出國報告（出國類別：學術交流）

名稱：【應能表達出國計畫主旨】

參加 iSATE2013 第 7 屆科技教育國際研討會報告

服務機關：國立聯合大學工業設計學系
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摘要（200-300 字）

本校向與日本大學、技術學院（高專）有密切國際交流，目前以交換學生短期參訪學習爲主，亟需進一步提升，最好能建立雙聯學制，並能交換教師致有校教學或做研究。本次基於科技教育教學經驗分享、瞭解世界工程教育趨勢、與擴大學術交流之洽談，由工業設計學系副教授兼主任周永平代表聯合大學至日本奈良市參加參加 iSATE2013 第 7 屆科技教育國際研討會，發表論文一篇（Engaging Technology with Design: a PBL model for effective learning of technology），並予與會學者進行學術交流，分享教學經驗。此外更與本校姐妹校木更津（Kisarazu National College of Technology）高專商談進一步之學術交流合作事宜。本次參加研討會歷經 2 天交流，瞭解了世界工程教育發展趨勢，與一些外國學者交換教學經驗，並與木更津高專 Prof. Kono 交換進一步合作建議，有利於回國後續之規劃。

目次

一、目的

1. 計畫目標：

    (1) 科技教育教學經驗分享

    (2) 瞭解世界工程教育趨勢

    (3) 擴大學術交流之洽談

2. 主題：科技教育與技術創新

3. 緣起：

    (1) iSATE 國際會議爲日本與新加坡發起，主要爲精進國際工程與科技教育；今年爲第 7 屆，由日本承辦，地點在古都奈良。

    (2) 本校向與日本大學、技術學院（高專）有密切國際交流，目前以交換學生短期參訪學習爲主，亟需進一步提升，最好能建立雙聯學制，並能交換教師致有校教學或做研究。

4. 預期效益

    (1) 發表英文論文一篇。（附件）

    (2) 瞭解工程教育國際新趨勢，帶回國內宣導。

    (3) 與日本國立木更津高專交換提升學術交流之意見。

5. 達成事項)

均達成；其中第（3）項回國續辦。

二、參訪過程

9 月 24 日下午出發，深夜抵達奈良市，入住 Comfort Hotel Nara。

9 月 25 日會議第一天。上午報到後有一開幕儀式，儀式後聽取第一天 keynote，由 Mori

Seiki 公司之 Okada 演講工具機產業發展世界趨勢與該公司織成功策略。參加有興趣之 parallel session。晚上有一 banquet。

9 月 26 日會議第二天，上午報到後聽取第二天 keynote，由 Ron Hugo 演講工程教育之歷史與當前問題與挑戰，並說明 MIT 所創之工程教育模式 CDIO 的內涵與目前普及的情形。並於 parallel session 在 11：00 口頭發表論文。中午與台灣代表與木更津之 Prof. Kono 共餐並討論國際交流事宜。下午參加 panel session，與一些日本、新加坡的技職教師交換意見。

9 月 27 日會議結束後，至京都、大阪重要地點速遊一遍。

9 月 25 日上午搭機回台。

三、任務執行情形

如「參訪過程」。

四、後續工作要項及初步工作計畫

(1) 提供深化與日本國際交流之規劃建議（研發處）。

(2) 說明 CDIO 之工程教育模式（教務處）。

(3) 進一步推動設計爲導向之工程教育（材料系）與科技-設計跨領域問題解決導向教學模式（工設系）。

五、心得及建議

(1) 導入設計思維與方法、跨領域偕同教學是世界工程教育之趨勢，宜跟上。

(2) 持續補助本校教師參與國際教育研討會，擴大國際視野，有助提升教學品質，

(3) 日本大學、高專相當友我，本校與之交流可爲學生節省遊學之學費，是國際化的捷徑，應積極耕耘。

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Engaging Technology with Design: a PBL model for effective learning of technology

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Abstract

Knowledge of emerging technologies is important to innovators, such as designers who are constantly involved with new product development. However, current courses in Taiwan's universities for introducing modern technologies cannot provide the essential context for deep learning - that is, knowing a technology deeply enough to judge its validity in an application. In this paper, we devise a PBL (problem-based learning) model for industrial-design students, featured by conceptual design with some promising technologies for solving user problems in the future. In the first stage, students study a new technology on their own via finding, organizing and presenting. By heuristic design methods, such as KJ method, the data contributed by all students regarding a technology are conceptualized and reduced to a set of form-making attributes. In the second stage, students discover potential user needs through scenario design. In the final phase, students connect the user needs and the form-making attributes by design methods to create tangible solution concepts. We apply this model to a course, New Product Technologies, in a department of industrial design and evaluate its effect on learning. From student survey and self-reflection, we find that the students do attain the competence criteria at the end of the course. At the same time, obstacles against the success of applying the model are identified. We also suggest ideas of improving practicing the PBL method in the future.

Keywords: *PBL, problem-based learning, technology education, design education, conceptual design*

Introduction

In a narrow sense, design is a creative activity that integrates technologies to find solutions to a user problem. Too narrow to interpret the meaning of design to our society (Vanderbeeken, 2009), but good enough to explain why design matters to technology education. A solution by design shall be converted into a tangible form so that users can use it and feel pleasant when using (Lidwell, Holden & Butler, 2010). A tangible solution can be a physical product, a piece of computer software, a system aligned to provide a service, or a combination of them.

Based on Bloom's taxonomy (Anderson & Krathwohl, 2001), we maintain that industrial-design students (ID students, hereafter) shall go beyond the level of "understanding" to higher levels of "applying" and "creating." After all, the core activity of design education is to create. Furthermore, to assess learning effectiveness, the outcomes from design activities evidence to what extent learners can apply the knowledge. On the other hand, modern education emphasizes scaffolding mechanisms for competence building (Wood, Bruner & Ross, 1976; Sawyer, 2006). Design is a learning scaffold for ID students in that it facilitates peer interactions and self-reflection, both aiding effective, self-organized learning[1]. Therefore, to ID students, design is not only for delivering evidence of creation but also for scaffolding learning.

In this exploratory study, we attempt to study the role of design in technology education, in the context for ID students. Accordingly, the research objectives are set to be: (1) proposing a model of PBL for ID students, (2) assessing the effectiveness of the model, and (3) suggesting criteria for the assessment.

Pedagogy and Assessment Methods

1. The Model

We propose a PBL model consisting of four stages – Find, Reduce, Create and Reflect. As shown in Figure 1, the students search for information about an emerging technology through the Internet. Each student group presents what is found in their search for the class. With the data from all groups, the students are asked to code, classify and cluster the data into few generic concepts. This is what should be done in the stage of Reduce. In the stage of Create, the students use scenario design to image future use contexts and identify user problems. The students then combine those generic concepts of the technology to form tangible solutions to a problem. Again, each of the groups presents what is created in their design activity for the class. In the stage of Reflect, peer feedbacks and self-reflection drive the revision of each design artefact. Ideally, Create and Reflect may go in loops for more than one round to deepen the learning of the themed technology.

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[1] The SOLE Challenge: http://www.ted.com/pages/sole_challenge

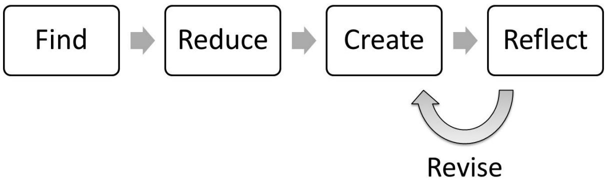


Figure 1 the flowchart of the PBL model

2. Process

We select three emerging technologies in the course and test the effectiveness of the model. They are 3D printing, solar power and education technology. Between the units of 3D printing and solar power, we further implant a unit for teaching the students a pair of methods for envisioning use contexts and identifying user problems - mind mapping and scenario design (Hanington & Martin, 2012). For example, a student group describes a scenario of using the 3D printing facilities in a future industrial-design department, as shown in Figure 2. The scenario is prescribed after the students deduced a school context by mind mapping; it is inspired by the information they have collected about the technology. The students use the scenario to identify a user problem and then design an online service to solve it.

Figure 2 a future scenario proposed by a student group in which ID students struggle for mismanaged 3D printing facilities in a design school

Forty-nine students of the class are divided into 11 groups for collaborative work. In each of units (except for the methodological second), the students search, collect and analyse information of a themed technology and then present before the class what they have found. The instructor facilitates the students to organize the body of information contributed by all groups and reduce it to some essential elements, thereby forming a type of conceptual knowledge about a themed technology[2].

The use of the reduced knowledge is twofold. On one hand, the students envision possible future scenarios that are developed in response to a disruptive technology and then find user problems therein. On the other hand, the students use concepts of the technology (and often in conjunction with other technologies) to ideate solutions to a problem. The students make the solutions tangible by sketches of physical products, service process and the associated use scenarios. Due to the teaching goal setting, we do not ask the students to detail their concepts; therefore, we call the outcomes “conceptual designs."

3. Content Analysis

To qualitatively assess the effectiveness of learning, we analyse the design outcomes by the student groups, according to the criteria as follows.

- *If a conceptual design is valid?* If a student understands a technology well, he or she will not propose a solution that violates the essence of the technology.
- *If the design is new?* The originality of a valid design implies true understanding because the idea is created from a process of learning, instead of copying other people's ideas.
- *If the design integrates at least two concepts from different technologies?* The ability to connect distant concepts implies a learner's comfort of applying technologies and thus better understanding.
- *If the design leads to further inquiries for the technologies involved?* Inquires lead to a positive feedback cycle of learning[3]. In a larger sense, tangible conceptual designs serve as a scaffold for effective self-organized, customized learning.

4. Questionnaire Survey

To quantitatively assess the effect of learning, we conduct a questionnaire survey at the end of the course. How deep should an ID student learn about a technology so that he or she can articulate correctly in a design context? We apply Bloom’s Taxonomy (Anderson & Krathwohl, 2001), in which a hierarchy of cognitive actions is elaborated. We maintain that a person shall go beyond the level of “understanding” to "applying" in that exploiting the information in similar situations is needed. Further, the very exercise of design is aimed at pushing the students to an even higher level of “creating” because we ask them to apply the knowledge to new situations. Transforming the knowledge of a technology into form-making attributes (Nordby, 2010; Lim, Lee & Kim, 2011) is necessary. The action of “creating” – here, conceptual design –

[2] We usually use the KJ method (Jing Yang, Su & Chen, 2002) to classify the concepts revealed by pieces of information and reduce a category to a generic concept. If the samples of a category are few, it is treated as a biased selection and discarded. Given the accessibility of information on the Internet, we maintain that the reduced information through group collaboration is almost as good as what an expert can offer. Take 3D printing as an example, we find key points reduced from what students have collected is just as creditable as an expert report (The Economist, 2012/8/21).

[3] For example, a conceptual design uses radio waves to transmit the electric energy generated in the high sky to the ground. What kinds of radio waves are suitable? In another example, to what level should a man be cloned, genome or consciousness? What makes up a person’s consciousness?

further requires a mental activity of concept combination (Wisniewski, 1997). Therefore, we define operationally the proficiency of ID students for applying a technology the abilities to: (1) single out concepts that are not relevant to a technology; (2) assess the feasibility of an application; and (3) combine two concepts, belonging to two different technologies, for solving a problem. We assume that if a student understands a technology, he or she will get high scores from a test of these abilities. Further, he or she will be capable of devising solutions, to a user problem, that are compatible with the technology.

How do we design a questionnaire survey for testing the above abilities? We divide into three parts. The first part is assessing the time distance of a prescribed application from when it is feasible. A number of applications associated with a technology are prescribed for the participants to assess. To reduce cognitive loads, we ask the participants to determine a time of realization for one application at a time. A time scale is provided for a participant to select, having five choices from "in 2 years" to "after 20 years". For each technology taught in this course, we prescribe 3-5 applications. Totally, 12 technological applications are included in this part of the survey. We rate the participants if they place the order of realization right, instead of the exact time they pick.

The second part is to measure participants' ability to identify concepts irrelevant to a technology against related others. One multiple-choice question is assigned to each of the three technologies for the participants to pick up unrelated concepts. The third part of the survey is two open questions each asking a student to connect concepts of the technologies taught to solve a user problem.

Due to time limitation on the course, the questionnaire survey is carried out online in the last two weeks. Each student can do three times before a deadline. The students are also asked to sign an honour creed and to do it at home.

Results and Discussion

1. Analysing student conceptual designs

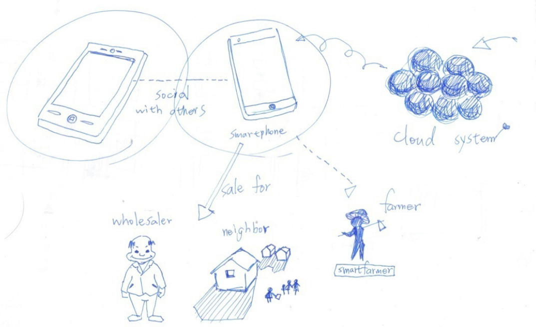
The last project for the student groups is applying at least one of the themed technologies to solve a user problem. The outcome shall consist of a product and an online service. The product can be a real thing or a software product. We list some better conceptual designs in Table 1 and evaluate them according to the four criteria for content analysis in the last section – validity (V), novelty (N), concept combination (C), and activating inquiries (I). A brief summary of the designs and their criterion check are shown in Table 1.

Table 1 a summary of some final conceptual designs

Brief Description of Design	Criteria Attained
1. A full cloud environment for 3D design and printing in whch users use software and archive digital files online, not only enhacing accessibility but also reinforcing copyright protection.	V, N, C
2. Airship solar-power stations - large airships equipped with solar panels anchored above a big city and self-guided to dodge clouds for providing easy-accessed charging service for mobile devices.	V, N, I
3. Mobile chargers for rent – solar-powered vending machines for renewing empty chargers and providing renewed chargers for rent.	V
4. A system for building 3D creativity for kids – consisting of hierarchical user interfaces for children to develop 3D cognition and creativity and a service for sharing and 3D-printing artworks.	V, N, C
5. A system for learning paper folding - consisting of two modes of user interfaces, one for individual through touch pads and the other for classroom through body movement sensors, on the purpose of learning ORIGAMI and sharing.	V, N
6. Solar-powered greenhouse – self-powered, Internet-controlled, and modular greenhouses with in a metropolitan for rent and making transactions.	V, N, C

From the final conceptual designs, we find that only 2 (out of 11) designs that are irrelevant to the themed technologies, which are therefore not valid for assessment. All valid designs are functionally compatible with the technologies, indicating that the students have attained a basic understanding. The majority of the designs are new, implying that they develop the idea on their own. Few designs attain the level of concept combination, showing higher efficacy to apply.

The results from assessing the final designs indicate a hierarchy within the four criteria – from low to high: validity, novelty, connection, and inquiry. Regarding the higher criteria, deeper engagement with the themed technologies in the form of tangible designs is essential because it opens a platform for interacting with peers and the teacher. Such further discussion will deepen their understanding of the technologies. However, pitifully, we did not implant an effective mechanism for peer review in this class. Subsequent interactions among the students by design critiques may foster advanced study. Advanced study will motivate and drive the students to improve their designs, putting them through a self-motivated and self-organized learning path. This is the essential scaffolding mechanism of learning technologies via design!



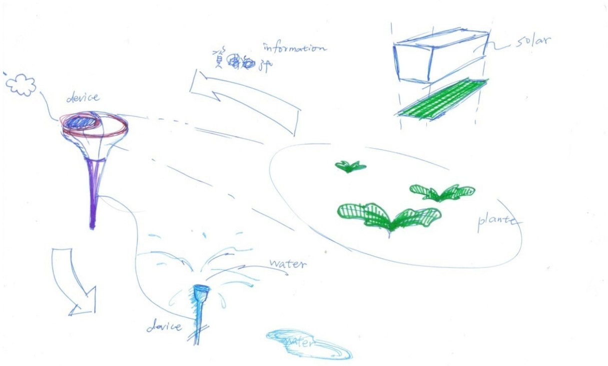


Figure 3 a student conceptual design - solar-powered greenhouse

2. Analysing questionnaire survey

Three parts of the questionnaire survey test the knowledge of the three technologies explored in the course respectively on factual, conceptual and creative levels. We interpret the scores in each of the categories all together to be the proficiency of technology.

Table 2 shows the proficiency of factual knowledge about the three themed technologies. The students are measured by how accurately they can pick out wrong descriptions of the technologies. Except for the last of solar power and two others about education technology, the students attain high accuracy, indicating that facts about the emerging technologies are well cognized among the students. More importantly, the students learned those facts on their own and from each other through group presentation.

Table 2 Percentage of accuracy the students pick out worng facts

		Fact 1	*Fact 2*	*Fact 3*	*Fact 4*
1.	3D Printing	97.92%	89.58%	77.08%	NA
2.	Solar Power	93.75%	97.92%	68.75%	NA
3.	Education Technology	77.08%	95.83%	68.75%*	52.08*

*** Facts that are not obviously worng**

The proficiency of conceptual knowledge about the technologies is measured by how they place the order of times when prescribed application scenarios of a technology come true; each technology has a set of scenarios to be determined. If a student places the order right, he or she will get 10 points. If not completely correct, he or she will get a score from 0 to 9 points[4]. For education technology, an objectively regarded order does not exist. We then take the average responses from the participants as a consensus for determining a participant's score. Table 3 shows the means of the scores and the percentages of participants who answered right in the survey. The students got fairly high scores in the three technologies. The part of solar power has a lower average score, and fewer people got the time order completely right. We think less time allocated to the subject during the course probably the main cause.

Table 3 Average scores of placing right time orders for the scenarios associated with three themed technologies

		Mean	*Percentage of Correctness*
1.	3D Printing	8.98	77.08%
2.	Solar Power	7.81	27.08%
3.	Education Technology	9.38	60.42%

Two open questions are assigned to the students for testing their proficiency of combining concepts for solving a problem. To measure the degree of creativity precisely is not the purpose of this survey; it is also difficult to measure objectively. We search for evidence of easiness when applying the knowledge, as indicated by the numbers of words a participant uses to answer a question. We find about 37.5% of the participants answering the first question with comfort and 70.8% for the second question. Why is such a difference? The first question is focused on solving a clearly defined problem taken from a news. The second question is prescribed to invent a device in a general direction. We tend to believe: (1) applying a technology to a new use scenario is a hard competence, and close to 40% of the students have acquired is reasonable; and (2) test question like the first one - converting knowledge to a solution to a narrowly defined problem within a limited time – is more valid.

Conclusions

This paper reports a preliminary study into the subject of blending design with technology education for ID students. We are able to draw a couple of conclusions as follows.

1. Based on the learning theories of Bloom's taxonomy, scaffolding and deep practice, we devise a model for learning technology via design, which is shown effective for at least ID students. In the process, students apply technology in the activities of design for delivering artifacts of conceptual design, which are used to activate peer feedbacks and self-reflection, thereby deeply processing of the knowledge of technology.
2. Students may feel ambiguous about to where the knowledge of technology drives them? Do we expect future scenarios or conceptual designs to be the design outcomes? To lessen their cognitive loads, we feel that the PBL model (shown in Figure 1) should be simplified by removing the element of scenario design, thereby emphasizing applying a themed technology to solve pre-defined user problems.

Since doing an exploratory study, we have much to improve for better validity. Regarding the effectiveness of education, design in a single shot is not sufficient, because the students have to leverage on the design artifacts to grow deeper understanding of a new technology. To do so, a positive feedback loop shall be activated. In this study, due to time limitation and a lack of managial tools, peer feedback is not properly

[4] If there are five scenarios for a technology, the answer can be broken into 10 pairs of scenarios, each having a right time order. A student's order is also broken into 10 pairs and compared pair-wise with the answer. The student scores one point for every right pair; therefore, he or she will get 0-10 points.

executed. With limited human resources, a better way for us to touch the goal in the next trial is using a learning platform that supports a function of peer review, such as the one many Coursera[5] courses are using.

Another issue needs a second thought is how to assess the learning effectiveness from student performances. Before a set of criteria for assessment are determined, we have to ask ourselves the meaning of learning new technologies (to designers, say). For this study, the meaning is defined to be structuring the knowledge of a technology so that it will stay in the long-term memory for effective and insightful application within the context of product design. We have not done thorough research on such a criterion setting up to this point, and hence have to do a further study to devise more valid criteria. In a larger sense, knowing the technology alone is not the only thing for designers to learn about an emerging technology. To unveil the most market potential out of a new technology, designers shall understand not only the technology itself but also its relationships with human. In this case, such a technology education should further include the goal of envisioning application scenarios. If the course domain is so extended, the criteria for assessment will be certainly different.

Acknowledgements

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