Singapore University of Technology and Design (SUTD) has been recognized as one of the top emerging engineering schools in the world [14] and it prides itself on fostering technically proficient leaders and innovators through its distinctive interdisciplinary design-based curricula [15][16]. Nevertheless, challenges remain in implementing design throughout the curricula, such as the difficulty to maintain coherence between the design

competencies taught in the various courses, the lack of clear progression pathways towards design competency, and the resulting struggle of students to comprehend the design process as a generic approach and identify their learnings and progression. Since SUTD expects design to be present in each course regardless of major or discipline a further challenge is the limited background in design methods and approaches among most of the faculty: they are expected to be involved in core design courses and incorporate design components in their own courses to teach and assess discipline-specific concepts. Nilsson et. al [17] pointed out that one challenge with the commonly described learning outcomes of a course is that they do not clarify the competencies that teachers should include in learning activities, provide feedback on, or assess in a clear and straightforward manner. For this very reason, the DesCA (Design Competency Assessment) framework was developed in collaboration with instructors of design courses and courses with design components at SUTD [18]. A competency framework should allow a more fine-grained identification of the competencies that a course, curriculum or program wishes to furnish its students and of the levels of competency expected at specific points in their learning journey, thus supporting the development of progression pathways. Learning activities, experiences and materials can then be designed to fulfil these needs [19]. A competency framework should also provide a common language for curricula, courses and activities that involve multiple disciplines, such as design projects. At least in design education, approaches, methods and tools do not provide a common ground.
In this paper we present a case study aimed at a first evaluation of DesCA's effectiveness in (1) identifying design competencies in the courses involved, (2) linking competencies to a time-based course structure and (3) providing a "common language" to improve collaboration between courses of different disciplines.

2 DESCA FRAMEWORK

From a literature review we inferred that competency refers to a comprehensive term that encompasses knowledge, skills, attitudes, and behaviours that are essential for an individual to succeed in professional, social, or learning settings [20]. When we refer to "design competencies," we mean the competencies required for designing. We believe that design can cultivate a wide range of competencies that can be applied in other courses and activities. At the same time, a wide range of courses can cultivate competencies that are required for design. Many of these competencies are discipline agnostic.
The DesCA framework was developed to help faculty identify design competencies in their courses (whether design courses or not) and provide them with a common vocabulary to collaborate effectively when planning, teaching and assessing design (especially in design activities such as DTP and DTI. The framework aims to: (1) provide an outline of a design process; (2) link design competencies to the phases of this process; (3) assist with determining the design competencies and levels of competency the course or curriculum aims to achieve; (4) suggest possible methods and tools based on the chosen competency and competency level; (5) guide the formulation of design deliverables and related learning outcomes; (6) support the assessment of learning outcomes based on competencies and deliverables [18]. The case study described in this paper addresses aims 2 and 3.
An action research approach was used to develop and evaluate the DesCA framework. In the first stage, the structure and initial content of DesCA were developed based on a literature review of accreditation requirements for design and design engineering courses [21, 22] and of some established frameworks [23–25], the material of the "Design Thinking and Innovation" (DTI) and the final year Capstone Design course at SUTD as well as on discussions with their leads. In the second stage four design and four non-design faculty were interviewed to gather their understanding of competencies and challenges and successes in fostering or assessing competencies. Valuable insights into required competencies were also obtained from design educators across other levels of education [20, 26]. The third stage involved applying the set of competencies through workshops and interviews with 33 faculty involved in 28 courses at SUTD to evaluate the applicability of the set by faculty of different disciplines, to analyse the students' perception on the competencies they learned in those courses, and to analyse the coherence, links, and progression of design across the curriculum [29]. This led on the one hand to changes in the courses and on the other hand to refinement of the list of competencies and the development of support for deconstructing the course content into competencies.
The DesCA framework currently includes 103 skills, 81 knowledge components, and 67 attitudes, all of which are linked to 12 overall abilities related to the main phases in a design process.
To support identifying competencies, DesCA includes: guidelines to distinguish between abilities, skills, knowledge, attitudes; a form (Figure 1) and a sequence of questions to identify abilities, skills,

knowledge and attitudes: (1) What abilities are being fostered? (2) What skills are being trained? (3) What knowledge is being imparted? and (4) What attitudes are being inculcated? In addition, we adapted Crawley's categorization of learning outcomes for the CDIO (Conceive, Design, Implement, Operate) syllabus for engineering education [23] to classify competencies as being introduced (I), taught (T), assessed (A), or expected (E) [23], [29].

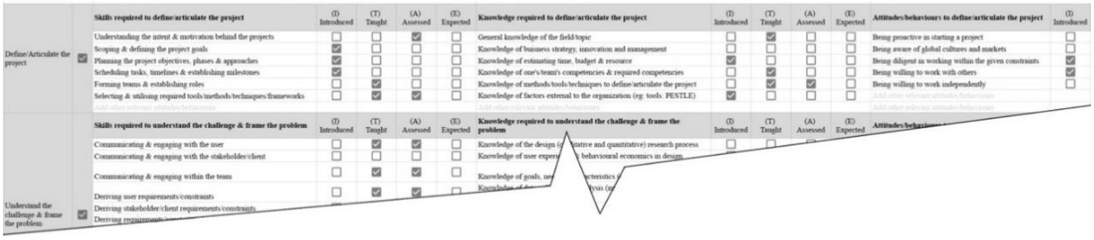

Figure 1. Course Competency sheet with abilities, skills, knowledge, attitudes and whether they are being introduced/taught/assessed/expected in the DTI course

We found that while faculty could easily indicate which of the 12 overarching abilities their courses foster, differentiating between skill, knowledge and attitudes is often challenging. To overcome this challenge and minimize subjective interpretation, we have identified pointers. They are as follows:
Abilities: This category can be identified using the learning objectives and measurable outcomes of the course and by asking the question "What do you want students to be able to do by the end of your course?". For example, students should "*be able to"* define and articulate the project.
Skills: These are characterized by verbs (ending in -ing) followed by the context and, by asking "What specific actions are students expected to perform?". For example, they are defin*ing*, articulating*ing*, identify*ing*, the problem, project (context), etc. We refer to Bloom's Taxonomy [27] for a list of verbs.
Knowledge: Once the skills have been identified, it can be difficult to relate what specific knowledge is required to perform them. It requires a deep understanding of the content covered in the course. In most cases, the knowledge component is related to the context in which the skill exists and can be identified by asking "What do they *need to know…?"* For example, students would need knowledge of the problem, project, etc., to perform the desired skill effectively.
Attitudes: We differentiate this category from skills and knowledge by adding "being" to the noun form of the verb and by asking the question "What specific attitudes should students exhibit?". For example, the course facilitates desirable attitudes, such as being proactive, being willing to learn, etc.
These pointers us helped us with the mapping competencies for the DTI and DTP courses which were part of our case study.

3 CASE STUDY

The nature of the DTI course and the DTP proved apt for studying our research questions: Can DesCA, as described above, be used to identify design competencies, overlay these onto a time-based course structure and provide a common language for enhanced and effective collaboration between courses?

3.1 Case

SUTD employs a unique four-dimensional (4D) pedagogy in its Bachelor programmes. This pedagogy utilizes design challenges at different levels or dimensions: 1D design activities involve a single course; 2D design activities involve all courses in a particular term; 3D design activities involve courses from different terms; and 4D design activities are course-independent and extracurricular activities [15]. The case study focuses on the Design Thinking Project (DTP) ([12] for details) and the 4 courses it integrates: DTP and the courses take place in Term 2, are mandatory for all SUTD students, and are facilitated by faculty from different disciplines, including architecture, mathematics, physics, and engineering, to name but a few. DTP is a 2D activity taking place in weeks 10-12 (of 14) of term. DTP serves as an extension of Design Thinking and Innovation (DTI), a Term 2 course aimed at cultivating the design thinking process using the UK Design Council's Double Diamond framework [28]. The other 3 courses on which DTP – as a 2D project – builds are: Modelling Space and Systems (MSS- mathematical modelling of real-life problems), Science for a Sustainable World (SSW - science and engineering approaches towards achieving sustainable development), and Technological World (TW - physics foundation for a holistic perspective of current and emerging technologies in modern society). DTP's purpose is to bridge the gap between the different subjects in the term: students have to demonstrate how the content of the 3 courses have influenced their projects or how their projects have helped them understand these subjects more deeply. The DTP project takes place in weeks 10-12 of the 14 week Term 2 and is facilitated during the DTI classes by the instructors of the three discipline-specific courses along with the DTI instructor, to allow students to consult with the instructors on applying the appropriate discipline specific concepts in their DTI project. This application is the main focus of these three weeks (For a detailed account of DTP, see [12]). The multi-disciplinary nature of the DTI course and the DTP project made them apt to study our research questions.

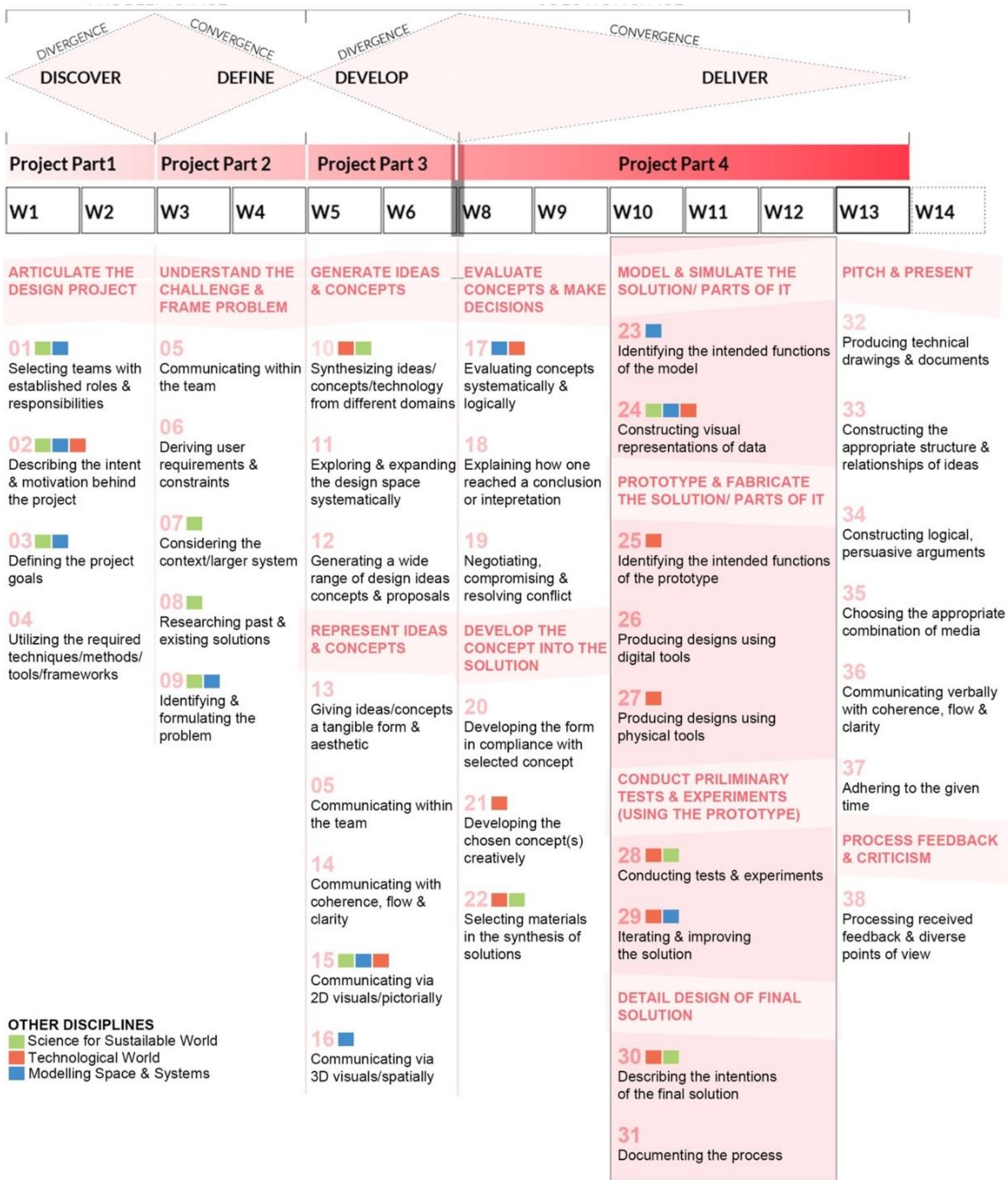

Figure 2. Competency-based plan for DTI showing 38 design competencies and the Double Diamond framework against the term weeks. The coloured squares indicate contributions to the design competencies by three non-design courses in that term and pink column indicates DTP project weeks

3.2 Results

Together with the course leads, we used DesCA's list of competencies and support described earlier to first identify the competencies for DTI (Figure 1) and for DTP and whether they are introduced, taught, assessed, or expected. The DTP design competencies are those fostered in the three discipline specific courses MSS, SSW, TW. Next, the four phases of the Double Diamond design process used in DTI were mapped against the weeks of the term (see Figure 2), followed by the mapping of the DTI abilities (red in Figure 2) and the related competencies (black). To maintain clarity and focus teaching and assessment, only the competencies that, according to the course leads, are being taught or trained explicitly, were included. Interestingly, this was only the case for skills and knowledge components. None of the identified attributes are explicitly taught or trained in DTI, yet. Finally, coloured squares were added to indicate whether a particular competency is being taught in one of the three discipline-specific courses. The scheme shown in Figure 2 is now used in the weekly DTI instructor meetings to reflect and actively used by the course lead for monitoring and planning during the course.

4 DISCUSSIONS

In earlier interviews the instructors of DTI and DTP reported having limited knowledge of what was being taught in the other courses, despite being expected to facilitate the cross-course DTP project. We observed that describing the courses in terms of competencies, providing forms and guidelines, and mapping the competencies against the course timeline and the design process model used, was effective in identifying and presenting competencies, in planning and monitoring when they were being addressed, and in providing a common language for instructors to discuss course content across disciplines. We expect that collecting this data for every course, a comprehensive understanding of the design competencies fostered across the curriculum could be obtained, supporting course and curriculum planning and coherence. The application of DesCA highlighted early in the term different perspectives on the course among faculty, possibly due to their background, which could affect teaching and assessment if not identified. It has to be noted that the courses take place in multiple rooms in parallel, each with their own instructors. The use of the schedule (Figure 2) in the instructor meetings helped instructors and course leads monitor and reflect on progress and take action if required, ensuring more coherence between classrooms.

The case study could only start a few weeks prior to the term. This affected the time available for training of the instructors and the possibility of adaptation of the course during the planning stage, e.g., the explicit training of some attitudes. Not all faculty are equally involved in the case study. Possible reasons are a lack of time or of interest. The case study is still ongoing at the time of writing this publication, so that final conclusions cannot be drawn yet. Additional case studies are necessary to confirm the findings.

5 CONCLUSIONS

Education has evolved from traditional discipline-based curricula to integrated education that focuses on knowledge application and generation. The complexity of global challenges necessitates a broad range of knowledge and skills, including those related to design, which is essential for problem-solving and innovative solutions. However, challenges exist in implementing teaching and implementing design throughout the curricula. The DesCA framework was developed to address these challenges by providing a competency-based approach. The case study shows that DesCA's list of competences, the form and guidelines, can help instructors of different disciplines and in the context of an interdisciplinary project (1) to identify design competencies, (2) plan a course, establish its links with other courses, and monitor progress through mapping the competencies onto a time-based course structure, and (3) provide a common language enhancing communication and collaboration between instructors within and between courses. Further case studies are necessary to confirm the results and improve the framework. We hope that the method to map competencies, the use of a competency framework and the resulting visualization can serve as a model for programs seeking to integrate design into their curricula.

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