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Transdisciplinary Learning Based on Problem Identification of Design Computational Thinking - A Case Study of the Topic of Marine Debris

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Abstract

Aim: The purpose of this study is to explore how design students can identify marine debris problems and generate insights through the computational thinking learning process to better develop design students' ability to learn across domains.
Methodology: We have set up a transdisciplinary learning course of "Design Computational Thinking", trying to introduce the knowledge of marine debris in the humanities and environmental sustainability into the course, combining design thinking and computational thinking processes, and guiding students to think about and evaluate problems in stages and complete thematic design. Finally, through the achievement report, Expert assessment, and semi-structured interviews with students, analyze and evaluate their learning effect.
Findings: It was found that students were creative in the way to deal with marine debris problems. Computational thinking can have an impact on the design process. In the process of design decision-making, students can think and express hierarchically, and use core strategies to solve problems.
Implications/Novel Contribution: This study provides a knowledge base for problem-solving through transdisciplinary and metacognitive learning. The combination of design thinking and computational thinking provides different levels of thinking models for problem-solving and generates insights.

Keywords: Transdisciplinary learning, Marine debris, Design thinking, Computational thinking, Problem identification.

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INTRODUCTION

This study conducts research through the interactive design teaching field. Interaction design, which includes graphics, programs, information, and interaction, is interdisciplinary. Teaching design skills is a complex and multi-layered challenge that involves input from many cross-disciplinary areas (Sharma, Mangaroska, van Berkel, Giannakos, & Kostakos, 2021). One important issue in interactive design teaching is how to balance the relationship between design and programming. The common problem in teaching is that students without a programming background rely on design inspiration or chance triggers for their designs. However, without theoretical background knowledge and systematic logic, it is often easy to produce unrealistic design works. In contrast, students with a programming background may have a more complete overall thinking structure, but their images and creativity may be limited compared to students with a design background who have rich aesthetics and imagination. How to help students deeply understand design theory, master effective design tools, and skills, and cultivate innovative thinking and problem-solving abilities have always been a challenge for teachers and students. Kuiphuis-Aagten, Slotman, and MacLeod (2019) pointed out that interdisciplinary ability has become the foundation for scientists, engineers, and others to solve real-world problems. Rienties and Héliot (2018) believed that interdisciplinary courses are a promising way for students to learn and apply knowledge from other disciplines. Rich, Egan, and Ellsworth (2019) also pointed out that learning Computational Thinking (CT) has become an important cognitive skill in all education fields. In other words, through CT learning, students with a design background can learn information-related fields across disciplines. Some educational institutions combine design and programming

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courses to provide comprehensive teaching programs to cultivate talents who have both design literacy and skilled programming techniques (Díaz-Lauzurica & Moreno-Salinas, 2019; Haq, Ramay, Rehman, & Jam, 2010).

Therefore, this study focuses on interactive design students and integrates the characteristics of design thinking and computational thinking to open a cross-disciplinary course called "Design Computational Thinking," which combines humanities and sustainable environmental problems related to marine debris. Through course training and the use of meta-cognition, students are guided to think critically about problems and gain insights. The focus is on improving students' theoretical knowledge and problem-solving abilities, and the results are evaluated through the completion of project designs, interviews, and expert assessments of their learning outcomes. The research results can provide a reference for environmentally sustainable development education and cultivate students' cross-domain thinking modes and connection to real-world challenges in the future.

LITERATURE REVIEW

Transdisciplinary Learning

Interdisciplinary and transdisciplinary are essentially the same in cross-domain learning. While Helmane and Briška (2017) pointed out the difference between interdisciplinary and transdisciplinary. Interdisciplinary means that interdisciplinary covers multiple fields of study, and they combine co-learning embedded in disciplines that are identifiable to emphasize interdisciplinary skills and concepts. Transdisciplinary brings together concepts, research processes, and topics, resulting in top innovative, unforeseen solutions. In terms of design, Hepburn (2022) believes that transdisciplinary learning transcends disciplinary boundaries and co-creates knowledge. And design orientation does this by informing and influencing change through engaging practices. Examples of Computational, Gravel, Millner, Tucker-Raymond, Olivares, and Wagh (2022) Aiding understanding of transdisciplinary STEM learning through mapping games and lessons of computational fabrication. And in the humanities, Holmén, Adawi, and Holmberg (2021) pointed out that Education for Sustainable Development (ESD) conducts inter- and transdisciplinary learning processes by engaging students in real challenges of social actors and centers.

The Problem of Marine Debris

Marine debris is one of the major challenges facing the world today. Marine debris highlights pollutants that are a global environmental and economic concern, including any persistent manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environments. Plastics are also considered to be the most important marine debris category, accounting for 50% to 90% of the total marine debris found globally, with other categories including paper, metal, textiles, glass, and rubber (Agamuthu, Mehran, Norkhairah, & Norkhairiyah, 2019; Mi-Youn, 2019). As part of the environment, educators, policymakers, and scientists are critical to achieving environmental sustainability (So, Lee, & Chow, 2019). A sustainable response to the marine environment can be established through educational action. Existing educational research conducted experiential marine debris courses to test the impact of college students on motivation, attitude, and behavior levels (Owens, 2018).

Design Thinking

In 2010, IDEO design consulting company Tim Brown proved the importance of design thinking, formally proposed the design thinking methodology and summarized five processes of empathy, define, ideate, prototype, and test (Plattner, Meinel, & Leifer, 2015). Schon (1984) argues that understanding that designers create the framework within which design activities take place is at the heart of design thinking. Emphasizing ideation, innovative iteration, and empathetic solution design, design thinking is a user-centered approach to design and problem-solving processes (Stefaniak, 2020). The mental map state of Design thinking is usually divided into two types: divergence and convergence, which are usually depicted in a double diamond map. The key to its implementation is to know clearly which stage of the process you are in (Lewrick, Link, & Leifer, 2018).

Through design thinking, professional fields such as engineering, architecture, and business can more effectively address the complexity and ambiguity of the unsystematic problem-solving process. In addition, from an educational point of view, design thinking helps to develop students' creativity and adaptability, so that they can acquire the knowledge, skills, and attitudes needed to solve complex problems and work collaboratively (Koh et al., 2015). Beckman (2020) argues that many of the insights into the way designers behave and perceive relate to the ability that designers have to frame problems and the strategies by which they act to change the framework in desirable ways. Lee and Park (2022) pointed out that through the effective tool of the design thinking process, cross-cultural and interdisciplinary teams can quickly implement their creative and globally applicable solutions through visually feasible schematic prototypes. Therefore, the divergence and convergence process provided by design thinking is no longer limited to design but also begins to be applied to the thinking mode of problem-solving in different professional fields.

Computational Thinking

Wing proposed the concept of computational thinking in 2008, which is very important for computer applications and can provide design and evaluation of large and complex systems (Wing, 2008). Computational thinking, as a way of thinking used by computer scientists, has been recognized as a type of thinking that is useful to anyone in solving problems they may encounter in their personal or professional life. It is widely accepted in education systems worldwide as an explicit form of learning and has begun to be included as part of compulsory education in many countries (Grover & Pea, 2013; Voogt, Fisser, Good, Mishra, & Yadav, 2015).

Computational thinking is relatively abstract, involving conceptualization, system design, etc., and summarizes the research of different scholars (Barr, Harrison, & Conery, 2011; Selby & Woollard, 2013; Wing, 2008), which is defined as a problem-solving process and applies to all disciplines (including mathematics, science, and humanities). Hoebeke, Strand, and Haakonsen (2021) found that by learning through programming students gain in-depth knowledge of the algorithmic elements of the discipline, as well as important knowledge of key topics in arts and crafts. People with a design background can learn to enter information-related fields through cross-domain learning through the logic training of computational thinking.

Metacognition Theory

Metacognition theory, first proposed by scholar Flavell in the 1970s, has become the basis for most scholars' theories and research on metacognition. Flavell believes that metacognition consists of two elements: "metacognitive knowledge" and "metacognitive experience" Interactive composition (Flavell, 1976). Paris further subdivides the post-cognition into two parts, one is self-appraised knowledge about cognition, including declarative knowledge, procedural knowledge, and conditional knowledge); the other is self-management of one's thinking, including planning, monitoring, and regulating (Cross & Paris, 1988). The metacognitive purpose is to monitor and regulate the cognition involved in a given mental activity, enabling people to effectively deploy and manage their cognitive resources to regulate their thinking and learning abilities (Allsop, 2019). A study of collaborative learning strategies for digital games found that, through metacognitive and interactive analysis and survey assessment, an operational thinking skills approach can stimulate interaction among learners and learn in a fun way to apply problem-solving strategies, solutions proposed to solve the problem (De Jesús & Silveira, 2021).

METHODOLOGY

"Design Computational Thinking" Course

The course "Design Computational Thinking" combines design thinking & computational thinking into the humanities and environmental sustainability topic and guides students to think and discuss in groups. This course is offered in the Department of Interaction Design, National Taipei University of Technology (NTUT). The participants are third-year students from the Department of Interaction Design, who have come from high schools with different backgrounds in the past. The main course structure of the 18-week course is shown in Table 1.

Problem-Based Learning

Based on the learning process of transdisciplinary courses, through the advantages of both design and computational thinking, it is carried out in systematic steps from the theme of marine debris, using the "problem teaching" method. Solve problems, to increase students' knowledge and skills, inspire students' thinking, identify problem points and solution strategies; combine the "group discussion" mode, through each staged discussion of problems close to life, without limiting students' imagination, The ideas or ideas that come to mind are extended and recorded step by step, and finally the core goal is identified and insights are provided for development.

Expert Assessment and Brief Interview Survey

In addition to the problem-based learning results, the development process is observed with the mind mapping of problem-solving strategies in the student's courses, and a comprehensive evaluation of thematic results is carried out through the expert assessment method and simple interview surveys after class sampling. The expert members are composed of four full-time teachers from an interdisciplinary professional from two different schools and different departments, with professional backgrounds and qualifications. We also interviewed three students who took this course. Student A is a design student, student B is a design student with basic programming ability, and student C is an engineering student. After class, we conducted brief interviews with the three students about course interests, course expectations, and thoughts on computational thinking.

Table 1: Design Computational Thinking Course

Week	Course Content	Design Thinking	Computational Thinking
1-2	Field Investigation & Lectures (Figure 1)	Empathize	Decomposition
3-5	Mind Mapping (5W3H)*	Define	Decomposition
6-8	Brainstorm & Insight	Ideate	Pattern Recognition
9-10	Exchange & Sharing		
11-12	Teaching & Making (Micro:bit)	Prototype & Test	Algorithms
13-14	Teaching & Making (Arduino)	Prototype & Test	Algorithms
15-16	Teaching & Making (APP & UI)	Prototype & Test	Algorithms
17-18	Exchange & Sharing		

*5W3H (what, why, who, where, when, how, how much, & how long)

Figure 1. Field Investigation

RESULTS & DISCUSSION

The research results show that after each expert evaluation and discussion, students re-adjust their strategies when faced with problem points. They can go through the process of 'mind mapping' to '5W3H inspection' to 'insight generation', gradually converge on the problem by divergent thinking to find a solution, and finally focus on the core of the theme. Value generates insights, such as in Table 2. According to the focus of the experts in the process according to the context of the problem, each group will repeatedly discuss their problems in 5W3H to evaluate and make suggestions, as shown in Table 3. After the class, three different students were sampled, and finally, through interviews with several students from different backgrounds, the problems and convergences discovered by the students themselves in the operation of the whole course were summarized, as shown in Table 4.

This research aims to provide students with a design background through transdisciplinary learning, inspired by the theme of marine debris, to learn multi-faceted thinking to establish procedural and systematic logic, to provide thinking models and generate insights for problem deconstruction, and to build oceans through classroom learning and sustainability concept. Under the general framework of the marine debris theme, experts converge on the core of the problem, and gradually generate different associations and types of details. For example, beach cleanup activities combine tourism industry marketing, localized and international service experience, or a combination of Schools or groups that use online course activities to educate audiences about environmental protection, and also bring artistic creation, interactive technology, and gamification design. From the beginning of the disorganized classification and distribution, through several teaching and activity exercises, students gradually can have their logical thinking mode and can analyze the direction of thinking events from a more subtle perspective. Finally, through after-class interviews, students can find that design students have positive comments on the mode of mind map-guided thinking, and students with engineering backgrounds are willing to think about the process of problems.

Table 2: Student Work Results (Part)

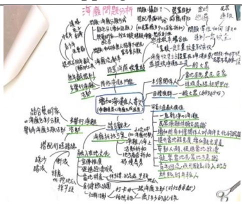
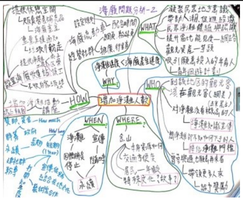
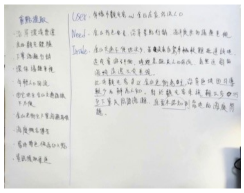
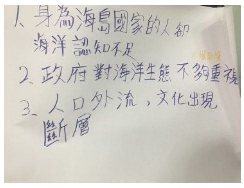
No	Mind Mapping	5W3H view	Generate Insight
			
1	How to increase the number of people cleaning the beach? ex. Target groups (general public), Maximum value creation (clean beaches/knowledge of marine ecology), Stakeholders (residents), Combined sightseeing (events/coupons), Lower threshold for beach cleaning (marine debris collection stations)	Increase the number of beach cleaners (5W3H) ex. WHAT? (to gather public awareness and increase visibility - internet) WHY? (beach cleaning speed<marine debris generation speed) WHERE? (Jinshan, convenient transportation?) WHEN? (propaganda) HOW? (operating social media) HOW MUCH? (government funding) HOW LONG? (artist collaboration)	Combining problems and developmental Insights: ex. People's beach cleaning experience and understanding (providing incentives to respond to environmental protection), Beach cleaning knowledge promotion (educational courses), Local culture and stories (eco-tourism/Jinshan Old Street), Sustainable development (enterprise/government cooperation), Online (combined with the Internet, and online registration)
			
2	Jinshan Sightseeing x Marine debris ex. Current problems (marine debris, population outflow), Routes/Traffic (walking, bus), Features (attractions, history, and culture), Customer groups (tourists, beach cleaners)	Jinshan Sightseeing x Marine debris(5W3H) ex. WHAT? (promote beach cleaning activities, publicize Jinshan tourism) WHY? (increase tourist flow, local transportation) WHERE? (Jinshan Old Street, Xialiao Beach) WHEN? (when obtaining Internet information, when visiting the local area) HOW? (carrier, community, image building) HOW MUCH? (development tools, manpower) HOW LONG? (semester time)	Key finishing Insights: ex. Clean and tidy coastal environment, Good sightseeing experience, Emphasis on environmental protection issues, Return of young people to their hometowns, Traffic routes, The entry point of local cultural characteristics, Information channels
			
3	Marine Knowledge Education ex. Content (relevant industry knowledge), Target audience (students, office workers), Media (board games, online courses), Ecology (prohibition of releasing alien species, promotion of ecological breeding), Fraud types (place of origin, species, date and time), Environmental protection (beach cleaning education, marine debris)	Marine Ecological Awareness (5W3H) ex. WHAT? (marine environment, seafood) WHY? (improve island culture awareness) WHERE? (city, school) WHEN? (now) HOW? (online course) HOW MUCH? (800,000 NTD, manpower) HOW LONG? (term time)	Insights: 1. Living in an island country but lacking knowledge of the ocean 2. The government does not pay enough attention to the marine ecology 3. Population outflow from rural areas, resulting in cultural gaps
Core	Determine the pattern of the problem, which dimensions can be extended? Explore the issue in a broader and deeper way	How does the problem converge? How to assign parameters, weights, prioritization and sequencing of events	How to highlight the key points, improve the level of problem solving, and master the core elements of the problem

Table 3: Expert Assessment

Team	Problem Convergence
1	• Find suitable cultural factors and create value • Separate strong links and weak links, and determine the order • It is necessary to use 5W3H to summarize the final core of the problem and find the insight according to the core of the problem • Need to refocus, create the focus of value, and then generate conclusions
2	• Create relevant elements of virtual art creation. • Insight and direction are two things. After the direction is decided, go to discover the insight, find the core, and establish the context. • The 5W3H analysis data lists key points but does not summarize and focus on problems. • How to convert the data into useful information after the positive tabulation VS negative tabulation?
3	• How does logical architecture insight generate context? • How to think about the creativity and accessibility of circular design? • Circular economy + design, garbage into art - value reversal, potential opportunities • Establish meaningful activities of beach cleanup x sightseeing, combining regions and connections
4	• Reinforce the overall goal • The use of interactive technology • Sightseeing-Beach Cleaning-marine debris 5W3H • Gamification of beach cleaning activities • The connection between service experience design and local culture • Ways, Opportunities, and Influence of Future Marketing
5	• The target group should be focused • Problem disassembly VS countermeasures, to be described in detail • Workload-Thinking Pattern • Clarity and immediacy of information dissemination • Game mode or online course teaching

Table 4: Student Brief Interview

Background	Find Problems for Self Convergence	Problems and Strategies
Design	• Try to integrate and integrate the needs of different target groups. • The richer the structure of the mind map is, the wider the range of divergence is, and the problem can be subdivided into several items, and then the convergence items can be clearly defined.	• Summarize which one has a greater impact on the market or consumers among the many contents. • The convergence of insights can be focused on Target Audience (TA) to see which side's needs are directed.
In Between	• To master the problem, propose various solutions. • Through the mind map, various aspects are enriched, and the selling point of attracting public participation is also mentioned, and the pros and cons can be analyzed more.	• There is detailed divergent thinking on problem discovery, planning methods, future processes, and how to achieve them, but there is some difficulty in convergence, and I feel that the problems found are a little different from the solutions. The solution seems to be just putting the problem into a template, and the problem should be more connected with the solution.
Engineering	• Failure to define the problem clearly can lead to a loss of focus on the problem to be solved. • From the collection of marine debris to sightseeing, the concept is converted, and from the planning of sightseeing, more details about the marine debris that can be experienced and understood by the public are proposed.	• I have made a lot of effort in solving the problem, thinking from different aspects, and gradually figuring out the real crux of the problem. • Detailed planning and implementation steps, and then splitting it a little more, will make people feel more feasible.

LIMITATIONS & FUTURE RESEARCH DIRECTIONS

Since the course of this study is an elective course, the number of participating students is limited. Based on the consideration of experimental errors due to insufficient quantitative statistical data, the experiment is biased toward qualitative research and analysis. We know that there are still deficiencies and look forward to further improvement in the future.

Through periodic course discussions and post-class interviews, this course has received positive feedback from students and teachers. This part provides teachers with a better understanding of cross-disciplinary students' thinking process on problem-solving and can be used as a reference guide for the application of teaching methods and techniques in developing courses in the future.

CONCLUSION

Nowadays, the environment around the world is gradually deteriorating, and the marine debris problem is a challenge for the sustainable development of the ocean. It is very important to realize the sustainable development of the environment based on educational work. In this research, we propose a design-computational thinking course, which is integrated into the operational thinking course through the mind map tool of design thinking. Through the transdisciplinary learning method identified by this research question, according to the experimental results, students can indeed stimulate students to think hierarchically, express themselves and get to the core of issues, insights, and strategies for marine debris and environmental sustainability. We will revise the course based on these materials, and the follow-up research will promote communication between students of different types and different professional backgrounds, hoping to cultivate students' cross-domain thinking mode and link with practical applications, discuss and solve the increasingly serious marine debris problem.

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