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Using design thinking for interdisciplinary curriculum design and teaching: a case study in higher education

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This study investigates the utilization of design thinking by a university instructor in the development and delivery of an interdisciplinary curriculum. It examines the challenges encountered and the coping strategies employed during the process. The research, conducted as a case study of an interdisciplinary program course at a university in southern Taiwan from September to December 2022, involved data collection through field observations, in-depth interviews, and document analysis. All data were transcribed verbatim, coded, and triangulated to enhance research validity. The findings suggest that design thinking serves as an effective methodology for interdisciplinary curriculum design and teaching. It emphasizes the integration of practice and application to facilitate students' interdisciplinary collaboration and co-creation. Additionally, the study evaluates teaching strategies, with a focus on the role of visual tools, communication, and on-site observation. The insights gained from this research provide valuable perspectives on challenges in interdisciplinary teaching, particularly in a post-pandemic context. They guided the development of effective practices in Taiwan and beyond, addressing crucial aspects such as the roles of instructors, resource allocation, and the cultivation of interdisciplinary talent. The study emphasizes the continuous need for adaptation and the prioritization of depth in learning outcomes.

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Introduction

Individuals and industries worldwide have encountered unprecedented challenges and changes in the aftermath of the COVID-19 pandemic. It is crucial for higher education to nurture future professionals capable of effectively addressing increasingly complex societal problems (Berasategi et al., 2020). With the proliferation of intricate global issues such as climate change, unemployment, healthcare, immigration, pollution, and safety (Hardy et al., 2021), interdisciplinary approaches have emerged as essential strategies. The surge in complex problems underscores the inevitability of interdisciplinary learning. Higher education, in response to these challenges, strives to cultivate skills that transcend traditional boundaries, including interdisciplinary thinking (Spelt et al., 2009). Major universities in Taiwan have demonstrated their commitment to promoting interdisciplinary education through mechanisms such as interdisciplinary courses, micro-credit courses, and credit programs. Interdisciplinary education aims to develop students' boundary-crossing skills, fostering problem-solving, communication, collaboration, critical thinking, entrepreneurship, and innovative practices. The implementation of interdisciplinary cooperation in teaching and learning becomes a key focus in cultivating future talent and enhancing students' integrated abilities.

Interdisciplinary learning involves transcending the boundaries of a single specific subject or field and providing students with connections and interactions between different subject areas. This interconnectivity helps them to understand the limitations and frameworks of their knowledge or skills and to integrate the knowledge of two or more disciplines to produce a cognitive advancement in ways that would have been impossible or unlikely through single disciplinary means (Spelt et al., 2009). It cultivates their ability to integrate different knowledge systems in facing complex problems in their careers or society. Moreover, interdisciplinary curriculum teaching significantly impacts instructors and learners, as compared to single-field curriculum teaching (Chang and Lin, 2019; McLaughlin et al., 2022; Spelt et al., 2009). Through interdisciplinary dialog, instructors can learn from others' experiences or identify their weaknesses, promoting professional growth, enhancing their teaching and curriculum planning abilities, and guiding students to think and cooperate to solve problems. Meanwhile, students have opportunities for multi-faceted exploration, using their knowledge and skills in their professional fields and collaborating with students from other fields. Interdisciplinary education influences students' learning styles and thinking patterns as they are exposed to different areas of expertise (Chen et al., 2017). Despite these benefits, instructors and learners face challenges in interdisciplinary collaboration. For instructors, the challenge lies in seamlessly integrating the cognitive and ideational aspects of individuals from diverse fields within the classroom, aiming for effective communication (Tsai, 2014). For learners, the challenges lie in communication problems arising from the heterogeneity of members' backgrounds, the ratio of team leaders to experts, how consensus is formed, and the ongoing conceptual analysis and evaluation conducted during the process (Tang and Lin, 2011).

Design thinking (DT) represents a 21st-century skill aimed at generating timely solutions to complex and practical problems (Tan, 2017). Therefore, in the post-epidemic era, as the trend to cultivate interdisciplinary talent increases, this case study investigates how a university instructor uses design thinking to design and teach a university interdisciplinary curriculum in the context of a university interdisciplinary program. Specifically, we explore the challenges encountered and coping strategies during the development of the interdisciplinary curriculum and teaching practice, and the professional growth and reflection resulting from the process. Our findings can serve as a reference to promote interdisciplinary education.

Literature review

Interdisciplinary teaching models. The term "interdisciplinary" is widely used to encompass a variety of activities related to communication, interaction, and integration among all disciplines. The dismantling of disciplinary boundaries characterizes interdisciplinary learning, and it can provide students with opportunities to engage and interact with different fields of study. The main objective of this approach is to guide students to gain a deeper understanding of the constraints and frameworks of their knowledge or skills while developing their capacity to comprehend and integrate different knowledge systems (Guo, 2008; Spelt et al., 2009). Students participating in interdisciplinary programs tend to develop a more holistic perspective and solution-oriented strategies rather than solely gaining content-specific knowledge from a single discipline. Interdisciplinary learning is aimed at cultivating multiple essential professional competencies, to address emerging social and employment challenges (Chang and Lin, 2019; Ivanitskaya et al., 2002; Repko, 2008; Repko and Szostak, 2021).

Previously, two inquiry-based teaching approaches, problem-based learning (PBL) and project-based learning (PjBL) were commonly used in interdisciplinary education (Majeski, 2005; Modo and Kinchin, 2011; Stentoft, 2017; Wróblewska and Okraszewska, 2020; Yang and Lin, 2015). These approaches differ in learning content, problem structure, and learning outcomes. For example, the PBL learning style is more divergent, guiding learners to form different sub-problems by setting out structurally ambiguous problems. On the other hand, PjBL is more convergent, forming sub-problems through perceiving different phenomena or exploring the impact of different variables (Yang et al., 2018).

More recently, interdisciplinary project-based learning (IPBL) has emerged. Like the approach businesses use to develop teams in multiple areas, IPBL provides sufficient training for teamwork and collaboration to students from different disciplines, preparing them to engage in complex technical, engineering, educational, and social projects. Students can promote their learning by contributing their strengths and resources (Carpenter et al., 2007; Johansen et al., 2009; Stozhko et al., 2015; Whitney, 2014). IPBL can help students develop creativity, overcome the barriers of disciplinary self-centeredness, facilitate the development of knowledge management processes, stimulate their interest and motivation in subject curricula, promote their participation in the learning process, and enhance their cognitive levels and satisfaction with learning outcomes (Biasutti and EL-Deghaidy, 2014; Yueh et al., 2015). Emphasizing teamwork and collaborative learning in interdisciplinary project teams can improve effective communication and problem-solving skills and prepare students for future community engagement and development in the real world. These benefits highlight the necessity, relevance, and importance of IPBL for interdisciplinary integration. Therefore, IPBL is considered an important model for cultivating relevant skills for students aiming to find their ideal professions (Hsu and Shiue, 2018).

However, these PBL learning modes have limitations in meeting students' learning needs for engagement with increasingly broad and complex challenges. A new emerging interdisciplinary inquiry-based learning approach: design-based learning (DBL) was proposed (Yang et al., 2018). DBL was initially proposed by D. Nelson, and its concept is deeply influenced by J. Dewey's philosophy, emphasizing learning

through practical operation and action. It incorporates design concepts such as prototypes into the curriculum, innovating teaching methods to provide students with an integrated learning experience (Nelson, 2004). It combines "design thinking" and "design practice", allowing students to explore and solve real-life problems through reflective learning processes and hands-on doing (Mehalik and Schunn, 2006). Design thinking (DT) is an iterative, human-centered approach to solving complex problems that have gained considerate popularity in business, education, medicine, etc. (Dukala et al., 2023; Li and Zhan, 2022; McLaughlin et al., 2022; Skywark et al., 2022). DT is frequently defined as the application of a designer's sensitivity and techniques to align the requirements of individuals with what is technologically possible and what a feasible business strategy can transform into customer value and market opportunity (Brown, 2008, p. 2). In the practical tasks of DBL, students are required to construct tangible artifacts, fostering higher-order thinking abilities and demonstrating creative, design, and decision-making thinking (Chen and Yang, 2020). Compared to PBL and PjBL, DBL places a greater emphasis on humanism, particularly focusing on the human-based problem-solving process, prototype testing, and iterative refinement stages (Wang, 2023; Yang et al., 2018). Therefore, using DBL as the core of interdisciplinary curriculum design and teaching is expected to be a concrete, feasible, and essential pedagogical strategy in the future.

Challenges and strategies in implementing interdisciplinary curriculum. Some interdisciplinary research has shown that implementing an interdisciplinary curriculum impacts instructors and learners significantly (Chang and Lin, 2019; McLaughlin et al., 2022; Spelt et al., 2009). For instructors, interdisciplinary dialog enables them to learn from others and identify their weaker areas, leading to professional growth and the ability to integrate knowledge from multiple fields. These benefits enhance their teaching and curriculum planning abilities and contribute to guiding students in their thinking and collaboration with a view to solving problems. Several aspects need to be considered when developing an interdisciplinary curriculum, including assessing the appropriateness of the course content, balancing different fields, encouraging creativity, collaborating with external partners, and addressing real-world problems and social trends. When designing interdisciplinary project courses, instructors should focus on how to teach the required hard skills for the topic, and as students begin to communicate with others, their need for soft skills becomes apparent. If instructors do not provide sufficient support, communication issues may hinder the development of hard skills. There is no need to distinguish between cultivating soft and hard skills during the learning process, as they are mutually beneficial.

However, without instructors providing scaffolding for these interactive processes, students may not automatically develop soft or hard skills in interdisciplinary project courses. Therefore, instructors engaging in interdisciplinary teaching must carefully consider how to offer guidance and scaffolding to students aiming to develop both hard and soft skills (Vogler et al., 2018). For learners, interdisciplinary learning provides opportunities for exploration from multiple perspectives, utilizing knowledge and skills from their field and collaborating with students from other fields. Interdisciplinary approaches prioritize the development of higher-order thinking skills, such as analysis, application, generalization, and forming meaningful connections between different disciplines. Although these approaches may be less effective than traditional methods in building in-depth knowledge of a single subject, they offer unique benefits that cannot be achieved through a single-subject focus (Ivanitskaya et al., 2002). Students who have received interdisciplinary education training, influenced by diverse ways of thinking in different fields, will have more diverse learning styles and thinking patterns (Chen et al., 2017).

In addition, implementing an interdisciplinary curriculum poses significant challenges. Instructors in higher education institutions often lack training in interdisciplinary or transdisciplinary education, viewing interdisciplinary project activities as intimidating, especially when they cut across different classes and disciplines (Vogler et al., 2018). Bridging cognitive and ideational gaps for effective communication among students from diverse fields in the classroom proves challenging (Tsai, 2014). Furthermore, successful interdisciplinary teaching requires close collaboration among scholars from different fields, and language and terminological differences between these fields commonly serve as barriers (Repko, 2008; Repko and Szostak, 2021). The skills involved in interdisciplinary learning are also challenging to teach or understand in the classroom (Katz and Martin, 1997). Therefore, instructors must design experiential activities to help students acquire relevant skills through hands-on learning. Learners may face time constraints due to their academic workload, semester schedules, financial support, or the necessity of taking on additional jobs, which can limit their ability to participate in and benefit from teaching activities (Ryser et al., 2009). Team collaboration may lead to communication problems arising from the heterogeneous backgrounds of members, the ratio of team leaders to team members, the formation of consensus and conceptual analysis during the process, and the evaluation of the project (Tang and Lin, 2011).

Based on the above, this case study delves into the development and delivery of an interdisciplinary curriculum within a university setting. It investigates the various instructional challenges encountered and strategies employed to nurture professional development and reflection, particularly in the unique circumstances of a university interdisciplinary curriculum post-pandemic. The insights derived from this study are intended to provide valuable guidance for the advancement of interdisciplinary education practices in Taiwan and beyond.

Methods

Participants

Research field and participants. This case study focuses on an interdisciplinary-related course offered by an interdisciplinary program at a university in southern Taiwan. The study has received ethical approval from the Human Research Ethics Committee, Taiwan, confirming its adherence to ethical guidelines. The participants included one instructor, one teaching assistant, and 38 students enrolled in the course. In the interests of research ethics, they were asked to fill in the research informed-consent form voluntarily and also to freely decide whether to agree to include the previously collected data in the final research analysis to protect their rights and interests. The case instructor's areas of expertise include cultural anthropology, material culture, globalization and localization, design and applied anthropology, and design thinking. The case instructor has taught this course for five semesters.

This course aims to cultivate students' comprehensive abilities to apply design thinking across interdisciplinary domains. This includes solving real-world problems, enhancing communication skills, developing divergent and convergent thinking, understanding various stages of the design thinking process, strengthening empathy, conducting on-site observations, translating insights into practical designs, and acquiring practical skills for production, modification, and presentation of end products. The course has three main learning objectives: design thinking

Table 1 Interview participants list.

Category	Interviewee	Gender	Current position
Interviewed instructor	TS	Male	Assistant Professor in an interdisciplinary program at a university in southern Taiwan
Interviewed students	SG	Female	Sophomore student majoring in interdisciplinary program at a university in southern Taiwan
	SL	Male	Senior student majoring in social sciences and minoring in interdisciplinary program at a university in southern Taiwan
	SW	Female	Sophomore student majoring in interdisciplinary program at a university in southern Taiwan
	SH	Female	Sophomore student majoring in interdisciplinary program at a university in southern Taiwan
	SP	Female	Sophomore student majoring in interdisciplinary program at a university in southern Taiwan
	SA	Male	Sophomore student majoring in interdisciplinary program at a university in southern Taiwan

Table 2 Interview outline.

Interview outline for the case instructor	Interview outline for the students
1. Provide an overview of the planning process for the course of design thinking.	1. Introduce yourself (major, academic year) and brief background of group members.
2. What are the objectives for each instructional task (e.g., observing a playground, facilitating a children's design thinking mini-workshop, creating a park, designing a cardboard game, delivering a thematic speech) in the course?	2. What are the key roles or influences of the classroom activities, such as observing playgrounds, conducting mini design workshops for children, creating parks, playing with cardboard boxes, and giving topic speeches, on the playground equipment design? What challenges were encountered and how were they addressed?
3. Why does the course involve having students design playground equipment and connect with the community (school)? What is the purpose?	3. In the course, which part was more difficult or easier? Which step is most important for playground equipment making?
4. What needs to be considered during the actual teaching and learning process? Were there any challenges encountered?	4. What is the role of the case instructor in the course?
5. What is the relationship between design thinking and interdisciplinary teaching and learning?	

fundamentals, maker skills, and mid- and final-term projects. In the mid-term project, students must use the design thinking techniques learned in class to design games for children. For the final project, students must design creative playground equipment for the community and organize a two-day community play equipment exhibition. This course is a transdisciplinary curriculum primarily focusing on real-world scenarios, such as designing creative play equipment for children.

This study focuses on the dynamic process of designing and implementing interdisciplinary courses and emphasizes the use of design thinking methodology. We conducted classroom observations and interviews and collected documents throughout a semester to analyze and synthesize the data exploring various aspects of interdisciplinary course design and implementation. The research team conducted weekly classroom observations from September to December 2022. The research team interviewed the case instructor three times, and the case instructor recommended one student from each group for an interview. Interview locations were chosen for their quiet and comfortable environment and suitability for recording and note-taking. Open-ended interviews were conducted using semi-structured questions. Table 1 lists the case instructor and student information.

The research team. The research team consisted of a university faculty member, R1 (researcher), who teaches in a department related to education, and a master's student, R2 (collaborative observer and interviewer), who works in a department related to education. R1 and R2 conducted classroom observations together, and R1 served as the primary interviewer during the interviews, with R2 conducting the collaborative interviews. The team conducted a member check meeting to analyze the data. R1 has 3 years of experience in interdisciplinary course design and teaching (since 2019) and has published two research papers on interdisciplinary course teaching.

The researcher distributed informed consent forms to the case instructor and students and proceeded with data collection only after obtaining their agreement. The data collection process was anonymous, and participants were informed that the collected data would only be used for academic research. The paper-based data would be placed in a locked cabinet, and a password would protect the electronic files to protect the participants' privacy. The case instructors and students were also free to include previously collected data in the research analysis.

Instruments

Participant observation data. Before starting the academic term, the researcher consulted with the case instructor to understand the curriculum, teaching context, student characteristics, observation focus and tools, and feedback session arrangements. During the teaching process, the researcher obtained written consent from the case instructor and students before conducting classroom observations and recording factual data about the case instructor's teaching and student behavior. After the teaching period ended, the researcher held feedback sessions with the case instructor to clarify the ideas and achieve a consensus. The observed data were derived from two sources: (1) observation records and photos taken during class, and (2) non-specific observations, such as incidental behavior or conversations between the case instructor and students during data collection in the classroom.

Interview process and outline. Semi-structured interviews (Table 2) were the primary data collection method, and the entire interview process was recorded. The research team conducted interviews about the interdisciplinary course design and teaching experiences. The interviews with the case instructor focused on how to design and teach an interdisciplinary course, address teaching challenges, and professional growth and reflections

Table 3 Examples of open coding and main coding.

Level 2: Main coding	Level 1: Open coding
The Challenges and Reflections of Interdisciplinary Instructors.	1. Community engagement and high costs
...	2 Considerations of time and schedule
	3. Importance of instructor feedback
	4. Instructor without a background in design
	5. Balancing classroom content with the real world
	6. The ability of student work to withstand market testing
	....

during the process. The interviews with students focused on the impact of course design and teaching activities on their learning.

Analysis. The interview content was transcribed verbatim and coded using NVivo 12 software to avoid disclosing the names of the research participants and other related privacy information. We used triangulation (Denzin, 1978) to enhance research validity (Maxwell, 1992). The data collection methods used to obtain the research data included interviews, observation records, and document data. "Data source triangulation" was adopted, inviting the case instructor, course students, and collaborative observers to participate in the study, to examine the data consistency. In addition, a recording pen was used to record data, to avoid missing or biased information. The researcher recorded interview and observation content in detail, carefully organized document data, and avoided over-inference to present the research's validity.

Each research subject was given three codes: the first code represented their identity (R1: Researcher 1; TS: instructor S; SY: student Y); the second code represented the data type (I: Interview; O: Classroom observation and reflection); and the third code represented the date. For example, SW_I_20221228 indicates that student W was interviewed on December 28, 2022, and R1_O_20221006 indicates that Researcher 1 conducted classroom observation on October 6, 2022. During the data classification and formation of categories, the research team referred to the relevant literature and compiled primary categories. Sections of a similar nature and content were placed under the same relevant category. At the same time, member checks and peer reviews (Miles and Huberman, 1994) were conducted for the interview content. Analysis was stopped when the data began to show patterns and became increasingly stable.

Data analysis began in February 2023 and was divided into two stages. The first stage involved open coding, where the researcher conducted a preliminary analysis of three instructor interview transcripts, six student interview transcripts, nine researcher classroom observation records, and nine co-observer classroom observation records for 27 files. The first level of open coding generated 83 codes. In the second stage, based on the first level of coding, the researcher extracted the main codes through axial coding, resulting in 12 main codes. Examples of the codes are provided in Table 3.

Results and discussion

Design and planning an interdisciplinary curriculum

Using design thinking as a methodology for curriculum design. Gaining insights into the pedagogical approaches and experiential aspects of design thinking in higher education enables educational institutions to enhance student learning, ensuring alignment with the demands of professionalism, personal development, and civic engagement (McLaughlin et al., 2022). The case instructor used the Stanford University D-School design thinking model to design and plan the interdisciplinary curriculum, consisting of five stages: "empathize", "define", "ideate", "prototype", and "test". The "empathize" stage helped participants understand the importance of empathy and learn how to cultivate it. The "define" stage clarified the problem through common methods, such as summarizing the key points and establishing connections, making the design goals clearer. The "ideate" stage taught participants ideation techniques to transform problems into solutions. The "prototype" stage proposed ideas closer to the final solution and the creation of prototypes to obtain user feedback. Finally, during the "test" stage, participants were encouraged to implement their prototypes, assess their effectiveness, and verify their solutions, gaining a deeper understanding of the importance of thorough testing (Henriksen et al., 2017; Wang and Sung, 2019).

The case instructor guided university students through three complete cycles of design thinking across three projects: the "Design Thinking Mini-Workshop," the "Mid-term Project," and the "Final Project." During the first cycle, in the third week of the course, the case instructor-led students in designing a chair for their partners as part of the Design Thinking Mini-Workshop. This phase aimed to familiarize students with two design thinking techniques—divergent and convergent thinking, five steps—empathize, define, ideate, prototype, and test, and three criteria—desirability, feasibility, and viability. In the second cycle, the case instructor directed students to use cardboard as the material for designing board games targeting elementary school children. The design thinking process was employed, and children were invited to test and play with the game prototypes. By the end of the course, each group leveraged observations from the game field, interviews with children, and feedback on their gaming experiences to design innovative wooden play equipment for children. This culmination of efforts served as the third cycle, wherein the groups collaborated with "Taiwan Parks & Playgrounds for Children by Children" to organize a two-day park play equipment exhibition in a southern Taiwan administrative district.

As part of the three design thinking cycles, the case instructor set different assignments to help students practice the two techniques, five steps, three criteria, and related design thinking tools (Fig. 1). These assignments included observing and documenting children's toys, observing and documenting children's game ideas, learning woodworking skills, explaining sketches for the final project, creating prototypes for the final project, designing a poster to introduce the project, and completing a nine-square personal business model.

Balancing resources and real-world impact: challenges and strategies in extended interdisciplinary courses. The case instructor has a humanities and social sciences background and has taught this course five times since 2018. He is adept at conducting field observations and interviews in different contexts and has independently studied courses related to design thinking and industrial design. He has a strong interest in design and art and has conducted two years of ethnographic research into the maker community in Taiwan. The case instructor's expertise lies in

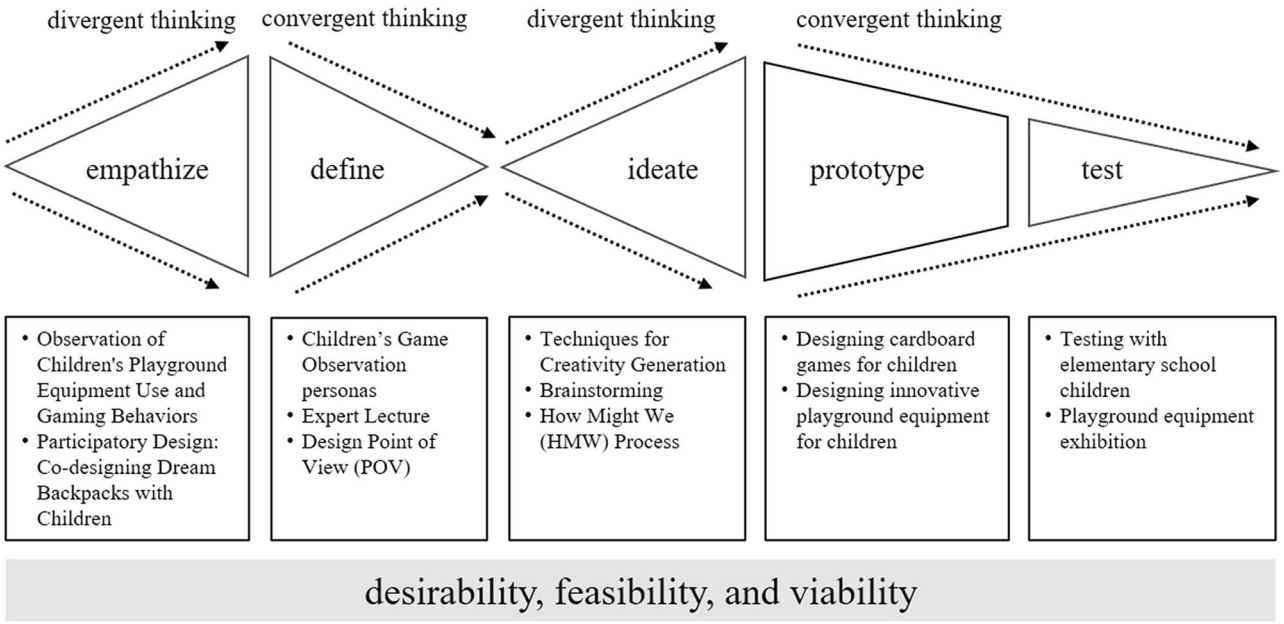

Fig. 1 The correspondence chart of design thinking and interdisciplinary course tasks.

guiding students' observations and interviews to discover the users' needs. However, to overcome the limitations of his lack of technical expertise, he invited industry experts to co-teach and introduce external resources into the classroom.

> TS: If students only stop at the proposing ideas stage, they will not see the final outcome, and the product cannot be iterated. Therefore, I hope that after completion, the students' work can undergo another market test, and the complete production process can be recorded as an important memory for them. Also, if we want to do this, we need resources, which need to be related to the community if we want to use USR (University Social Responsibility: one project in Taiwan) … These outcomes are very expensive, including both the teaching of certain techniques, as well as giving students the opportunity to practice these techniques, for which you need tools, and every step costs money. If only proposals are made and no prototype is produced, the students' understanding and perception of the entire project or their understanding of design thinking will not be deep enough. (TS_I_20230104)

As part of university-level interdisciplinary education, students were encouraged to solve real-world problems. The case instructor didn't want students to only reach the proposal stage; he introduced more time, supported resources, and practical venues to establish a stronger connection between classroom content and the real world. Therefore, this course tended to be longer, and the holidays were often utilized. For example, the regular class time is three hours per week. However, during the later prototype production stage, students often used the holidays to make wooden playground equipment in rented venues. In addition, the resources needed to support classroom activities, such as professional guidance from industry experts, learning woodworking skills, mechanical equipment, wooden materials, and hourly fees, are costly. While balancing classroom learning and not allowing students to spend too much money, the case instructor must also administer the operation of the course before conducting a class. For example, he must apply for government project funding, invite corporate cooperation and sponsorship, contact primary schools for cooperation, and identify exhibition venues to ensure sufficient resources and venues for teaching.

Interdisciplinary teaching strategies and tools

Creating a culture of equitable instructor–student relationships through effective questioning and example-setting to foster classroom discussion. During the first week of class, the case instructor told the students, "Don't call me 'instructor' or 'professor', please call me C (the case instructor's name) or coach. The reason is that I don't want you to give up thinking, and I want to create an equal atmosphere in the classroom to encourage you to speak up more (R1_O_ 20220908)." During class, the case instructor is skilled in using questioning as a scaffold for student learning, often using "what", "why", and "how" to ask questions. Starting from the students' experiences, the case instructor connects them to the concepts to be elaborated by the case instructor, to train students to think in more abstract ways.

> TS: Have you ever experienced good design? Why was it good? What would happen if that design didn't exist? How would you use that design to solve a problem if it were you?
>
> TS: Next, I will introduce the inspiration and function of the EAT WELL product (a universal tableware design) through a crowdfunding video, which is mainly designed for patients with dementia. What is special about this tableware? What was the motivation behind creating it? What other special features were mentioned in the video? Was there any reference to the color used in other materials?… (R1_O_20220908)

During the process, the case instructor utilized questioning, scenario simulation, and discussions to facilitate students' exploration of user needs, identification of underlying reasons, and generation of viable solutions through mutual discussion based on their life experiences or relevant cases. Subsequently, the case solutions were decided with a view to training students' insights.

> (During the class, a student was invited to simulate the perspective of an IDEO researcher role-playing a patient.)

TS: IDEO wants to improve the patient experience in Minnesota hospitals--starting with a change of perspective. (When you spend the whole day lying in bed in the hospital, all you can see is the ceiling.) So, once you change perspectives, what does the person see in the world?

…

TS: Why should the floor color in the hospital ward be divided into different areas?

TS: People can be in a more comfortable state, just like being at home. Although the hospital is also a public building, we also hope they will want to make patients feel comfortable when they see a doctor. (R1_O_20220929)

Encouraging the use of visual tools and vertical communication to facilitate dialog. The tools and methods commonly used in design thinking include ethnographic methods, personas, journey maps, brainstorming, mind maps, visualization, prototyping, experiments, and others (Micheli et al., 2019). These visualization tools allow users to engage in experiential learning and reflect on their actions (Elsbach and Stigliani, 2018). Therefore, using visualization tools for communication is crucial in design thinking. Significant disparities may exist due to individuals' diverse cognitive and linguistic habits, especially in heterogeneous groups. Hence, in the second week of the course, the case instructor helped students establish a habit of using visual communication, extensively employing visual and graphic means to discuss issues, and encouraging students to conduct vertical communication after pasting their data on the wall, thereby making the process of design thinking more three-dimensional (Fig. 2).

Fig. 2 Peer feedback using sticky notes (R2_O_20220915).

TS: Please come up to the front with a pen and some sticky notes, and practice sharing and giving feedback to others. This process will help everyone develop the habit of team communication and collaboration.

(Students verbally share their observations on children's game behaviors, while others give feedback using sticky notes.)

TS: Why do children want to play with this toy? Let's think about it together. Did this child gain any value from playing with it?

S: This is a 7-year-old girl with a lively and imaginative personality. She plays a role-playing game with her own dolls, pretending to be a teacher and the students, because her mother does not buy her toys very often. (R2_O_20220915)

The case instructor also considered explicitly teaching students how to integrate ideas from different sources and imparting basic teamwork skills to provide comprehensive support for interdisciplinary learning. Achieving consensus is often necessary for feedback or teamwork for decision-making. The case instructor suggested that students can use dot stickers to provide their opinions, and when there is disagreement, using them to vote is useful. Subsequently, students often used this method for group discussion in assignments.

The idea is that everyone provides an idea, and if we want to select one, we vote. I think we use voting because C (the case instructor) first taught us a "dot-sticking" method, and then I just changed it to being online and then voting. (SL_I_20221228)

The purpose of the prototype was to generate ideas and solve problems. Regarding communication, a picture is worth a thousand words, and a prototype is worth a thousand pictures (Wang and Sung, 2022). Therefore, the case instructor suggested that students use geometric elements such as triangles, circles, and squares to complete a basic three-dimensional structure of the work and only use red, blue, yellow, black, and white colors. The paper version is cut into triangles, circles, and squares for combination (Fig. 3).

Experiential teaching activities: a study on site observation and user experience. Designers must observe, interview, or experience users' daily lives to understand the users' needs. The critical task of design thinking is to transform the observed or interviewed data into insights and create products and services that can improve people's lives. Through empathy, designers can connect

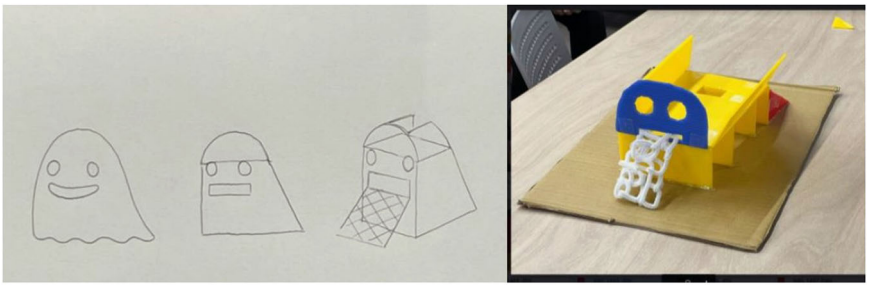

Fig. 3 Low-fidelity to high-fidelity prototypes (R1_O_20221027).

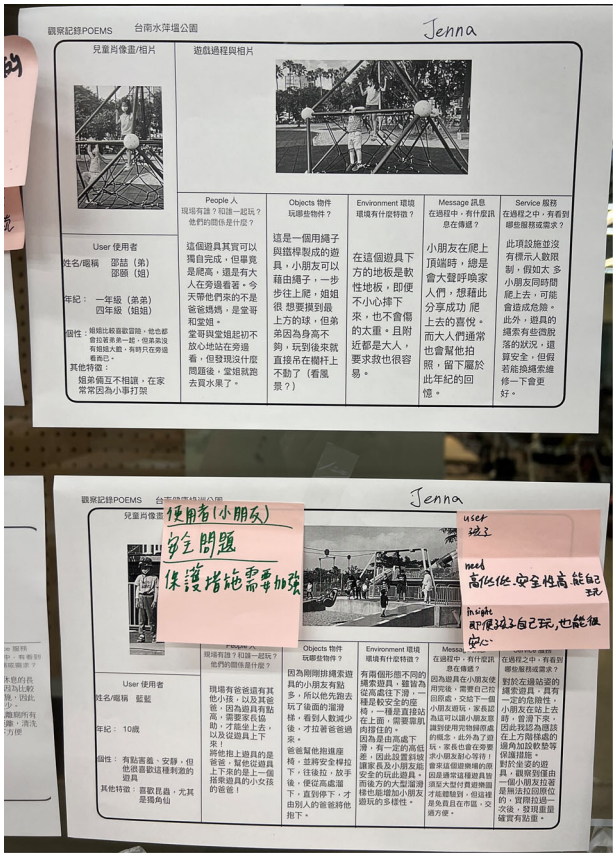

Fig. 4 Observation of children's play behaviors at a play area (R1_O_20220929).

these insights with others' perspectives and understand and feel the world through their experiences and emotions (Brown, 2009). However, this type of learning is not easy to teach or understand in the classroom. In interdisciplinary classrooms, instructors must design experiential activities that allow students to acquire relevant skills through experiential learning (Ryser et al., 2009). In this case, the case instructor asked students to observe children's behavior in the playground (Fig. 4), interact with them, and help third and fourth-grade elementary school children design their dream backpacks. These all represent ways whereby students may observe children and explore their play needs.

Progressive practice of the design Point of View (POV). It is essential to define clearly the problem to be solved, to generate a design point of view (POV). A POV can help designers gain deeper insights into the research object and problem, including the users, needs, and insight elements, by organizing user needs that have not been met from the collected data. With a clear POV, designers can develop focused problem statements and generate high-quality solutions. Therefore, designers must analyze, observe, and discover data, form unique insights through an integrative interpretation of a large amount of data, and help other designers to move to the next stage through an actionable problem statement. There may be multiple insights, and the designer must select the insight that meets the current users' needs (Liu, 2021).

When defining the problem, the case instructor used progressive exercise tasks from existing cases and field data collected by students to enable them to practice forming POVs and improve their problem-solving skills. The case instructor used practical business cases for students to practice writing a POV and compared the differences with a case POV.

> TS: Please watch the "Lucky Iron Fish: Shape of Health" video. The locals in Cambodia suffer from iron deficiency, which often causes dizziness, miscarriage, lack of focus in children, osteoporosis, etc. If a method could be found to provide enough iron ions to Cambodians through their typical fish and rice meals, the problem of iron deficiency could be solved. The research discovered that using iron cookware during cooking could release iron ions and address iron deficiency. How can the locals willingly put a piece of iron into the pot during cooking when they cannot afford to use expensive iron pots? Please practice writing the POV for this case. (R1_O__20220929)

After gaining experience writing case-based POVs, students practiced writing POVs using observation data from children's play areas and from conducting dream backpack design workshops with children (see Fig. 5).

During the practice, the case instructor reminded the students that questioning is crucial to uncovering needs, and observation can reveal other needs. At the same time, the case instructor used questioning to refine the quality of the students' POVs.

> S: The elementary school student's original backpack is a Transformer with a hard shell. It has compartments on the left and right sides for storing umbrellas and water bottles.
>
> TS: What are his expectations and difficulties in using the backpack?
>
> S: He hopes it can be made easier to carry, as the hard shell makes it feel heavy on his back and waist. He wants it to look like a regular backpack and provide protection against bad guys.
>
> TS: From this perspective, what needs might he have? He may be afraid of bullying and need protection and safety. (R1_O_20221006)

Through a progressive POV exercise, students can quickly discern a child's play traits and tendencies from the types of games and play equipment they use. For example, a child inventing their own rules for playing a game indicates a more proactive and imaginative nature. A child drawing game equipment that involves shooting or destruction suggests a high need for stimulation. Conversely, more introverted children may require independent play equipment.

> S: The elementary school students in our group drew slides, climbing nets, mazes, aggressive equipment, and obstacle courses. Therefore, our insights suggest they enjoy pursuing excitement, challenging limits, and continuous obstacle courses. (R1_O_20221020)

Collecting feedback for prototype testing and refinement. During the testing phase of the design thinking process, the main approach was to collect feedback from others to conduct testing and make revisions. Before testing, the case instructor invited students from other groups to provide feedback and suggestions on the prototype.

> (Group feedback and questions after a board game proposal)

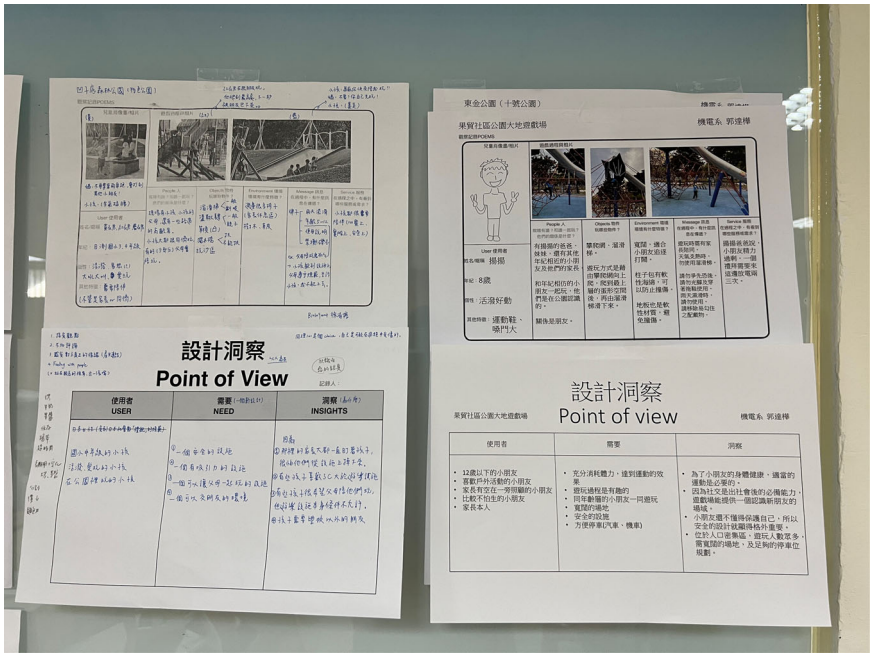

Fig. 5 POV exercise (R1_O_20221013).

S1: Does just moving the cup provide enough hands-on experience for the children? The gameplay may be a bit monotonous; perhaps there could be more variation.

S2: What's the difference between this and playing ping pong with yourself? What's the selling point of this device to attract children to play? It feels like it could be made more exciting.

S3: How does the ball drop? Will the size be changed again?

S4: Chopsticks could be added to provide a barrier; otherwise, the ball drops too quickly.

TS: Does someone need to throw the ball from the top and someone catch it at the bottom? Maybe this could be less interactive and physical, and the gameplay could be more diverse. If more of these are made, can children compete and increase the richness of the gameplay? It is also important to spend time testing the spacing and adding unpredictability. (R2_O_20221103)

During the production of the play equipment, a professional carpenter was invited to provide structural recommendations for the student's production of the 3D prototype of the wooden plank play equipment (Fig. 6).

The professional carpenter: This group of students is highly motivated. They encountered a problem with the positioning of the slope and its connection with the hexagonal structure. The slope is placed on a rectangular frame, and there is a possibility that the frame may collapse when children climb on it. One solution is to make the frame square instead of rectangular. For the upper part of the structure, two ladders are used. The thickness of the wood for the ladders needs to be determined. The structure may sag in the middle if the wood is not thick enough. Therefore, support poles may need to be added to the bottom, and the design of the upper wooden board also needs to be considered. (R1_O_20221117)

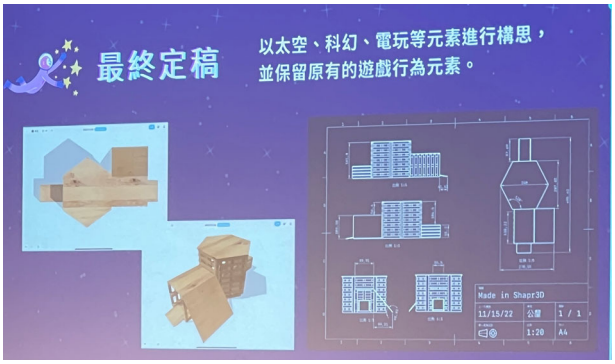

Fig. 6 3D prototype of the creative play equipment designed by a group (R1_O_20221117).

The role of the case instructor: guiding student thinking and providing direction and strategies. In interdisciplinary classrooms, besides teaching professional knowledge, the case instructor played a crucial role in guiding students' thinking and providing problem-solving strategies and directions.

R1: What is C's (the case instructor) role?

SG: He tends to play the role of "guiding without being overly directive". In other words, he would provide us with some resources in the early stages but does not interfere too much with the content we discuss. If we encounter problems, we can discuss them with him. For example, when we were facing the second prototype revision round at one elementary school, he came to discuss it with us. As our entire play equipment was too big, he suggested a direction and guided our discussion toward the idea of "modular play equipment". (SG_I_20221222)

As interdisciplinary educators, we must be prepared to allow students to feel uncomfortable and uncertain in their learning environments. However, we must also maintain a safe learning

environment where students are free to make mistakes and their perspectives are valued and understood (Gardiner, 2020). Therefore, when students' approaches and definitions of problem-solving deviate from the topic, instructors must intervene and guide them while valuing their ideas. The following is a discussion that the case instructor had with group members after class, as they had deviated from the main theme while working on their final proposal for play equipment.

> TS: Last week's successful experience seemed to have limited you to focusing only on game design instead of equipment design, which led you to break out of the original scope of the assignment to design equipment. I do not agree that you violated the assignment rules by making a game. I appreciate your out-of-the-box thinking, but this assignment was not about game design. You could incorporate fighting or obstacle race concepts and create various obstacles, such as throwing actions. I can accept starting with archery or throwing games as a basis for obstacle racing and turning the field into a space of thieves, where breaking through various obstacles can allow the children to complete different missions. (R1_O_20221117)

The challenges and responses of interdisciplinary teaching

Interdisciplinary teaching in practice: addressing technical skill gaps and enhancing learning experiences. The case instructor has a humanities and social sciences background. Despite being able to introduce external experts and resources to compensate for their lack of technical expertise, some students still feel insufficient time is allocated for learning certain technical skills, such as woodworking.

> The case instructor taught some content too quickly, and the time he spent teaching woodworking was very short for those who didn't know. When he taught, he compressed some content, making me feel that professional learning was insufficient, and I needed to find additional information to understand it. … Although his manual skills were not very good, his biggest help to me was that he would ask us to conduct field investigations, which allowed us to observe many details. (SA_I_20221228)

Ideal interdisciplinary teaching requires close collaboration among scholars from different fields. Regular professional communication and dialog are essential to understand the interrelationships and differences between each other's subjects and facilitate collaborative teaching with two or more instructors from different disciplines. Joint preparation is also required to discuss the goals, content design, teaching methods, and assessment strategies for interdisciplinary learning (Chang and Lin, 2019). However, due to school resources and practical considerations, a single instructor often undertakes interdisciplinary teaching in Taiwan. Therefore, a sole instructor of interdisciplinary courses must engage in interdisciplinary learning to accumulate different forms of professional knowledge and new perspectives. The case instructor must frequently engage in metacognitive reflection on professional limitations, introduce resources from other fields as appropriate, and have a basic understanding of other fields to become a bridge for students to engage in learning from different disciplines.

> My major is not in design, so I must resort to some simple methods that students can brainstorm with. At this point, I learned about Bauhaus, a design school from before World War II who influenced design education worldwide. What I learned from Bauhaus was that, with the simplest colors, one could create many basic, minimalist designs. We don't need to make students do something fancy. Instead, they can start learning about what design is and what form is by being able to decompose or transform the combination of these simple geometric shapes. I think that's enough. I think the design thinking curriculum is not simply about learning about form but also about solving problems, and that form is just one problem-solving method. (TS_I_20230104)

Most university instructors typically have a single disciplinary background, and to engage in interdisciplinary course instruction, they must be open-minded and capable of reflective thinking. An open-minded attitude is essential in learning about different fields and understanding the professional terminology used in other fields. Additionally, interdisciplinary instructors need specialized knowledge, educational expertise, or teaching skills. They should constantly reflect on the content of the course and its relevance to the real world, finding a balance between reflection and routine and between thinking and action (Zeichner and Liston, 1996).

Navigating constraints: challenges in implementing design thinking cycles and community exhibitions in a limited-time academic semester. In a 16-week course with only three hours per week, students were expected to complete three design thinking cycles and organize a public exhibition in the community of their wooden play equipment. Throughout the process, the case instructor and students must overcome resource and funding challenges, work collaboratively in teams, and invest significant time and effort in completing various assignments and tasks. Due to their academic course loads, semester schedules, financial constraints, and the need for additional employment, students might encounter time limitations that may affect their participation in and ability to benefit from all the activities (Ryser et al., 2009). While most students showed a strong commitment to learning, the researcher observed that some students could not dedicate additional time outside of class to construct their wooden play equipment due to the required time investment.

> For most of the courses I have taken, the requirements usually involve writing a paper or presenting a proposal. If it's even simpler, like if everyone just wants to pass, we might do a group project where we all contribute information, and one person compiles it all to complete the report. However, in this class, I feel that many complex discussions and divisions of labor are required because we're not just preparing a report. We also have to assign carpentry work, decide how to make proposals. and allocate labor. (SL_I_20221228)

In Taiwan, a typical university semester lasts 16 to 18 weeks, with each course typically consisting of 2 to 3 classes per week. Different schools have different regulations regarding semester length and course schedules. These regulations often constrain interdisciplinary courses, making it difficult for students to have a coherent or in-depth learning experience. Therefore, the school administration's cooperation is essential (such as cross-departmental course selection systems, credit granting, and instructor allocation) (Chang and Lin, 2019). The case instructor believes that design thinking should have different learning directions at various stages of the academic system and suggests that schools should have more flexible implementation schedules for interdisciplinary courses, allowing instructors to design courses that enable students to have greater involvement and apply what they have learned (TS_I_20230104).

Balancing interdisciplinary teaching content and pedagogical principles: challenges and considerations. This interdisciplinary course requires three cycles of design thinking. Therefore, the

case instructor had a busy and full teaching schedule in the classroom, potentially resulting in the omission of some skills instruction. For example, when university students designed dream backpacks with children, the researcher observed that the university students needed to improve their interviewing skills.

> In one group of elementary school students working on the design of a dream backpack, the group of university students kept asking the elementary school students questions, which caused them to hesitate in their ideation of the backpack. They were unsure whether it was due to difficulty responding to too many questions, making it difficult to draw their ideas immediately. The university students asked many questions to stimulate the elementary school students' imagination regarding the backpack design, but the elementary school students did not respond much. (R1_O_20221006)

In interdisciplinary courses, forming student teams is also challenging. The case instructor asked the students to post their expertise on the wall and recruit members with different skills to form teams. The case instructor hoped to have students from different disciplines on each team; this was a modification he made after teaching the course for four rounds. However, one group in which all seven students were from the same discipline remained, and they could not find another group to join. The case instructor compromised on this principle and allowed students from the same field to form a group.

> Last year, there was another event where some people couldn't be grouped due to overly strict grouping, and it seemed like we were exposing some people to exclusion. This year, a few people couldn't be grouped with anyone else, such as students J, B, or C. It was difficult to divide them up, so I thought giving them a sense of belonging and letting them be in the same group rather than strictly enforcing the grouping was more important. Of course, I asked their opinions, "Are you willing to sacrifice your rights to work with people from other departments or different people?" They said they were willing, so I let them continue in the same group. (TS_I_20230104)

Furthermore, in authentic field-based courses, the case instructor allowed students opportunities for free exploration if they did not deviate too much from the topic. Even if the students had not considered the specific characteristics of the final practical field, they were usually given the freedom to proceed without too many restrictions.

> In this group, I feel that they did not consider that the playground equipment should be placed in a park because the playground equipment exhibition is an event. Their initial proposition was "no pressure", wanting introverted children to hide in the playground equipment alone. However, most of the people who come to play with the equipment in the park are accompanied by their parents, and basically, it is just for children to release their energy. Therefore, this setting is unsuitable, but I wanted to let them try it out. (TS_I_20230104)

Interdisciplinary teaching is a highly complex process that requires instructors to possess a level of interdisciplinary background and teaching knowledge to balance the learning proportion of professional knowledge, interdisciplinary teaching content, and principles in curriculum design. At the same time, they must also have sufficient resources, time, and practical experience to connect classroom content with the real world and consider using different teaching tasks to provide students with guidance scaffolding to develop hard and soft skills (Vogler et al., 2018). In addition, interdisciplinary design thinking courses should include growth-oriented reflection, explicit group work skills, and content with a real-world application (Skywark et al., 2022). As interdisciplinary instructors, they must also have a degree of flexibility and openness to accept unexpected situations that may arise during the process and afford students the space to try and learn from their mistakes.

Conclusions and suggestions

Conclusions

Design thinking as a methodology for interdisciplinary curriculum design and teaching. In higher education, instructors often lack interdisciplinary education and training in using interdisciplinary methods in teaching. Drawing on the case instructor's interdisciplinary curriculum design and teaching experience in this study, we propose that design thinking is a suitable methodology for interdisciplinary curriculum design and teaching. Design thinking emphasizes starting from practical situations and problems, exploring users' potential needs and challenges, and valuing human-centered design and innovative solutions. In interdisciplinary courses, students come from diverse backgrounds and professions, and they can work together using design thinking to integrate their knowledge and skills to solve complex problems.

Interdisciplinary teaching strategies and tools. In interdisciplinary teaching, it is crucial to assess effective methods for fostering teacher-student relationships and promoting classroom discussions. Researching the roles of visual tools and communication in interdisciplinary dialog provides valuable insights, contributing to a deeper understanding of their impact on learning. Additionally, the study explored the influence of on-site observation and user experiences on students, assessing the feasibility of integrating these activities. Analyzing the progressive practice of the design POV sheds light on its effects on students' problem-solving abilities. The study also emphasized the importance of feedback collection during prototype testing, presenting best practices and improvement recommendations. Lastly, an evaluation of instructors' roles in interdisciplinary teaching concluded the exploration, offering insights and practical recommendations for enhanced teaching effectiveness.

The challenges and responses of interdisciplinary teaching. This case study investigated the development and delivery of an interdisciplinary curriculum within a university setting, exploring instructional challenges and strategies for professional development and reflection, particularly in the unique circumstances of a university post-pandemic. The insights aimed to guide the advancement of interdisciplinary education practices in Taiwan and beyond. The research examined strategies used by instructors to balance disciplinary knowledge acquisition in interdisciplinary teaching, addressing limitations in their professional background and how this balance impacts student expectations. An evaluation assesses the resource and time investment required for interdisciplinary course development, exploring strategies to overcome associated challenges. Emphasizing the intricate connection between interdisciplinary course content and the real world, the study underscores the need for ample resources, time, and practical venues.

Cultivating interdisciplinary talent is crucial in higher education, leading to recommendations for allocating fixed funds in future university academic development plans. Instructors are encouraged to actively seek government research project funds and collaborate with established partners for enduring learning opportunities. Despite increased time investment and potential

term-related limitations in interdisciplinary learning, the suggestion is to enhance student learning depth by introducing flexibility into the curricular structure, such as adopting a modular or intensive course system. The ongoing challenge of balancing interdisciplinary teaching content and principles necessitates continuous adjustments. In designing learning tasks, instructors should prioritize depth over breadth, avoiding superficial outcomes. It is crucial to adapt courses based on student feedback to achieve interdisciplinary teaching objectives.

Limitations and suggestions. This study investigated how a university instructor utilizes design thinking in interdisciplinary curriculum design and explored the teaching challenges and coping strategies. Due to space limitations, this study primarily focused on the case instructor's perspective and did not present the students' views on interdisciplinary learning. Additionally, to avoid disrupting classroom learning, the researcher and the collaborative observer only observed from the periphery of the classroom and did not observe student interactions during group discussions, so some information could only be obtained through post-interviews.

Furthermore, in this case, the case instructor had a humanities and social science background and thus emphasized observation and interviews. This issue requires further exploration into interdisciplinary curriculum design. The emphasis on interdisciplinary curriculum design could differ if the focus were shifted to instructors or students from a science and technology background. Future research could conduct comparative studies of interdisciplinary teaching among instructors from diverse backgrounds to understand their perspectives on interdisciplinary curriculum design. Finally, future research could also investigate students' attitudes and opinions on interdisciplinary learning to understand more fully their needs and expectations of interdisciplinary education.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Competing interests

The author declared no competing interests.

Ethical approval

The study has received ethical approval from the Human Research Ethics Committee at National Cheng Kung University, Taiwan, confirming its adherence to ethical guidelines [NCKU HREC-E-110-637-2].

Informed consent

The study has received ethical approval from the Human Research Ethics Committee, Taiwan, confirming its adherence to ethical guidelines. In the interests of research ethics, the participants were asked to fill in the research informed-consent form voluntarily and also to freely decide whether to agree to include the previously collected data in the final research analysis to protect their rights and interests.

Additional information

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