Introduction

Until recently, the classical style syllabus still dominated most university-level industrial design education, placing emphasis on elements impacting the user's physical body, such as ergonomics, colour, texture, shape, and volume. Though such a structure has successfully answered the industry's needs for decades, today's mobile, wireless communication and pervasive computing technologies have transferred the traditional perception of product design into more complex 'smart' products, such as 'e-Product' and 'Smart-System', that focuses specifically on 'behaviour'. As Malouf (2010) suggested 'Due to the incredible increase in both product and system complexity that the use of advance technology enables, it is more important than ever for industrial designers to step up and engage more directly with interaction design—the design discipline focused on the design of the behaviours between products, systems and humans.' Industrial designers today must understand 'computing and networked products introduce a new dimension of interactivity beyond the product's physical form' (Ann, 2003).

But what sort of products should industrial designers innovate in the information age? From an educational perspective, how can we develop an appropriate syllabus to nurture a new generation of designers? What should be the new ingredients to the current syllabus? Tangible Interaction is the key to addressing these new challenges. From an interaction design perspective - not merely human–computer interaction (HCI), but human interactions - human-environment interactions should focus on embracing physical functionality, usability and user experiences. Such shifts in the design curriculum and teaching developments have already taken place in other institutions, such as Zokei University in Japan and Purdue University. As Qian, Visser, and Chen (2010) advocated, 'for a designer, being able to merely design interaction is a good skill, but being able to control, amplify, and support the human-product interaction is even more desirable.' It is the responsibility of design educators to not only to teach students hands-on skills but more importantly to support and nurture the quality of students in areas of creativity, aesthesis, flexibility, practicality, and method. Therefore, the aim of altering the existing syllabus is to support graduates enabling them with knowledge and abilities that would offer them more innovative and rewarding design careers.

The objectives of this paper are to:

- illustrate the background and articulate the necessity to integrate Tangible Interaction into the curriculum of Japanese industrial design education;
- describe how the Tangible Interaction philosophy has been implemented in the teaching and learning on an industrial design programme at a Japanese design university;
- present and discuss research carried out to investigate and evaluate those pedagogic developments; and
- present a Tangible Interaction focused teaching model, and student learning outcomes that can operate successfully under this pedagogic development.

Why Embrace Tangible Interaction Design?

Tangible Interaction Design (TID) is a growing field that draws technology and methods from disciplines as diverse as human–computer interaction (HCI), industrial design, engineering, and psychology. If the idea of ubiquitous computing (Weiser, 1991) is computation integrated seamlessly into the world in different forms for different tasks, tangibility gives physical form and meaning to computational resources and data.

Djajadiningrat *et al*. (2004) suggest that Tangible Interaction has focused on a data-centred approach to mapping the physical and digital worlds that does not make full use of human perceptual–motor skills. As an alternative, they propose an approach based on industrial design that focuses on creating meaning from giving intangible systems controls that communicate their purpose through their physical form and the actions they require. (Mazalek and Hoven, 2009)

The paper has two components, which reflect these objectives. The first section explains the motivation to develop the existing industrial design curriculum under a Japanese design education context. It then goes on to outline their current practices of Interaction Design teaching activities. The later section includes further discussion and proposes a process model of how Tangible Interaction featured industrial design teaching and learning activities can be successfully utilized in a (Japanese) university-level industrial design program.

Tangible Interaction Design Education

Tangible Interaction is vital to our process of syllabus development for its emphasis on contextual and behavioural centred perspectives. Originally, Tangible Interaction was a term from computer science which took a 'data-centred approach' to map the physical and digital worlds. This term was integrated into the field of design at the early-stage with Ullmer and Ishii (2000) describing Tangible Interaction as a method of 'giving physical form to digital information and its subsequent physical control'. Thus the great challenge of Tangible Interaction is how to integrate digital functions and manipulations into physical forms in an appropriate and meaningful manner.

In this paper we cite a Japanese Tangible Interaction pedagogy development case study. We intend to reflect on this case study as inspiration for a new syllabus model, which could contribute to the developmental processes of emerging design programs in Australia.

Since the mid-1970s, the Department of Industrial Design at Zokei University, Japan, developed an approach to teaching industrial design students across diverse arenas, such as product design, sustainable design projects, industrial design and design management. Over the years, its teaching model has evolved greatly to consolidate its reputation as one of the leading institutions in this field.

Colleagues at Zokei conducted research into how leading Japanese manufacturers developed new products through years of collaboration with Toyota, Hitachi, and Toshiba. It became clear companies were changing their focus from traditional physical products, which had been driven by ergonomics, engineering and manufacturing to more innovative smart systems, services and virtual products which were driven by information technologies, connections and user's behaviours.

In this paper the module will be referred to as the 'Tangible Interaction Design Education - TIDE module'. The teaching team's aim in developing this module is to offer students the chance to develop vital knowledge and skills, which would be valuable in the rapidly changing world of industrial design.

Drawing on the teaching team's experience, plus appropriate investigations into current professional interaction design activities, three distinct strands or topics of teaching were initially worked into the TIDE module. These are: ‘context’, ‘user's behaviour’ and 'system anatomy', which place importance on the interactive elements of new product development (Figure 1). The team developed a module for the basic introduction to the concept of context: methods to analyse user's behaviour, affordances, behaviour-centred design approach, anatomy of an existing system, interaction design process, interaction design evaluation, Tangible Interaction design and designing the context-awareness. The aim is to encourage innovation in terms of interaction and Tangible Interaction as essential to the design activities/focus for emerging industrial designers.

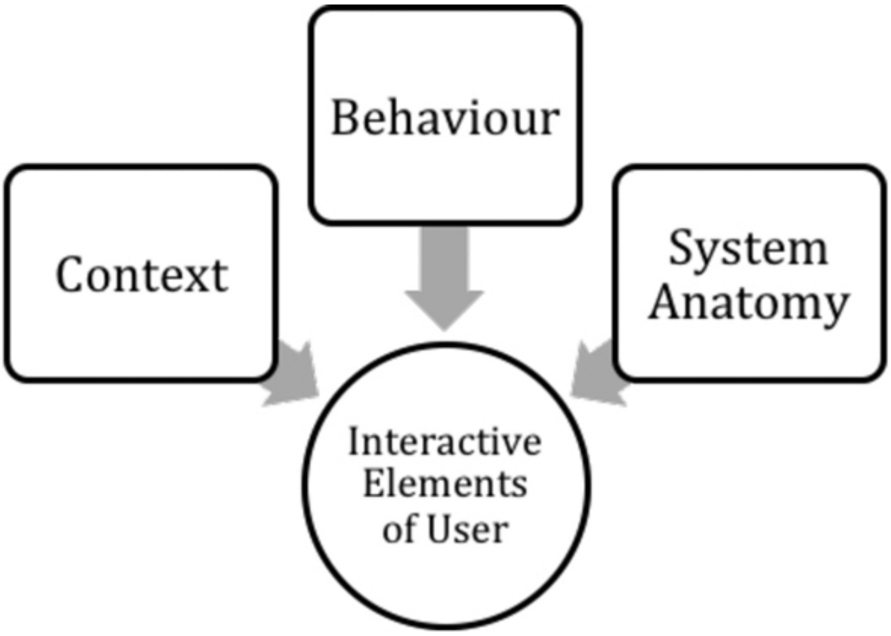

Figure 1: The importance of interactive elements in the process of new product development.

Using this module, during the first half of an academic year the students are introduced to the topics of interaction design and affordance intensively, aiming for basic abilities of relevant investigation and synthesis. The second half is based on gained knowledge from the first half with the students exposed to topics more relevant to TIDE, such as context, behaviour–centred design, context-awareness etc. Students are then able to exploit, and further apply and develop these skills and knowledge in a specifically designed project.

During the two teaching semesters at Tokyo Zokei University, two main topics have been introduced to students: 'photography system' for the first semester and 'e-health' for the second semester.

The undergraduates investigate issues related to the interactive systems with emphasis on the user's needs and various contexts. The student activities usually take the form of researching a well-known chosen system to reveal its context and to create a graphical diagram to communicate this essence. This activity contains the essential aspects, such as the 'goal' of the system, which could differ from the user's needs; the technology context; the social and cultural context; the marketing context- the positioning of the product in relation to the intended target market; and the information context. The information input and information output are also explored in the teaching.

Research Portfolio

The first formal outcome required is a detailed 'research portfolio', in order to demonstrate that the student has empathy with relevant users and has identified significant goals and needs, which can guide downstream design work. The research has been achieved by investigating a sample user group (normally contains 5-10 users) that represents an archetypal target group of users. This outcome is usually a selection of relevant evidence, in the form of pictures and text, which is meant to communicate the essential nature of the user experiences or ritual. The ideal experience board has highly relevant observations and insights of user behaviour and actions, as well as ‘painting a picture’ of the experience itself. Figures 2 and 3 show a sample Research portfolio produced by a student Chisato Yoshimi who has been taking the TIDE module.

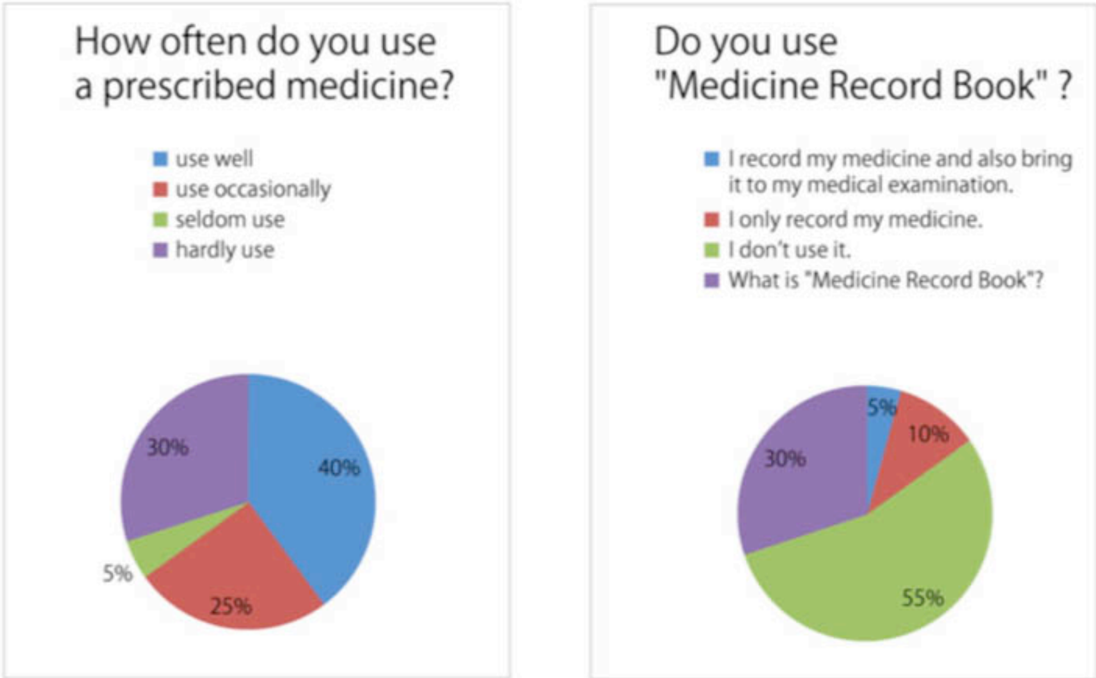

Figure 2: Research portfolio – investigation.

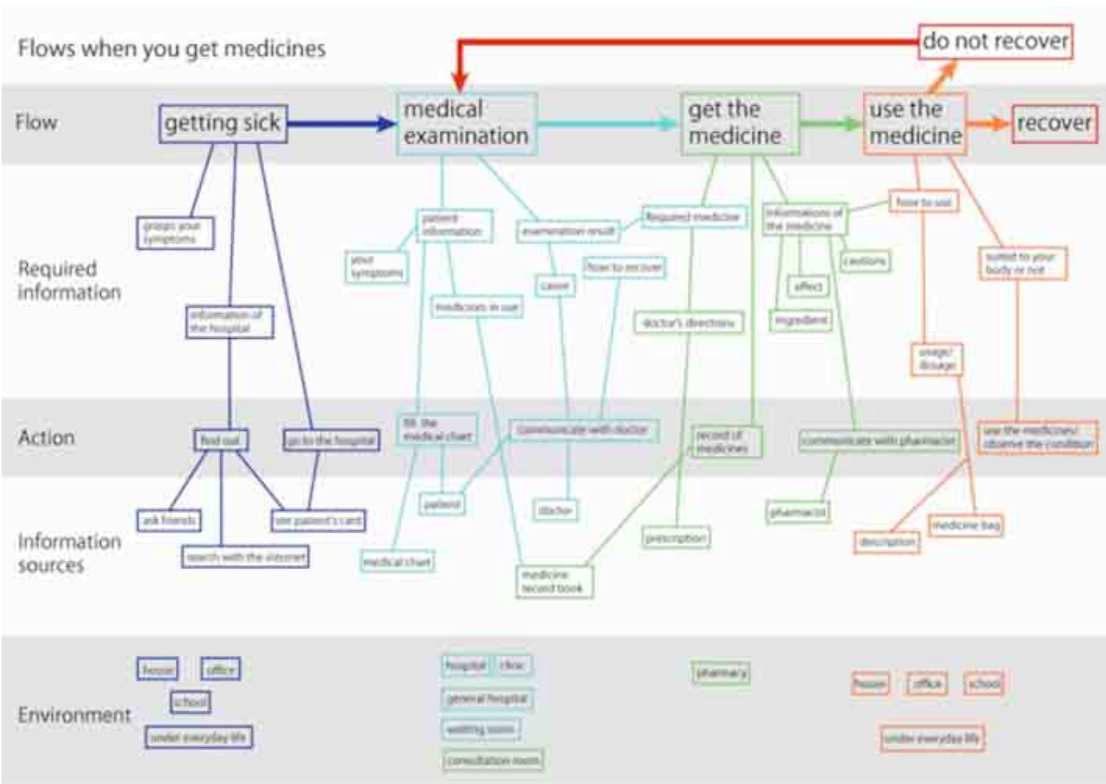

Figure 3: The analysis of users' behaviour.

Utilizing the TIDE module, one significant element of the investigation and research is it focuses on the behaviours of the target user group. User research has investigated areas such as processes, behaviours, actions, information, environment and context.

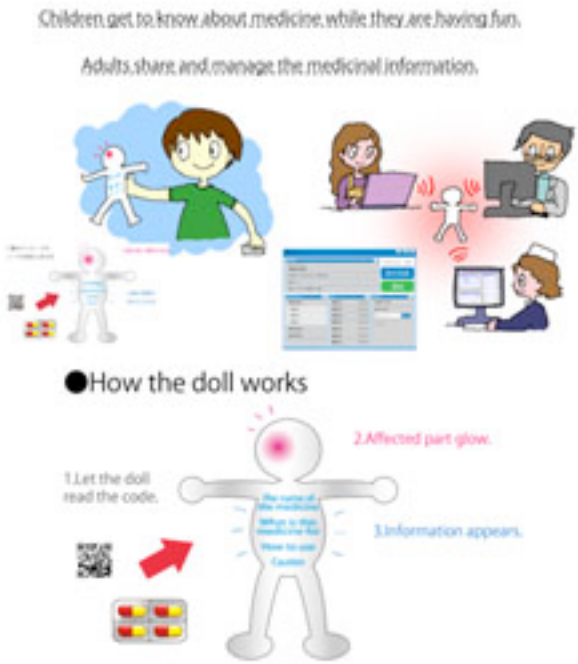

Figure 4: Design outcome.

The features of such a model have been explored as following:

- System design method & information hierarchies;
- Production and design outcomes, consideration of interaction design functions and contexts;
- Design project documentation and reflection;
- Dynamic interfaces and user experiences; and
- Advanced interface design and interaction.

Students learn that their TIDE design research material (users and their contexts) can be regarded as a highly important and productive outcome in its own right. A well-presented research folio, rich with visual and contextual material, has proven to be a valuable resource and highly regarded by collaborating companies, and potential future employers. The requirements for submission material from student teams re-enforce this view by asking for ‘professionally’ presented research documentation. Note that the teaching team took a deliberate decision to separate pre-brief user research from any downstream '(product) designing' activity. Hence it was intentional that the student user research outcomes will not be limited as a designed product, it will also include systematic structure, designed interface and scenario.

This was initiated by a desire to bring about change in a curriculum, especially to introduce completely new topics to an undergraduate industrial design programme.

1. Gather the e-Health related information, such as various healthcare systems, appliances, applications or mobiles;
2. Ethnographic research focuses on the custom, culture, social environment of user's daily life, such as observing the health related behaviours of the user;
3. Draft the interaction-oriented contextual map based on a behaviour-centered method and convert it into a graphical Context Analyze Diagram (CAD);
4. Innovate by re-constructing CAD;
5. Discuss with lecturer, settle the range, direction, objective, target user group and process of individual design topic;
6. Investigate the topic relevant (or potentially relevant) technology;
7. Define the concept;
8. Build the scenario;
9. Re-consider the concept through the in-class discussion;
10. Final presentation to explain the concept, CAD, scenario, interface and tangible aspects (3D model); and
11. Assignment submission

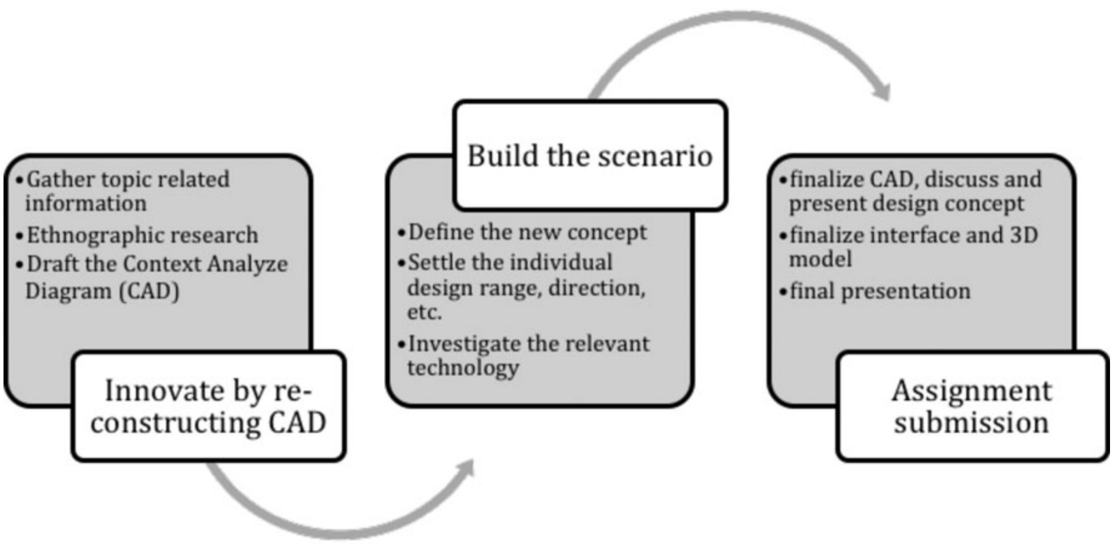

Figure 5: Description of the developed design process of the TIDE module.

Discussion: Why Take Such An Approach?

With regard to the fundamental motive of taking such an approach, we cannot agree more with Malouf (2010), who argued, ‘due to the incredible increase in both product and system complexity that the use of advance technology enables, it is more important than ever for industrial designers to step up and engage more directly with interaction design – the design discipline focused on the design of the behaviours between products, systems and humans.’ When considering behaviours, the traditional 'data-centred' approach of interaction design does not accomplish the task: it's lacking concern for human perceptual-motor skills (Djajadiningrat, Wensveen *et al.*, 2004). Therefore, ‘to nurture students to be the designers with adequate design skills for the information age,’ we adopt such an approach, which is based on industrial design that focuses on creating meaning from giving intangible systems controls that communicate their purpose through their physical form and the actions they require (Djajadiningrat, Wensveen *et al.* 2004).

Tangible Interaction design shares some common rationales with industrial design. Industrial designers are accomplished in physical shape, ergonomics, usability, and aesthetics etc., which are also the desirable elements in the field of Tangible Interaction design. Furthermore, Hornecker and Buur (2006) have created a framework that focuses on the user experience level, which is the traditional interest in the design field. The framework consists of four themes: tangible manipulation, spatial interaction, embodied facilitation, and expressive representation, which are intended to support analysis and conceptual guidance for design.

Interaction Design education is an emerging field, until recently most design schools around the world had considered interaction design separately to industrial design. To articulate the feature of such integration (exploration), we need to be clear on five major differences between Tangible Interaction Design Education (TIDE) compared to general interaction design education; industrial design education; IT/ computing science based interaction design; media art/design; and information design.

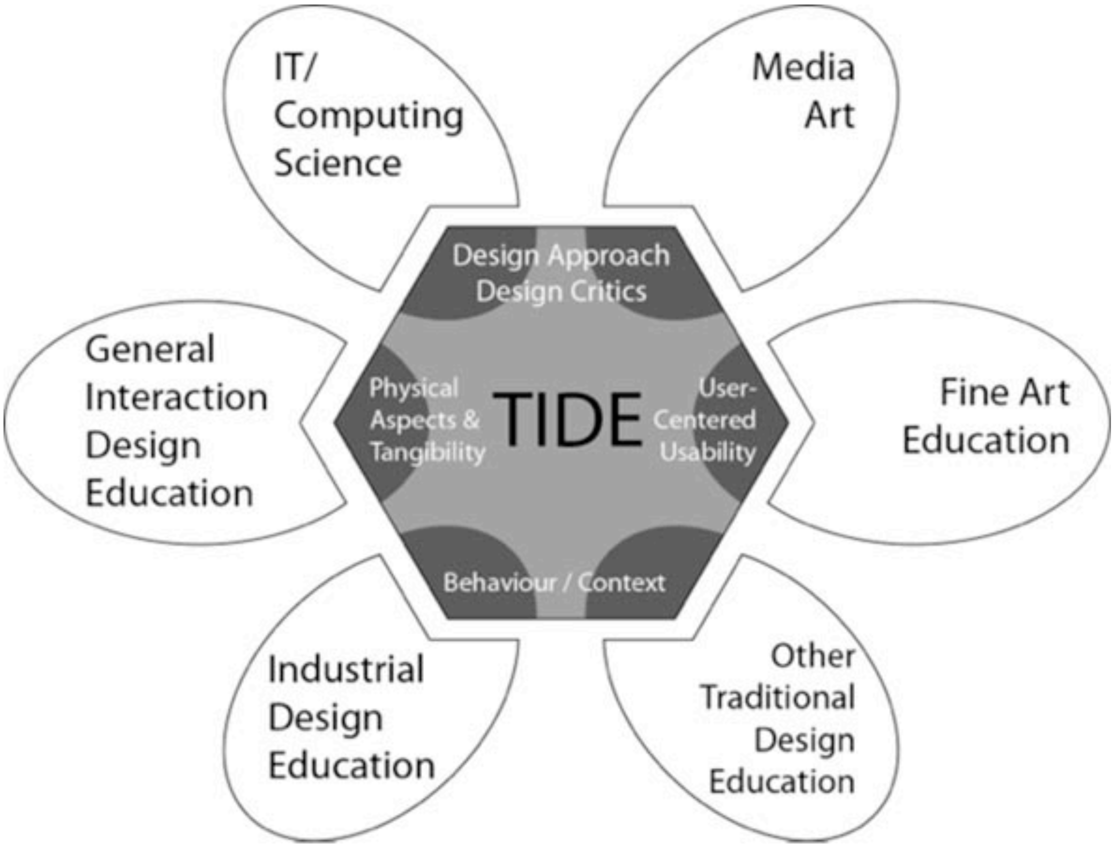

Figure 6: Positioning Tangible Design Education.

TIDE is, in essence, a program with a more specific focus on tangibility and therefore more related to direct interaction with the physical aspects of a user's body. Physical objects can have a rich variety of expressive properties, such as weight, texture and elasticity. Dynamic systems include speed, inertia, etc, for consideration. As Djajadiningrat, *et al.* (2004) point out, use of form, materials and movement of physical objects can serve as a strong means to convey expression and offer a rich palette that can be used to elicit expressive actions and create meaning in interaction. At the same time, this feature presents a challenge to our TIDE module: that is, how to teach industrial students to focus on 'tangibility' when approaching interaction design method?

- Focus on 'context' & 'behavior'.

One of the main issues in the current industrial design curriculum is the lack of focus on 'context'. The new program with TIDE components considers 'context of use' as a core method in guiding function and form. Like many other design fields, interaction design also has an interest in form, but its main focus is on behaviour. Such position also brings the challenge about how to integrate the perspectives of 'context' and 'behaviour' into the existing industrial design curriculum.

- Focus on 'usability', 'functionality', and adopt a 'user-centered' approach.

Rather than centre on the technical issues or artistic excitement, TIDE is heavily focused on satisfying the user's needs. In fact, 'Design is essentially a creative process to plan something that does not exist. On the other hand, cognitive science, research methodologies, and information technology are all focused on what does exist. We must recognize and bridge the gaps' (Qian, Visser *et al.,* 2011). Nowadays, many products are equipped with microcomputers with a high computing capability and increasing processing speed. The TIDE module focuses on the hybrid nature of both hardware and software components. Furthermore, the Internet allows networking between products – that is, PDA, mobile phones, etc. – and these products can store and share digital information almost immediately (Ann, 2003).

- Focus on both training of 'traditional design' and 'information technology'.

Designers are not trained to understand programming. In fact, the programming process is different to the design one. Researchers would argue that even if designers did know how to code this could pose a problem (Qian, Visser *et al.*, 2011). 'If the designer implements his own design, he is beholden to two different goals: clean code and great user experience. The two goals contradict each other and in many cases he may make premature decisions and compromise' (Mathis, 2009). In our view, separating the interface design and interaction design is problematic.

- Focus on 'critical analyzing' of design approaches.

The design outcome focuses on 'products, environments and services'. Compared to information design (it's also been called info-visualization design), TIDE does share a common rationale with information design to a certain degree; for instance, both have the goal of conveying information to the user more efficiently and effectively. However, rather than emphasising the visual impact, TIDE focuses more on the design process, methods, approaches and inclusive critical analysis.

Conclusion: Tangible Interaction Activities In University Design Education

In Japan especially, there is a case for design education to strengthen a designer's skill set and expand their knowledge scope to explicitly include 'user behaviour analyzing', 'user context analyzing' and 'learning from existing systems'. How design education prepares students for these new and different interactive behaviours, which they may face in professional practice, is a central issue of this paper.

Undergraduate industrial and product design education has been lacking focus on 'behaviour', 'system', 'service', and 'information technology'. What is required is a different design model and process in order to address these problematic issues. As shown in Figure 7, the major knowledge components of Tangible Interaction Design are (from left to right): Computer Science, System Design, General Interaction Design, Service Design, and Industrial Design. To integrate these components into traditional design field, such as industrial design adds the lacking components and nurtures the quality of industrial design students.

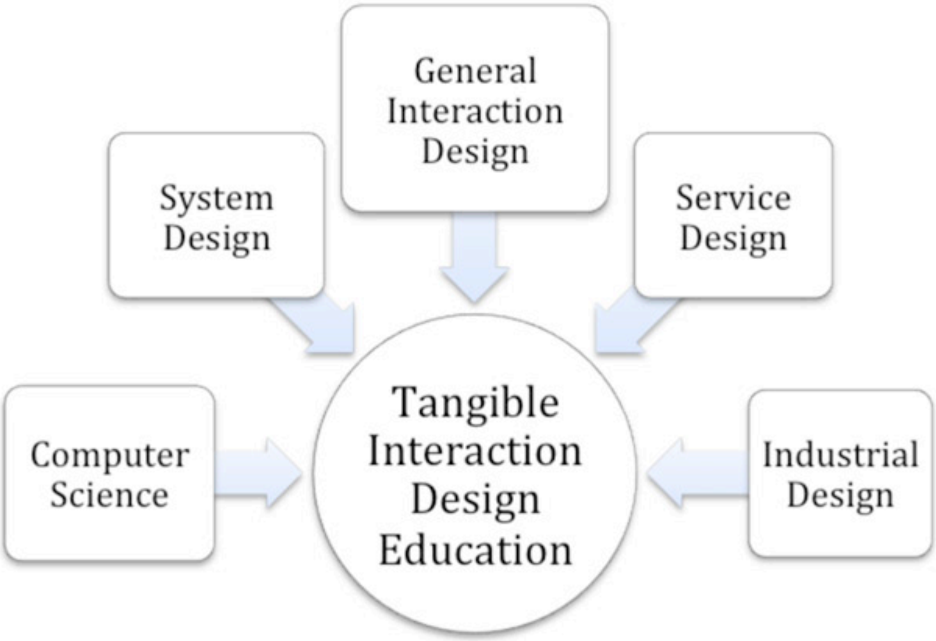

Figure 7: A fairly basic view of the knowledge components of Tangible Interaction Design Education (TIDE).

The motive to utilize the TIDE module in our industrial design is to respond to the issue raised by Dourish (2001): there is still a need for conceptual frameworks that unpack why ‘tangible interaction’ works so well for users. Thus, to increase literacy in the ‘physical quality of experience and to enhance students' capacity for understanding the implication of embedded technologies’ in human-centred product innovation it is crucial to prepare the students to face current industrial challenges (Sato and Verplank, 2000). There is also a strong emphasis on tangible design outcomes.

Bibliography

ANN, E (2003) *Interaction Design: Industrial Design in the Information Age*, speaker at the Industrial Designers Society of Hong Kong Interaction Design Seminar, http://www.kaizor.com [accessed May 7, 2012]

BUUR, J., JENSEN, M.V. & DJAJADININGRAT, T. (2004) Hands-only scenarios and video action walls: novel methods for tangible user interaction design, in *Proceedings Of The 5th Conference On Designing Interactive Systems: Processes, Practices, Methods, And Techniques, Cambridge,USA, 1-4 August*, New York: ACM.

DJAJADININGRAT, T., OVERBEEKE, K. & WENSVEEN, S. (2002) But how, Donald, tell us how?, in *Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, 25-28 June, London*, New York: ACM.

DJAJADININGRAT, T., WENSVEEN, S., FRENS, J. & OVERBEEKE, K. (2004) Tangible products: Redressing the balance between appearance and action, *Personal and Ubiquitous Computing*, 8(5): 294-309.

DOURISH, P. (2001a) Seeking a foundation for context-aware computing, *Human-Computer Interaction*, 16(2): 229-241.

DOURISH, P. (2001b) *Where the Action Is: the foundations of embodied interation*, Cambridge: MIT Press.

HORNECKER, E. & BUUR, J. (2006) Getting a Grip on Tangible Interaction: A Framework on Physical Space and Social Interaction, in *Proceedings of ACM CHI 2006 Conference on Human Factors in Computing Systems*, *Montréal, Québec, Canada*, New York: ACM.

ISHII, H. & ULLMER, B. (1997) Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms, in *Proceedings of ACM CHI 1997 Conference on Human Factors in Computing Systems*, *Atlanta, Georgia, 22-27 March,* New York: ACM.

MALOUF, D. (2010) Interaction Design and ID: You're already doing it...don't you want to know what it's all about?, *Core 77: Industrial Design Supersite*, http://www.core77.com/reactor/02.08_ixd.asp [accessed June 12, 2012].

MATHIS, L. (2009) *Designers are not programmmers*, http://ignorethecode.net/blog/2009/03/10/designers-are-not-programmers/ [accessed May 7, 2012].

MAZALEK, A. & HOVEN, V.D.E. (2009) Framing tangible interaction frameworks, *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, 23(3): 225-235.

QIAN, Z.C., VISSER, S. AND CHEN, V.Y. (2011) Integrating User Experience Research into Industrial Design Education: The Interaction Design Program at Purdue, in *NCIIA 15th conference,* 24-26 March, Washington DC.

SATO, K. AND VERPLANK, W. (2000) Panel: teaching tangible interaction design, in *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques*, New York: ACM.

ULLMER, B. & ISHII, H. (2000) Emerging frameworks for tangible user interfaces, *IBM Systems Journal*, 39(3-4): 915-931.

WEISER, M. (1991) The computer for the 21st century, *Scientific American,* 265(3): 94-104.

Acknowledgements

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